Trends in Medical Research

ISSN 1819-3587

Academic Journals Inc.

www.academicjournals.com

Trends in Medical Research 10 (2): 26-36, 2015
ISSN 1819-3587 / DOI: 10.3923/tmr.2015.26.36
© 2015 Academic Journals Inc.

Are the Thigh Circumference, Waist-to-Thigh Circumference Ratio and Serum Creatinine Better Markers of Type II Diabetes than the Body Mass Index?

Robert A. Ngala, Martin A. Akilla and Edwin D. Doodaah
Department of Molecular Medicine, School of Medical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Corresponding Author: Robert A. Ngala, Department of Molecular Medicine, School of Medical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana Tel: +233 0207722162

ABSTRACT

Overweight and obesity, associated with type 2 diabetes have been characterized by Body Mass Index, waist circumference or waist-to-hip ratio. However, because of the limitation of the Body Mass Index in expressing fat distribution and the fact that visceral obesity has been more implicated in type 2 diabetes than subcutaneous fat, other diabetes markers are being investigated. A hospital-based case control study, using convenience sampling techniques, sought to determine the most appropriate surrogate makers of type 2 diabetes, among Ghanaian diabetics, using thigh circumference, waist-to-thigh ratio, waist circumference, Body Mass Index, plasma creatinine and lipid profile. The 134 diabetics and 70 control subjects were enrolled. Demographics were gathered and anthropometric variables considered were; body weight, measured with scale (Hospibrand ZT-120, England), waist circumference and thigh circumference, measured with a measuring tape (Gay Mills, WI), while height measured with stadiometer (Fischer Scientific). About 5 mL of overnight fasting venous blood sample were drawn for biochemical assays: Plasma glucose, total cholesterol, high density lipoprotein, low density lipoproteins and triglycerides were determined by enzymatic methods and the creatinine assessment based on the Jaffé reaction, were all done on COBAS Intergra 400 Plus auto analyzer (Germany). Data were analysed using Graph Pad Prism version 5.0 (Graph Pad Software, San Diego, California). Continuous variables expressed as Mean±SD. Subjects compared using unpaired t-tests, one-way ANOVA followed by the Bonferroni test for multiple comparisons. Total body weight, waist circumference, waist-to-thigh ratio and triglycerides were significantly elevated in the diabetic subjects, while High density lipoprotein was significantly reduced. Considering gender and the diabetics compared to control group, there was no significant difference in plasma creatinine levels. Though Waist Circumference (WC), Waist-to-Thigh Ratio (WTR) and Body Mass Index (BMI) were significantly higher in the diabetics as compared to the controls, only WC and WTR predicts dysglycaemia in a linear regression analysis. Waist circumference and waist-to-thigh circumference ratio were better markers of type 2 diabetes in individuals, who are moderately obese than BMI.

Key words: Diabetes mellitus, fat distribution, thigh circumference, waist circumference, waist-to-thigh ratio

INTRODUCTION

Diabetes Mellitus (DM) was once thought a rare disease in Africa. But now Africa is experiencing one of the most rapid epidemiological transitions, with the burden of non-

communicable diseases and especially diabetes, overwhelming to Africa's health care systems. This increasing burden is not paralleled by resources. A decade ago, the prevalence estimates in Rural Sub Saharan Africa was put at 0-2.2% and that of for Urban Sub Saharan Africa, at 2.2-6.7% (Sobngwi *et al*., 2001). There is no substantial data of diabetes prevalence in Ghana. Amoah *et al*. (2002) put a crude prevalence at 6%. The identification of factors associated with individuals in early stages of DM is crucial in order to potentially prevent the occurrence of DM and its related, systemic complications particular, Cardiovascular Diseases (CVD), the leading cause of morbidity and mortality for patients suffering from DM (Ryden *et al*., 2003).

The skeletal muscle is the most important organ in energy expenditure, accounting for 60-80% of energy expenditure, of which basal metabolic rate comprises 50-80% of daily energy expenditure (Ravussin *et al*., 1986). However, this is not exactly the same among individuals due to differences in body weight and body composition (Bray *et al*., 2012; Tataranni and Ravussin, 1995). This variability has been expressed in differences shown in the skeletal muscle metabolism (Zurlo *et al*., 1990). Skeletal muscle is one of the major target organs of insulin resistance and metabolic syndrome (Kelley *et al*., 1999).

