Chapter

Association of Anthropometric Parameters with Blood Pressure and Blood Glucose among Ellisras Children

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Abstract

Obesity as directly measured by anthropometric parameters has been demonstrated to be associated with hypertension and type 2 diabetes mellitus, which are common risk factors for CVD. The study aimed at assessing the relationship between blood pressure, blood glucose and anthropometric parameters in Ellisras children. A total of 492 children aged 6 to 11 years, participated in the study. Neck circumference, waist circumference, body mass index, waist-to-height ratio, fasting blood glucose, systolic and diastolic blood pressure were measured using standard procedures. Linear regression showed significant association ($P < 0.05$) of anthropometric parameters (except waist-to-height ratio) with blood pressure. Fasting blood glucose was significantly associated with neck circumference when adjusted for age and gender. Positive correlation was found for systolic blood pressure with neck and waist circumference and body mass index in both genders and for diastolic blood pressure, the correlation was only found in boys. Fasting blood glucose was negatively correlated with neck circumference. Waist circumference ($P = 0.025$, $\beta = 1.208$, 95% CI = 1.017–1.285) was better than BMI ($P = 0.046$, $\beta = 1.340$, 95% CI = 1.005–1.788) in predicting elevated systolic blood pressure. These findings suggest that it is crucial to manage anthropometric parameters in the Ellisras community in order to decelerate the increase of hypertension and diabetes mellitus.

Keywords: body mass index, neck circumference, waist circumference, waist to height ratio, fasting blood glucose and blood pressure

1. Introduction

Obesity is a key global public health alarm with about 500 million people worldwide affected [1, 2]. In epidemiological studies, anthropometric parameters, body mass index (BMI), waist circumference (WC), neck circumference (NC) and waist-height ratio (WHtR) are often used as measures of obesity [2–5]. Obesity as directly measured by anthropometric technique has been demonstrated to be associated with hypertension and type 2 diabetes mellitus, common risk factors for CVD [6, 7].

The diagnosis of diabetes is often based on a fasting plasma glucose, random plasma glucose, a 2-hour plasma glucose value in a 75 g oral glucose tolerance test or a glycated hemoglobin (A1C) measurement, but generally on fasting plasma glucose, partly because of its better sensitivity to diagnose diabetes [5, 8]. Hypertension uses information about systolic blood pressure (SBP) and/or diastolic blood pressure (DBP) to derive an estimate for diagnosis [9].

In view of the burden of obesity, hypertension and diabetes and their impact on children and the scarcity of information on the relationship of blood glucose, blood pressure with anthropometric parameters in rural South African communities, more especially in Ellisras, the present study aimed to determine the relationship of blood pressure and blood glucose with anthropometric parameters among Ellisras rural children aged 6 to 11 years and to determine which of the anthropometric parameters is associated with greater odds of high blood pressure and high blood glucose levels in this population.

2. Methodology

2.1 Geographical area

Ellisras, also known as Lephalale, is a relatively deep rural area located within the North- western area of Limpopo province, South Africa. The population consist of approximately 50000 people residing in 42 settlements and are adjacent to the Botswana border. Majority of residence in this population work at Iscor coal mine and Matimba electricity power station, whereas the remaining work class is involved in subsistence farming, while the minority is in civil services and education [10].

2.2 Sampling and study design

Research design and sampling method for the Ellisras Longitudinal study (ELS) have been reported elsewhere [10].

In this study, a total of 492 children (n = 296 boys; n = 196 girls) aged 6 to11 who are part of the ELS, participated in this study. Ethical approval prior to this study was obtained from Ethics Committee of the University of Limpopo. Guardians were provided with, and signed, written informed assent.

2.3 Anthropometry

Anthropometric measurements were done according to the International Society for the Advancement of Kin-anthropometry (ISAK). Weight was measured on an electronic scale to the nearest 0.1 kg, and a Martin anthropometry was used to measure height to the nearest 0.1 cm. Flexible steel tape was used to measure NC and WC. Waist circumference was measured midway between the lower costal margin and iliac crest immediately after exhalation. Neck circumference was measured directly below the thyroid cartilage perpendicular to the long axis of the neck. All measurements were taken with the participants standing in an anatomical position.

