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Anthropometric indicators and their correlation with hypertension comorbidly occurring with diabetes in some residents of Abeokuta, Nigeria

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ABSTRACT

Objectives: To compare anthropometric measurements of general obesity and central obesity and assess the respective associations with type 2 diabetes (T2DM) comorbidly occurring with hypertension, and also to determine if the association between the anthropometric indices and cardiovascular risk factors varies with gender. **Methods:** Age and sex matched control subjects (n=150) and patients (n=470) [hypertensive non-diabetics (n=179), normotensive diabetics (n=132), hypertensive diabetics (n=159)] presenting at the Medical Out-Patient Clinic of the State Hospital, Abeokuta, Nigeria were recruited. The examination included a fasting blood sample, fasting plasma glucose (FPG), blood pressure measurements and questionnaires to assess treatment for hypertension and T2DM. Weight, height, umblical circumference (UC), waist circumference (WC), hip circumference (HC), were measured using standard procedures; body mass index (BMI), body fat percentage (BF%), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and other body composition were calculated to assess overweight and obesity. **Results:** BMI and BF % were significantly increased in all the patients. There was significant difference in gender BMI and BF%. In both controls and patients, BMI and BF% were significantly ($p < 0.05$) higher in female when compared with their male counterparts. Also UC, WC, HC, WHR, WHtR were significantly higher in patients in both sexes when compared with their control counterparts. WHtR has more significantly positive correlation with hypertension and/or T2DM when compared with all other anthropometric parameters. WHtR was still a slightly better predictor in men, whereas in women, WC was slightly better than others. **Conclusions:** The association of central and general obesity varied with gender. In addition, the useful anthropometric predictors for known risk factors for cardiovascular disease (T2DM, hypertension and their comorbidity) risk factors were WHR for men, and WC for women.

KEY WORDS: Anthropometry, type 2 diabetes, hypertension, obesity, comorbidity

INTRODUCTION

Epidemiological studies have found a progressive increase in the prevalence of hypertension and type 2 diabetes mellitus (T2DM) with increasing body fat accummulation and complex interactions among hormonal, homodynamic and nutritional factor [1-3]. Obesity, T2DM and hypertension are common and important problems in primary care [4-6]. In the recent decade many prospective and cross-sectional studies have been done in order to evaluate the anthropometric measurement methods to assess patients with elevated blood pressure and fasting plasma glucose, which are dominant cardiovascular risk factor [5-7]. Different anthropometric measurements like body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), subscapular thickness or triceps skin fold (TSF) measurement as a part of index of trunk or peripheral skin folds are investigated for this purpose [7-9]. Body mass index (BMI) is widely used for classification of overweight and obesity, but it does not account for the wide variation of the fat distributions. In addition, not all overweight or obese patients have these metabolic diseases, and vice versa. Therefore, there is currently overwhelming evidence of central (abdominal or visceral) obesity as a greater risk factor for cardiovascular diseases (CVD) than general obesity [2, 3].

While these simple clinical concepts may be well-accepted among many clinicians and researchers, and assumed to be readily accessible in the medical literature, primary care physicians are confronted by a remarkable heterogeneity among their patients [10, 11]. A simple question rises; which anthropometric measurements may be useful and effective to screen for the central obesity type of body fat of patients with elevated blood pressure and fasting plasma glucose in primary care practice? It has been recommended that every population should determine their best anthropometric measurement tool(s) in order to screen general and visceral adiposity [1, 5]. We are not aware of any previous reports in Nigeria in which data regarding the important relationship

between general obesity and central obesity, and their correlation with known CVD risk factors are investigated.

Thus, this study aimed to compare anthropometric measurements of general obesity body mass index (BMI), body fat percentage (BF %)] and central obesity [umblical circumference (UC), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR)] and assess the respective associations with type 2 diabetes, hypertension and their comorbidity, and also to determine if the association between the anthropometric indices and cardiovascular risk factors varies with gender.

MATERIALS AND METHODS

Study area and subjects

The study was carried out in Abeokuta the capital city of Ogun State, Nigeria, between 2010 and 2012. Abeokuta is an urban township in Southwestern Nigeria with about 800,000 inhabitants based on an annual growth rate of 3.5% from the 1991 census figures (Department of Statistics, Ministry of Finance, Abeokuta, Nigeria). Its topography is undulated i.e. not leveled but rocky. In it is situated the Federal University of Agriculture, Abeokuta with a population of about 15,000 made up of academic and non-academic staff and students from all over the country, with a preponderance of the population from the western coast. They basically consume typical Nigerian low fat, high carbohydrate and protein diets. Apart from this, they live an active life-style in the community [12].

