Original Research Paper

Anthropometrics Evaluations in Type 2 Diabetes Mellitus Patients, with and Without Metabolic Syndrome. A Case Control Study

Robert A. Ngala[1], Martin A Awe[1], Paul Nsiah[2],

[1]Department of Molecular Medicine, School of Medical Science, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
[2]Department of Chemical Pathology, University of Cape Coast,- Ghana

ABSTRACT

Back ground: Many developing countries have taken measures to shift from curative to preventive medical services, and Ghana has since spearheaded a Regenerative Health and Nutrition (RHN) programme aimed at empowering lay communities to adopt healthy lifestyles through the application of anthropometric measurements. It is against this background that this work is designed to determine the correlation between some anthropometric indices as predictors of diabetes, obesity and metabolic syndrome in a section of Ghanaian population. Methods: Anthropometric parameters; Waist circumference, hip circumference and height were measured using a non extensible tape and WHtR, WHR, calculated. BMI was determined by weighing subject with weighing scale and dividing the weight by the height squared in meters. Blood pressure was measured using a standard mercury sphygmomanometer. Fasting blood glucose and lipid profile were determined by enzymatic methods, using Envoy® 500 reagents on BT 5000® Random Access Chemistry Analyzer. Results: Diastolic and systolic Blood Pressure and all other anthropometric parameters; waist circumference, hip circumference, BMI, WHtR, were significantly (p< 0.0001) higher in the diabetic subjects. Waist circumference, hip circumference, BMI, WHtR were significantly (p< 0.0001) higher in the female diabetics than in male diabetics.WHR and WTR were significantly and positively correlated (r=0.218; r=0.205**) with triglycerides. Whilst WHtR was positively correlated (r=0.300**, ,r=0.299**) with LDL and TC. WHR, WHtR, WC,WTR, and BMI predicted obesity by 83.4%, 79.8%,50.9%, 31.9% 30.7% respectively. BMI and WHtR and WC were significantly (p< 0.0001) higher in the diabetics with metabolic syndrome. Conclusion: WHR and WHtR were more predictive of obesity than BMI and WTR, whilst, WC was more definitive of central obesity. In the female diabetics WC, HC, BMI, WHtR were more predictive of obesity in that order. Obesity remains the predictor of type II diabetes.**

Keywords: Diabetes mellitus, obesity fat distribution, anthropometry

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Corresponding Author: Dr Robert A. Ngala, Department of Molecular Medicine, SMS-KNUST, Kumasi, Ghana
Email: rngala2000@yahoo.com

INTRODUCTION

Chronic non communicable diseases (NCDs), such as diabetes mellitus, heart disease, hypertension, stroke and various forms of cancers are the major causes of disability, premature death, poor quality of life and increasing health-care costs, in low and middle-income, as well as in high-income countries (WHO 2000a, WHO 2004, WHO 2008). As a result of the current demographic and socioeconomic changes, Sub-Saharan Africa is experiencing fastest rates of urbanization, increasing sedentary life styles and the cosumption of westernised food which is thought to be mainly responsible for the rising incidence of diabetes and other noncommunicable diseases (Unwin et al., 2006, Mbanya et al., 2010, Dalal et al., 2011)

Anthropometry, is a relatively inexpensive and non-invasive tool used for assessing the risk of some non-communicable diseases associated with body weight and fat distribution (Tulloch-Reid et al., 2003, Nishida, 2010). Anthropometric indices measurements usually include height, weight, head circumference, body mass index (BMI), Triceps skin fold thickness (TSF), WHR (Waist-to-hip ratio), WC (waist circumference) (Nishida et al., 2010). BMI has been used as a measure of total body obesity and waist circumference and waist-to-hip ratio (WHR) as measures of central obesity (WHO 2000b). Hypertension, defined as systolic blood pressure >140 mmHg and/or diastolic blood pressure >90 mmHg is another anthropometric parameter included in defining a metabolic syndrome. The epidemiology of diabetes mellitus and metabolic syndrome can be predicted through the use of these measures (Fezeu et al., 2010).

Clinical evidence suggests that the association between diabetes and central obesity is stronger than its association with general fat. Studies using computed tomography (CT) and magnetic resonance imaging (MRI) have provided evidence to support that central obesity, visceral adipose tissue, and upper-body non-visceral fat are the major contributors to these metabolic complications (Brambilla et al., 2006). There is also a well-known strong association between visceral fat and cardiovascular risk factors (Sargeant, 2002). BMI, WC, WHR, WHtR have been identified to be close expressions of cardiovascular risk factors (Laaksonen et al., 2002). WC, however, is outstanding in the estimation of abdominal visceral adipose accumulation than WHtR and may be a better predictor of multiple cardiovascular risk factors than WHR when computed tomographic scanning is used to measure adipose tissue (Garnett et al., 2008, Hsieh and Yoshinaga, 1995).

There are however, still controversies in the interpretation and use of these anthropometric indices, since these vary among various ethnicities and sex (Mabchour et al., 2015). For example research has shown that women in Ghana have higher WC than their male counterparts (Ngala et al., 2015). Also, a study on obesity and cardiovascular risk factors in Kumasi-Ghana supported the use of lower BMI and WC levels as indices for obesity and its associated health risks than using the Caucasians criteria (Owiredu et al., 2008). Higher obesity risks have been reported to occur at lower BMI's in Asians (Deurenberg et al., 2003, Kuk et al., 2008).

In a 2009 WHO report on 'the use and interpretation of anthropometry' stated that anthropometry provides the most portable, universally applicable, inexpensive and non-invasive method for assessing the size, proportions and composition of the human body (Botti et al., 2009). This reflects both health and nutritional status and predicts wellbeing. However, this valuable tool is currently underutilized for guiding public health policy and clinical decisions, particularly in less resourced countries which should have taken advantage of these non expensive but effective procedures.

In 2005, however, the Ministry of Health (MOH) in Ghana announced a paradigm shift from curative to preventive medical services and has since spearheaded a Regenerative Health and Nutrition (RHN) programme aimed at empowering lay communities to adopt healthy lifestyles through application of anthropometric measurements (Aikins, 2007). However, owing to the absence of specific cutoff points, waist circumference (WC) cutoffs, abdominal obesity and BMI are defined in Africans using the generic cut-off values primarily determined in Europeans (Osei, 2008),

It is against this background that this work is designed to assess the anthropometric indices as predictors of diabetes and metabolic syndrome in a section of the Ghanaian population, since these parameters are ethno-specific, sex and environmentally influenced (Mabchour et al., 2015).

