The association of fat patterning with blood pressure in rural South African children: the Ellisras Longitudinal Growth and Health Study

KD Monyeki,1* HCG Kemper2 and PJ Makgae3

Accepted 20 April 2005

Background Hypertension is one of the major causes of death in developed and underdeveloped nations. Essential hypertension and obesity may have their inception in childhood, with little data in African children to support these findings. Objectives were to determine the prevalence of overweight and hypertension in rural children in South Africa. Additionally, the association between fat-patterning ratios and blood pressure (BP) was investigated.

Methods Data were collected from 1884 subjects (967 boys and 917 girls), aged 6–13 years, participating in the Ellisras Longitudinal Study. Height; weight; and triceps, biceps, subscapular, and suprailliac skinfolds were measured according to the protocol of the International Society for the Advancement of Kinanthropometry. Skinfold ratio was used as an indicator of the central pattern of body fat. Internationally recommended cut-off points for body mass index (BMI) were used. Hypertension, defined as the average of three separate BP readings where the systolic BP or diastolic BP is >95th percentile for age and sex, was determined.

Results The prevalence of hypertension ranged from 1 to 5.8% for boys and 3.1 to 11.4% for girls, and that of overweight from 1.1 to 2.9% for boys and 0.6 to 4.6% for girls. The association between high systolic BP and high BMI was 3.0, while that for high diastolic BP and high BMI was 0.68.

Conclusions The prevalence of hypertension is evident from the age 6 years for girls, while that of overweight was low. Overweight became evident from the age 10 to 13 years for both sexes. A significant association between high diastolic BP and high BMI was noted, while children with low BMIs were less likely to be hypertensive. Investigating habitual physical activity, fitness and dietary patterns will shed more light on the association of fat patterning and BP in this population.

Keywords Body fat, body mass index, skinfold thickness, blood pressure, children, rural communities

Introduction Hypertension is one of the major causes of death in developed and underdeveloped nations.1–4 The causes of hypertension are generally unknown, and high blood pressure (BP) of unknown origin is usually referred to as ‘essential’ hypertension. Prevalence studies in childhood have the important advantage that they may lead to the prevention of high BP before its harmful sequence occurs.5
Overweight and hypertension are common conditions in the South African black adult population. Overweight has been reported to be 34% in urban black women in Cape Town,6–9 and 28–32% in rural women.6–9 Obesity is known to be one of the most important risk factors contributing to hypertension, which has been reported in 19–35% of black men studied in Durban and Cape Town.10–14 Although reliable statistics on stroke are sparse and difficult to obtain for black South Africans, recent studies have indicated that the incidence is higher in the black than in the white population, i.e. 244/100 000 in the 55- to 64-year-old group.11,12,14–16 However, no published data on overweight, fat patterning, and BP in rural South African children exist to support these findings.

Elevated arterial BP is a strong predictor of cardiovascular and renal disease. Cardiac output and systemic vascular resistance determines the level of arterial BP.17 It is not known whether the increase in BP occurring early in life is a result of increased cardiac output.18 In children, high cardiac output plays a part in the early pathogenesis of hypertension.19

Several factors have been suggested to be related to the BP level in children. These include genetic factors, maturation, obesity and low physical activity, body size, endocrine and renal factors, dietary factors (particularly high sodium intake), environmental cardiac exposure, oral contraceptives, noise, and psychological and social influences.18–28 The role of any of these factors on the level or change of BP during childhood and adolescence has still to be determined in rural South African children.

It has been recognized that overweight which starts early in life and persists into adulthood, increases the risk of overweight-related conditions, such as hypertension, later in life.21,19 Adolescence is also known to be an important stage to develop central patterning of body fat, which predisposes to CHD at a later age.21 Furthermore, essential hypertension may have its inception in childhood.19

The main objectives of this study were to determine the prevalence of overweight and hypertension in the initial cross-sectional sample of children, aged 6–13 years, participating in Ellisras Longitudinal Study (ELS). Additionally, the association of fat patterning and BP was investigated.

Methods

Geographical area

Ellisras is a deep rural area situated within the north-western area of the Limpopo province, South Africa. The population is ~50 000 people residing in 42 settlements.29 These villages are ~70 km from the Ellisras town (23° 40S 27° 44W), now known as Lephalale, adjacent to the Botswana border. The Iscor coal mine and Matimba electricity power station are the major sources of employment for many of the Ellisras residents, whereas the remaining workforce is involved in subsistence farming and cattle rearing, while a minority is in education and the civil service.