Patients presenting at the Medical Out-patient Clinic, State Hospital, Ijaiye, Abeokuta, Ogun State, Nigeria were used for the study. The protocol for the study was approved by the Research and Ethics Committee of the State Hospital as well as the postgraduate committe of the Department of Biochemistry, Federal University of Agriculture, Abeokuta. Patients (diagnosed by a Consultant Physician in the Department of Internal Medicine of the State Hospital) were made of age and sex-matched indigenous Nigerian normoglycaemic hypertensives; normotensive type 2 diabetes mellitus and patients with comorbidity of hypertension and type 2 diabetes. The diagnosis of diabetes mellitus was based on the World Health Organisation criteria [13]. Patients on oral hypoglycaemic drugs or whose diagnosis of diabetes was made at the age of 40 years and above with no record of ketosis were considered to have type 2 diabetes mellitus. Hypertensive patients were diagnosed based on World Health Organisation-International Society of Hypertension Guideline cut-off point of 140 mmHg and above for systolic and/or 95 mmHg and above for diastolic blood pressure, and also if it was previously detected and the subject was on treatment [13]. Inclusion criteria included being hypertensive for ≥ one year, use of neutral antihypertensive agents such as calcium channel blockers, angiotensin converting enzyme inhibitors, and angiotensin II receptor blockers. Excluded from the study during routine interviews, clinical investigations and laboratory tests were patients with a history of smoking, drinking alcohol, human immunodeficiency virus (HIV), systemic lupus erythematosus, systemic inflammation or systemic infection, taking oral contraceptives, lipid lowering drugs. Age and sex-matched volunteers certified clinically and biochemically to be healthy, on no medication; normotensive and normoglycaemic served as controls. They were made of staff and students of Federal University of Agriculture, Abeokuta, Nigeria. They were recruited in the study at the same period with the patients. Participation in the study by individual subject was voluntary. Before enrollment in the study, all subjects were informed about the objectives and requirements of the study, as well as the risks and discomfort that might be involved in participating in the study. Demographic data including age, sex, race, and duration of hypertension and diabetes were collected using questionnaire. Table 1 summarizes the study population.

Table 1. Study population

Subject	Male	Female
Control	74	76
Hypertensive non-diabetics	76	103
Normotensive diabetics	64	68
Hypertensive diabetics	68	91

Anthropometry

Anthropometric measurements were carried out as described by Dalton et al., 2003 [14] Height was measured to the nearest 0.5 cm without shoes using a stadiometer. Each participant stood with heels, buttocks and shoulders resting lightly against the backing board so that the Frankfort plane (a line connecting the superior border of the external auditory meatus with the infraorbital rim) was horizontal (i.e. parallel to the floor). Weight was measured after removal of shoes and when wearing light clothing only, using a digital bathroom weighing scale, and was recorded to the nearest 0.1 kg. Body mass index (BMI) was calculated by dividing the body weight (in kilograms) by the square of height (in meters). Umblical circumference was measured using a flexible but inelastic calibrated measuring tape, with measurements made at the navel in a horizontal plane. Each participant stood erect with the abdomen relaxed, arms at the sides and feet together, with the tape making contact with the skin. Waist circumference was measured halfway between the lower border of the ribs, and the iliac crest in a horizontal plane. Hip circumference was measured at the widest point over the buttocks. For each of umblical, waist and hip circumference, two measurements to the nearest 0.5 cm were recorded. If the variation between the measurements was greater than 2 cm, a third measurement was taken. The mean of the two closest measurements was calculated. WHR was obtained by dividing the mean waist circumference by the mean hip-circumference. Body fat

percentage (BF %) was estimated from the BMI as described by Deurenberg et al., 1991 [15].

Other body composition

Body Surface Area (BSA), Body Fat Mass (BFM), Fat Free Mass Index (FFMI), Total Body Water (TBW), Intracellular Fluid (IF) and Extracellular Fluid (EF) were calculated from weight and height [12]. Questionnaire interviews were conducted to gather information on variables such as current smoking status, alcohol consumption, and education status.

Mmeasurements of blood pressure

Blood pressure and pulse were measured two times on the left arm in each subject in a supine position using Omron manual inflation blood pressure monitor (model HEM. 412C, Omron Healthcare Inc. Illinois, USA). Each measurement was spaced twenty minutes apart and was usually performed before collection of blood samples. The average of the two measurements was used for all analyses. To obtain the final measurement of blood pressure, the mean of the first two readings was calculated, unless the difference between these readings was greater than 10 mmHg, in which case the mean of the two closest of three measurements was used as the SBP and DBP values. Pulse pressure (PP) was calculated as SBP minus DBP. Mean arterial pressure (MAP) was estimated as (SBP+2DBP)/3 [16].