METHODS

Subjects

A cross-sectional comparative study was carried out at the Diabetic Clinic of the Upper East Regional Hospital (Bolgatanga-Ghana), on diabetic subjects visiting the facility.   The subjects were made of 163 enrolled diagnosed type 2 diabetics aged between 30-65 years who reported at the diabetic clinic and 168 healthy non-diabetic volunteers from the same locality aged matched with the diabetics were used as the control. Pregnant subjects were excluded. Samples were collected between March 2013 and September 2014.

Ethical

Ethical clearance was approved by the Committee on Human Research Publication and Ethics of School of Medical Sciences, KNUST Kumasi, Ghana (CHRPE/Student/113/09). A written consent form was completed and signed/thumb-printed by the participants recruited into the study after explaining the rational of the study to them in a language they understand.

Anthropometric parameter measurements

Body weight of the subjects was measured (to the nearest 0.5 kilogram) with the subject standing on an electrical weighing scale (Seca Alpha, GmbH&CO. ,Igni, France) in light clothing. Height was measured (to the nearest 1.0 millimeter) with the Subject standing erect against a

vertical scale of portable stadiometer (Pfifter, Carlstadt, N.J,U.S.A), with the head positioned so that the top of the external auditory meatus was in level with the inferior margin of the bony orbit. Waist circumference (WC) was measured using constant tension tape at the end of a normal expiration, at the midpoint between the lower part of the lowest rib and the highest point of the hip on the mid-axillary line, hip circumference. (HC) was measured on the maximal circumference over the buttocks and at the level of greater trochanters and thigh measurements were taken in the mid-way between the inguinal fold and the proximal border of the patella with a tape measure. All measurements were made in duplicates, to the nearest centimeter and the mean values were used for subsequent analysis, as recommended by the World Health Organization (WHO, 2006). BMI was calculated as weight in kilograms divided by squared of the height in meter, waist-to-hip ratio were calculated as WC divided by HC and the waist-to-height ratio was calculated as WC divided by Ht and waist to thigh ratio was calculated by dividing WC by thigh circumference.

BLOOD PRESSURE

Blood pressures were measured two times in a seated position after 10 min of rest using a standard mercury sphygmomanometer; measurements were made between the hours of 7:00am and 10:00 am. High systolic blood pressure (SBP) and high diastolic blood pressure (DBP) were defined using WHO, 1998 criteria.

BIOCHEMISTRY ANALYSIS

Sample collection:

5.0 ml of venous blood samples from overnight fasting subjects was aseptically collected from the median antecubital or cephalic veins and 4.0 ml dispensed into labeled plain BD vacutainer®, tubes and 1.0 ml in fluoride oxalate coated tubes (Becton Dickenson, Plymouth, UK), for fasting blood glucose determination. After clotting, blood sample in the plain tubes were centrifuged at 3000 g for 4 min and the serum stored at -20°C until ready for analysis for lipid profile and other biochemical parameters. Serum fasting insulin
Serum insulin measurement kit was purchased from CALBIOTECH, Fasting serum insulin was determined using ELISA method; a solid phase direct sandwich immunoassay method, with precision coefficient of variation of both intra-Assay and inter-Assay on two serum samples as 6.3% ,8.1% and 8.5%, 7.4% respectively.
Lipid Profile and electrolytes: The lipid profile and glucose were assayed using Envoy® 500 reagents (Vital Diagnostics, USA) adhering to the manufacturer'sprotocol on BT 5000® Random Access Chemistry Analyzer (Biotecnica, Italy). Serum TC, TG, LDL-C and HDL-C and glucose were determined by enzymatic methods. HDL-cholesterol was separated from low density lipoprotein and very low density lipoprotein by selective precipitation with phosphotungsten acid in the presence of Mg2+ ions. HDL-cholesterol remaining in the supernatant was separated

after centrifugation and its concentration determined by the cholesterol oxidase method. LDL-cholesterol concentration was calculated based on Friedwald's equation as follows; LDL-cholesterol = total cholesterol-(triglycerides/2.2+HDL) mmol/L. Glucose was assayed by the glucose oxidase method.

STATISTICAL ANALYSIS

All statistical analyses were performed using Graph Pad prism 5.0 (Graph Pad Software, San Diego CaliforniaUSA, www.graphpad.com.) and Microsoft Excel 2007. Continuous variables were expressed as mean ± SEM, while categorical variables expressed as proportion. Comparisons of the subjects and control group, were performed using unpaired t-tests or Fisher exact tests, where appropriate after data checked for normality. Odds ratio and their 95% confidence intervals were used to ascertain the risk of subjects in highly risk population. A level of $p<0.05$ was acceptable as statistically significant. Comparison of clinical variables, biochemical markers and anthropometrics between diabetics and control groups was by Pearson Correlation Coefficient. Correlation was significant at the 0.05, 0.01, 0.001 levels (2-tailed)

RESULTS

General demographic, clinical and anthropometric characteristics of study participants

Variables	Total (n=331)	Control (n=168)	Case (n=163)	p-value
AGE (years)	52.19 ± 0.72	51.96 ± 1.23	52.43 ± 0.69	0.7232
Gender				
Male	138 (41.7%)	78 (46.4%)	60 (36.8%)	0.0943
Female	193 (58.3%)	90 (53.6%)	103 (63.2%)	0.0943
Blood pressure				
SBP (mmHg)	126.67 ± 1.27	120.5 ± 1.29	138.7 ± 1.67	< 0.0001
DBP (mmHg)	81.67 ± 0.82	76.53 ± 0.88	89.20 ± 1.02	< 0.0001
Anthropometrics				
Height (m)	1.65 ± 0.01	1.67 ± 0.02	1.64 ± 0.01	< 0.0001
Weight (kg)	68.11 ± 0.76	62.71 ± 1.05	73.50 ± 1.13	< 0.0001
BMI (kg/m^2)	26.05 ± 0.28	23.57 ± 0.38	27.52 ± 0.41	< 0.0001
WC (cm)	85.92 ± 0.78	79.95 ± 0.86	92.76 ± 0.96	< 0.0001
HC (cm)	95.88 ± 0.65	91.32 ± 0.78	98.92 ± 0.88	< 0.0001
WHR	0.89 ± 0.01	0.88 ± 0.01	0.94 ± 0.01	< 0.0001
WHtR	0.52 ± 0.01	0.49± 0.01	0.57 ± 0.01	< 0.0001
THIGHT (cm)	49.51 ± 0.42	46.21 ± 0.60	50.25 ± 0.54	< 0.0001
WTR	1.75 ± 0.01	1.75 ± 0.02	1.86 ± 0.02	< 0.0001

