Journal of
Obesity & Weight Loss Therapy

Ramoshaba et al., J Obes Weight Loss Ther 2015, 5:1
DOI: 10.4172/2165-7904.1000243

Research Article | Open Access

The Relationship between Blood Pressure and Anthropometric Indicators in Rural South African Children: Ellisras Longitudinal Study

Ramoshaba NE[2], Monyeki KD[2*], Zatu MC[1], Hay L[1] and Mabata LR[2]

[1]*Department of Human Physiology, University of Limpopo (Medunsa Campus), South Africa*

[2]*Department of Physiology and Environmental Health, University of Limpopo (Turfloop Campus), South Africa*

[*]**Corresponding author:** Prof. Monyeki KD, Principal Investigator: Ellisras Longitudinal Study (ELS), Department of Physiology and Environmental Health, University of Limpopo (Turfloop Campus), Private Bag X1106, Sovenga, 0727, South Africa, Tel: +27 15 268 2209; Fax: +27 15 268 2209; E-mail: dmonyeki@yahoo.com/ kotsedi.monyeki@ul.ac.za

Received date: November 28, 2014; **Accepted date:** January 23, 2015; **Published date:** February 10, 2015

Abstract

Background: Underweight, overweight and high blood pressure (BP) are known cardiovascular risk factors in children. The objective of the study was to investigate the relationship between the neck circumference (NC) and mid upper arm circumference (MUAC) with BP in Ellisras rural children age 5-12 years.

Methods: All children (n=1029 boys, n=932 girls) had BP and anthropometry measured. The receiver operating characteristics curve was used to discriminate children with high BP. Linear regression was used to assess the relationship between BP and anthropometric indicators.

Results: NC and MUAC significantly discriminated children with high BP. The regression analysis showed a significant association for Systolic blood pressure (SBP) with NC (β=0.764, 95% CI 0.475 to 1.052) and MUAC (β=1.286, 95% CI 0.990 to 1.581) for unadjusted and adjusted for age and gender NC (β=0.628 95% CI 0.303 to 0.953) and MUAC (β=1.351 95% CI 1.004 to 1.697) also showed a significant association.

Conclusion: The prevalence of underweight was high in these children. NC and MUAC can predict children with high BP. There was a positive significant association between BP and anthropometric indicators in this study population.

Keywords: Malnutrition; Rural South African children; Neck circumference; Mid upper arm circumference; Body composition; Cardiovascular disease

Abbreviation

BP: Blood Pressure; NC: Neck Circumference; MUAC: Mid Upper Arm Circumference

Introduction

Obesity is one of the major challenges in the world and is a risk factor for cardiovascular disease (CVD). Together with underweight and high blood pressure (BP), they are directly associated with the prevalence of morbidity and mortality from CVD [1]. It is estimated that one-third of the cases of arterial hypertension in adults are related to obesity. Obesity and underweight are likely to predict CVD risk in the long term if they manifest themselves amongst children at an early stage [1-3].

Several well-known anthropometric indicators that are in use to diagnose underweight and obesity are waist circumference (WC), hip circumference (HC), body mass index (BMI), neck circumference (NC), mid upper arm circumference (MUAC) and skinfolds [4-6]. Both longitudinal and cross sectional studies have shown that these anthropometrics indicators are associated with blood pressure in adults [7-9]. Recently, NC and MUAC were reported to be having a significant association with BP in children in developed countries [4,5]. However, the association between NC, MUAC and BP has not been studied extensively in children from rural areas of Africa.

Therefore, the objectives of the present cross-sectional study were to investigate 1) the prevalence of malnutrition (underweight and overweight), 2) assess the susceptibility of NC and MUAC to discriminate children with elevated BP, and finally, 3) the relationship between the anthropometric (NC and MUAC) indicators and BP of Ellisras rural children aged 5-12 years.