Collection of blood samples

Blood samples (10.0 ml) were collected between 08.00 a.m. and 11.00 a.m. on each clinic day from the antecubital vein of the participants after an overnight fast for 12-14 hours. The blood was transferred into a lithium heparin anticoagulated tube, and mixed gently by inverting the stoppered tube several times. The blood samples were stored in a cooler box and transferred to the laboratory for analyses. Plasma was separated from erythrocyes and fasting plasma glucose (FPG). Packed cell volumes (PCV), haemoglobin (Hb), creatinine and urea concentration were determined.

Statistical analysis

Data obtained were entered into SPSS (Statistical Package for Social Sciences) software for Window version 16 (SPSS Inc., Chicago, Illinois, USA). Data were expressed as Mean±S.E.M. Analysis of Variance (ANOVA) was carried out to test for the level of homogeneity among the groups. Where heterogeneity occurred, the groups were separated using Duncan Multiple Range Test (DMRT). The level of interaction among the parameters was determined using Pearson correlation. p values of < 0.05 were considered to be statistically significant.

RESULTS

The demographic and clinical characteristics of patients and controls are shown in Table 2. The controls, hypertensive non-diabetics (HND), normotensive diabetic (ND) and hypertensive diabetics (HD) were similar ($p > 0.05$) in age. The duration of diagnosis of hypertension was 5.04±2.19 years among the HND male and 4.87±1.60 years among the HD male; it was 5.26±1.66 years vs 4.94±1.62 years among the HND female and HD female respectively ($p < 0.05$). The duration of diagnosis of diabetics was also similar ($p > 0.05$) between the ND male, HD male, ND female and HD female; 4.07±1.55 years, 4.05±1.48 years, 4.22±1.19 years and 3.98±1.09 years respectively. In the diabetic patients fasting plasma glucose (FPG) was similar ($p > 0.05$) among the ND male and ND female (196.42±3.66 mg/dL vs 188.97±4.43 mg/dL ($p > 0.05$) but significantly ($p < 0.05$) higher when compared with HD male and HD female patients (174.39±3.73 mg/dL vs 172.24±3.71 mg/dL). Blood pressure increased significantly ($p < 0.05$) among the HND male, HD male, HND female and HD female (171.26±3.79/109.25±2.12 mmHg, 177.69±3.16/111.13±2.17 mmHg, 168.98±2.80/105.17±1.80 mmHg and 173.54±3.08/106.01±1.97) respectively when compared with their corresponding controls. In both sexes, the pulse pressure (PP), mean arterial pressure (MAP) and heart rate were significantly ($p < 0.05$) increased in HND and HD when compared with their respective control counterparts. While no significant difference ($p > 0.05$) was observed in the mean packed cell volume (PCV) and haemoglobin (Hb) values of ND male, ND female and HD female when compared with their control counterparts; PCV and Hb values of HND male and HND female increased significantly ($p > 0.05$). However, the PCV and Hb of HD male decrease significantly ($p < 0.05$). Plasma creatinine increased significantly ($p < 0.05$) as a result of the presence of either or both diseases. The increase was more marked in HD male. While ND male plasma urea has no significant ($p > 0.05$) difference when compared with their control counterparts, plasma urea in other patients increased significantly ($p < 0.05$), the increase was more marked in HND male. Quantitatively plasma urea of the male and female patients was between 8% to 18% and 20% to 33% respectively higher than their control counterparts. There was significant ($p < 0.05$) difference in gender creatinine and urea concentration. In both controls and patients, plasma creatinine and urea were significantly ($p < 0.05$) higher in male when compared with their female counterparts.

The anthropometric characteristics of the subjects are depicted in Table 3. Analyses of the antropometric parameters determined in the subjects revealed unsystemic statistically significant differences between controls and the patients. The controls and hypertensive and/or diabetic patients were similar ($p < 0.05$) in height. Weight was significantly increased in patients in both sexes when compared to their control counterparts, the increase was more pronounced in ND female. In the real sence, men were significantly heavier and taller than the women ($p < 0.05$). Mean value of the anthropometric indicators for general obesity [body mass index (BMI) and body fat percentage (BF%)] were significantly ($p < 0.05$) increased in all the patients. For BMI,

the increase was more marked in ND female (30.39±0.48 Kg/m2) while the BF% was more pronounced in HD female (40.43±0.49%). There was significant ($p < 0.05$) difference in gender BMI and BF%. In both controls and patients, BMI and BF% were significantly ($p < 0.05$) higher in female when compared with their male counterparts.