Table 1.

n =number of subjects. Comparison between means was done using un-paired t-test. p < 0.05 was considered statistically significant.
SBP; systolic blood pressure, DBP; diastolic blood pressure; WHR : Waist to hip ratio; WTR : Waist to thigh ratio; WHtR : Waist to height ratio; BMI: Body mass index; WC: Waist circumference; HC: Hip circumference;

Clinical, Anthropometrics and biochemical characteristics of study participants stratified by gender in the diabetic population

Variables	Male (n=60)	Female (n=103)	p-value
AGE (years)	53.14 ± 1.27	51.93 ± 0.82	0.4068
Anthropometrics			
WC (cm)	88.03 ± 1.83	95.52 ± 1.03	0.0002
HC (cm)	93.42 ± 1.35	102.1 ± 1.02	< 0.0001
BMI (Kg/m^2)	24.89 ± 0.41	29.28 ± 0.48	< 0.0001
WHR	0.94 ± 0.01	0.93 ± 0.01	0.7755
WHtR	0.52 ± 0.01	0.60 ± 0.01	< 0.0001
WTR	1.89 ± 0.04	1.84 ± 0.02	0.1109
Blood pressure			
SBP (mmHg)	135.5 ± 2.94	140.5 ± 1.99	0.1521
DBP (mmHg)	86.30 ± 1.84	90.89 ± 1.18	0.0294
Lipid profile			
TC (mmol/l)	4.150 ± 0.16	4.852 ± 0.14	0.0015
TG (mmol/l)	1.510 ± 0.14	1.510 ± 0.09	0.9999
HDL-C (mmol/l)	1.394 ± 0.08	1.493 ± 0.06	0.2951
LDL-C (mmol/l)	3.765 ± 0.15	4.430 ± 0.12	0.001
FBG (mmol/l)	10.84 ± 0.70	9.86 ± 0.36	0.1699
Biomarkers			
Insulin (µIU/mL)	14.38 ± 2.41	10.25 ± 1.27	0.098

Table 2:
Comparison between means was done using un-paired t-test. p<0.05 was considered statistically significant.
n =number of subjects; SBP; systolic blood pressure, DBP; diastolic blood pressure FBG; Fasting blood glucose TC; total cholesterol; TG: triglyceride; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; WHR: Waist to hip ratio; WTR: Waist to thigh ratio; WHtR: Waist to height ratio; BMI: Body mass index; WC: Waist circumference; HC: Hip circumference;

Demographic, anthropometrics and biochemical characteristics of subjects with DM only an diabetes with Metabolic Syndrome

Variables	DM only (n=51)	Met. Synd. (n=112)	p-value
AGE (years)	51.27 ± 1.34	52.96 ± 0.81	0.2627
Gender			
Male	27 (52.9%)	33 (29.5%)	0.005
Female	24 (47.1%)	79 (70.5%)	0.005
Anthropometrics			
BMI Status			
Underweight	5 (9.8%)	2 (1.8%)	0.0314
Normal	21 (41.2%)	24 (21.4%)	0.0135
Overweight	14 (27.5%)	47 (42.0%)	0.0435
Obese	11 (21.6%)	39 (34.8%)	0.0351
WC (cm)	87.02 ± 1.83	95.62 ± 1.03	< 0.0001
BMI	25.55 ± 0.77	28.42 ± 0.47	0.0011
WHR	0.92 ± 0.01	0.95 ± 0.01	0.0653
WHtR	0.53 ± 0.01	0.58 ± 0.01	< 0.0001
WTR	1.83 ± 0.03	1.88 ± 0.02	0.1681
Lipid profile			
TC (mmol/l)	4.355 ± 0.18	4.703 ± 0.13	0.1362
TG (mmol/l)	1.356 ± 0.11	1.581 ± 0.09	0.1729
HDL-C (mmol/l)	1.441 ± 0.08	1.463 ± 0.06	0.8229
LDL-C (mmol/l)	3.957 ± 0.16	4.289 ± 0.12	0.1197
FBG (mmol/l)	11.30 ± 0.73	9.73 ± 0.37	0.0345
Biomarkers			
Insulin (µIU/mL)	13.11 ± 2.64	11.16 ± 1.27	0.4532

Table 3.
Values are represented as Mean SEM and frequency (percentage). Comparison between means was done using un-paired t-tes . p<0.05 was considered statistically significant ,
n =number of subjects; DM: diabetes; Met. Synd Metabolic syndrome.WHR : Waist to hip ratio; WTR: Waist to thigh ratio; WHtR : Waist to height ratio; BMI : Body mass index ;W C:Waist circumference; FBG : Fasting blood glucose; insulin; TC ;total cholesterol ;TG : triglyceride ; HDL-C : high density lipoprotein cholesterol ; LDL-C : low density lipoprotein cholesterol ;

