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Physiological and anthropometric correlates of metabolic risk factors among selected non obese adults in Zaria, Northern Nigeria

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Recent publications on clinical definitions have transformed the metabolic syndrome from a physiological curiosity to a major focus of research, clinical and public health interests on non obese adults. The purpose of this study therefore, was to determine the relationship between anthropometrics and cardiometabolic variables that reflect the existence of metabolic syndrome among non obese adults. One hundred and seventy four (174) adults, with mean age of 47.13 ± 8.10 (male) and 44.96 ± 9.58 (female) were recruited for this cross sectional study. Descriptive statistics, partial correlation and multiple regression analysis were used to determine the relationship between anthropometric measurements and cardiometabolic variables after controlling for age. Anthropometric indices, lipid profile, fasting glucose and blood pressure were among the variables assessed using standard procedures. The best correlation among the anthropometrics ($p \leq 0.05$) was presented between waist circumference and waist-height ratio (male r = 0.925, female r = 0.916) and body fat (%) and fat mass (male r = 0.956, female r = 0.944). Fat mass, waist-height ratio and waist circumference in male and waist-height ratio in female were found to have the largest correlation relative to at least 3 risk factors. Combination of three components of cardiometabolic risk factors were significantly more in male than female. Regression analysis also showed that waist-height ratio appears optimal for predicting components of cardiometabolic risk factors among non obese adults. Among all obesity measures studied, waist-height ratio, waist circumference and fat mass explained comparatively larger amount of variance of cardiometabolic risk factors among non-obese adults. Non obese male were significantly more likely to have two or more risk factors than female participants. However, the greater risk of developing metabolic syndrome was associated with increasing waist-height ratio, which could be used as simple and non-invasive method for detecting dyslipidemia among non obese adults, and use of this method was suggested in clinical and epidemiological fields.

Key words: Metabolic syndrome, non obese adults, anthropometric indices.

INTRODUCTION

Obesity and its associated metabolic abnormalities have been the focus of many researchers lately, especially

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physiologists, epidemiologists and geneticists. More so, there are individuals who by standard weight/body mass index (BMI) tables are not obese or even overweight, but who have metabolic abnormalities that are characteristically associated with adult onset obesity. The constellation of these abnormalities also known as metabolic syndrome (MetS) have been widely investigated (Song et al., 2006; Opie, 2007; Zhao et al., 2010).

International Diabetes Federation (IDF) proposed a definition for MetS for use in epidemiology studies and clinical practice, which would allow for comparison between different population groups and the assessment of its relationship with various health outcomes (Motala et al., 2009). The IDF, (2005) defined a participant as having MetS if he or she had central obesity (Ethnicity specific waist circumference values) plus at least 2 of the following criteria: (1) triglyceride level ≥ 1.7 mmol/L; (2) reduced high density lipoprotein-cholesterol (HDL-C) levels of less than 1.03 mmol/L in men, less than 1.29 mmol/l in women; (3) raised systolic or diastolic blood pressure of 130/85 mmHg or higher, or previously diagnosed hypertension; and (4) raised fasting plasma glucose level of 5.6 mmol/L or higher, or previously diagnosed type 2 diabetes mellitus (T2DM) (Cornier et al., 2008).

A prerequisite in the IDF definition of the MetS is central obesity measured by ethnicity-specific waist circumference and it is recommended that European cut points be used for populations for which such data are not available, for example in Sub-Saharan Africans (Motala et al., 2009). Because risk factors cluster, and because the cardiovascular risk factors for the MetS are linear in their damaging effects, different definitions of the metabolic syndrome make little difference in the prognostic implications (Opie, 2007). Although data in the developing countries and particularly in the sub-Saharan African remain scarce (Okosun et al., 2000; Addo et al., 2007; Motala et al., 2009; Kimani-Murage et al., 2010), high prevalence of MetS has often been documented in developed countries and increasingly so in developing countries (Ford et al., 2008; Kjeldsen et al., 2008; Rufus et al., 2008).

Measurement of waist circumference is recommended by the US National Cholesterol Education Program (NCEP) for the assessment of central obesity, whereas the World Health Organization (WHO) recommends waist-hip ratio (WHpR) for the same purpose. All of the mentioned anthropometric indices have been found to be associated with all-cause mortality, diabetes mellitus, cardiovascular morbidity and mortality in prospective studies (WHO, 1997; Ahmet et al., 2008). Some authors have proposed waist-height ratio (WHtR) as the best anthropometric index to predict cardiovascular disease (CVD) risk, and MetS and hip circumference (HC) has been found to be inversely associated with diabetes, CVD morbidity and mortality in a prospective study (Lissner et al., 2001; Hsieh and Muto, 2006).

The results of prospective and cross-sectional studies that have attempted to find the best anthropometric index are not uniform, studies from the Eastern Mediterranean area do not agree on the best anthropometric index to predict cardiometabolic risk (Yalcin et al., 2005; Ahmet et al., 2008). Work in Turkey has suggested that WHpR might better indicate CVD risk than BMI and WC, the same study also showed that both WC and WHpR were strongly associated with BMI, age, diastolic blood pressure and plasma triglyceride (TG); also, WHpR was significantly associated with prevalent coronary heart disease (CHD) only in Turkish women. Fasting glucose, insulin, HDL cholesterol (HDL-C) and Low density lipoprotein cholesterol (LDL-C) levels were not ascertained, and the association of anthropometric indices with MetS was not reported in that study (Onat et al., 1999). On the other hand, Kayode et al. (2009) showed in their study that WHtR and abdominal height (measured as the distance from the exam table to the top of the belly when the patient is lying supine) predicted CVD than any other anthropometric measurement including BMI, WC, WHpR and skin-fold thickness.