Materials and Methods

Geographical area

Ellisras, now known as Lephalale, is a deep rural area situated within the north-western area of Limpopo Province, South Africa. The population is ~50 000 people residing in 42 settlements. These villages are ~70 km from the town of Ellisras (230 40S 270 44W) adjacent to the Botswana border. The Iscor coal mine and Matimba electricity power station are the major sources of employment for many residents in Ellisras, whereas the remaining workforce is involved in subsistence farming and cattle rearing, while a minority is in education and the civil services.

Sample

The Ellisras Longitudinal Study (ELS) initially followed a cluster sampling method. In brief, we estimated the prevalence size from the literature, selected a level of significance (P<0.05) and then determined the power of the test which produced a significant difference at a given significant level. 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 1999, medical students from VU University, Amsterdam included the BP parameter in the ongoing anthropometric measurements of the ELS participants, and this was performed on 1029 boys and 932 girls (n=1961), aged 5-12 years. The Ethics Committee of the then University of the North, now known as University of Limpopo, granted ethical approval prior to the survey, and the parents or guardians provided informed consent.

Anthropometry

All children underwent a series of anthropometric measurements according to the International Society for the Advancement of Kinathropometry (ISAK) [10]. 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. Neck circumference and mid upper arm circumference were measured in centimeters with a flexible steel tape.

Blood pressure

Using an electronic Micronta monitoring kit, at least three BP readings of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken at an interval of five minutes apart after the child had been seated for 5 minutes or longer [11,12]. 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.

Quality control

All training of anthropometric measurements was done in accordance with the standard procedures of the ISAK [10]. Reliability and validity of anthropometric measurements were reported elsewhere [13,14]. In brief, the absolute and relative values for intra- and inter-tester technical error of measurements (% TEM) for stature, ranged from 0.04-4.16 cm (0.2-5.01%), for body mass from 0.01-0.02 kg and girth measurements range from 0.0-3.4 cm (0-4%).

Statistical analysis

Descriptive statistics were presented for NC, MUAC, BMI, BP, height and weight in the Ellisras rural children aged 6 to 12 years. The independent t-test was applied to test the significance level (P<0.05) between sexes. All children were classified as overweight and obese according to Cole et al. [15] cutoff points. The international cutoff points for underweight (grade one, two, and three) by sex for exact ages defined to pass through BMI of 16, 17, and 18 kg/m^2 were used [16,17]. Hypertension was defined as the occurrence of SBP and DBP levels greater than or equal to the 95th percentile of height and sex-adjusted reference levels [10]. We assessed the susceptibility for NC, MUAC and BMI to discriminate children with elevated BP. For this purpose, we produced sex-specific receiver operating characteristics (ROC) curves and used the corresponding area under curves (AUC) to determine the ability of each anthropometric indicator in identifying children with elevated BP. The ROC curve is a plot of true-positive rate (sensitivity) against the false-positive rate (1-specificity). A good test has ROC skewed to the upper left corner with AUC of 1, whereas an AUC of 0.5 means that the test performs no better than chance [18,19]. Sensitivity and specificity of NC and MUAC have been calculated at all possible cutoff points to find optimal cutoff value. The optimal sensitivity and specificity were the values yielding maximum sums from the ROC curves (clinical significance of cutoff was checked with the Youden index). Cutoff values and the corresponding AUCs as well as positive predictive value (PPV) and negative predictive value (NPPV) of NC and MUAC for underweight were computed along age and gender. The Linear regression models were used to assess the relationship between BP and anthropometric indicators (NC and MUAC) adjusted for age and sex. 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

Table 1 showed descriptive statistics for weight, height, NC, MUAC, BMI and BP by gender and age group for Ellisras rural children aged 5 to 12 years. Boys (25.6 to 26.2 cm) showed a significantly (P< 0.05) higher mean NC than girls (25.0 to 25.8 cm) from age 9 to 11 years, while girls (17.9 cm) exhibited a significantly higher mean MUAC than boys (17.4 cm) at age 11 years. Boys and girls did not show significant differences with their mean BP throughout the age range.

	n		Height (cm)		Weight (Kg)		NC (cm)		MUAC (cm)		SBP (mmHg)		DBP (mmHg)		BMI (Kg.m^{-2})	
Age (yrs)	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
			M	M	M	M	M	M	M	M	M	M	M	M	M	M
			(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)	(sd)