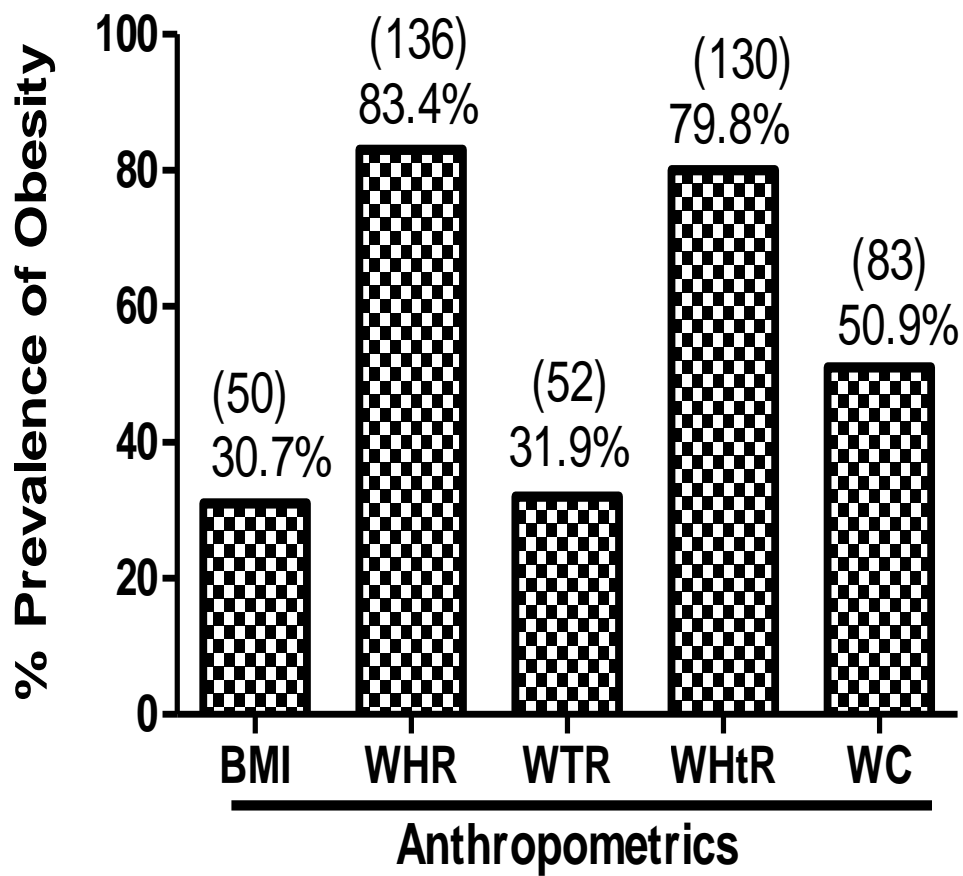Prevalence of obesity according to the various anthropometric measurements among diabetics.

Fig.1.

Values in parenthesis are frequencies. Obesity was defined by BMI≥30 Kg/m^2; WHR m>0.9cm; f>0.85cm; WTR> 0.45; WHtR>0.8; WC m>102cm; f>88cm.

Binary logistic regression of factors associated with type II diabetes mellitus among hypertensive patients

Factors	OR	95% CI of OR	p-value
Gender			
Male	1(reference)		
Female	1.539	0.972 to 2.438	0.0809
WC (cm)			
Central obesity	5.251	3.095 to 8.908	0.0007
Normal	1(reference)		
BMI			
Normal	1(reference)		
Overweight	2.289		0.0029
Obese	4.245	2.235 to 8.062	< 0.0001
WHR			
Normal	1(reference)		
Obese	7.447	4.314 to 12.86	< 0.0001
WHtR			
Normal	1(reference)		
Obese	6.920	4.115 to 11.64	< 0.0001
WTR			
Normal	1(reference)		
Obese	13.61	5.611 to 33.01	0.0013
TG (WHO Criteria)			
Normal	1(reference)		
Dyslipidaemia	2.853	1.498 to 5.435	0.0011
TG (NCEP III Criteria)			
Normal	1(reference)		
Dyslipidaemia	2.706	1.508 to 4.858	0.0009
HDL(WHO Criteria)			
Good	1(reference)		
Bad	0.7683	0.4439 to 1.330	0.4056
HDL (NCEP III Criteria)			
Good	1(reference)		
Bad	0.6546	0.4016 to 1.067	0.1095

Table 4.
OR: Odds ratio; CI: Confidence interval.
W C:Waist circumference, BMI : Body mass index ; WHR : Waist to hip ratio; WHtR : Waist to height ratio; WTR: Waist to thigh ratio;TG : triglyceride ; HDL-C : high density lipoprotein cholesterol

Prevalence of Metabolic Syndrome and the incidence of its components among Cases and Controls

CRITERIA	DM (n=51)	p-value	DM + HTN (n=112)	p-value	Total CASE (n=163)	CTRL-G (n=168)	p-value
WHO ??							
BMI>30Kg/m2	11 (21.6%)	0.0508	39 (34.8%)	< 0.0001	50 (30.7%)	14 (8.3%)	0.0001
WHR m>0.9cm; f>0.85cm	35 (68.2%)	< 0.0001	101 (90.2%)	< 0.0001	136 (83.4%)	49 (29.1%)	<0.0001
TG>1.9mmol/l	9 (17.6%)	0.2209	26 (23.2%)	0.0009	35 (21.5%)	15 (8.9%)	0.013
HDL m<0.9mmol/l; f<1.0mmol/l	8 (15.7%)	0.091	20 (17.9%)	0.0729	28 (17.2%)	57 (33.9%)	0.027
BP>140/90mmHg	0 (0.0%)	0.8999	79 (70.5%)	< 0.0001	79 (48.5%)	9 (5.4%)	<0.0001
FBS>6.1mmol/l	45 (88.2%)	< 0.0001	96 (85.7%)	< 0.0001	141 (86.5%)	8 (4.7%)	<0.0001
Metabolic syndrome	**10 (19.6)**	**< 0.0001**	**45 (40.2%)**	**< 0.0001**	**55 (33.7%)**	**5 (2.97%)**	**<0.0001**
NCEP III ‡‡							
WC m>102cm; f>88cm	16 (31.4%)	0.0041	67 (59.8%)	< 0.0001	83 (50.9%)	17 (10.1%)	<0.0001
TG>1.7mmol/l	13 (25.4%)	0.0843	29 (25.9%)	< 0.0001	42 (25.8%)	20 (11.9%)	0.015
HDL m<1.0mmol/l; f<1.3mmol/l	11 (21.6%)	0.0113	29 (25.9%)	0.0114	40 (24.5%)	58 (34.5%)	0.002
BP>135/85mmHg	3 (5.9%)	0.3864	85 (75.9%)	< 0.0001	88 (54.0%)	4 (2.3%)	<0.0001
FBS>6.1mmol/l	45 (88.2%)	< 0.0001	96 (85.7%)	< 0.0001	141 (86.5%)	4 (2.3%)	<0.0001
Metabolic syndrome	**28 (54.9%)**	**< 0.0001**	**55 (49.10%)**	**< 0.0001**	**83 (50.9%)**	**8 (4.76%)**	**< 0.0001**
Joint Interim Statement							
WC m>94cm; f>80cm	27(52.9%)	< 0.0001	90(80.4%)	< 0.0001	117(71.8%)	48(28%)	< 0.0001
TG >1.7 mmol/L	13(25.5%)	< 0.0001	29(25.9%)	< 0.0001	42(25.8%)	24(14.3%	< 0.0001
HDL m<1.0mmol/l; f<1.3mmol/l	11(21.6%)	0.0016	29(25.9%)	< 0.0001	40(24.5%)	102(60.7%)	< 0.0001
BP>130/85mmHg	4(7.8%)	< 0.0001	99(88.4%)	< 0.0001	103(63.2%)	28(16.7%)	< 0.0001
FBS>5.6mmol/l	48(94.1%)	< 0.0001	102(91.1%)	< 0.0001	159(92.0%)	32(19.0%)	< 0.0001
Metabolic syndrome	**8(15.7%)**	**< 0.0001**	**89(79.5%)**	**< 0.0001**	**97(59.5%)**	**5(3.0%)**	**< 0.0001**