The development of obesity is associated with increased energy intake and reduced energy expenditure (Simoneau *et al*., 1999). Obesity and insulin resistance are well established risk factors for type 2 diabetes mellitus (Haffner *et al*., 1990; Hofso *et al*., 2009). Skeletal muscle is the most important site of insulin resistance and accounts for approximately 90% of overall glucose disposal (Ferrannini *et al*., 1985).

The BMI has often been used to quantify the degree of obesity as a marker of insulin resistance but this could be misleading, because the quantity and the distribution of body fat has been shown to be the main determinants of insulin resistance in obesity (Taylor *et al*., 1998; Mazess *et al*., 1990). Visceral fat rather than subcutaneous fat has been more implicated in insulin resistance and the development of type 2 diabetes (Bjorntorp, 1991). Some sports men especially body weight builders may have BMI greater than 30 kg m^{-2} but with no sign of insulin resistance or carbohydrate dysregulation (Witt and Bush, 2005), hence some researchers have rather tried to look at the total skeletal mass, waist-to-thigh ratio, waist-to-hip ratio and thigh circumference as indices for the development of insulin resistance or type 2 diabetes rather than BMI (Snijder *et al*., 2003).

Skeletal mass also correlates to the thigh circumference. Muscle mass contains 98% of total creatinine, which is filtered by the kidney. Creatinine is formed from muscle creatinine. The amount of creatinine per unit of skeletal muscle is stable and proportional to skeletal mass; hence plasma creatinine concentration therefore is a direct reflection of skeletal mass. In subjects with normal renal function, creatinine measurement gives a good reflection of muscle mass (Bonsnes and Taussky, 1945). Low serum creatinine level was found to be associated with a high risk of type 2 diabetes in non obese middle-aged Japanese men (Harita *et al*., 2009). In another study in Japan, whole-body skeletal muscle mass was found not associated with either glucose tolerance or insulin sensitivity in overweight and obese men and women (Kuk *et al*., 2008).

Skeletal muscles in obese mice have been shown to have reduced number of mitochondria and therefore reduced skeletal muscle utilization of glucose and lipids (Bonnard *et al*., 2008) partly responsible for the observed insulin resistance in obese subjects.

If there is association between skeletal muscle mass and type 2 diabetes, then plasma creatinine must have an association with type 2 diabetes, since plasma creatinine reflects total body mass. Low skeletal muscle mass is associated with insulin resistance and metabolic syndrome (Lithell *et al*., 1981). Serum creatinine may therefore serve as surrogate marker of muscle mass and provide a possible relationship between low serum creatinine and type 2 diabetes.

There is no substantial data on the prevalence of obesity in Bolgataga or Ghana. However, the sudden proliferation of fast foods and increasing sedentary life styles and as many people are becoming more affluent due to the improvement of the economy to middle income status, appears to be increasing the prevalence of obesity in Ghana. It is therefore important to relate skeletal mass and lipid profile to the occurrence of diabetes mellitus.

In this study we determined the association between thigh circumference, waist-to-thigh ratio and plasma creatinine level and the lipid profile on type 2 diabetes in diabetic subjects as predictive markers of type 2 diabetes.

MATERIALS AND METHODS

A cross-sectional comparative study was carried out at the Diabetic Clinic of the Upper East regional Hospital (Bolgatanga, Ghana, among diabetic subjects visiting the facility. All procedures were approved by the Committee on Human Research Publication and Ethics of School of Medical Sciences, KNUST Kumasi, Ghana (CHRPE/Student/113/09). A written informed consent form was completed by all the participants who were recruited into the study after the study was explained in a language they understand.

Subjects: The study population was made up of 134 sequentially enrolled diagnosed type 2 diabetics aged between 25-70 years who reported at the diabetic clinic and 70 non-diabetic healthy individual volunteers of similar age range some, who accompanied their sick relatives to the centre. Consent was sort from all subjects, after the project objective was explained to them and they were issued with a consent form, which was duly completed and signed/thumb-printed. Data was also obtained from the participants through administered questionnaire. Because life style is known to have an effect on fat distribution and glucose metabolism, smokers, sedentary subjects, high alcohol intake were excluded in the study after an interview/questionnaire. However, it was difficult to determine the degree of inactivity to be considered sedentary and the limitations in the subjects' ability to give the exact amount of cigarette and alcohol consumption, hence estimations were made from the questionnaires. For example office workers who never did some form of physical exercise were considered sedentary and those who took more than an estimated 24 g alcohol per day were considered high drinkers (Greenfield and Kerr, 2008).