Also, the mean values of the anthropometric indicators for central or abdominal obesity (WC, waist circumference; HC, hip circumference; UC, umbilical circumference; WHR, waist to hip ratio; WHtR and waist to height ratio) were significantly ($p < 0.05$) higher in patients in both sexes when compared with their control counterparts. With the exception of FFBM of HND female and HD female, analyses of body composition parameters revealed statisticaly significant differences between hypertensive and/or diabetic patients and controls. Specifically, body surface area (BSA), fat free body mass (FFBM), fat mass, total body water (TBW), intracellular fluid (IF), extracellular fluid (EF) were significantly ($p < 0.05$) increased in all the patients. In both controls and patients; BSA, FFBM, TBW, IF and EF were significantly ($p < 0.05$) higher in male when compared with their female counterparts.

Intensity of association between age and anthropometric indices stratified by gender in the patient and control subjects is shown in Table 4. Age was significantly positively correlated with BF% in HND male ($r = 0.594$, $p < 0.01$), ND male ($r = 0.522$, $p < 0.01$) HD male ($r = 0.619$, $p < 0.01$), HND female ($r = 0.345$, $p < 0.01$), ND female ($r = 0.313$, $p < 0.01$) and HD female ($r = 0.395$, $p < 0.01$). Age was also significantly positively associated with HC in HND male ($r = -0.212$, $p < 0.05$), WHR in HD male ($r = 0.263$, $p < 0.05$) and HD female ($r = 0.306$, $p < 0.01$). However, age was significantly negatively associated with BMI in HND male ($r = 0.387$, $p < 0.01$), HD male ($r = 0.246$, $p < 0.01$), HND female ($r = 0.215$, $p < 0.01$), ND female ($r = 0.225$, $p < 0.01$) and HD female ($r = 0.226$, $p < 0.01$). Age was also significantly negatively associated with HC in HND male ($r = 0.243$, $p < 0.01$).

Correlation analyses as calculated by the Pearson's method were done to see whether any association existed among the anthropometric parameters and blood pressure component (Tables 5 and 6). The following were observed. A significant negative correlation between SBP and WC in control female ($r = -0.294$, $p < 0.05$), MAP and WC in control female ($r = -0.331$, $p < 0.05$), heart rate was also negative correlation with BMI in HND male ($r = -0.361$, $p < 0.05$), BF% in HND male ($r = -0.285$, $p < 0.05$) and WC in control female ($r = -0.280$, $p < 0.05$). However, a significant direct relationship was observed between SBP and WHtR in ND male ($r = 0.272$, $p < 0.05$); HD male ($r = 0.338$, $p < 0.05$) and ND female ($r = 0.351$, $p < 0.05$). Also, a significant direct relationship was observed between DBP and WHtR in ND male ($r = 0.240$, $p < 0.05$); HD male ($r = 0.318$, $p < 0.01$); HND female ($r = 0.305$, $p < 0.05$) and ND female ($r = 0.349$, $p < 0.05$). A significant positive association was observed between FPG and WHtR in HND male ($r = 0.276$, $p < 0.05$); ND male ($r = 0.341$, $p < 0.05$); HD male ($r = 0.350$, $p < 0.05$); ND female ($r = 0.334$, $p < 0.05$) and HD female ($r = 0.273$, $p < 0.05$). FPG was also significantly positively associated with BMI ($r = 0.350$, $p < 0.05$), BF% ($r = 0.326$, $p < 0.05$) and HC ($r = 0.301$, $p < 0.05$) in HD female. A significant positive correlation was also observed between FPG and BF% in ND male.

