Association of waist and hip circumferences with the presence of hypertension and pre-hypertension in young South African adults.

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Abstract

Background: Obesity is one of the most important risk factors for cardiovascular diseases (CVDs) including hypertension (HT) which is itself a risk factor for CVDs. Recent studies suggest that waist circumference (WC) may be more sensitive than Body Mass Index (BMI) in determining individual risk scores for CVDs.

Objectives: The current study aimed at investigating the influence of various anthropometric variables on blood pressure status in a group of students from Walter Sisulu University.

Methods: Informed consent was obtained from 216 male and female students from Walter Sisulu University with a mean age of 22.1±0.2 years. Anthropometric measurements were performed for each participant. Blood pressure was measured in triplicates after 10 minutes of rest and the average computed.

Results: Just over 46% of the subjects were diagnosed with hypertension (HT) and pre-HT. The gender specific prevalence of HT/pre-HT was higher in the male (76.7%) compared to the female (30.5%) group. Waist circumference (WC) and total body fat (TBF) correlated significantly with blood pressure and HT/pre-HT in females but not males. ROC analysis showed that with the exception of waist-to-hip (WHR), all other anthropometric measurements and ratios studied can be used to discriminate blood pressure in young adult females not males.

Conclusion: Increased WC and HC were associated with HT and pre-HT in young adult females in the Walter Sisulu University.

Keywords: anthropometry, waist circumference, hip circumference, hypertension, pre-hypertension

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Introduction

The prevalence of obesity has reached epidemic proportions in both industrialized and developing countries: urban and rural communities alike. Several studies have reported elevated blood pressure associated with increasing adiposity[1]. Obesity is an important primary health care problem as it is associated with many other conditions including HT[2-4]. Both obesity and HT are important risk factors for cardiovascular diseases. Obesity is generally assessed using BMI which gives information on the distribution of weight with respect to height but fails to give insight into adipose tissue distribution phenotype. Evidence gathered from several studies shows that central obesity (accumulation of fat in the abdominal area) is a greater risk factor for CVDs compared to other types of obesity[5-7] hence the need to know the distribution of fat in patients to facilitate assessment of patient's risk profile for CVDs. This has led investigators to use various anthropometric measurements such as WC, HC, WHR, waist-to-height ratio (WHtR), visceral fat (VF) and total body fat (TBF) as well as skin fold thickness[8-10] to establish which of these variables would show better association with CVDs or help predict risk.

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The Jackson Heart Study showed a strong association between VF as measured by WC and cardiometabolic risk factors in adult African Americans even after accounting for BMI[11]. Importantly this team showed that though African Americans had lower VF mass than the Caucasian and Asian populations, WC was associated with higher blood pressure in African Americans but not in the other two races[12].

Cardiovascular diseases are the second most common cause of death after infectious diseases accounting for 11% of total deaths in developing countries[13]. Importantly, these deaths occurred mostly in the economically active sector of the population (35-65 years old). In South Africa, approximately 195 people die every day from CVD related causes[14]. Indeed CVDs are the second leading cause of death after HIV and accounted for up to 40% of deaths among South African adults in 2008[15] compared to only 32% in the USA in 2010[16]. The World Health Organization has predicted that CVDs will dominate the global mortality trend in the next few years[17].

Even though several studies have shown an association between anthropometric variables and the risk for CVD in many populations, very few studies have investigated the relationship between anthropometric measurements and blood pressure in young South Africa Adults[18]. The aim of this study was therefore to investigate the relationship between various anthropometric measurements and blood pressure in Walter Sisulu University students.

Methods

A cross sectional study was carried out on the Walter Sisulu University, Nelson Mandela Drive campus in Mthatha. Mthatha is a peri-urban community which is the feeder town for many rural localities. Participation was voluntary and the convenience sampling method was used. All participants were required to sign a consent form after the purpose of the study was explained to them. Anthropometry and blood pressure measurements were performed in the comfort of each student's room in the various student residential halls. Male and non-pregnant, non-lactating female student of Walter Sisulu University aged between 19 and 31 years old were included in the study.

Height

All participants were requested to take off all shoes and headgears for this procedure. Height was measured while the participant was standing with heels together against the stadiometer with the body held in a maximally erect position and hands placed on hips and head held in the Frankfurt plane[19]. Height was measured to the nearest 0.1 cm.

Waist and hip circumference measurements

Waist and hip circumferences were measured using WHO STEPS protocol. Briefly, participants were advised to stand erect with both feet together, arms at the side and not retract abdomen during measurement[20]. A non-elastic measuring tape was used to determine WC at the smallest diameter of the waist and HC at the widest diameter of the buttocks. All measurements were recorded to the nearest cm.