Table 5: *?? One of the 3 criteria of insulin resistance and at least 2 other criteria are diagnostic of the metabolic syndrome . ‡‡ Three or more criteria are diagnostic of the metabolic syndrome . Each comparison is performed between Case groups individually (DM –diabetes , DM + HTN both diabetes and hypertension) and the CTRL G- control group . Fisher exact test was used test association between case and controls. WHO, World Health Organization ; NCEP , National Cholesterol Education Program ; HDL-C, high-density lipoprotein cholesterol ; BP, blood pressure ; FBG : fasting blood glucse ; BP : blood pressure ; TG , triglycerides . Data are presented as n (%).*

Pearson Correlation coefficient between biochemical markers and Anthropometrics for CASES (Upper Right-Hand Side) and CTRL-G (Lower Left-Hand Side)

	TG	LDL	TC	HDL	FBG	BMI	WHR	WTR	WHtR
TG		**0.258**[**]	**0.372**[**]	-0.121	**0.216**[**]	0.117	**0.218**[**]	**0.205**[**]	**0.206**[**]
LDL	0.120		**0.965**[**]	**0.237**[**]	-0.023	**0.277**[**]	0.117	-0.012	**0.300**[**]
TC	0.117	**0.939**[**]		**0.324**[**]	0.005	**0.275**[**]	0.129	-0.014	**0.299**[**]
HDL	0.013	**0.185**[*]	**0.431**[**]		0.027	0.082	-0.029	-0.112	0.025
FBS	**0.310**[**]	-0.067	-0.027	0.043		-0.217[**]	0.033	-0.077	**-0.217**[**]
BMI	**0.193**[*]	**0.216**[*]	**0.204**[*]	0.040	0.079		0.217[**]	0.122	**0.880**[**]
WHR	**0.289**[**]	0.040	0.018	-0.018	**0.223**[**]	0.222[**]		**0.579**[**]	**0.517**[**]
WTR	0.116	-0.008	-0.015	-0.005	**0.263**[**]	0.033	0.130		**0.388**[**]
WHtR	**0.227**[**]	**0.190**[*]	**0.204**[*]	0.084	0.133	**0.783**[**]	**0.377**[**]	**0.259**[**]	

Table 6.
*Values are presented as correlation coefficient (r). *Correlation is significant at the 0.05 level (2-tailed) , **. Correlation is significant at the 0.01 level (2 –tailed) , ***. Correlation is significant at the 0.001 level (2-tailed). Na : Sodium ; K⁺ : Potassium ; Cl⁻ : chlorine ; FBG : Fasting blood glucose ; BMI : Body mass index ; WHR : Waist to hip ratio ; WTR : Waist to thigh ratio ; WHtR : Waist to height ratio . Underline and boldface represent correlation coefficient (0.3 <r <0.5) ; TC ; total cholesterol ; TG : triglyceride ; HDL-C :high density lipoprotein cholesterol ;LDL-C : low density lipoprotein cholesterol ,*

Correlation matrix for measures of adiposity in male participants (TOP RIGHT) in female participants (LOWER LEFT)

PARAMETERS	WEIGHT	HEIGHT	WC	THIGH (cm)	BMI	WHR	WTR
WEIGHT(Kg)	1	0.435***	0.9044****	0.3396**	0.8804****	0.4499***	0.5065****
HEIGHT(cm)	0.3585***	1	0.1961	0.07461	0.05085	0.00607	0.1362
WC(cm)	0.8303****	0.06808	1	0.3393**	0.8741****	0.6804****	0.6078****
THIGH(cm)	0.8205****	0.1583	0.6828****	1	0.534****	0.1024	-0.5036****
BMI	0.9192****	-0.03245	0.8647****	0.8161****	1	0.4493***	0.3544**
WHR	0.04062	-0.1641	0.4575****	-0.0568	0.1123	1	0.5497****
WTR	0.02754	-0.1139	0.403****	-0.3883****	0.07653	0.6311****	1

Table 7.
Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed),*Correlation is significant at the 0.0005 level (2-tailed) and ****Correlation is significant at the 0.0001 level (2-tailed) Critical
value: 0.2050 P: ≤0.05

Diastolic and systolic Blood Pressures and all other anthropometric parameters WC, HC, BMI, WHtR, were significantly (p< 0.0001) higher in the diabetic subjects.There was no statistical difference in age between the case subjects and the controls and between the male and female subjects. WC, HC, BMI, WHtR were significantly (p< 0.0001) higher in the female diabetics than the male counterparts, whilst WTR and WHR were non significantly different. Fasting plasma insulin and glucose were not also significantly different between the sexes.