Sample

The ELS followed a cluster sampling method initially.30 In brief, the study was undertaken at 22 schools (10 preschool and 12 primary schools) randomly selected from 68 schools within the Ellisras area. Birth records were obtained from the principals of each school. Only those records that were verified against health clinic records were used to determine the age of each potential participant. Each of the 22 selected schools was assigned a grade with the expectation that most of the children in a particular age category (3–10 years) would be found in that grade.

In May 2000, medical students from VU University, Amsterdam included the BP parameter in the ongoing anthropometric measurements of the ELS. Measurements were performed on 967 boys and 917 girls (n = 1884), aged 6–13 years. The Ethics Committee of the University of the North granted ethical approval prior to the survey, and the parents or guardians provided informed consent.

Anthropometry

All children underwent a series of anthropometric measurements. Weight was measured on an electronic scale to the nearest 0.1 kg, and a Martin anthropometer was used to measure height to the nearest 0.1 cm. Skinfolds (suprailiac-SPIL, subscapular-SSCP, triceps-TRCP, and biceps-BCP) were measured using a Slim Guide skinfold caliper. All training and measurements were done in accordance with the standard procedures of the International Society for the Advancement of Kinanthropometry.31 To achieve technical error of measurement within the accepted limits, the fieldworkers underwent testing for reliability of measurements as part of their training.31

Fat patterning

The sum of the four skinfolds (SPIL + SSCP + TRCP + BCP) (S4SK) was used as an indicator of total body fatness. The proportion of body fat on the trunk relative to that on the limbs was used as an indicator of the central pattern of body fat (visceral fat). This was calculated by three equations.21,32

\[
\text{S/T ratio: } \frac{\text{Subscapular}}{\text{Triceps}} \quad (1)
\]

\[
\text{S/ST ratio: } \frac{\text{Subscapular}}{\text{Subscapular + triceps}} \quad (2)
\]

\[
\text{SS/SSBT ratio: } \frac{\text{Subscapular + Suprailiac}}{\text{Subscapular + Suprailiac + Biceps + triceps}} \quad (3)
\]

Blood pressure

Using an electronic Micronta monitoring kit, at least three BP readings were taken after the child had been seated for 5 min or longer.33 The bladder of the device contains an electronic infrasonic transducer that monitors the BP and pulse rate, displaying these concurrently on the screen. This versatile instrument has been designed for research and clinical purposes. In a pilot study, conducted before the survey, a high correlation (r = 0.93) was found between the readings taken with the automated device and those taken with a conventional mercury sphygmomanometer.

Statistical analyses

Data were expressed as median and inter-quartiles. Body mass index (BMI) was calculated for each participant as weight divided
by height (in meters) squared. The non-parametric t-test was applied to test the significance level ($P < 0.05$) between sexes. Internationally recommended cut-off points for BMI in children were used. Hypertension, defined as the average of three separate BP readings where the systolic BP (SBP) or diastolic BP (DBP) is $>95$th percentile for age and sex, was determined. Fisher’s exact test was used to test for a significant association in the overweight and hypertension groups. Linear regression models were used to assess the relationship between BP and other fat-patterning variables adjusted for age and sex. Logistic regression analysis was applied to determine whether subjects falling within the high body fat categories are more likely to have hypertension than those with lower body fat. All the statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS). The statistical significance was set at $P < 0.05$.

**Results**

Figures 1 and 2 present the median and inter-quartile BP by age group. Boys and girls exhibited a gradual increase in the median SBP throughout the age range, with girls having a significantly higher median SBP than boys at age 12 ($P < 0.05$) and 13 ($P = 0.018$) (Figure 1). There was a gradual increase over age, with 12-year-old ($P = 0.040$) and 13-year-old ($P = 0.027$) girls having a significantly higher DBP than boys (Figure 2).

The prevalence of hypertension starts at age 7 for boys (2.5%) and 6 for girls (3.8%) and range from 1 to 5.8% for boys and 3.4 to 11.4% for girls (Table 1). Although a high prevalence of hypertension was found in girls at age 12, and in 9-year-old boys, this was not statistically significant. The prevalence of overweight is evident in this sample at age $>10$ years, ranging from 1.1 to 2.9% for boys and 0.6 to 4.6% for girls. The 12-year-old boys (2.9%) and 13-year-old girls (4.6%) had the highest prevalence of overweight.