Weight determination

Weight was determined using the Omron Body Composition Monitor BF511 which was calibrated to each individual's data using age, sex and height. Participants were requested to take off all heavy clothing, shoes and socks and to step with bare feet on to the equipment's feet electrodes. Weight was measured to the nearest 0.1 kg while participants stood with hands on the monitor's horns and held at waist level. When weight was read, participants stretched their arms forward while holding them at right angles to their bodies until the LCD screen stopped scanning. Weight, TBF, VF and BMI were automatically calculated and displayed. Bosy-Westphal, et al.[21] validated this instrument as reliable for body composition monitoring[21]. Obesity was defined as BMI ≥30 kgm-2[22]

Blood pressure measurement

Blood pressure was measured using the right arm for all participants after 10 minutes of rest in the seated position using a Microlife BP monitor which is accredited by the British Hypertension Society. Arm size appropriate cuffs were selected for participants. The cuff was placed and evenly tightened around the upper right arm 2 cm away from the elbow joint. Systolic and diastolic blood pressure as well as heart rate were automatically measured by the BP monitor. Three blood pressure measurements were taken and the average values computed. Normal blood pressure was defined as mean systolic blood pressure (MSBP) <120 mmHg and mean diastolic blood pressure (MDBP) <80 mmHg, pre-hypertension as MSBP from 120-139 mmHg and MDBP from 80-89 mmHg while hypertension was defined as MSBP ≥140 mmHg and MDBP ≥90 mmHg (Meier et al, 2013)[23].

Statistical analysis

Descriptive statistics were computed for anthropometric measurements and blood pressure in the whole cohort and in sex specific groups. SPSS version 22.0 statistical software (SPSS Inc., Chicago, IL) was used to determine the relationship between MSBP and MDBP with individual anthropometric variables. Results were expressed as mean±sem. P-values <0.05 were considered significant. Pearson's correlation coefficients were obtained from linear regression analysis of the relationship between blood pressure and anthropometric measurements. Receiver operating characteristic curves were constructed to determine the ability of anthropometric variables to discriminate high blood pressure in females and males.

Results

Two hundred sixteen participants were recruited into the study however complete data was obtained from 214 participants. The average age of participants was 22.1±0.2 years though the females were significantly younger than males (21.7±0.3 yrs vs 22.9±0.4 yrs; $p<0.05$). Females were significantly shorter and weighed less than the males (Table 1).

Table 1: Descriptive statistics of research subjects.

	Whole Group	Male Subjects	Female Subjects
No. of subjects	216	74	142
Age (yrs)	22.1±0.2	22.9±0.4	21.7±0.3*
Height (cm)	163.5±0.6	171.8±0.8	159.7±0.6**
Weight (kg)	66.5±0.8	68.2±1.5	65.7±1.1
BMI (kg/m^2)	25.7±0.8	25.2±2.0	26.1±0.6
WC (cm)	77.3±0.6	76.1±1.1	77.9±0.9
HC (cm)	100.1±0.8	90.1±1.0	102.1±1.1**
Visceral fat (%)	5.2±0.2	5.6±0.4	5.1±0.3
Total fat (%)	16.5±2.1	21.3±0.9	43.1±3.0**
WHR	0.84±0.08	0.79±0.01	0.88±0.12
WHtR	0.47+0.01	0.44±0.01	0.49±0.01**
Mean SBP (mm Hg)	118±1	125±2**	115±1
Mean DBP (mm Hg)	73±1	77±2**	72±1

BMI = body mass index; WC = waist circumference; HC = hip circumference; WHR = waist-to-hip ratio; WHtR = waist-to-height ratio; SBP = systolic blood pressure; DBP = diastolic blood pressure. *$p<0.05$; **$p<0.01$.

Females tended to have higher BMI and WC compared to males though the differences were not statistically significant. Females also had significantly bigger HC (102.1±1.1 cm vs 90.1±1.0 cm; $p<0.01$) and higher TBF (43.1±3.0 % vs 21.3±0.9%, $p<0.01$). Although females were shorter than males, they had significantly higher WHtR (0.49±0.01 vs 0.44±0.01, $p<0.01$) compared to males. Males on the other hand had significantly higher MSBP (125±2 mm Hg vs 115±1 mm Hg, $p<0.01$) and MDBP (77±2 mm Hg vs 72±1 mm Hg, $p<0.01$) compared to females.

The relationship between MSBP/MDBP and various anthropometric measurements was determined using Pearson's correlation coefficients. In females, there was a moderate and statistically significant correlation between mean MSBP and BMI WC (r=0.360), HC (r=0.292) and TBF (r=0.22). Mean DBP also correlated significantly but moderately with WC (r=0.216) and TBF (r=0.374). In males on the other hand only weak and non-significant correlations were noted between mean MSBP/MDBP and all anthropometric measurements studied (Table 2).