The lipid profiles of diabetics with metabolic syndrome were not significantly different from diabetics without metabolic syndrome. However, BMI and WHtR and WC were significantly higher in the diabetics with metabolic syndrome. There was also a higher percentage of

overweight (42%) and obese (39%) in diabetics with metabolic syndrome Figure 1 shows the prevalence of Obesity according to the various anthropometric measurements among diabetics. WHR predicted a higher proportion (83.4%) of obesity followed by WHtR (79.8%), WC (50.9%), WTR (31.9%) and BMI (30.7%)

The binary logistic regression analysis indicates obesity remains the predictor of type II diabetes among the hypertensive participants. Table 4 presents the binary logistics regression of factors associated with type II diabetes mellitus among hypertensive patients. Binary logistic regression indicated that obesity as depicted by increase WC (OR=5.251 (3.095 to 8.908); p=0.0007), BMI (OR=4.245 (2.235 to 8.062); p<0.0001), WHR (OR=7.447 (4.314 to 12.86); p<0.0001), WHtR (OR=6.920 (4.115 to 11.64); p<0.0001) and WTR (OR=13.61 (5.611 to 33.01); p=0.0013) was an independent risk factor for diabetes mellitus in hypertensive subjects after adjusting for age. Dyslipidaemia per the WHO criteria increase one odds of 2.9 fold while that per NCEP III was associated with 2.7 time increase odd for diabetes mellitus among hypertensive.

According to the WHO criteria, about 20% of the diabetics had metabolic syndrome whilst 40% of the diabetic s with hypertension had metabolic syndrome. NCEPIII criteria, has 54.9 of the diabetic having a metabolic syndrome whilst 49% of diabetic with hypertension had metabolic syndrome. According to the Joint Interim Statement, 16% of the diabetics had metabolic syndrome, whilst about 80% of the diabetics with hypertension had metabolic syndrome

Triglycerides (TG) was significantly positively correlated with, fasting blood glucose; (r=0.216**) among the diabetics and BMI, WHR, WTR, and WHtR (r=0.193* r=0.289**; r=0.227**) respectively among controls. Elevated levels of Low density lipoprotein (LDL) cholesterol, was positively correlated with total, body mass index (BMI) (r=0.277**) and waist to height ratio (WHtR) (r=0.300**) in diabetics. The total cholesterol levels in diabetics were shown to have positive correlation (r= 0.275**,r=0.299**) with BMI, and WHtR respectively.

Adiposity in the male and female diabetics was assessed. In the female, WTR was significantly positively correlated with WC (r=0.403), WHR (r= 0.631) and negatively correlated with thigh circumference (r=-0.388). In the male participants, WTR significantly positively correlated with weight (r=0.506), WC (r=0.608) BMI (r=0.354), and WHR (r=0.549) and significantly negatively correlated with thigh circumference (r=-0.504).

DISCUSSION

World Health Organization (WHO) Expert Consultation on anthropometric parameters on WC and WHR was convened in Geneva from 8 to 11 December 2008 to consider approaches to developing international guidelines for indices and action levels in order to characterize health risks associated with these measures of body fat distribution using anthropometrics. However there are still many bottle-necks in attempt to unify these anthropometric measurements as predictors for some NCDs.

There is an increasing concern that the European BMI and WC cutoff points for overweight and obesity might underestimate health risks, in some African populations because of differences in body composition, body fat distribution and associated health risks at a given BMI level among Africans compared with other populations. For example in Ghana, women are shown to have higher WC than their male counterparts (Ngala et al., 2015), and also Owiredu et al's study on obesity and cardiovascular risk factors in Kumasi-Ghana has shown that lower BMI and WC levels are predictive of obesity and its associated health risks (Owiredu et al., 2008) compared to the international reference points. There is therefore the need for appropriateness of waist circumference and waist-to-hip cut-offs for different ethnic groups (Lear et al., 2010).

All the anthropometric parameters seem to be implicated in the aetiology of diabetes. WC, HC, WHR, BMI, WHtR were significantly (p< 0.0001) higher in the diabetics than the controls (Table 1). This picture clearly shows overweight (BMI =27.52 ± 0.41 kg/m2) diabetics that have a tendency to develop central obesity (WC= 92.76 ± 0.96cm). Waist circumference is a simple anthropometric parameter that better predicts the adverse metabolic profile of the metabolic syndrome. The lipid profile did not show severe dyslipidaemia between the sexes or between diabetics with or without metabolic syndrome (Table 2 & 3). However, the WC and WHR showed central obesity when compared to the controls. Also the high significance difference of WC between the diabetics (WC= 92.76 ± 0.96cm) and the controls (79.95 ± 0.86cm),and a mean plasma glucose of 10.35± 0.53mmol/l, a BMI of 27.52 ± 0.41 kg/m2 and BP 138.7 ± 1.67/89.20 ± 1.02 clearly depicts metabolic syndrome as defined by Joint Interim Statement (JIS) (Alberti et al., 2009). Indeed 16% of the diabetics had metabolic syndrome, whilst about 80% of the diabetics with hypertension had metabolic syndrome.

According to the WHO and NCEPII criteria, about 20% and 55% respectively had metabolic syndrome. When the diabetics were grouped in term of blood pressure, 40% and 49% of these subjects were classified as having metabolic syndrome respectively (Table 5). This is an indication that the cut of points of anthropometric parameters as indicators of central obesity and metabolic syndrome in the Ghanaian diabetics needs a second look at, as suggested by Owiredu et al., 2008). The female diabetics had higher mean WC of 95.52 +1.03 cm and the male 88.03+ 1.83 cm (Table 2) contrary to the male and female WC cut off point included as predictors of metabolic syndrome by NCEPII and the JIS criteria. Indeed Motala et al, showed a high prevalence of metabolic syndrome using the JIS criteria with lower WC in the Zulu population as compared to the European cutoff point for metabolic syndrome (Motala et al., 2011).

Gender is another factor to consider in the interpretation, classification and diagnosis in the use of anthropometric indices. In a study in Iran, ATP III definition put central obesity at 54.4% in females and 13.9% in males (Esteghamati et al., 2009), and obesity was about 46.3% in females and 29.8% in males in the US (Ford et al., 2002). Caucasian men generally have a higher WC than the women, therefore, one would have

expected a higher prevalence of obesity in the male since WC is the key determinant index of obesity. Here, the female showed a significantly (p< 0.0001) higher WC, HC, BMI, WHtR (Table 2).