Table 2. Demograhic and clinical characteristics of the subjects

	Control male	Hypertensive non-diabetics male	Normotensive diabetics male	Hypertensive diabetics male	Control female	Hypertensive non-diabetics female	Normotensive diabetics female	Hypertensive diabetics female
Age (years)	42.58±1.36^{a}	43.29±1.31^{a}	46.45±1.35^{a}	46.33±1.52^{a}	42.70±11.61^{a}	46.75±1.17^{a}	42.46±11.49^{a}	44.80±1.32^{a}
SBP (mmHg)	117.16±1.20^{a}	171.26±3.79^{c}	114.88±1.24^{a}	177.69±3.16^{d}	113.51±1.11^{a}	168.98±2.80^{b}	117.71±2.79^{a}	173.54±3.08^{c}
DBP (mmHg)	77.50±0.98^{a}	109.25±2.12^{b}	78.62±0.76^{a}	111.13±2.17^{b}	76.12±1.15^{a}	105.17±1.80^{b}	78.97±0.79^{a}	106.01±1.97^{b}
PP (mmHg)	39.66±1.30^{a}	62.01±1.96^{b}	36.25±1.08^{a}	66.56±1.47^{bc}	37.39±0.96^{a}	63.81±1.56^{bc}	38.74±2.65^{a}	67.18±1.96^{c}
MAP (mmHg)	90.72±0.86^{a}	129.92±2.63^{b}	90.71±0.81^{a}	133.32±2.45^{b}	88.58±1.04^{a}	126.44±2.05^{b}	91.88±1.20^{a}	128.52±2.21^{b}
Heart rate (beats/mins)	84.60±0.92^{a}	123.76±1.38^{b}	82.86±0.93^{a}	124.96±1.70^{b}	84.14±0.87^{a}	123.40±1.57^{b}	84.06±0.87^{a}	123.04±1.81^{b}
FPG (mg/dL)	71.04±1.32^{a}	77.84±1.40^{a}	196.42±3.66^{c}	174.39±3.73^{b}	75.36±1.41^{a}	75.36±1.73^{a}	188.97±4.43^{c}	172.24±3.71^{b}
Duration of HTN (yrs)	0.00±0.00^{a}	5.04±2.19^{b}	0.00±0.00^{a}	4.87±1.60^{b}	0.00±0.00^{a}	5.26±1.66^{b}	0.00±0.00^{a}	4.94±1.62^{b}
Duration of DM (yrs)	0.00±0.00^{a}	0.00±0.00^{a}	4.07±1.55^{b}	4.05±1.48^{b}	0.00±0.00^{a}	0.00±0.00^{a}	4.22±1.19^{b}	3.98±1.09^{b}
PCV (%)	43.34±0.72^{b}	46.60±0.85^{c}	43.44±0.72^{b}	39.26±0.46^{a}	39.16±0.68^{a}	41.84±0.48^{b}	39.24±0.67^{a}	38.58±0.57^{a}
Haemoglobin (g/dL)	14.41±0.23^{b}	15.41±0.28^{c}	14.42±0.23^{b}	13.07±0.15^{a}	13.17±0.25^{a}	14.16±0.19^{b}	13.23±0.24^{a}	12.84±0.19^{a}
Plasma creatinine (mg/dL)	0.97±0.03^{ab}	1.14±0.04^{cd}	1.10±0.04^{cd}	1.20±0.05^{d}	0.88±0.04^{a}	1.05±0.03^{bc}	1.10±0.04^{cd}	1.09±0.04^{cd}
Plasma urea (mg/dL)	29.24±0.81^{b}	34.59±1.08^{d}	31.53±1.30^{bc}	33.88±0.92^{d}	24.25±1.106^{a}	32.45±1.04^{cd}	29.12±1.04^{b}	30.67±0.97^{bc}

Each value represents the mean±S.E.M. Values within the same row with different superscripts are significantly different at $p<0.05$

SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; MAP, mean aterial pressure; FPG, fasting plasma glucose.

Table 3. Anthropometric characteristics and body composition of the subjects

	Control male	Hypertensive non-diabetics male	Normotensive diabetics male	Hypertensive diabetics male	Control female	Hypertensive non-diabetics female	Normotensive diabetics female	Hypertensive diabetics female
Weight (Kg)	67.29±1.13^{b}	74.14±1.00^{c}	74.48±1.17^{c}	73.27±1.16^{c}	63.29±0.96^{a}	69.26±1.17^{b}	75.44±1.39^{c}	69.98±1.11^{b}
Height (cm)	169.55±0.81^{c}	169.32±0.74^{c}	169.21±0.90^{c}	166.94±1.08^{b}	159.09±0.87^{a}	157.56±0.71^{a}	157.54±0.85^{a}	157.41±0.68^{a}
BMI (Kg/m^2)	23.41±0.35^{a}	25.84±0.29^{bc}	26.04±0.37^{bc}	26.29±0.32^{c}	25.07±0.38^{b}	27.90±0.43^{d}	30.39±0.48^{e}	28.21±0.38^{d}
Body Fat %	21.39±0.55^{a}	26.97±0.39^{b}	26.73±0.58^{b}	27.23±0.47^{b}	33.83±0.65^{c}	40.64±0.54^{d}	42.84±0.59^{e}	40.43±0.49^{d}
BSA (m^2)	1.79±0.02^{c}	1.86±0.02^{d}	1.87±0.02^{d}	1.84±0.02^{d}	1.66±0.02^{a}	1.72±0.02^{b}	1.78±0.02^{c}	1.72±0.02^{b}
FFBM (Kg)	54.02±0.56^{c}	55.87±0.52^{d}	55.85±0.61^{d}	54.70±0.69^{cd}	42.87±0.45^{a}	44.11±0.47^{a}	45.87±0.56^{b}	44.26±0.46^{a}
Fat Mass (Kg)	13.27±0.72^{a}	18.27±0.59^{b}	18.64±0.77^{b}	18.57±0.65^{b}	20.42±0.64^{b}	25.16±0.77^{c}	29.57±0.91^{d}	25.72±0.71^{c}
TBW (litre)	38.98±0.43^{c}	40.97±0.40^{d}	40.96±0.47^{d}	40.25±0.50^{d}	31.18±0.40^{a}	31.75±0.39^{ab}	32.88±0.46^{b}	31.83±0.38^{ab}
IF (litre)	21.44±0.24^{c}	22.53±0.22^{d}	22.53±0.26^{d}	22.14±0.28^{d}	17.15±0.22^{a}	17.46±0.21^{ab}	18.08±0.26^{b}	17.51±0.21^{ab}
EF (litre)	17.54±0.19^{c}	18.44±0.18^{d}	18.43±0.21^{d}	18.11±0.23^{d}	14.03±0.18^{a}	14.29±0.17^{ab}	14.79±0.21^{b}	14.32±0.17^{ab}
WC (cm)	78.70±1.02^{a}	91.00±1.18^{bc}	90.86±0.98^{bc}	88.66±1.14^{b}	82.61±1.07^{a}	95.85±1.71^{d}	98.08±1.76^{d}	94.53±1.58^{cd}
HC (cm)	92.51±1.16^{a}	99.26±1.19^{b}	98.52±0.99^{b}	96.57±1.18^{b}	97.16±1.10^{b}	103.70±1.28^{c}	109.85±1.97^{d}	104.76±1.49^{c}
UC (cm)	80.62±1.80^{a}	90.66±2.96^{b}	90.81±2.65^{b}	91.42±2.12^{b}	79.62±1.84^{a}	97.98±2.14^{b}	90.78±5.10^{b}	96.84±2.94^{b}
WHR	0.85±0.07^{a}	0.92±0.01^{b}	0.92±0.01^{b}	0.92±0.01^{b}	0.85±0.01^{a}	0.93±0.01^{b}	0.90±0.01^{b}	0.90±0.01^{b}
WHtR	0.46±0.01^{a}	0.54±0.01^{b}	0.54±0.01^{b}	0.53±0.01^{b}	0.52±0.01^{b}	0.61±0.01^{c}	0.62±0.01^{c}	0.60±0.01^{c}