Table 2: Linear regression between anthropometric variables and blood pressure

	Correlation coefficients / p-value	
	Females	Males
Effect of BMI on MSBP	0.196 / 0.020	0.052 / 0.661
Effect of BMI on MDBP	0.029 / 0.732	0.031 / 0.792
Effect of WC on MSBP	0.360 / 0.000	0.200 / 0.092
Effectof WC on MDBP	0.216 / 0.010	0.136 / 0.171
Effect of HC on MSBP	0.292 / 0.000	0.105 / 0.387
Effect of HC on MDBP	0.163 / 0.054	0.041 / 0.736
Effect of VF on MSBP	0.175 / 0.039	0.099 / 0.406
Effect of VF on MDBP	0.003 / 0.973	0.071 / 0.549
Effect of TBF on MSBP	0.220 / 0.009	0.044 / 0.711
Effect of TBF on MDBP	0.374 / 0.000	0.009 / 0.93

BMI = body mass index; WC = waist circumference; HC = hip circumference; VF = visceral fat; TBF = total fat mass. MSBP = mean systolic blood pressure; MDBP = mean diastolic blood pressure.

The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure guidelines[25] were used to classify subjects as either normotensive or HT/pre-HT. A higher proportion of female compared to male subjects were classified as normotensive. Table 3 shows that over 53.9% of the participants (45.8% females and 7.9% males) were normotensive while 46.1% of participants (20.0% females and 26.1% males) were HT/pre-HT.

Table 3: Prevalence of HT and pre-HT

	Whole group	Females	Males
Sample size	214	141	73
Normotensive (n)%	116 (54.2%)	98 (69.5%)#	17 (23.3%)#
Pre-HT (n)%	86 (40.2%)	40 (28.4%)#	46 (63.0%)#
HT (n)%	13 (6.1%)	3 (2.1%)#	10 (13.7%)#

Pre-HT = pre-hypertensive; HT = hypertensive; where pre-HT is defined as SBP of 120-139 mmHg or DBP of 80-89mmHg; HT as SBP ≥140 mmHg and DBP≥90 mmHg 25]. # proportion of normotensive, pre-HT or HT in sex specific groups. Gender specific ratios were calculated for males and females.

Gender specific analysis showed that many more females were normotensive compared to males (69.5% vs 23.3%). The overall prevalence of pre-HT in the male cohort was 73.0% compared to 28.4% in females while the prevalence of HT was 13.7% in males compared to only 2.1% in females.

The differences in anthropometric data between normotensive and pre-hypertensive subjects were explored in Table 4. Hypertensive and pre-hypertensive participants were slightly older than the normotensive subjects. Hypertensive and pre-HT subjects had significantly higher, HC (102±1.1 vs 98.7±1.2) and BMI (25.4±0.5 vs 24.3±0.3) and VF (35.7±0.3 vs 34.7±0.1).

Table 4: Comparison of anthropometric data between normotensive and HT/pre-HT subjects.

	Normotensive	HT/Pre-HT	p-value
Age (yrs)	21.9±0.3	22.3±0.4**	<0.01
BMI (kg/m^2)	24.8±0.7	26.9±1.5**	<0.01
WC (cm)	75.4±0.8	79.4±1.1	>0.05
HC (cm)	98.7±1.2	102±1.1**	<0.01
Visceral fat (%)	4.8±0.1	5.7±0.3	>0.05
TBF (%)	35.7±0.8	34.7±4.3**	<0.01

BMI = body mass index; WC = waist circumference; HC = hip circumference; HT/pre-HT = hypertensive/pre-hypertensive. **p<0.01.

The presence of HT/pre-HT correlated moderately and significantly with WC in both females and males (r=0.345; r=0.237 respectively) while a significant moderate correlation was observed with HC (r=0.323) and VF (r=0.236) only in females. The HT/pre-HT status correlated less well with BMI even though participants with HT/pre-HT had higher BMI compared to normotensive participants (Table 5). There was a much weaker and non-significant correlation of HT/pre-HT with HC, VF and TBF in males.

Table 5: Correlation between HT/pre-HT and anthropometric measurements

	Correlation coefficient/p-value	
	Females	Males
BMI	0.197/0.019	0.106/0.374
WC	0.345/0.000	0.237/0.045
HC	0.323/0.000	0.201/0.095
VF	0.236/0.005	0.138/0.244
TBF	0.192/0.023	0.037/0.756

BMI = body mass index; WC = waist circumference; HC = hip circumference; VF = visceral fat; TBF = total body fat.