The Japanese Society of Internal Medicine also announced a definition of the MetS for the Japanese which is now used in Japan. Most of these definitions employ WC as an indicator of central or abdominal obesity. However, several reports have argued that other indices, for example the WHtR and WHpR are superior to WC for identifying subjects with cardiovascular risk factors. In particular, reports from Japan have proposed using the WHtR (Ishikawa-Takata et al., 2002; Masayuki et al., 2008). Little is known about the relationship between the anthropometric indices and various metabolic disorders in Nigerian adult population (Okosun et al., 2000; Olatunbosun et al., 2000) and there has been paucity of recent literatures relating to local incidence, particularly in Kaduna, Nigeria (Bello-Sani et al., 2007).

The aim of this study is to investigate the interrelationship between anthropometrics and MetS among non-obese adults of Zaria, Northern Nigeria. This study will attempt to investigate the correlations between anthropometric indices and risk factor accumulation (RFA) defined as the existence of any two (or three) of the following disorders: hypertension, dyslipidaemia (defined by high TG and/or low levels of HDL) and fasting hyperglycaemia, each of which is a component of MetS (Masayuki et al., 2008), and their cut-off points in this study were based on the IDF (2005) criteria of metabolic syndrome because they consider the sub-Sahara Africans in their values.

Statements of hypotheses

On the basis of previous research evidences, it was hypothesized that there are no significant relationships among anthropometric indices and RFA, and that central adiposity does not predict metabolic risk factors better than overall obesity.

MATERIALS AND METHODS

Research design

This study is a correlational research that cross-sectionally examines the covariation among some physiological and anthropometric indices, and assess their predictability as regards to metabolic risk indicators.

Sampling technique

The subjects for this study were form Zaria, northern Nigeria; based on interest and willingness to participate in the study. The stratified random sampling technique was used to stratify the subjects by wards, and subjects were subsequently constituted by using purposive sampling technique. These were adopted because only subjects who satisfied the predetermined exclusion and inclusion criteria of being healthy, non-obese and aged 35 to 70 years were selected for the research. The criteria for BMI (Lincoln et al., 2002) were adopted to assess obese and non-obese subjects.

Study population

The participants for this study were 174 male and female adults in Zaria; northern Nigeria; aged between 35 and 70 years. The subjects were not obese, not on any special diet and not hypertensive or diabetic (if so, medically controlled). Exclusion criteria also include diagnosed major medical conditions such as CHD and kidney disease. Also, subjects on any medication known to influence energy regulation were not included. The subjects were certified fit by a physician at the Ahmadu Bello University Teaching Hospital (ABUTH), Family Medicine Out-Patient Department, and were adequately informed about the rationale behind this study. In addition, participating adult female subjects were ensured not to have been pregnant or had a laparotomy procedure in the past 2 years.

Study site

This study was carried out between May and October, 2011 in Zaria, Kaduna state, Northern Nigeria. Zaria is a cosmopolitan city, inhabited by about 408,198 people as stated by the 2006 census report and is the second largest city in Kaduna state. It is located at latitude 11° 3' N and longitude 7° 42' N. The city lies on the high plains of Northern Nigeria, in the Sub-Saharan Africa. It is about 643.7 km from the coast of Nigeria. Different tribes and ethnic groups could be found in Zaria, the three major ethnic groups: Hausa, Yoruba and Igbo and minorities grouped together as others. Zaria has many tertiary institutions of learning and research, including Ahmadu Bello University, Zaria. The climate is savannah with annual rainfall ranging from 0.0 to 816.0 mm/month and minimum and maximum temperature of 15.3 and 36.25°C, respectively (Avidime et al., 2011).

Instruments

The equipments for this study were stadiometer, weighing scale, sphygmomanometer, tape rule measure, skinfold caliper, stopwatch and spectrophotometer. The IDF (2005) guideline of the MetS with ethnic specific WC for Sub-Sahara Africans was used as the main outcome measures. Normal-weight BMI was defined as a range of 18.5 to 24.9 kg/m^2 and overweight BMI ≤ 27 kg/m^2 was considered because BMI ≥ 28 kg/m^2 has been shown to be a significant prognostic factor for all-caused and cardiovascular mortality among adults (Asefeh et al., 2001; Ofei, 2005).

Ethical committee approval

This research was submitted to the Joint Institutional Scientific and Ethical Committee of the Ahmadu Bello University Teaching Hospital, Shika, Zaria, for review, screening and approval. The informed consent of the subjects was sought before they were included in the study and confidentiality was maintained in accordance with standard medical practice.

Format of testing

All the readings and measurements were carried out in the Department of Human Physiology Laboratory, Faculty of Medicine, Ahmadu Bello University, Zaria. Each subject in their gymnasium kits made a total of two visits to this same venue for the purpose of this study. The first visit was basically familiarization and screening of subjects to ensure their fitness for the study. All the exclusion and inclusion criteria were strictly observed. A routine BMI check for obese subjects was also carried out and consent forms signed. The actual readings and measurements were taken on the second visit. The subjects reported at 09.00 h in their gymnasium kits to the same venue in the morning of the appointed day (expected to have fasted for at least 12 h). They were allowed to rest for about 30 min after which the readings and measurements were taken as follows:

Anthropometric measurements

These were used for body composition assessments. The methodology is based on the assumption that body fat is distributed at various sites on the body specifically chest, abdomen and thigh in men; triceps, suprailiac and thigh in women (Gallagher et al., 1996). With the use of a skinfold caliper, the skinfold thickness in (mm) at these sites was taken twice, and the average at each site recorded. WC, weight, height and HC were also measured, and WHpR and WHtR were calculated.