Citation: Ramoshaba NE, Monyeki KD, Zatu MC, Hay L, Mabata LR (2015) The Relationship between Blood Pressure and Anthropometric Indicators in Rural South African Children: Ellisras Longitudinal Study. J Obes Weight Loss Ther 5: 243. doi: 10.4172/2165-7904.1000243

5	53	37	111.6	110.2	17.3	17.1	23.9	23.4	15.0	15.1	100.6	102.3	61.3	59.4	13.9	14.0
			6.1	6.7	2.1	3.0	1.4	1.5	0.8	1.2	11.7	13.3	8.3	9.5	0.9	1.4
6	64	58	116.9	116.5	18.9	18.7	24.1	23.6	15.1	15.5	102.1	98.4	61.3	59.7	13.8	13.7
			5.1	5.8	2.2	2.7	1.2	1.3	1	1.2	13.8	13.8	10.9	9.2	0.9	1.1
7	97	73	122.2	122.7	20.9	20.8	24.8	24.3	15.7	15.8	96.9	96.3	59.7	57.5	13.9	13.8
			5.6	6.4	2.8	3	1.3	1.4	1.1	1.1	12.2	12.8	9.3	8.4	1.1	1.1
8	117	115	127.7	127.3	23.4	22.8	25.3	24.6	16.1	16.2	97.3	96.4	59.1	59	14.3	14
			6.5	5.3	3.2	3	3	1.2	1.1	1.2	10.2	10	9.1	9.7	1.2	1.1
9	184	180	133.5	133.1	25.5	25.4	25.6*	25*	16.5	16.5	99.7	99	61.9	61	14.3	14.3
			6.2	5.3	3.3	4.1	1.3	1.5	1.2	1.4	10.7	11.3	9.9	9.8	1.1	2
10	231	220	137.7	137.1	27.6	27.5	26*	25.3*	17	17.1	99.5	99.7	60.2	59.8	14.5	14.6
			6.1	6.1	3.7	4.5	1.4	1.3	1.4	1.6	9.7	10.2	9.4	9.2	1.2	1.6
11	187	178	141	142.1	29.3*	30.4*	26.2*	25.8*	17.4*	17.9*	101.6	102	62	60.9	14.7	15
			7.1	6.6	4.6	5.1	1.5	1.4	1.6	1.8	10.8	11.9	9.2	9.3	1.4	1.9
12	96	71	142.6*	145.6*	30*	32.5*	26.5	26.4	17.5	18.5	101.9	101.8	60.8	63.1	14.7*	15.3*
			6.2	7.6	4.6	5.7	1.5	1.5	1.5	1.9	9.6	10.4	8.1	8.4	1.4	1.9

Table 1: Descriptive statistics of an absolute body size of Ellisras children aged 5-12 years (*P<0.05; n: Sample size; M: Mean; sd: standard deviation; NC: Neck Circumference; MUAC: Mid Upper Arm Circumference; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BMI: Body Mass Index).

Table 2 showed low prevalence of hypertension (0 to 4.7%), and overweight/ obesity (0 to 2,7%) using BMI amongst Ellisras rural children 5-12 years. The prevalence of underweight was ranging from 0.9 to 41.6% in the severe, moderate and mild group.