Girls showed higher BMIs at age 11 onwards, and reached a statistically significant level ($P < 0.05$) at age 13 compared with boys (Figure 3). The median S4Sk for girls was significantly higher than in boys ($P < 0.01$ to $P < 0.001$) throughout the age range (Figure 4). The median S/T ratio was significantly higher for boys than girls ($P < 0.05$ to $P < 0.001$) (Figure 5a). The median S/ST and SS/SSBT ratios for boys were significantly higher than for girls ($P < 0.05$ to $P = 0.0001$) throughout the age range (Figures 5b and c).

The regression analysis showed a positive significant association for the variables BMI, the S/ST and SS/SSBT ratios.

**Table 1** The prevalence of hypertension and overweight in Ellisras rural children aged 6–13 years

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>$n$</th>
<th>Hypertension$^a$ (%)</th>
<th>Overweight$^b$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Boys</td>
</tr>
<tr>
<td>6</td>
<td>33</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>79</td>
<td>65</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>97</td>
<td>85</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>117</td>
<td>110</td>
<td>5.8</td>
</tr>
<tr>
<td>10</td>
<td>175</td>
<td>177</td>
<td>2.8</td>
</tr>
<tr>
<td>11</td>
<td>216</td>
<td>214</td>
<td>3.7</td>
</tr>
<tr>
<td>12</td>
<td>172</td>
<td>183</td>
<td>2.3</td>
</tr>
<tr>
<td>13</td>
<td>91</td>
<td>62</td>
<td>4.5</td>
</tr>
</tbody>
</table>

$^a$ The average SBP and DBP $>95$th percentile for age and sex were measured for at least three separate occasions.

$^b$ Internationally recommended body mass index cut-off points in children, Cole et al.34

**Figure 1** Median SBP for Ellisras rural children aged 6–13 years ($n = 967$ boys, 917 girls)

**Figure 2** Median DBP for Ellisras rural children aged 6–13 years ($n = 967$ boys, 917 girls)

**Figure 3** Median BMI for Ellisras rural children aged 6–13 years ($n = 967$ boys, 917 girls)

**Figure 4** Median sum of skinfolds for Ellisras rural children aged 6–13 years ($n = 967$ boys, 917 girls)
and the sum of the skinfolds with SBP ($P < 0.001$) (Table 2). No significant association is seen between the fat-patterning variables and DBP. High SBP was related to high BMI (Table 3) although the association was not significant. However, a significant ($P < 0.05$) association was observed between high DBP and high BMI (Table 3).

The most valid and reliable method for the assessment of fat patterning in children is the dual-energy X-rays absorptiometry, which was not used in our study. However, height, weight, and skinfold thickness that were used to determine the BMI, central pattern, and general adiposity have measurement validity. More importantly, these measurements in children and adolescents have been associated with future development of increased BP. In our sample, we performed the regression analysis for BP, with age corrected for $S4Sk$, for boys and girls separately (Table 4). The increase in the SBP and DBP was partly because of the increased fat around the arm with increasing age as reported earlier.

**Discussion**

In this study, cross-sectional results of fat patterning and BP measurements of children from Ellisras rural area in South Africa are presented. The prevalence of hypertension is evident from a younger age group among girls in this sample, while that of overweight was low. Overweight became evident from age 10–13 years for girls and boys. Hypertension in the present study was observed in 48 boys (4.8%) and 77 (5.1%) girls aged 6–13 years, while in the West Indies this was observed in only
23 children (0.46%) aged 5–17 years. The number of hypertensive children in the West Indies study dropped from 160 to 23 following the re-evaluation of hypertensive children.

Elevated BP must be confirmed on repeated visits before characterizing an individual as having hypertension. A more precise characteristic of an individual’s BP level is an average of measurements taken over weeks or months. Therefore, a follow-up of the present study might yield different results among these hypertensive children, as was the case with children in the West Indies study. However, this study provided valuable information on hypertension in rural South African children, and could be followed by an intervention study to uproot this particular public health problem in rural South African communities. BP measurements between the 90th and 95th percentile are high and warrant further observation and consideration of other risk factors, since this level of BP could relate to disease in adulthood. 