Physiological parameters

These included the blood pressure, heart rate and blood sample analysis of TC, triglyceride (TG), HDL and fasting plasma glucose. LDL was calculated using the Friedewald´s formula:

LDL = TC – HDL - (TG / 2.17) mmol/l (provided TG values are less than 4.52 mmol/l).

Data analysis

Data was analyzed using statistical package for social sciences (SPSS Inc, version 16. 0; Chicago). Descriptive statistics of mean and standard deviation was computed for the purpose of data interpretation. Partial correlation analysis was used to identify the significance and trend of relationships among the variables.

Table 1. Anthropometric characteristics of the study participants.

Measurements	Male (n=91)	Female (n=83)
	Mean±SD	Mean±SD
Age (years)	47.13±8.10	44.96±9.58
Weight (kg)*	69.55±9.60	62.90±7.96
Height (cm)*	173.32±6.42	162.58±6.09
Waist circumference (cm)	87.90±8.17	86.87±7.70
Hip circumference (cm)*	93.37±6.12	99.27 ±6.48
Body mass index (kg/m^2)	23.13±2.73	23.78±2.42
Waist-hip ratio*	0.941±0.050	0.876±0.06
Waist-height ratio*	0.508±0.048	0.535±0.05
Percentage body fat (%)*	20.20±5.89	34.682±7.65
Fat mass (kg)*	14.40±5.47	22.14±6.55
Fat free mass (kg)*	55.154±6.034	40.763±4.68

*Statistical significant difference of equality of means at (95% CI, P ≤ 0.05; critical value: 1.960; Df: 172).

Correlations were considered significant at P ≤ 0.05 with critical values located at 0.2050 (male), 0.2172 (female). To find the variables that best prevent the prediction errors, the accuracy of simple and derived anthropometrics were assessed further by stepwise multiple regression analysis in which the data included the predictive variables that correlated with the RFA as dependent variables. Differences were considered significant at P ≤ 0.05.

RESULTS

Anthropometric characteristics of the study participants

Participants were within the BMI class of normal weight (male: 23.13 ± 2.73, female: 23.78 ± 2.42). A total of 56 subjects were excluded on the basis of the study criteria, the remaining 174 subjects were included in statistical analyses. The physical and anthropometric characteristics of study participants are summarized in Table 1. The mean age of study participants was 47.13 years for male and 44.96 years for female. Using statistical t-test of equality of means at confidence interval: 95%, P ≤ 0.05; critical value: 1.960; Df: 172, male were significantly taller (173.32 ± 6.42), with narrower hips (93.37 ± 6.12), smaller fat mass (14.40 ± 5.47) and higher resting energy expenditure (1571 ± 166.85) as compared to female (162.58 ± 6.09, 99.27 ± 6.48, 22.14 ± 6.55 and 1.347.17 ± 97.38), respectively. The waist-height ratio (0.535 ± 0.05) and fat% (34.682 ± 7.65) were higher in female than in male (0.508 ± 0.048, 20.20 ± 5.89), respectively. No significant difference was observed between males and females with respect to waist circumference (male: 87.90 ± 8.17, female: 86.87 ± 7.70) and BMI (male: 23.13 ± 2.73, female: 23.78 ± 2.42).

Clinical characteristics of the study participants

The summary of the clinical parameters of the study participants is shown in Table 2. Participants were normotensive (mean arterial blood pressure: 95.02 ± 12.76 in male and 99.398 ± 17.94 in female). Statistical mean values of the systolic blood pressure (127.03 ± 20.14), diastolic blood pressure (79.01 ± 10.76), mean arterial blood pressure (95.02 ± 12.76), and high density lipoprotein (0.944 ± 0.325) in male were lower than in female (132.77 ± 26.05, 82.71 ± 26.05, 99.398 ± 17.94, 1.150 ± 0.82, 0.955 ± 0.37), respectively. Triglyceride (1.37 ± 1.11) and total cholesterol (3.017 ± 0.83) were found to be slightly higher in male than female group (1.150 ± 0.82 and 3.017 ± 0.83), respectively. Statistical t-test of equality of means at (Confidence interval 95%, P ≤ 0.05; critical value: 1.960; Df: 172) did not show any significant difference except for pulse rate.

Relationships among measures of adiposity

Tables 3 and 4 show the relationships among all anthropometric variables that were examined in this study at critical value: 0.2050 (male), 0.2172 (female); P ≤ 0.05. In male, waist circumference exhibited the strongest correlation among the anthropometric variables studied (weight, r = 0.797**; BMI, r = 0.851**; waist-height, ratio r = 0.925**; waist-hip ratio, r = 0.727**; fat mass, r = 0.956**), followed by waist-height ratio (weight, r = 0.580**; BMI, r = 0.840**; waist circumference, r = 0.925**; waist-hip ratio, r = 0.807**; fat mass, r = 0.776**) as shown in Table 3. Similarly, in female, waist circumference exhibited the strongest correlation among the anthropometric variables studied (weight, r = 0.721**; BMI, r = 0.774**; waist-height ratio, r = 0.916**; waist-hip ratio, r= 0.692**; fat mass, r = 0.689**), followed by waist-height ratio (weight, r = 0.474**; BMI, r = 0.775**; waist circumference, r = 0.916**; waist-hip ratio, r = 0.666**; fat mass, r = 0.553**) as shown in Table 4. Comparatively,

Table 2. Clinical characteristics of the study participants.