These anthropometries show a tendency towards obesity. Indeed 63% of the diabetics were females and were overweight (BMI 29.28 ± 0.48kg/m2) and had higher central obesity (WC 95.52 ± 1.03 cm and HC 102.1 ± 1.02 cm) as defined by both the WHO and NCEP III criteria, and had metabolic syndrome. WHR and WTR were not significantly different between female and male diabetics. Adiposity determined by the various anthropometric parameters shows that in the female, WC was significantly positively correlated with WTR, WHR and negatively correlated with the thigh circumference. In the male, WC was significantly positively correlated with WTR, BMI, WHR and also negatively correlated with the thigh circumference (Table 7).

A high WTR is an expression of a larger skeletal mass and an increased capacity for fatty acid and glucose disposal and it is therefore associated with low plasma glucose and fatty acids (Kelley et al., 1999), thus accounting for the negative correlation between adiposity and thigh circumference. Defining obesity by the WHO and the NCEP III criteria, BMI, WHR, WTR, WHtR, and WC gave a prevalence of 30.7%, 83.4%, 31.9%, 79.8%, 50.9% respectively (Fig1).Other finding though similar to this study, showed that WC gives a better prediction of obesity compared to the other anthropometric parameters (Valsamakis et al., 2004) whereas WHR gave a higher prevalence of obesity in this study. This implies that different criteria for expressing central obesity may be used for different populations or ethnicity.

Sixty eight percent of the diabetic patients were, overweight or obese and in addition had metabolic syndrome (Table 3) with significantly higher WC, BMI, WHtR. Significantly higher values of these parameters have been shown to be associated with NCDs (Shen et al., 2006). Obesity is one of the criteria for defining metabolic syndrome. Overt obesity is however low in some countries including Asia but these populations have relatively high prevalence of metabolic risks (Nishida et al., 2010). In another study, the percentages of obesity risk factors in metabolic syndrome were highest for W/Ht ≥0.5 in both genders (Hsieh and Muto, 2006). The binary logistic regression analysis suggest that, obesity remains the predictor of type II diabetes among the hypertensive participants (Table 4).

WHR, WTR and WHtR significantly and positively correlated with TG. BMI and WHtR also significantly positively correlated with LDL and TC. However, WHtR significantly negatively correlates with FBG (Table 6). WHtR alone has positive correlation with triglycerides, low density lipoprotein cholesterol and total cholesterol levels. In the control group, WHR was observed to have positive correlation with only one of the components of the lipid profile; triglycerides, despite its higher rate of prediction of obesity in diabetics. However, it is significantly positively associated with fasting blood glucose levels and the body mass index measurements.

The waist-to-height ratio alone has shown a remarkable association with two of the components of the lipid profile; TG and total cholesterol, known to be the key lipids associated with obesity. The WTR which indicated as the second poorest in the measurement of obesity prevalent rates (31.9%) in the diabetics indicated a positive correlation coefficient (r) with FBG. In this study WHR, and WHtR (Fig 1) were the best predictors of obesity and these were not gender dependent as WC. It has also been shown that WHTR allows the same boundary values for men and women and for different ethnic groups (Ashwell and Hsieh, 2005)

CONCLUSION

WHR and WHtR were more predictive of obesity than BMI and WTR and WC for all gender. WC was higher in the female diabetics than the male counterpart. In the female diabetics WHtR and WC, were more predictive of obesity in that order. WC may not be the key index defining central obesity in this section of Ghanaian population. However, obesity remains the predictor of type II diabetes. This implies different indices may better express obesity in different gender and ethnic/environment population.

LIST OF ABBREVIATIONS

WHR: Waist to hip ratio; WTR: Waist to thigh ratio; WHtR: Waist to height ratio; BMI: Body mass index ; W C:Waist circumference

DECLARATION

 Authors have no conflict of interest

CONSENT TO PARTICIPATE

A written consent form was completed and signed/thumb-printed by all the participants who were recruited into the study after the study was explained to them in a language they understand.Consent to publish:

CONSENT TO PUBLISH

Participant gave permission for the data to be published on condition that: "No one, except the research would have access to these details and no identifying details would appear in our published results".

AUTHORS' CONTRIBUTION

1.   Financial competing interests
In the past five years authors have not received reimbursements, fees, funding, or salary from an organization that may in any way gain or lose financially

from the publication of this manuscript, either now or in the future

2.   Stock

Authors do not hold any stocks or shares in an organization that may in any way gain or lose financially from the publication of this manuscript, either now or in the future

3.   Authors do not hold or are currently applying for any patents relating to the content of the manuscript? And have not received reimbursements, fees, funding, or salary from an organization that holds or has applied for patents relating to the content of the manuscript.

4.   Non-financial competing interests

There are no non-financial competing interests (political, personal, religious, ideological, academic, intellectual, commercial or any other) to declare in relation to this manuscript

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REFERENCES

1.   Aikins Ad.-G (2007). Ghana's neglected chronic disease epidemic: a developmental challenge. Ghana medical journal.41: 154.

2.   Alberti KG, Eckel RH, Grundy SM, et al. (2009). International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; International Association for the Study of Obesity. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association;World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation.120:1640–164

3.   Ashwell M and Hsieh SD (2005). Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international publichealth message on obesity International Journal of Food Sciences and Nutrition. 56: 303-307

4.   Botti AB, Pérez-Cueto F, Monllor PV and Kolsteren P (2009). Anthropometry of height, weight, arm, wrist, abdominal circumference and body mass index, for Bolivian Adolescents 12 to 18 years-Bolivian adolescent percentile values from the MESA study. Nutr Hosp. 24: 304-311

5.   BrambillaP, BedogniG, Moreno LA, Goran MI,Gutin B, FoxKR, Peters P, Barbeau DM, Simone M De and Pietrobelli A (2006). Cross validation of anthropometry against magnetic resonance imaging for the assessment of

visceral and subcutaneous adipose tissue in children. International Journal of Obesity. 30: 23–30

6.   Dalal, S, Beunza J J, Volmink J, Adebamowo C, Bajunirwe F,Njelekela M, Mozaffarian D, Fawzi W, Willett W, Adami. H-O,and Holmes M D (2011). Non-communicable diseases in sub-Saharan Africa: what we know now. International Journal of Epidemiology. 40:885–901.

7.   Deurenberg P, Deurenberg-Yap M, Foo LF, Schmidt G and Wang J(2003). Differences in body composition between Singapore Chinese, Beijing Chinese and Dutch children. Eur J Clin Nutr. 57: 405-409.