	Sample size		High SBP		High DBP		Hypertension		Body mass index							
									Severe		Moderate		Mild		Overweight/Obese	
Age (yrs)	Boys	Girls	Boys %(n)	Girls %(n)	Boys %(n)	Girl % (n)	Boys %(n)	Girls % (n)	Boys %(n)	Girls %(n)	Boys %(n)	Girls %(n)	Boys %(n)	Girls %(n)	Boys %(n)	Girls %(n)
5	53	37	1.3	18.9	-	5.4	-	5.4	7.5	10.8	22.6	13.5	35.8	32.4	-	2.7
			(6)	(7)	-	(2)	-	(2)	(40)	(4)	(12)	(5)	(19)	(12)	-	(1)
6	64	58	14.1	17.2	9.4	1.7	4.7	-	9.4	8.6	17.2	13.8	34.4	34.5	-	-
			(9)	(10)	(6)	(1)	(3)	-	(6)	(5)	(11)	(8)	(22)	(20)	-	-
7	97	73	4.1	8.2	1.0	2.7	-	-	6.2	5.5	15.5	13.7	36.1	38.4	-	1.4
			(4)	(6)	(1)	(2)	-	-	(6)	(4)	(15)	(10)	(35)	(28)	-	(1)
8	117	115	0.9	1.7	0.9	3.5	-	-	0.9	4.3	11.1	12.2	40.2	33.9	0.9	-
			(1)	(2)	(1)	(4)	-	-	(1)	(5)	(13)	(14)	(47)	(39)	(1)	-
9	184	180	2.7	3.3	2.2	3.3	1.1	1.1	6	3.9	13.6	21.1	38.0	32.2	-	0.6
			(5)	(6)	(4)	(6)	(2)	(2)	(11)	(7)	(25)	(38)	(70)	(58)	-	(1)
10	231	220	0.4	2.3	-	2.7	-	1.4	4.8	7.3	14.7	13.6	41.6	40	-	2.3
			(1)	(5)	-	(6)	-	3	(11)	(16)	(34)	(30)	(96)	(88)	-	(5)

11	187	178	1.1	2.2	0.5	1.7	0.5	0.6	5.9	9.6	19.8	14.6	41.2	41.0	-	1.7
			(2)	(4)	(1)	(3)	(1)	(1)	(11)	(17)	(37)	(26)	(77)	(73)	-	(3)
12	96	71	1.0	-	-	-	-	-	13.5	15.5	18.8	15.5	38.5	32.4	-	1.4
			(1)	-	1	-	-	-	(13)	(11)	(18)	(11)	(37	(23)	-	(1)

Table 2: The prevalence of malnutrition using BMI and hypertension amongst Ellisras rural children aged 5-12 years (SBP:Systolic Blood pressure; DBP: Diastolic blood pressure; BMI: Body mass index).

The receiver operating characteristic (ROC) curve analyses showed a gender-specific ability of anthropometric indicators to correctly identify children with high BP. AUC for NC (0.698), MUAC (0.677) and BMI (0.636) for boys were statistically significant (P<0.05) for high SBP, while in girls AUC of BMI was not significant (P>0.05) for high DBP (Table 3).

	High systolic blood pressure			High diastolic blood pressure			Hypertension		
ROC analysis	AUC	95%CI		AUC	95%CI		AUC	95%CI	
BOYS									
NC	0.698*	0.596	0.800	0.729*	0.588	0.871	0.409	0.174	0.644
MUAC	0.677*	0.589	0.775	0.656*	0.513	0.798	0.449	0.247	0.651
BMI	0.636*	0.532	0.740	0.557	0.425	0.688	0.546	0.411	0.681
GIRLS									
NC	0.606*	0.516	0.696	0.442	0.332	0.552	0.410	0.247	0.574
MUAC	0.640*	0.551	0.729	0.450	0.324	0.576	0.363	0.168	0.559
BMI	0.550	0.461	0.638	0.430	0.297	0.563	0.398	0.184	0.612

Table 3: Gender-specific areas under the receiver operating characteristic (ROC) curves showing the ability of anthropometrics measures to identify children with high BP (*P<0.05; AUC: Area Under Curve; NC: Neck Circumference; MUAC: Mid Upper Arm Circumference; BMI: Body Mass Index).

Tables 4-5 showed the AUC for each age group including the optimal NC and MUAC cutoff points and the corresponing sensetivities and specificities for classifying children into low BMI groups in boys. The predictive values for each cutoff point were also shown. For example, PPV for a 12 year old girl with NC<26.2 cm and MUAC<18.6 cm indicate that she is more likely to be underweight (Table 5).