Measurements	Male (n=91)	Female (n=83)
	Mean±SD	Mean±SD
Systolic blood pressure (mmHg)	127.03±20.14	132.77±26.05
Diastolic blood pressure (mmHg)	79.01±10.76	82.71±14.74
Pulse rate (beats/min)*	68.73±8.92	75.81±11.79
Mean arterial blood pressure (mmHg)	95.02±12.76	99.398±17.94
Total cholesterol (mmol/dl)	3.13±1.12	3.017±0.83
Triglyceride (mmol/dl)	1.37±1.11	1.150±0.82
High density lipoprotein (mmol/dl)	0.944±0.325	0.955±0.37
Low density lipoprotein (mmol/dl)	1.63±0.904	1.581±0.71
Fasting plasma glucose (mmol/dl)	3.997±1.40	4.174±1.32

*Statistical significant difference of equality of means at (95% CI, P ≤ 0.05; critical value: 1.960; Df: 172).

Table 3. Correlation matrix for measures of adiposity in male participants.

Parameter	WT	HT	WC	HC	BMI	WHpR	WHtR	FAT (%)	FM	FFM
WT	1.000									
HT	0.507**	1.000								
WC	0.797**	0.124	1.000							
HC	0.878**	0.391*	0.842**	1.000						
BMI	0.842**	-0.034	0.851**	0.775**	1.000					
WHpR	0.313**	-0.260*	0.727**	0.211*	0.530**	1.000				
WHtR	0.580**	-0.261*	0.925**	0.651**	0.840**	0.807**	1.000			
FAT (%)	0.624**	0.053	0.825**	0.734**	0.690**	0.537**	0.782**	1.000		
FM	0.816**	0.232*	0.890**	0.849**	0.800**	0.508**	0.776**	0.956**	1.000	
FFM	0.852**	0.597**	0.462**	0.628**	0.615**	0.037	0.220*	0.127	0.393**	1.000

**Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed) Critical value: 0.2050 P: ≤0.05

Table 4. Correlation matrix for measures of adiposity in female participants

Parameter	WT	HT	WC	HC	BMI	WHpR	WHtR	FAT (%)	FM	FFM
WT	1.000									
HT	0.545**	1.000								
WC	0.721**	0.128	1.000							
HC	0.735**	0.161	0.648**	1.000						
BMI	0.796**	-0.07	0.774**	0.761**	1.000					
WHpR	0.251*	0.017	0.692**	-1.000	0.296*	1.000				
WHtR	0.474**	-0.280*	0.916**	0.559**	0.775**	0.666**	1.000			
FAT (%)	0.563**	0.086	0.589**	0.547**	0.618**	0.261*	0.534**	1.000		
FM	0.793**	0.272*	0.689**	0.681**	0.751**	0.261*	0.553**	0.944**	1.000	
FFM	0.521**	0.508**	0.213	0.245*	0.248*	0.044	-0.001	-0.402**	-0.106	1.000

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed), critical value: 0.2172, P ≤ 0.05.

male group had higher values of correlation coefficient and the strength of correlation was more than that of the female group. The pattern of correlation was also similar for waist circumference, waist-height ratio and BMI; with waist circumference showing the strongest attitude in both groups.

Table 5. Correlation between measures of adiposity and cardiometabolic risk factors in male participants.

Parameter	SBP	DBP	PULSE	MABP	TG	HDL	LDL	FPG
WT	0.124	0.284*	0.182	0.225*	0.102	0.092	0.327**	0.16
HT	-0.172	0.108	-0.093	0.03	-0.131	-0.003	0.286**	0.066
WC	0.258*	0.271**	0.270**	0.288**	0.272**	0.143	0.251*	0.131
HC	0.13	0.271**	0.2	0.221*	0.1	0.173	0.394**	0.165
BMI	0.241*	0.248*	0.264*	0.266*	0.203	0.106	0.202	0.152
WHpR	0.282**	0.131	0.226*	0.222*	0.352**	0.043	-0.043	0.027
WHtR	0.312**	0.216*	0.297**	0.286**	0.318**	0.139	0.137	0.104
FAT (%)	-0.259*	0.212*	0.269**	0.255*	0.181	0.069	0.168	0.042
FM	0.246*	0.271**	0.264**	0.281**	0.159	0.078	0.246*	0.089
FFM	0.026	0.206*	0.05	0.102	0.018	0.076	0.298**	0.174

**Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed). Critical value: 0.2050. P ≤ 0.05.

Table 6. Correlation between measures of adiposity and cardiometabolic risk factors in female participants.

Parameter	SBP	DBP	PULSE	MABP	TG	HDL	LDL	FPG
WT	0.124	0.284*	0.182	0.225*	0.102	0.092	0.327**	0.16
HT	-0.172	0.108	-0.093	0.03	-0.131	-0.003	0.286**	0.066
WC	0.258*	0.271**	0.270**	0.288**	0.272**	0.143	0.251*	0.131
HC	0.13	0.271**	0.2	0.221*	0.1	0.173	0.394**	0.165
BMI	0.241*	0.248*	0.264*	0.266*	0.203	0.106	0.202	0.152
WHpR	0.282**	0.131	0.226*	0.222*	0.352**	0.043	-0.043	0.027
WHtR	0.312**	0.216*	0.297**	0.286**	0.318**	0.139	0.137	0.104
FAT (%)	-0.259*	0.212*	0.269**	0.255*	0.181	0.069	0.168	0.042
FM	0.246*	0.271**	0.264**	0.281**	0.159	0.078	0.246*	0.089
FFM	0.026	0.206*	0.05	0.102	0.018	0.076	0.298**	0.174

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed) critical value: 0.2172. P ≤ 0.05.