Children with BMI <85th, ≥85th and ≥ 95th percentile were considered normal, overweight and obese, respectively [7]. Children with WC ≥90th percentile were considered to have abdominal obesity, and those with NC 90th ≥ were considered to have obesity [3, 11]. BMI was calculated as weight in kilograms (kg) divided by the square of height in metres (m), whereas waist to height ratio was calculated as waist circumference divided by height.

2.4 Blood pressure

To measure blood glucose, the participants were first made comfortable, by sitting on the chair for at least five minutes before measurements. From each subject at least three reading blood pressure (systolic and diastolic) measurements were taken, at an interval of five minutes apart. Blood pressures readings were taken using electronic Micronta monitoring kit. The device has a bladder which contains an electronic infrasonic transducer that monitors the blood pressure and pulse rate, thus displaying these on the screen. Hypertension was defined by systolic and diastolic blood pressure ≥ 95th percentile of age and sex adjusted reference level [6].

2.5 Blood glucose

To measure blood glucose level all subjects were asked to do an 10 hours overnight fasting prior to the test, in the morning their capillary blood sample were obtained by a finger prick and blood was caught up in little cuvettes, which were prepared with below mentioned reagents (glucose oxidase and reagents to measure the generation of hydrogen peroxide such as non-toxic phenol red and horseradish peroxidase was bonded to filter paper). After mixing with the reagents, fasting blood glucose was measured using Hemocue® [8]. Type 2 diabetes mellitus was defined by fasting blood glucose ≥7.1 mmol/L of sex and age adjusted reference level.

2.6 Statistical analysis

All the statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 25. Data comparison was done using student t-test for 2 groups. Descriptive statistics were performed for age, anthropometric parameters, fasting blood glucose and blood pressure (systolic and diastolic). The Linear regression model was used to assess the association between blood pressure (systolic and diastolic), blood glucose and anthropometric parameters after adjusting for potential confounders. The logistic regression was used to determine the risk of developing hypertension and type 2 diabetes mellitus using anthropometric parameters. Statistical significance was set at a probability level of 0.05 (**Figures 1** and **2**).

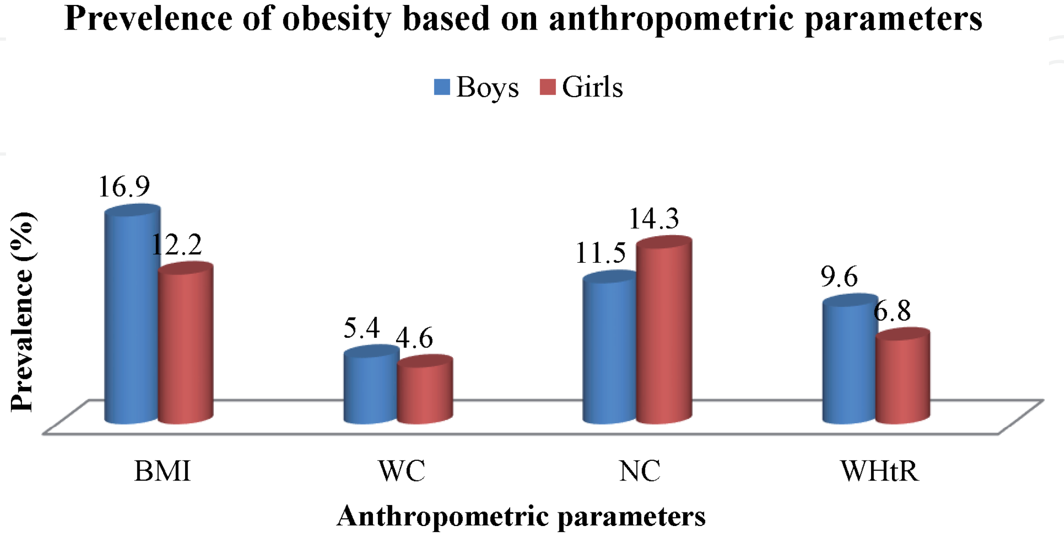

Figure 1.
Gender specific prevalence of obesity based on WC, BMI, WHtR and NC among Ellisras children aged 6 to 11 years. The prevalence of obesity was higher in boys measured by BMI (16.9%), WC (5.4%) and WHtR (9.6%), as compared to girls BMI (12.2%), WC (4.6%) and WHtR (6.2%) and that measured by NC was higher in girls (14.3%) than in boys (11.5%).