Age (years)	Variables	AUC-ROC (95% CI)	Cut-off value	Sensitivity	Specificity	PPV	NPV
5	NC	0.582 (0.414-0.750)	23.2	37.1	72.2	1.33	0.87
	MUAC	0.677 (0.516-0.839)	14.8	42.9	72.2	1.54	0.79
6	NC	0.850 (0.755-0.946)	24.1	66.7	84.0	4.17	0.40
	MUAC	0.874 (0.791-0.958)	15.5	76.9	80.0	3.85	0.29
7	NC	0.749 (0.652-0.847)	24.7	62.5	75.6	2.56	0.50
	MUAC	0.873(0.805-0.942)	15.8	78.6	85.4	5.38	0.25
8	NC	0.770 (0.685-0.856)	24.8	63.9	80.4	3.26	0.45
	MUAC	0.820 (0.746-0.893)	16.0	65.6	83.9	4.07	0.41
9	NC	0.767 (0.700-0.834)	25.5	60.4	78.2	2.77	0.51
	MUAC	0.854 (0.800-0.907)	16.4	69.8	80.8	3.64	0.37

10	NC	0.802 (0.742-0.861)	25.9	63.1	80.0	3.16	0.46
	MUAC	0.872 (0.825-0.920)	17.2	80.9	80.0	4.05	0.24
11	NC	0.732 (0.657-0.806)	26.1	62.4	75.8	2.58	0.50
	MUAC	0.866 (0.811-0.922)	17.5	73.6	83.9	4.57	0.31
12	NC	0.810 (0.657-0.806)	26.1	62.4	75.8	2.58	0.50
	MUAC	0.929 (0.882-0.977)	18.0	82.4	85.7	5.76	0.21

Table 4: Optimal cut-off points for NC and MUAC in Ellisras rural boys for underweight. (AUC: Area Under Curve; ROC: Receiver Operative Characteristics; NC: Neck Circumference; MUAC: Mid Upper Arm Circumference; PPV: Positive Predictive Value; NPV: Negative Predictive Value).

Age (years)	Variables	AUC-ROC (95% CI)	Cut-off value	Sensitivity	Specificity	PPV	NPV
5	NC	0.789 (0.644-0.933)	23.3	57.1	81.2	1.06	0.23
	MUAC	0.878 (0.765-0.991)	15.4	85.7	81.2	4.50	0.18
6	NC	0.817 (0.704-0.930)	23.4	57.6	80.0	2.88	0.53
	MUAC	0.839 (0.740-0.939)	15.5	72.7	84.0	4.54	0.33
7	NC	0.766 (0.654-0.877)	23.9	52.4	83.9	3.25	0.57
	MUAC	0.835 (0.741-0.930)	15.8	71.4	80.6	3.68	0.35
8	NC	0.726 (0.634-0.819)	24.1	51.7	75.4	2.10	0.64
	MUAC	0.871 (0.806-0.936)	16.3	81.0	82.5	4.63	0.23
9	NC	0.713 (0.638-0.788)	24.6	59.2	79.2	2.85	0.52
	MUAC	0.871 (0.821-0.922)	16.5	75.7	83.1	4.48	0.29
10	NC	0.681 (0.611-0.751)	25.0	50.0	80.2	2.53	0.62
	MUAC	0.868 (0.821-0.914)	17.1	74.6	80.2	3.77	0.32
11	NC	0.758 (0.682-0.833)	25.6	58.6	75.8	2.42	0.55
	MUAC	0.864 (0.805-0.925)	18.0	80.2	79.0	3.82	0.25
12	NC	0.779 (0.669-0.890)	26.2	62.2	80.8	3.24	0.47
	MUAC	0.910 (0.842-0.978)	18.6	84.4	80.8	4.40	0.19

Table 5: ROC curve analysis of NC and MUAC in Ellisras rural girls for underweight (AUC: Area Under Curve, ROC: Receiver Operative Characteristics, NC: Neck circumference, MUAC: Mid Upper Arm circumference, PPV: Positive Predictive Value; NPV: Negative Predictive Value).