8.   Esteghamati A, Meysamie A, Khalilzadeh O, Rashidi A, Haghazali M, Asgari F Kamgar M, Gouya MM and Abbasi M (2009). Third national surveillance of risk factors of non-communicable diseases (SuRFNCD-2007) in Iran: methods and results on prevalence of diabetes, hypertension, obesity, central obesity, and dyslipidemia BMC Public Health. 9:167

9.   Fezeu L, Balkau B, Sobngwi E, Kengne A-P , Vol S, Ducimetiere P and Mbanya J-C (2010). Waist circumference and obesity-related abnormalities in French and Cameroonian adults: the role of urbanization and ethnicity. International Journal of Obesity. 34, 446–453.

10.   Ford ES, Giles WH, Dietz WH (2002). Prevalence of the metabolic syndrome among US adults: findings from the third National Health and Nutrition Examination Survey. JAMA; 287:356-359

11.   Garnett SP, Baur LA and Cowell CT (2008). Waist-to-height ratio: a simple option for determining excess central adiposity in young people. International Journal of Obesity 32: 1028

12.   Hsieh SD: Muto T (2006). Metabolic syndrome in Japanese men and women with special reference to the anthropometric criteria for the assessment of obesity: Proposal to use the waist-to-height ratio Prev. med. 42: 134-139

13.   Hsieh, SD and Yoshinaga H (1995). Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. Int J Obes Relat Metab Disord. 19: 585-589

14.   Kelley DE, Goodpaster B, Wing RR and Simoneau JA (1999). Skeletal muscle fatty acid metabolism in association with insulin resistance, obesity and weight loss. Am. J. Physiol. Endocrinol. Metab. 277: E1130-E1141

15.   Kuk JL, Kilpatrick K, Davidson LE, Hudson R and Ross R (2008). Whole-body skeletal muscle mass is not related to glucose tolerance or insulin sensitivity in overweight and obese men and women. Applied Physiol. Nutr. Metab., 33: 769-774.

16.   Laaksonen DE, Lakka HM, Niskanen LK, Kaplan GA, Salonen JT and Lakka TA (2002) Metabolic syndrome and development of diabetes mellitus: application and validation of recently suggested definitions of the metabolic syndrome in a prospective cohort study. Am J Epidemiol. 157: 1070 – 1077

17.   Lear SA, James P, Ko GT, Kumanyika S (2010). Appropriateness of wait circumference and waist-to-hip cut-offs for different ethnic groups. Eur J ClinNutr 64:42-61

18.   Mabchour AEL, Delisle H, Vilgrain C, Larco P, Sodjinou R and Batal M (2015). Abdominal obesity and other cardiometabolic risk biomarkers in two urban population groups with a common African heritage: Cotonou (Benin) and Port-au Prince (Haiti).Integr Obesity Diabetes. 133-140

19.   Mbanya JC, Motala AA, Sobngwi E, AssahFK, Enoru ST(2010). Diabetes in sub-Saharan Africa. Lancet. 375:2254–2266

20.   Motala AA, Esterhuizen T, Pirie   FJ, OMar MAK (2011). The Prevalence of Metabolic Syndrome and Determination of the Optimal Waist Circumference Cutoff Points in a Rural South African Community. Diabetes Care. 34:1032–1037

21. Ngala RA, Akilla MA and Doodaah ED (2015). Are the Thigh Circumference, Waist-to-Thigh Circumference Ratio and Serum Creatinine Better Markers of Type II Diabetes than the Body Mass Index? Trends in Medical Research.10: 26-36

22. Nishida C, Ko GT and Kumanyika S (2010) Body fat distribution and noncommunicable diseases in populations: overview of the 2008 WHO Expert Consultation on Waist Circumference and Waist–Hip Ratio. European Journal of Clinical Nutrition. 64, 2–5

23. Osei K (2010). Metabolic Syndrome in Blacks: Are the Criteria Right?   Current Diabetes Reports 10:199-208

24. Owiredu WKBA, Adamu MS, Amidu N, Woode E, Barn V, Plunger-Rhule J. and Opoku-Okrah C (2008). Obesity and cardiovascular risk factors in a Pentecostal population in Kumasi-Ghana. J. Med. Sci. 8: 682-690

25. Sargeant LA, Bennett FI, Forrester TE, Cooper RS and Wilks RJ (2002). Predicting incident diabetes in Jamaica: the role of anthropometry. Obes Res. 10: 792-798.

26. Shen W, Punyanitya M, Chen J, Gallagher D, Albu J, Pi-Sunyer X, Lewis CE,   Grunfeld C,   Heshka S and Heymsfield SB (2006). Waist Circumference Correlates with Metabolic Syndrome Indicators Better Than Percentage Fat Obesity. 14: 727–736,

27. Tulloch-Reid MK, Williams DE., Looker HC., Hanson RL. and Knowler WC (2003). Do measures of body fat distribution provide information on the risk of type 2 diabetes in addition to measures of general obesity? Comparison of anthropometric predictors of type 2 diabetes in Pima Indians. Diabetes Care. 26, 2556-2561

28. Unwin N,McLartyD,Machibya H,etal (2006).Changes in blood pressure and lipids associated with rural to urban migration in Tanzania. J Hum Hypertens. 20:704–706

29. Valsamakis G, Chetty R, Anwar A, Banerjee AK, Barnett A and   Kumar S (2004). Association of simple anthropometric measures of obesity with visceral fat and the metabolic syndrome in male Caucasian and Indo-Asian subjects. Diabetic Medicine. 21:1339–1345,

30. WHO (2000a). Global Strategy on Prevention and Control of Non communicable Diseases. Resolution of the Fifty-third World Health Assembly (WHA 53.17). WHO: Geneva

31. World Health Organization. Obesity (2000b). Preventing and Managing the Global Epidemic:Report of a WHO Consultation.Geneva, World Health Org (Tech. rep. ser.no. 894

32. WHO Expert Consultation (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet; 363, 157–163. Erratum in: Lancet. 363: 9412:902.

33. WHO (2008). 2008–2013 Action Plan for the Global Strategy for the Prevention and Control of Noncommunicable Diseases. Resolution of the Sixty-First World Health Assembly (WHA 61.14). WHO:Geneva