Each value represents the mean±S.E.M. Values within the same row with different superscripts are significantly different at p<0.05
WC, waist circumference; HC, hip circumference; UC, umbilical circumference; WHR, waist to hip ratio; WHtR, waist to height ratio; BMI, Body mass index; BSA, Body Surface Area; FFBM, fat free body mass; TBW, Total Body Water; IF, Intracellular Fluid; EF, Extracellular Fluid.

Table 4. Intensity of association between age and anthropometric indices stratified by gender in the patient and control subjects

	Control male	Hypertensive non-diabetics male	Normotensive diabetics male	Hypertensive diabetics male	Control female	Hypertensive non-diabetics female	Normotensive diabetics female	Hypertensive diabetics female
BMI	0.81	-0.387^{b}	-0.026	-0.246^{a}	0.307^{b}	-0.215^{a}	-0.225^{a}	-0.226^{a}
BF%	0.652^{b}	0.594^{b}	0.522^{b}	0.619^{b}	0.745^{b}	0.345^{b}	0.313^{b}	0.395^{b}
UC	0.230	0.021	0.237	0.368	0.064	-0.025	-0.127	0.031
WC	-0.395^{b}	-0.134	0.039	0.108	-0.176	0.212^{a}	-0.064	0.116
HC	-0.183	-0.243^{a}	0.033	-0.016	-0.028	0.078	-0.167	-0.034
WHR	-0.330^{b}	0.176	0.019	0.263^{a}	-0.285	0.193	0.232	0.306^{b}
WHtR	-0.426^{b}	-0.0.57	0.049	0.122	-0.078	0.195^{a}	-0.075	0.133

a Correlation is significant at p< 0.05

b Correlation is significant at p< 0.01

DISCUSSION

Previous studies have used body weight, BMI, total and abdominal fat, body circumferences and their ratios, and skinfolds and their ratios for the assessment of overweight and fat distributions. Both total fat and abdominal fat can now be precisely measured by double energy X-ray densitometry, CT and MRI, respectively. Measurements of total fat and abdominal fat could more precisely predict the impacts on health. However, due to the high costs and complex instruments involved, these methods are rarely used in large epidemiological studies, primary care hospitals and self-assessments. Skinfolds have been widely used to assess total fat and fat distribution in epidemiological studies, especially in children, but there are considerable variances among different measurements, and among different operators, particularly in obese subjects [17,18]. The limitations of these methods undermine their usefulness for adults. Thus, body circumferences have been widely used as indicators of obesity because of ease of measurement and greater reliability. BMI is by far the most widely used measurement to reflect general obesity, while WHR, WC and abdominal sagittal diameters are used as indices of central obesity.

Studies have found that total fat as well as abdominal fat distribution play an approximately equal role in cardiovascular diseases [19,20]. Mykkanen et al., 1992 [21] and Spiegelman et al., 1992 [22] also found obesity per se, rather than its distribution, a more significant predictor of metabolic risks. In this present study, we compared the correlation between the seven obesity parameters (BMI, BF%, UC, WC, HC, WHR and WtHR) and cardiovascular risk factors such as diabetes mellitus and/or hypertension.