Despite considering non obese subjects in this study, FM showed some interesting trend and strength with other variables in male (weight, r = 0.816**; waist circumference, r = 0.890** and BMI, r = 0.800**) and (weight, r = 0.793**; waist circumference, r = 0.689** and BMI, r = 0.751**) in female group. However, both groups presented best correlation between fat% and fat mass: r = 0.956 in male, r = 0.944 in female followed by waist circumference and waist-height ratio: r = 0.925 in male, r = 0.916 in female.

Correlation between measures of adiposity and cardiometabolic risk factors

Tables 5 and 6 show correlation between anthropometrics and cardiometabolic risk factors at critical value: 0.2050 (male), 0.2172 (female); P ≤ 0.05. Among male subjects, higher values of waist-height ratio and waist-hip ratio were associated with increasing cardiometabolic risk factors (mean arterial blood pressure, r = 0.286** and 0.222*; triglyceride, r = 0.0.318** and 0.352**; waist circumference, r = 0.925** and 0.727**), respectively, and overall association did not vary substantially among the indices. Associations were somewhat weaker in the female group with only waist-height ratio showing association with mean arterial blood pressure (r = 0.257*) and waist circumference (r = 0.916**). Gender differences in the correlation of obesity pattern with metabolic risk factors were further confirmed. Among the male group, waist-height ratio demonstrated the strongest gradient in association with risk factors, followed by waist-hip ratio. Though, the correlation of risk factors with waist-height ratio among female was weaker,

Table 7. Multivariate correlations of measures of adiposity and risk factor accumulations in male participants.

Parameter	Wt	HC	WHtR	WHpR	BMI	Fat (%)	FM
WC	0.797**	0.842**	0.925**	0.727**	0.851**	0.825**	0.890**
SBP	-	-	0.312**	0.282*	0.241*	-0.259*	0.246*
DBP	0.284*	0.271*	0.216*	-	0.248*	0.212*	0.271*
TG	-	-	0.318**	0.352**	-	-	-
HDL	-	-	-	-	-	-	-
FPG	-	-	-	-	-	-	-

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). Critical value: 0.2050, P ≤ 0.05.

Table 8. Multivariate correlations of measures of adiposity and risk factor accumulations in female participants.

Parameter	Wt	HC	WHtR	WHpR	BMI	Fat (%)	FM
WC	0.721**	0.648**	0.916**	0.692**	0.774**	0.589**	0.689**
SBP	-	-	0.267*	-	-	-	-
DBP	-	-	0.234*	-	-	-	-
TG	-	-	-	-	-	-	-
HDL	-	-	-	-	-	-	-
FPG	-	-	-	-	-	-	-

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed) Critical value: 0.2172 . P: ≤0.05.

the existence of waist-height ratio in both groups was phenomenal and no correlation existed with fasting plasma glucose in both groups.

Multivariate correlation of risk factors accumulation with measures of adiposity

Multivariate correlation of risk factors accumulation with various measures of adiposity at critical value: 0.2050 (male), 0.2172 (female); P ≤ 0.05 is presented in Tables 7 and 8. The tables show the relationships of various measures of adiposity with risk factors accumulation. Waist-height ratio showed the strongest relationship with risk factors accumulation in male (waist circumference, r = 0.925**; systolic blood pressure, r = 0.312**; diastolic blood pressure, r = 0.216* and triglyceride, r = 0.318**) (Table 7). Waist-hip ratio also showed relationship with risk factors accumulation, but not as strong as waist-height ratio in the male group, and no relationship was found in the female group (Table 8). The common combination of risk factors accumulation was the existence of large waist circumference, high blood pressure and hypertriglyceridemia. Risk factors accumulation was present in male group not in female group.

Logistic regression analysis of measures of adiposity and cardiometabolic risk factors

Logistic regression analyses were used to investigate the independent relation between the obesity indices and cardiometabolic risk factors after adjusting for age (*significant at 95% confidence interval and P ≤ 0.05). In the male group (Table 9), only waist-height ratio predicted the existence of large waist circumference (0.000*) and two other components of metabolic syndrome, that is, elevated triglycerides (0.002*) and systolic blood pressure (0.003*). None of the obesity measures predicted elevated fasting blood glucose. No prediction of these combinations of cardiometabolic risk factors existed in the female group. Similarly, using the odd ratio values (R^2), Figure 1 further showed the strength of waist-height ratio in predicting existence of risk factors accumulation in the male group (waist circumference, R^2 = 0.855; systolic blood pressure, R^2 = 0.098 and triglyceride R^2 = 0.101), while waist-hip ratio predicted systolic blood pressure (R^2 = 0.069) and triglyceride (R^2 = 0.124). Other measures of adiposity did not exhibit predictions with risk factors accumulation. No prediction was found for risk factors accumulation in female participants (Figure 2). Measures of adiposity did not show relationships with fasting plasma glucose, and

Table 9. Regression analysis of obesity measures and cardiometabolic risk factors in male participants

Dependent variables predictors	β	R^2	Significance
Systolic blood pressure, waist-height ratio	0.312	0.098	0.003*
Waist-hip ratio	0.263	0.069	0.007*
Waist circumference, waist-height ratio	1.027	0.855	0.000*
Height	0.393	0.144	0.000*
Triglyceride waist-Hip ratio	0.352	0.124	0.001*
Waist-height ratio	0.318	0.101	0.002*

*Significant (95% CI, P ≤ 0.05).