The regression analysis showed a positive significant (P<0.05) association for SBP with NC (β=0.764, 95%CI 0.475 to 1.052) and MUAC (β=1.286, 95% Cl 0.990 to 1.581) for unadjusted and adjusted for age and gender NC (β=0.628 95% Cl 0.303 to 0.953) MUAC (β=1.351 95% CI 1.004 to 1.697) showed a significant association with SBP. However, MUAC had a significant association with DBP for both unadjusted and adjusted for age and gender (Table 6).

	Unadjusted				Adjusted for age and gender			
	β	P-value	95% CI		β	P-value	95% CI	
SBP								
NC	0.764	0.000	0.475	1.052	0.628	0.000	0.303	0.953
MUAC	1.286	0.000	0.990	1.581	1.351	0.000	1.004	1.697
DBP								
NC	0.325	0.009	0.082	0.568	0.186	0.182	-0.087	0.460
MUAC	0.578	0.000	0.327	0.829	0.563	0.000	0.269	o.857

Table 6: Linear regression coefficients, P-value and 95% confidence intervals for the association between Neck circumference (NC), mid upper arm circumference (MUAC) and blood pressures in Ellisras

children age 5-12 years (β: Beta, CI: Confidence Interval, SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure).

Discussion

The relationship between anthropometric indicators and BP is important in evaluating the health of children and adolescents, since cardiovascular abnormalities are becoming more common these days. In this present study, we found that the prevalence of underweight (severe, moderate and mild) was high while overweight and obese by BMI was low amongst these children. NC and MUAC significantly discriminated boys with both high SBP and DBP, while in girls NC and MUAC only identified high SBP. However, BMI discriminated boys with only high SBP.

In this study, we measured NC and MUAC to describe underweight defined by BMI. We recommend that each country must determine their own cutoff points for NC, MUAC and BMI. While the use of BMI as a surrogate for fat distribution among children raises debates, NC and MUAC are increasingly recognized as a useful indexes refletive of both fat distribution and risk of metabolic syndrome. The primary contribution of this present study was that both NC and MUAC can be substituted for one another as an additional evaluation tool next to BMI in detecting underweight in the Ellisras rural children.

The results showed a strong positive significant association between BP and anthropometric indices (NC and MUAC) in this sample though the association of DBP and NC disappeared after adjustments for age and gender. Similar findings do exist in literature that supports our results [5]. However, it seems that the prevalence of overweight, obesity and high BP of the cited studies were high compared with the current study, which showed high prevalence of underweight (Table 2). These differences may be due to the fact that those studies were carried out in developed countries in contrast to our study which is exclusively based on under-resourced rural settings. According to WHO [20], the prevalence of overweight or obesity increases as a country develops. It is possible that nowadays the aforementioned changes and developments in South Africa have resulted in increased prevalence of overweight and obesity [21].

Few studies have reported the association of high BP and several anthropometric indicators. However, it is still controversial whether absolute (general adiposity) or relative body fat (central adiposity) is a better predictor for hypertension [22]. Most studies are supporting central adiposity as the good predictor for high BP [23,24]. NC and waist circumference (WC) as a marker of central adiposity appeared to have the accuracy of discriminating children with high BP in America [5,25]. Moreover, compared with waist circumference, NC seems to be an ideal measure as it does not change during the day [26]. The present study agree with the previous studies as NC discriminated children with high BP and also added that MUAC can also be used to identify children with high BP.

For the association of anthropometrics and BP, Nafiu et al. [5] found a positive association between BP and NC in American children aged 6-18 years. NC showed an independent association with various cardiometabolic risk markers including BP [27] and had strong correlation with BMI [28]. Mazicioglu et al. [4] reported that MUAC is strongly associated with both SBP and DBP in adolescents aged 11-17 years from Turkey. Bassaroe et al. [29] also reported that MAUC had a significant relationship with systolic BP but not diastolic BP in Sardinian children aged 11-14 years. Therefore present study concurs with previous studies on the association of NC and MUAC with BP.