Table 5. Intensity of association between anthropometric indices and blood pressure (SBP, DBP and PP) stratified by gender in the patient and control subjects

SBP	Control male	Hypertensive non-diabetics male	Normotensive diabetics male	Hypertensive diabetics male	Control female	Hypertensive non-diabetics female	Normotensive diabetics female	Hypertensive diabetics female
BMI	-0.036	0.142	0.029	0.173	-0.082	0.106	0.088	-0.238
BF%	-0.203	0.213	0.057	0.037	-0.140	0.054	0.078	-0.122
WC	0.289[a]	0.031	0.053	0.101	-0.294[a]	0.330[a]	0.250[a]	-0.229
HC	0.223	0.039	0.047	0.004	-0.230	0.123	0.269[a]	-0.135
WHR	0.206	0.129	0.020	0.263	-0.158	0.011	0.026	-0.242
WHtR	0.095	0.100	0.272[a]	0.338[a]	-0.241	0.128	0.351[a]	-0.276
DBP								
BMI	241[a]	-0.207	0.078	0.224	0.013	0.184	-0.040	-0.263
BF%	0.431[b]	-0.222	0.056	0.059	-0.095	0.107	0.030	-0.061
WC	-0.103	-0.002	0.091	0.016	-0.334[a]	0.340[a]	0.123	-0.192
HC	0.036	-0.064	0.075	-0.103	-0.258	0.119	0.075	-0.097
WHR	-0.231[a]	0.103	0.043	0.283[a]	-0.196	0.038	0.135	-0.235
WHtR	0.020	0.149	0.240[a]	0.318[a]	-0.300	0.305[a]	0.349[a]	-0.278
PP								
BMI	-0.215	-0.029	-0.070	0.041	-0.169	0.025	0.166	-0.128
BF%	-0.511[b]	-0.157	-0.153	-0.158	-0.120	0.033	0.086	-0.150
WC	0.343[b]	0.069	-0.012	0.185	-0.061	0.099	-0.044	-0.193
HC	0.178	0.003	-0.004	0.151	-0.052	0.113	-0.033	-0.132
WHR	0.261[a]	0.138	-0.014	0.144	-0.010	-0.033	-0.027	-0.167
WHtR	0.427[b]	0.066	-0.035	0.225	-0.012	0.146	0.079	-0.180

a Correlation is significant at p< 0.05, **b** Correlation is significant at p< 0.01

Table 6. Intensity of association between anthropometric indices and blood pressure (MAP and heart rate) and FPG stratified by gender in the patient and control subjects

MAP	Control male	Hypertensive non-diabetics male	Normotensive diabetics male	Hypertensive diabetics male	Control female	Hypertensive non-diabetics female	Normotensive diabetics female	Hypertensive diabetics female
BMI	-0.052	0.181	0.050	0.207	-0.025	0.151	0.017	-0.261
BF%	0.044	0.222	0.008	0.019	-0.117	0.085	0.055	-0.091
WC	-0.046	0.013	0.079	0.053	-0.331[a]	0.136	0.098	-0.216
HC	0.062	0.054	0.067	-0.059	-0.257	0.122	0.057	-0.118
WHR	-0.168	0.117	0.035	0.282[a]	-0.188	0.026	0.114	-0.246
WHtR	-0.015	0.028	0.117	0.214	-0.288[a]	0.116	0.160	-0.287
Heart Rate								
BMI	-0.068	-0.361[a]	0.079	0.256	-0.094	-0.117	-0.006	-0.179
BF%	-0.031	-0.285[a]	0.061	0.103	0.008	-0.033	-0.019	-0.046
WC	-0.089	-0.059	0.079	0.002	-0.280[a]	0.101	0.166	-0.065
HC	-0.007	-0.089	0.065	-0.100	-0.243	0.081	0.113	-0.009
WHR	-0.112	0.041	0.035	0.231	-0.123	0.037	0.165	-0.126
WHtR	-0.069	0.163	0.133	0.167	-0.252	0.090	0.182	-0.147
FPG								
BMI	-0.181	0.075	0.253	0.040	0.157	-0.052	0.276	0.350[a]
BF%	0.007	0.158	0.292[a]	0.048	0.247	-0.020	0.274	0.326[a]
WC	0.152	0.075	0.183	0.215	-0.051	0.022	0.015	0.229
HC	0.262	0.107	0.200	0.044	-0.017	0.076	0.221	0.301[a]
WHR	-0.184	0.034	0.047	0.039	-0.065	-0.122	-0.008	-0.162
WHtR	0.147	0.276[a]	0.341[a]	0.350[a]	0.039	0.030	0.334[a]	0.273[a]

a Correlation is significant at p< 0.05 **b** Correlation is significant at p< 0.01