The longitudinal data are not yet available to allow an assessment of the extent of the prevalence of hypertension in this study. Other epidemiological studies reported that elevated BP was associated with overweight. In the present study elevated DBP was significantly associated with a high BMI, while the association for SBP with a high BMI was not significant. However, obesity in terms of overweight was reported to be low in this population, with the prevalence of malnutrition being high in the older age group. 

Although no empirical data are available on nutritional intake and food practices in these villages, one of the current authors (KDM) lived in this area throughout childhood and reports that girls spend their time in and around the house, and would be likely to have the food they themselves, their mothers, grandmothers, or other female siblings prepare. The capability of boys to become independent goat and cattle herders coincides with their school attendance. They will return from school each afternoon to carry out their herding chores. During this time, their nutritional intake is likely to deteriorate because they are distanced from the preparation and source of food, which is unlikely to be kept for them on their return. The boys, usually aged 7–15 years, rely on gathering vegetable foods (berries etc.), trapping rabbits and hares, and/or killing birds, which they cook and eat during the day. Therefore, they do not have a guaranteed daily nutritional intake. The staple family diet is porridge (mealie-meal/maize), which is prepared daily in most families by female siblings or parents. This porridge remains in the cooking pot for members of the family to serve themselves when they are hungry. In common with the data on Pedi children reported by Steyn et al., it may be that these children, who are mainly from Tswana origin, have two meals a day with very low energy intake. While the above description is anecdotal and may be viewed as having little scientific basis, such reports of dietary behaviour regarding children in Southern Africa are rare in the literature and, therefore, should not be ignored as a possible explanation of rural South African nutritional intake.

Furthermore, elevated BP was associated with the degree of physical fitness and physical activity. Though the physical activity and physical fitness level of the present sample was not part of our analysis, Monyeki et al. reported low physical activity patterns among girls compared with boys. In this study, the measurement estimates of height and weight were associated with poorer performance in physical fitness tests. 

One would expect a statistically significant association between BP and fat-pattern ratio over age, which is not the case in this sample. Furthermore, Stallones et al. reported a statistically significant association between central fat patterning and SBP in 12- to 17-year-old white males, and a weaker association in 13- to 17-year-old females in the Bogalusa Heart Study. van Lenthe et al. reported a significant association of BP with fat-pattern ratios in girls who showed signs of early menarche. Girls in this study currently report their age at menarche as ranging from 9.56 to 13.13 years.

Conclusion
Hypertension and overweight are evident in the present sample, although the number of affected children is very small. A significant association between high DBP and high BMI is noted in this population. Investigation of the habitual physical activity, physical fitness, and dietary patterns will shed more light on the association of the fat pattern and BP in this population.

Acknowledgements
The authors would like to thank Dr FJ van Lenthe at Department of Public Health, Erasmus Medical Center, Rotterdam, and Dr LLJ Koppes from the VU University Medical Center, Institute for Research in Extramural Medicine, Amsterdam, The Netherlands for their critical inputs. The financial support received for ELS from VU University Medical Center, the University of Limpopo South Africa, the National Research Foundation, and Medical Research Council of South Africa is appreciated. The authors are indebted to the ELS administrators Mr LP Monyeki, PS Majadibodu, and UT Motlogeloa for coding the ELS data. Ms Jean Fourie, Chronic Disease of Lifestyle Unit, Medical Research Council is thankfully acknowledged for editing this manuscript.

KEY MESSAGES
- The prevalence of hypertension was evident in younger age groups in the Ellisras rural population of South Africa.
- Overweight occurred during the adolescence for boys and girls although the prevalence was very low.
- A positive significant association between BMI, subscapular/subscapular + triceps, subscapular + suprailliac/ supraillia + subscapular + biceps + triceps, and the sum of four skinfold measurements with systolic BP exists.
- No significant association between the fat-patternning ratios and DBP exists.
- There was a significant association between high DBP and high BMI.
FAT PATTERNING AND BLOOD PRESSURE IN RURAL CHILDREN


References


44 Stallones L, Mueller WH, Christensen BL. Blood pressure, fatness, and fat patterning among USA adolescents from two ethnic groups. *Hypertension* 1982;4:483–86.