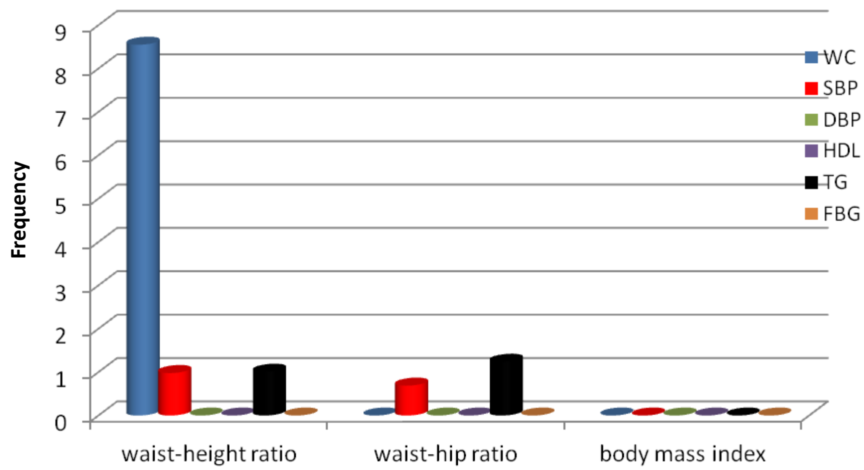

Figure 1. Predictability of measures of adiposity for risk factors accumulation in male participants. WC – waist circumference, SBP – systolic blood pressure, DBP – diastolic blood pressure, HDL – high density lipoprotein, TG – triglyceride, FBG – fasting blood glucose.

no prediction was exhibited in both male and female groups.

Summary of result

In summary, statistical correlation analysis showed that four variables (waist-height ratio, waist circumference, fat% and fat mass) were sufficient to explain relationships among the factors being investigated in non-obese adults in this study.

1. Weight, waist-height ratio and waist circumference reflected strength of correlation among all anthropometric indices in both male and female groups.
2. Male group had higher base-line levels of total and abdominal obesity, triglyceride, low density lipoprotein and lower high density lipoprotein, fasting plasma glucose, systolic blood pressure, diastolic blood pressure and fat mass.

2. Fat mass, waist-height ratio and waist circumference in male group and waist-height ratio in female group were found to have the strongest correlation coefficients relative to at least three risk factors. Risk factors accumulation is present in male not in female.
3. Regression analysis showed that waist-height ratio was optimal for predicting components of cardiometabolic risk factors among non-obese male adults, there were no predictions found in the female group.
4. The variability of low density lipoprotein with other anthropometric indices was higher than that of high density lipoprotein, and no correlation or prediction was found for fasting plasma glucose in both groups.

Test of hypothesis

Based on the findings of this study, the test of hypothesis showed that among non-obese adult subjects investigated in this study:

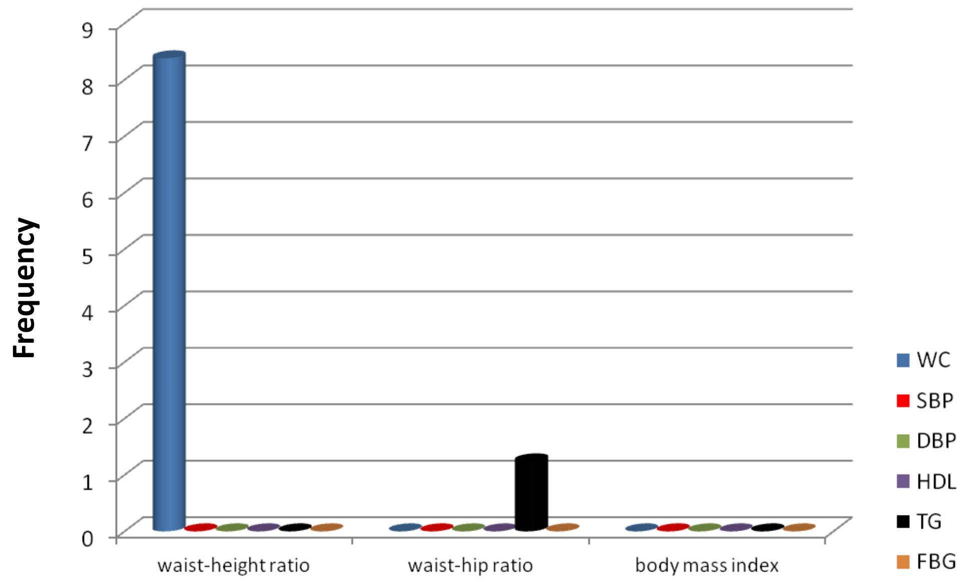

Figure 2. Predictability of measures of adiposity for risk factors accumulation in female participants. WC – waist circumference, SBP – systolic blood pressure, DBP – diastolic blood pressure, HDL – high density lipoprotein, TG – triglyceride, FBG – fasting blood glucose.

1. There were strong and positive relationships between anthropometric indices and risk factors accumulation.
2. Central adiposity predicts cardiometabolic risk factors better than overall obesity.
3. The initial null hypotheses were therefore rejected.

DISCUSSION

Metabolically obese normal weight (MONW) individuals, who despite having a normal weight BMI, present with metabolic disturbances typical of obese individuals. And the associated metabolic disorders among non obese are often ignored relatively to obesity (Ruderman et al., 1998; Succuro et al., 2008). The main findings of this study suggested that waist-height ratio provides a marginally superior tool for discriminating high cardiometabolic risks among non-obese adults compared with waist circumference, BMI and waist-hip ratio. Slightly higher odd ratios were observed in males compared to females, suggesting that discrimination is more precise on average, in male. Linear correlation analyses also showed that measures of adiposity were positively and significantly associated with cardiometabolic risk factors in both sexes, with the exception of fasting plasma glucose.