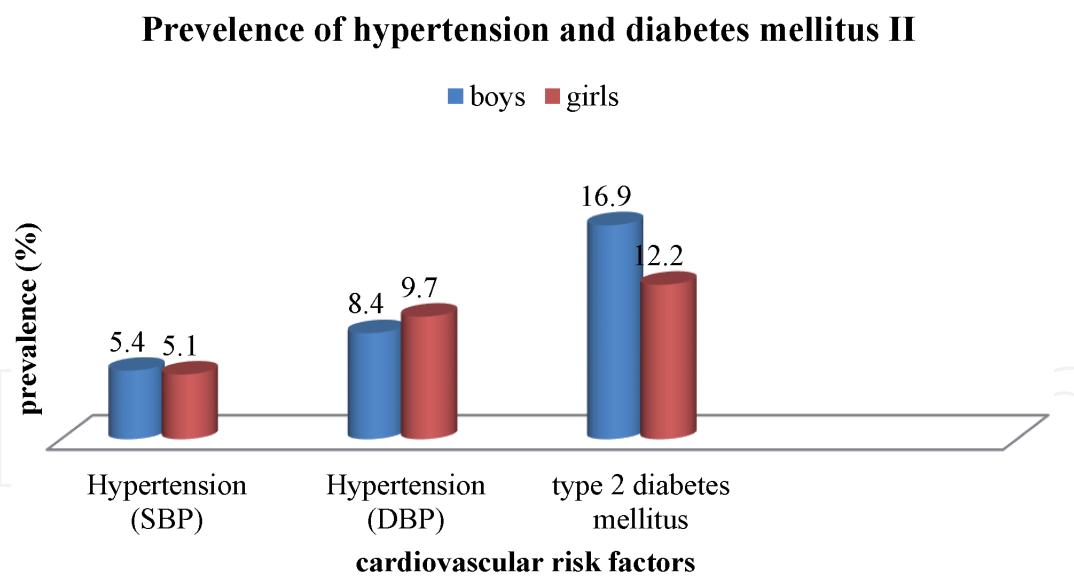

Figure 2.
Gender-specific prevalence of hypertension and type 2 diabetes mellitus among Ellisras children age 6 to 11 years. The prevalence of hypertension defined by SBP was higher in boys (5.4%) than in girls (5.1%), hypertension defined by DBP was higher in girls (9.7%) than in boys (8.4%) and that of type 2 diabetes mellitus was higher in boys (16.9%) as compared to girls (12.2%).

3. Results

Table 1 showed descriptive statistics of anthropometric parameters, blood pressure and fasting blood glucose stratified by gender. The study population comprised predominately boys (60%) with boy to girl ratio of 1.51:1. Boys showed higher mean values of age NC, WC, BMI and WHtR than girls. In contrast, girls had higher mean SBP, DBP and FBG values.

Table 2 showed positive correlation for systolic blood pressure with NC (0.261** and 0.252**), WC (0.276** and 0.208**) and NC (0.264** and 0.233**) in boys and girls respectively. Positive correlation was found for diastolic blood pressure with NC (0.176**), WC (0.272**) and BMI (0.212**) in boys. Negative correlation was found for fasting blood glucose with NC (−0.147*) and positive correlation for fasting blood glucose with BMI (0.176*)

Variables	Boys	Girls
Age (years)	9.637 (1.351)	9.341 (1.086)
SBP (mmHg)	96.621 (11.569)	97.740 (10.540)
DBP(mmHg)	65.426 (8.930)	66.300 (9.216)
FBG (mmol/L)	4.542 (1.900)	4.707 (1.160)
BMI (kg/m^2)	14.411 (1.203)	14.182 (1.368)
NC (cm)	25.850 (1.350)	25.287 (1.275)
WHtR	0.411 (0.022)	0.407 (0.023)
WC (cm)	54.720 (3.153)	53.853 (3.354)

M = Mean; SD = standard deviation; NC = Neck Circumference (cm); WC = waist circumference (cm); BMI = body mass index (kg/m^2); WHtR = waist to height ration; SBP = systolic blood pressure (mmHg); DBP = diastolic blood pressure (mmHg); FBG = fasting blood glucose (mmol/L).