Study Limitations

In our study we did not consider the socioeconomic status of families of the participants in the analysis. Insulin resistence as metabolic condition characterized by an impaired ability of plasma insulin at normal concentrations to promote peripheral glucose clearance, suppress glucoseneogenesis in the liver and inhibits very low density lipoprotein output. This condition together with an increase in BMI values worsen the endothelial parameters, independent of malnutrition of children were not investigated in our study [30-32]. Furthermore, even though the data of the study was collected in year 1999, it is possible that prevalence of overweight and obesity has increased, at present time, due to developments and changes in South Africa [21].

The anthropometric and BP measurements were taken directly, and hence recall or estimation bias will not prevail in our study. In addition, we measured BP during early childhood, demonstrating that proper monitoring should be started from children's early days from a viewpoint of screening for vulnerable individuals [33].

Conclusion

The prevalence of underweight (severe, moderate and mild) was high, while overweight was low amongst Ellisras rural children. NC and MUAC can predict both high SBP and DBP in boys while in girls NC and MUAC can only predict high SBP. However, BMI can only predict high SBP for boys only. There was a positive significant association between BP and anthropometric indicators in this study population, though the association of DBP and NC disappeared after adjustments for age and gender. Further research is recommended to establish the NC and MUAC cutoff points for overweight, especially in low-resourced settings as these indices are inexpensive to use and can be used in larger populations.

Acknowledgement

The financial support received by the ELS from the VU University Medical Center, Amsterdam; the University of Limpopo, South Africa; and the National Research Foundation, South Africa is appreciated. Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors and therefore the above mentioned findings and sources do not accept any liability in regard thereto. We thank Vrije medical students, Amsterdam for measuring BP in all ELS children. The authors are indebted to the ELS administrators Mr. TT Makata, PP Tselapedi and RJ Majadibodu, for coding the ELS data.

References

1. World Health Organization (2005). Preventing chronic diseases: a vital investment: WHO global report.
2. Longo-Mbenza B, Lukoki Luila E, M'Buyamba-Kabangu JR (2007) Nutritional status, socio-economic status, heart rate, and blood pressure in African school children and adolescents. Int J Cardiol 121: 171-177.
3. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, et al. (2004) Obesity and the metabolic syndrome in children and adolescents. N Engl J Med 350: 2362-2374.
4. Mazıcıoğlu MM, Hatipoğlu N, Oztürk A, Ciçek B, Ustünbaş HB, et al. (2010) Waist circumference and mid-upper arm circumference in

evaluation of obesity in children aged between 6 and 17 years. J Clin Res Pediatr Endocrinol 2: 144-150.