In the Pearson correlation analysis, WHtR has more significantly positive correlation with hypertension and/or T2DM when compared with all other anthropometric parameters. WHtR was still a slightly better predictor in men, whereas in women, WC was slightly better than others. WC has been proposed as a general measurement of abdominal obesity by other authors [23]. Possibly, the fact that WHtR takes differences in body height into account, contribute to higher positive significant Pearson correlation values. It has been shown that WHtR is a better predictor of mortality

and cardiovascular risk factors than WC [24]. Yusuf et al., 2005 [25] have proposed that WHR is also a good predictor of cardiovascular events. The results of this study found it to be most weakly associated to diabetes and/or hypertension. Possibly, this is due to the fact that we have examined high risk diseases with a high prevalence of morbidity and obesity especially the T2DM. Here, the concomitant increase in hip circumference might have rendered the WHR less useful, since hip circumference significantly increased in all the patients (hypertension and/or T2DM) investigated.

The hip circumference was also positively marginally associated to hypertension and/or T2DM patients. In an Australian study, surprisingly, a lower prevalence of newly diagnosed diabetes and dyslipidemia was found in subjects with higher hip circumferences [26]. In a case-control study by Yusuf et al., 2005 [25], higher hip circumferences were also found to be protective against myocardial infarction. The reason for these different results is unclear. Possibly, differences in statistical methods (such as adjustment for waist and other factors), definitions of conditions (newly diagnosed risk conditions vs. all patients with risk conditions), and methods of measurement of hip circumference (at the great trochanters vs. at the largest hip circumference) played a role. Moreover, in the study by Yusuf et al., 2005 [25] patients from other hospital wards were included as controls. Possibly, presence of other diseases among the controls might have led to potential bias [26].

Our results of a positive, albeit less strong association of hip circumference with cardiovascular risk factors [FPG, BP components (SBP, DBP, PP and MAP)] suggest that not only visceral fat is involved in the cardiovascular risk of obesity. It is not clear, though, whether this association is a consequence of direct detrimental effects of subcutaneous fat or, rather, an indirect effect due to the fact that hip circumference is also an indicator of overall fatness, including visceral fat. This positive association might also explain why the WHR had the weakest association to hypertension and/or T2DM. If both waist and hip circumferences are positively associated with risk factors it can be expected that the ratio of both has a weaker association. Even though, in some studies the WHR has been shown to be strongly associated with cardiovascular risk factors, it has also been criticized for masking accumulation of abdominal fat, if the hip circumference is also increased [27].

This study was designed to reflect every-day routine in primary care (medical out-patients). The fact that we have found clear results shows that these anthropometric parameters can be used in daily routine and that they have a predictive value if applied in daily routine. The WHtR has already been suggested as a common measurement of central obesity for an Asian population; here, a cut-off level of 0.5 for both sexes has been recommended (Schneider et al., 2006). This cut-off level has also been suggested for use in European subjects [28]. Our study suggests the use of a higher cut-off 0.54 ± 0.05, 0.54 ± 0.04, 0.53 ± 0.04, 0.61 ± 0.11, 0.62 ± 0.08 and 0.60 ± 0.09 for hypertensive non-diabetics male, normotensive diabetics male, hypertensive diabetics male, hypertensive non-diabetics female, normotensive diabetics female and hypertensive diabetics female respectively. These studies differ to our study because it was conducted in the general population, whereas our study was carried out in a primary care setting (medical out-patients). Thus, our sample is more representative of the high-risk population seen in general practice where the question of weight management often arises. The issue of ethnic differences in abdominal obesity has been addressed by a large-scale international study [29]. In summary, this case-control study demonstrates that adjusted for age, we observed that the association of obesity indices and cardiovascular risk factors varied with gender. The strongest predictors of type 2 diabetes and/or hypertension were central obesity for the male and female subjects. Among the seven studied anthropometric indices, WHtR and WC were the best predictor of cardiovascular risk factors for men and women respectively. We recommend that, in addition to BMI, WC and WHtR should be an additional measurement to be documented in clinical assessments. The WHtR is a parameter that is simple to assess. It has advantages over BMI as it is easier to calculate and to understand for lay persons (no square term is used in the formula) and less clothes need to be removed for measurement. Moreover, measurements including WC are more sensitive to diet and training than the BMI as increase of muscle mass might lead to little change of BMI but clear changes in WC and WHtR. The WHR is not only more complicated to assess, it also has been shown to be a far weaker predictor of cardiovascular risk factors. Our study favours the use of an anthropometric parameter of abdominal obesity over BMI.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

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