Table 6 shows data obtained from univariate analysis by receiver operating characteristic curves (ROC) where the area under the curve greater than 0.5 indicates a positive predictive power while lower values show less predictive power. Indeed the AUC is a measure of the degree of accuracy in prediction. The accuracy of the test depends on how well the test separates the group being tested into those with and without the condition in question. Accuracy is measured by the area under the ROC curve (AUC) as follows: AUG of 0.90-1 = excellent; 0.80-0.90 = good; 0.70-0.80 = fair; 0.60-0.70 = poor; 0.50-0.60 = Fail test. All studied anthropometric measurements and ratios with the exception of WHR showed significant ability to discriminate higher blood pressure in young adult females. In males on the other hand only WC and WHtR had good predictive ability for higher blood pressure while TBF had only a weak predictive power. For similar data, the AUC was significantly higher in females than in males except in the case of WHR which was lower and non-significant in females compared to males.

Table 6. Receiver operated characteristic curve analysis of relationship between HT/pre-HT status and anthropometric measurements.

		AUG	SE	95% CI	p-value
Females	BMI	0.777	0.047	0.685-0.870	0.000
	WC	0.749	0.047	0.658-0.840	0.000
	HC	0.769	0.047	0.675-0.858	0.000
	TBF	0.778	0.048	0.684-0.877	0.000
	WHtR	0.716	0.051	0.616-0.816	0.000
	WHR	0.594	0.054	0.488-0.700	0.000
Males	BMI	0.610	0.067	0.479-0.741	0.000
	WC	0.676	0.067	0.553-0.799	0.018
	HC	0.620	0.067	0.489-0.752	0.111
	TBF	0.531	0.074	0.378-0.675	0.675
	WHtR	0.658	0.065	0.530-0.785	0.033
	WHR	0.634	0.066	0.504-0.764	0.070

Discussion

It is important to determine valid anthropometric measurements which may be useful for predicting obesity-related cardiovascular disease risk in young adults. In this study we demonstrated that five anthropometric measurements (BMI, WC, HC, TBF and WhtR) were more consistent in predicting CVD risk as determined by presence of HT/pre-HT than WHR in females while in males besides WC all the other anthropometric measurements were only weakly associated with CVD risk. Linear regression studies showed that both BMI and percentage TBF correlated only weakly with HT/pre-HT. This observation corroborates previous findings which showed that TBF had no advantage over BMI and WC in predicting obesity related complications and metabolic conditions[26,27]. Indeed Després argued that because there is a wide range of WC for every BMI value, it will be simplistic to think that WC is a better measure of CVD risk over BMI especially given that WC may be influenced by subcutaneous or VF[26]. On the other hand, WC and HC correlated moderately with HT/pre-HT in both males and females while VF showed a moderate relationship only in females.

Unlike BMI, WC correlated strongly with both systolic and diastolic blood pressures in females while HC correlated well with Systolic blood pressure only. However, neither of these two anthropometric measurements had a strong influence on blood pressure values in males. Furthermore, TBF was modestly related to both systolic and diastolic blood pressures. Indeed Choy et al,[28] showed an association between increased WC and raised blood pressure. Although several studies have shown that a larger HC is protective against HT and metabolic diseases[29,30], our study showed such protection in males only while larger HC was associated with higher blood pressure in females. Some of these studies which showed that a large HC confers protection against CVDs also demonstrated that without controlling for BMI or WC, HC was associated with higher blood pressure in females[33,34]. Indeed, an Australian study[35] showed that HC was independently associated with increased risk for CVD in Aboriginal Australians, this relationship was however lost when BMI and WC were accounted for in their study population.

Waist circumference correlated well with higher blood pressure in both males and females. Waist circumference is a measure of abdominal obesity and is related to percentage abdominal fat mass. These results corroborate the findings of Liu et al,[11] who showed a strong association between WC and cardiometabolic risk in African Americans irrespective of BMI. Indeed several studies have shown that WC may be a more sensitive predictor of CVD risk than the other measures of obesity[31,32]. However, VF was also associated with higher blood pressures only in females and not males.

In our study of ROC analysis, WHR was weaker in predicting HT/pre-HT compared to WHtR which showed a significant discriminatory capacity between high and normal blood pressure in both males and females. Indeed Lee et al,[27] and Tatsumi et al,[36] showed that WHtR was a better predictor of CVDs in Japanese women compared to WC. These authors showed that WC and WHtR were more closely associated with metabolic risk factors than other indices of general adiposity. These authors also demonstrated the fact that there was a weak relationship between WHR and blood pressure in females. This observation could be explained by the fact that in the effect of WHR the effect of WC is often masked by the increase in HC which generally accompanies a big WC.

Conclusion

We found that higher waist and hip circumferences were modestly associated with the presence of HT/pre-HT in South African young adult females of African ancestry, thus highlighting the importance of weight management in the prevention of cardiovascular diseases in this population.

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