Relationship between anthropometrics and cardiometabolic risk factors

The results from this study showed that WC, WHtR, fat (%) and FM were the strength of correlation between anthropometrics and cardiometabolic risk factors. In addition, WHtR, HC and WC had a greater influence on cardiometabolic risk factors and the influence was more conspicuous among the male group of non-obese adults investigated. The correlation among the anthropometric indices observed in this study however shows that they carry the same information of adiposity and the associated health risk factors among non obese adults. The results are in agreement with the findings of other investigators who earlier showed that the concept of the metabolically obese normal weight individual is based on the observation that these same characteristics may be found in normal weight individuals with disorders often associated with obesity (St-Onge et al., 2004; Tsai, 2009).

Correlation and prediction of cardiometabolic risk factors exhibited by WHtR

Palacios et al. (2011) showed in their study that general and abdominal adiposity were both associated with cardiometabolic risks, and that WC, WHpR and WHtR appear to be slightly better predictors than BMI among the population studied. Although several anthropometric indices serve as simple clinical tools for the measurement of central adiposity, it is not particularly clear which surrogate marker is the most reliable predictor of metabolic risk factor accumulation. BMI measurements in childhood are associated with abnormal metabolic clustering in adulthood, but the usefulness of BMI is limited for the following reasons: (1) its inability to distinguish fat from muscle mass; (2) its tendency to under-represent body fat distribution; and (3) its inability to measure central adiposity in a direct fashion, and for WC, there are currently no agreements about a health-related classification; varying percentile has been considered as a cut-off point for high WC. Both of these measures are also age and sex dependent (Vasan et al., 2011).

WHtR takes into account the distribution of body fat in the abdominal region which has been shown to be more associated with cardiovascular risks than body weight. WHtR adds significantly to cardiometabolic risk prediction over BMI and waist circumference in men, and it is an important index of central obesity, which is free from any bias due to hip width changes along with waist circumference of short and tall subjects (Dhall et al., 2011). The significant correlation and strength of prediction exhibited by WHtR in this study could then mean that it carries the burden of cardiometabolic risks among non obese individuals investigated in this study; so much so that the recommended optimal cut-off point of 0.5 for men and women (Browning et al., 2010) is higher in this study (0.508 in men and 0.535 in female). This is in agreement with the findings of Park et al. (2009) and Nambiar et al. (2010) who showed WHtR to be a better predictor of cardiovascular diseases than other anthropometric measurements, including BMI, WC, WHpR and skinfold thickness.

This observation was also reflected in recent studies on non obese adults by Gomes-ambrosi et al. (2011), Knowels et al. (2011) and Vasan et al. (2011) who proved that WHtR was the best predictor of both hypertension and dyslipidaemia for both male and female, and that BMI was the least accurate predictor of hypertension. Similar observation was also noted in this study, but more pronounced in male than female. The heterogeneity in findings across studies that have assessed cardiometabolic risk factors in relation to indices of adiposity may be attributable to difference in race, ethnicity, age and gender distribution of participants across study population (Duncan et al., 1995; Deurenberg et al., 1998).

WHtR is a recently introduced index to assess central fat distribution; an increased circumference is most likely associated with elevated risk factors because of its relation with visceral fat accumulation, and the mechanism may involve excess exposure of the liver to fatty acid. The combination of WC and Ht that is, WHtR could manifest better, the morphology of an enlarged abdomen with inappropriate short stature (Lin et al., 2002; Kayode et al., 2009). As was also observed in Kayode et al. (2009) and Wint et al. (2011), HC assessment in non-obese is more relevant than in obese individuals. This is particularly so because BMI does not reflect body fat distribution. Indeed, other anthropomeric indices such as WC, HC, WHtR and WHpR have been used as alternatives.

This study also showed that both HC and WHpR were significantly correlated with various cardiometabolic risk factors, but in a smaller degree than WC and WHtR. This means that the use of Ht rather than HC adjusted for WC better indicates the clustering of cardiometabolic risk factors. Generally, incorporating either HC or Ht may provide more information on cardiometabolic risk than WC alone; the universal use of WC therefore may cause overestimation of risk factors in tall persons and underestimation in short persons (Ahmet et al., 2008).

Hypertension is now recognised globally as a major public health problem in terms of well-known risk factors for cardiometabolic diseases (Nobukazu et al., 2005; Ghosh and Bandyopadhyay, 2007). In this study, WHtR showed strong and consistent correlation with systolic blood pressure (SBP) > diastolic blood pressure (DBP) > mean arterial blood pressure (MABP) in both male and female groups, followed by WC, FM and abdominal skinfold. This fact could then mean that WHtR, WC and abdominal skinfold carry same information of visceral obesity. Therefore, the significant correlations with SBP, DBP and MABP observed also in this study could suggest that a decrease in intra-abdominal fat could reduce blood pressure and shows consistence with previous studies (Ilse and Luc, 2000; Wang and Hoy, 2004; Roopakala et al., 2009).

Metabolic syndrome among non-obese adults

Noteworthy, obesity is defined as an excess accumulation of body fat with the amount of this excess fat being responsible for most obesity associated health risks (Vasan et al., 2011). In this study, BMI cut off values, even at the highest quintile (27.0 in male and 26.60 in female) did not show strong associated risk of MetS compared to WC, WHtR and fat (%). The findings signify that although BMI may help in categorising obesity, it is not a reliable predictor for MetS in this study and may not reflect cardiometabolic risks clustering among non obese adults.