Table 1.
Descriptive statistics of anthropometric parameters, systolic and diastolic blood pressure and blood glucose of Ellisras children age 6 to 11 years.

	SBP		DBP		FBG	
	Boys	Girls	Boys	Girls	Boys	Girls
FBG	−0.029	0.075	0.044	0.131		
NC	0.261**	0.252**	0.176**	0.102	−0.147*	−0.027
WC	0.276**	0.208**	0.272**	0.065	−0.065	0.111
BMI	0.264**	0.233**	0.212**	0.096	−0.004	0.176*
WHtR	−0.046	0.058	0.064	0.025	0.031	0.035

***p < 0.001; *p < 0.05 statistical significant; NC = Neck Circumference (cm); WC = waist circumference (cm); BMI = body mass index (kg/m^2); WHtR = waist to height ration.*

Table 2.
Pearson correlation coefficient (r) of blood pressure (systolic and diastolic) and blood glucose with anthropometric parameters.

	Unadjusted			Adjusted for age and sex		
Para meters	β	P-value	95%CI	B	P-value	95%CI
Systolic blood pressure						
BMI	0.244	<0.001	1.390–2.901	0.161	<0.001	0.942–2.529
WC	0.240	<0.001	0.528–1.120	0.186	<0.001	0.296–2.072
WHtR	−0.009	0.838	−49.434–40.129	0.069	0.135	−10.957–80.784
NC	0.242	<0.001	1.294–2.724	0.197	<0.001	0.780–2.485
Diastolic blood pressure						
BMI	0.156	<0.001	0.487–1.731	0.072	0.004	0.319–1.640
WC	0.177	<0.001	0.249–0.734	0.171	<0.001	0.190–0.758
WHtR	0.043	0.337	−18.486–53.846	0.091	0.053	−0.463–75.012
NC	0.134	0.003	0.307–1.488	0.120	0.026	0.098–1.515
Fasting blood glucose						
BMI	0.046	0.312	−0.056–0.173	0.083	0.081	−0.014–0.229
WC	−0.018	0.692	−0.054–0.036	0.034	0.516	−0.035–0.070
WHtR	0.027	0.551	−4.582–8.586	0.011	0.824	−6.137–7.704
NC	−0.120	0.008	−0.254–-0.039	−0.104	0.054	−0.257–0.002

P value < 0.05 = statistical significant; CI = confidence interval; β = beta; NC = Neck Circumference (cm); WC = waist circumference (cm); BMI = body mass index (kg/m^2); WHtR = waist to height ration.

Table 3.
Linear regression analysis for the association of anthropometric parameters with, blood glucose and blood pressures.

Table 3 shows the linear regression for the association of anthropometric parameters (NC, BMI, WC and WHtR) with DBP, SBP and FBG. There was a significant association of SBP with BMI (β = 0.244, 95%CI = 1.390–2.901), WC (β = 0.240, 95%CI = 0.528–1.120) and NC (β = 0.242, 95%CI = 1.294–2.724).

Table 4 showed binary logistic regression analysis for determining the odds of high blood pressure and high blood glucose using anthropometric parameters. After multivariate adjustment by age and gender, BMI (P = 0.046, β = 1.340, 95% CI = 1.005–1.788) showed to have significantly greatest odds for high SBP followed by WC (P = 0.025, β = 1.143, 95% CI = 1.017–1.285).