5. Nafiu OO, Zepeda A, Curcio C, Prasad Y (2014) Association of neck circumference and obesity status with elevated blood pressure in children. J Hum Hypertens 28: 263-268.
6. Monyeki KD, Kemper HC, Makgae PJ (2006) The association of fat patterning with blood pressure in rural South African children: the Ellisras Longitudinal Growth and Health Study. Int J Epidemiol 35: 114-120.
7. Zhou Z, Hu D, Chen J (2009) Association between obesity indices and blood pressure or hypertension: which index is the best? Public Health Nutr 12: 1061-1071.
8. Mirzaei M, Taylor R, Morrell S, Leeder SR (2007) Predictors of blood pressure in a cohort of school-aged children. Eur J Cardiovasc Prev Rehabil 14: 624-629.
9. Ben-Noun L, Laor A (2003) Relationship of neck circumference to cardiovascular risk factors. Obes Res 11: 226-231.
10. Norton K, Olds T (1996) Anthropometrica. University of New South Wales Press: Sydney 396-410.
11. National High Blood Pressure Education Program (NHBPEP) working group on hypertension control in children and adolescents (1996) Update on the 1987 task force report on high blood pressure in children and adolescents: a working group report from the National High Blood Pressure Education Program. Pediatrics 98: 649-58.
12. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (2004). The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics 114: 555-76.
13. Monyeki MA, Kemper HCG, Twisk JWR, Monyeki KD, Toriola AL, et al. (2003) Anthropometric indicators of nutritional status and physical fitness of Ellisras rural primary school children, South Africa. Med Sport 7: E93–E104.
14. Monyeki KD, Toriola AL, de Ridder JH, Kemper HC, Steyn NP, et al. (2002) Stability of somatotypes in 4 to 10 year-old rural South African girls. Ann Hum Biol 29: 37-49.
15. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH (2000) Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 320: 1240-1243.
16. Cole TJ, Flegal KM, Nicholls D, Jackson AA (2007) Body mass index cut offs to define thinness in children and adolescents: international survey. BMJ 335: 194.
17. Cameron N (2007) Body mass index cut offs to define thinness in children and adolescents. BMJ 335:166-7.
18. Zhou X-H, Obuchowski NA, McClish DK (2002) Statistical Methods in Diagnostic Medicine. Wiley-Interscience: New York, NY, USA.
19. Schisterman EF, Faraggi D, Reiser B, Trevisan M (2001) Statistical inference for the area under the receiver operating characteristic curve in the presence of random measurement error. Am J Epidemiol 154: 174-179.
20. World Health Organization (2011) Global strategy on diet, physical activity and health. What is overweight and obesity?
21. Van Den Ende C, Twisk JW, Monyeki KD (2014) The relationship between BMI and dietary intake of primary school children from a rural area of South Africa: The Ellisras longitudinal study. Am J Hum Biol 26: 701-706.
22. Spiegelman D, Israel RG, Bouchard C, Willett WC (1992) Absolute fat mass, percent body fat, and body-fat distribution: which is the real determinant of blood pressure and serum glucose? Am J Clin Nutr 55: 1033-1044.
23. Hansen ML, Gunn PW, Kaelber DC (2007) Underdiagnosis of hypertension in children and adolescents. JAMA 298: 874-879.
24. Han TS, van Leer EM, Seidell JC, Lean ME (1995) Waist circumference action levels in the identification of cardiovascular risk factors: prevalence study in a random sample. BMJ 311: 1401-1405.
25. Watts K, Bell LM, Byrne SM, Jones TW, Davis EA (2008) Waist circumference predicts cardiovascular risk in young Australian children. J Paediatr Child Health 44: 709-715.
26. Laakso M, Matilainen V, Keinänen-Kiukaanniemi S (2002) Association of neck circumference with insulin resistance-related factors. Int J Obes Relat Metab Disord 26: 873-875.
27. Kurtoglu S, Hatipoglu N, Mazicioglu MM, Kondolot M (2012) Neck circumference as a novel parameter to determine metabolic risk factors in obese children. Eur J Clin Invest 42: 623-630.
28. Nafiu OO, Burke C, Lee J, Voepel-Lewis T, Malviya S, et al. (2010) Neck circumference as a screening measure for identifying children with high body mass index. Pediatrics 126: e306-310.
29. Bassareo PP, Marras AR, Barbanti C, Mercuro G (2013). Comparison between waist and mid-upper arm circumferences in influencing systolic blood pressure in adolescence: the SHARP (Sardinian Hypertensive Adolescent Research Programme) study. JPNIM 2:e020207.
30. Ciccone MM, Scicchitano P, Salerno C, Gesualdo M, Fornarelli F, et al. (2013) Aorta structural alterations in term neonates: the role of birth and maternal characteristics. Biomed Res Int 2013: 459168.
31. Miniello VL, Faienza MF, Scicchitano P, Cortese F, Gesualdo M, et al. (2014) Insulin resistance and endothelial function in children and adolescents. Int J Cardiol 174: 343-347.
32. Ciccone MM, Miniello V, Marchioli R, Scicchitano P, Cortese F, et al. (2011) Morphological and functional vascular changes induced by childhood obesity. Eur J Cardiovasc Prev Rehabil 18: 831-835.
33. Monyeki K, Kemper H (2008) The risk factors for elevated blood pressure and how to address cardiovascular risk factors: a review in paediatric populations. J Hum Hypertens 22: 450-459.