Since the correlation between BMI and central obesity can vary considerably from one individual to another, it has been suggested that what causes normal weight individuals to have MetS is having a greater body fat or abdominal obesity at a normal BMI range (Hadaegh et al., 2007). The association of uric acid with CVD is controversial (Tsai, 2009) but it is a risk factor in definition of MONW individuals (Ruderman et al., 1998).

Insulin resistance, not obesity (Baba et al., 2010), non alcoholic fatty liver disease (Kim et al., 2004) and independent role of leptin concentration (Esteghamati et al., 2011) have also been found to be significantly associated with MetS according to IDF definition and is independent of overall and central obesity among obese and non-obese subjects. This could also, in combination with familial and genetic background, explain the non correlation or prediction for FPG found in male and female of this study. Although mean fasting blood glucose was higher in female compared to male, none of the study population had fasting blood sugar greater than 5.6 mmol/L; more so, since fasting blood glucose did not show any correlation with anthropometrics and no prediction were shown, therefore it cannot be encountered as a metabolic risk factor in this study.

Similar finding was detected in a population of non obese Egyptian children (Saleh et al., 2010) and Iranian adolescents (Esmaillzadeh et al., 2006) with hypertriglyceridemic and waist phenotype, where they had higher prevalence of all metabolic risk factors except elevated fasting glucose. Dietary intake might be an important factor in determining blood glucose (Parillo and Riccardi, 2004). Moebus et al. (2011) also observed that the carbohydrate content and metabolic demands of last meal before the time of fasting blood glucose measurement, coupled with observed fasting state by subjects, might be another contributing factor. Infections (Ugwu et al., 2008) and stress (Wing et al., 1985) have also been mentioned.

Normal weight, low fitness individuals have also been identified. In a study of 855 coronary artery disease patients by Kashish et al. (2011), It was found that overweight, high-fitness subjects (determined by cardiopulmonary exercise testing) had a much lower risk of dying compared with normal-weight, low-fitness subjects. It is believed that a number of protective factors may come into play, including the site of excess weight (abdominal weight is more dangerous than weight carried around the hips), good physical activity levels, and following a healthy weight-reduction diet, along with normal metabolic biomarkers, such as blood pressure, blood sugar, and blood lipid levels.

Gender differences and prevalence of MetS

Studies on gender differences and prevalence by sex of MetS among non-obese supported results from this study which showed high prevalence of 20.4% in men and 15.3% in women (Hwang et al., 2007) and 15.5% in men and 10.5% in women (Lin et al., 2006). The most common component was hypertension and abdominal obesity. More so, the gender difference in the development of MetS among non-obese has been attributed to low serum sex-hormone-binding-globulin, low total testosterone and symptomatic androgen deficiency, and may provide early warning signs for cardiovascular risk and consequently an opportunity for early intervention in non-obese men (Varant et al., 2006). Generally, the hormonal environment plays a key role in determining body fat distribution. This is because sex hormones are known to affect regional fat deposition; the changing hormonal environment during puberty may contribute to the development of sex differences and large individual changes in fat distribution (Goran and Gower, 1999).

Gender specificity has also been attributed to the heterogeneity of two different anthropometric indices in prediction of cardiometabolic risk factors among non-obese males and females in this study. The females were more acclimatized to household work and not involved in vigorous physical activities voluntarily or habitually, thus disposing them to be more overweight or obese. On the other hand, males being in business sector also had sedentary behaviour along with omnipresent anxiety which comes with business competition, this not only predisposed them to prehypertension, it also increased the fat amount which might have exaggerated the already existing androidal fat pattern typical of males, thus the relation of WHtR among males (Dhall et al., 2011). Sex-related differences in MetS prevalence are not universal; the differences within specific countries may also be due, for example, to differing socio-economic status, work-related activities, and cultural views on body fat (Cameron et al., 2007).

CONCLUSION

Based on the findings of this study and in view of its limitations, the following conclusions were drawn:

1. Same anthropometric indices which were correlated in obese individuals, were also correlated among non-obese adults in this study.
2. This study clearly revealed the gender specificity and relative effectiveness of anthropometric indices in the relationship and prediction of cardiometabolic risks among non-obese adults.
3. Waist circumference and waist-height ratio mediate the correlation between cardiometabolic risk factors and anthropometrics among non-obese adults, with men being at greater risk than women.
4. Of all the anthropometric indices investigated, waist-height ratio appears to be better predictor of cardiometabolic risk factors among non-obese adults.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

1. Optimal intervention strategies should be directed towards prevention of fat accumulation and improving fitness by a regular, coordinated and supervised exercise

programme and dietary modifications.

2. Waist-height ratio, as shown in this study, should be used by physicians as screening tool for metabolic abnormalities in persons with a BMI at the upper end of the normal weight and lower end of the overweight spectrum, since the early detection of metabolic obese normal weight individuals may be beneficial in the prevention of diabetes and cardiovascular disease.

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ABBREVIATIONS

BMI, Body mass index (kg/m^2); **CHD,** coronary heart disease; **CVD,** cardiovascular disease; **DBP,** diastolic blood pressure (mmHg); **FFM,** fat free mass (kg); **FM,** fat mass (kg); **HC,** hip circumference (cm); **HDL,** high density lipoprotein (mmol/l); **LDL,** low density lipoprotein (mmol/l); **MetS,** metabolic syndrome; **MABP;** mean arterial blood pressure; **SBP,** systolic blood pressure (mmHg); **T2DM,** type 2 diabetes mellitus; **TC,** total cholesterol (mmol/l); **TG,** triglyceride (mmol/l); **WC,** waist circumference (cm); **WHpR,** waist-hip ratio; **WHtR,** waist-height ratio; **Wt,** body weight (kg).

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