	Unadjusted		Adjusted for age and gender
	Systolic blood pressure		
Parameters	**OR(95% CI)**	**P value**	**OR (95% CI)**
BMI	1.340 (1.005–1.788)	0.046	1.258(0.925–1.709)
NC	1.208 (0.903–1.617)	0.203	1.080(0.763–1.530)
WC	1.143 (1.017–1.285)	0.025	1.115(0.975–1.276)
WHtR	1.510 (1.106–1.666)	0.579	1.413(0.752–1.777)
Diastolic blood pressure			
BMI	1.150 (0.909–1.456)	0.244	1.210(0.941–1.558)
NC	1.076 (0.856–1.354)	0.529	1.189(0.901–1.571)
WC	1.069 (0.973–1.174)	0.164	1.120(1.004–1.249)
WHtR	1.042 (0.144–1.317)	0.092	0.172(0.093–3.181)
Fasting blood glucose			
BMI	0.987 (0.827–1.177)	0.884	1.009(0.838–1.215)
NC	0.831 (0.701–0.986)	0.034	0.813(0.663–0.998)
WC	0.975 (0.910–1.045)	0.479	0.983(0.907–1.066)
WHtR	0.137(0.124–1.432)	0.083	0.978(0.809–1.183)

P value < 0.05 = statistical significant; CI = confidence interval; OR = odds ratio; NC = Neck Circumference (cm); WC = waist circumference (cm); BMI = body mass index (kg/m^2); WHtR = waist to height ration.

Table 4.
Binary logistic regression analysis of anthropometric parameters with systolic and diastolic blood pressure.

4. Discussion

The main purpose of the study was to determine the relationship of blood pressure, blood glucose with anthropometric parameters among Ellisras children aged 6 to 11 years old and several major findings emerged.

The present study showed that NC is significantly associated with blood glucose, which corroborates the previous findings that increased NC is an emerging risk factor for high blood glucose [12]. However, it is difficult to explain in the present study why only NC was associated with fasting blood glucose, although BMI, WC and WHtR are also anthropometric parameters. One possible explanation for these findings may be that different anthropometric parameters have varied impact on blood glucose. The mechanism linking anthropometric parameters with blood glucose levels is not clear but main schools of thought on the matter suggest different mechanisms. Firstly, in obesity (i.e WHR >0.90 or BMI >30 kg/m2), abundance of circulating fatty acids and liver-derived triglyceride (VLDL) provide an excellent fuel for muscle, decreasing their requirement for glucose [13]. People with obesity tend to be sedentary, and thus muscle consumes less glucose [14]. In obesity, increased delivery of fatty acids to the liver (as in visceral obesity) enhances gluconeogenesis and thus leading to production of glucose [15]. In obesity the increased fatty acid cause insulin resistance directly by activating enzymes that decrease the response to insulin, thereby aggravates the pre-existing insulin resistance which results in elevated blood glucose level and eventually type 2 diabetes mellitus [16].

The study also demonstrated that NC, WC and BMI are significantly associated with blood pressure, which confirms the observations of the previous findings around the relationship between mean anthropometric parameters and blood pressure values [4, 7, 17]. However, the precise mechanism by which anthropometric parameters act to increase blood pressure is not fully understood. One possible mechanism is linked to the prognostic importance of visceral adipose tissue assessments by WC rather than general obesity assessments by BMI [18, 19]. Visceral adipose tissue produces angiotensinogen, interleukin-6 and leptin [20]. An imbalance in production of these adipokines, particularly angiotensinogen leads to the activation of the rennin-angiotensin system, causing vasoconstriction and reabsorption of sodium [20]. The constriction of blood vessels increases blood pressure and eventually the development of high blood pressure.

This study has several limitations. Firstly this is a cross sectional study and does not allow establishment of cause-effect relationship, secondly the study model does not provide information regarding the ability of anthropometric parameter to future health outcome, and lastly the study was conducted in rural areas in Ellisras so the findings might not be generalizable to the overall Ellisras population.

5. Conclusion

The study shows that both blood glucose and blood pressure are associated with some anthropometric parameters. These findings suggest that it is crucial to manage and control traditional risk factors in rural South African communities in Ellisras in order to decelerate the increase in obesity, hypertension and type 2 diabetes mellitus and to reduce the burden of cardiovascular disease. The present study highlights the need of incorporating body mass index (BMI), waist circumference (WC), neck circumference (NC) and waist-height ratio (WHtR) while evaluating the association of easily accessed anthropometric parameters with CVD risk factors.

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Conflict of interest

The authors declare no conflict of interest.

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