Sample collection: About 5.0 mL of venous blood samples was aseptically collected from the median antecubital or cephalic veins of the study subjects, after an overnight (12 h) fast was aseptically collected. The blood was then dispensed into labelled plain BD vacutainer®, tubes and fluoride oxalate coated tubes (to prevent glycolysis) for fasting blood glucose (Becton Dickenson, Plymouth, UK). Samples for blood glucose assay were immediately analysed. After clotting, blood sample in the plain tubes were centrifuged at 3000 g for 3 min and the serum stored at -20°C until ready for analysis for creatinine and the lipid profile.

Anthropometric measurement: Body weights were measured (to the nearest 0.5 kg), with the subject standing on a weighing scale (Hospibrand ZT-120, England), wearing light clothing after the weighing scale was adjusted to zero kg and calibrated using known weights. Heights were measured (to the nearest 1.0 cm), with the subject standing in an erect position against a vertical scale of a stadiometer (Fischer Scientific) and an L-square placed on the head and the head positioned so that the top of the external auditory meatus was in level with the inferior margin of

the bony orbit. The measurements of the thigh circumference were taken in the middle point between the inguinal fold and the proximal border of patella. The waist measurements were taken from the middle point between the iliac crest and the last rib, as recommended by the World Health Organization (WHO., 2009). Waist and thigh circumferences were measured twice to the nearest centimeter and the mean were used for subsequent analysis. All measurements were recorded in centimeters (cm) but the height was converted to meters. The BMIs were then calculated as weight in kilograms divided by the height in meter squared.

Biochemical assay: Serum total cholesterol, HDL, LDL, VLDL cholesterol and triglycerides were determined by enzymatic assay procedure (on COBAS Intergra 400 Plus auto analyser: Roche). Interassay coefficient of variation (2.3 and 2.1%) for low and high total cholesterol controls, respectively comply with National Cholesterol Education Programme recommendation (National Heart Lung and Blood Institute, 1988). Plasma glucose and serum creatinine were similarly determined enzymatically on the same automated machine with specific reagent kit designed for the equipment.

Statistical analysis: Results were expressed as Means±SEM. Data were analysed by one-way ANOVA followed by the Bonferroni test for multiple comparison using Graph Pad Prism version 5.0 (Graph Pad Software, San Diego California). Unpaired Student t-tests were used to assess for significance. Statistical significance was set at p-value≤0.05 for the various parameters in the study. A linear regression and univariate regression analyses, was done considering gender and the measures of fat distribution to find predictors of glucose level from the various parameters.

RESULTS

Table 1 and 2, show the metabolic changes in diabetics and controls and the effect of gender on these metabolic changes among the diabetic male and female only. Body weight, BMI, WC, FBS total cholesterol, WTR, TG and VLDL were significantly higher in the diabetics compared to the non diabetic population. However, HDL was significantly higher in the normal population than the diabetics. There was no significant change in creatinine levels. Gender was a factor in obesity, which shows female diabetics with significantly higher BMI, WC, total cholesterol and LDL

Table 1: General characteristics of the entire population

Parameters	Subjects (n = 134)	Control (n = 70)	p-value
Age (year)	50.63±11.38	49.17±7.89	0.5402
Wt (kg)	66.85±13.96	62.33±10.49	0.0182
BMI (kg m^{-2})	24.50±5.09	22.46±4.16	0.0043
WC (cm)	90.13±17.09	78.81±10.30	<0.0001
Thigh circumference (cm)	50.63±10.82	51.80±6.11	0.4022
WTR	1.82±0.41	1.53±0.18	<0.0001
FBS (mmol L^{-1})	12.83±4.08	5.53±0.59	<0.0001
TC (mmol L^{-1})	3.81±1.24	3.62±0.85	0.2661
TG (mmol L^{-1})	1.23±0.97	0.53±0.41	<0.0001
HDL-C (mmol L^{-1})	2.27±2.52	3.45±2.45	0.0016
LDL-C (mmol L^{-1})	1.96±0.98	2.21±1.51	0.1549
VLDL-C (mmol L^{-1})	1.33±6.59	0.24±0.19	0.1679
SCRT (µmol L^{-1})	106.40±7.7	122.50±8.4	0.1866

Data are presented as Mean±SD, Wt: Weight, BMI: Body mass index, WC: Waist circumference, WTR: Waist-to-thigh ratio, FBS: Fasting blood sugar, TC: Total cholesterol, TG: Triglyceride, HDL-C: High density lipoprotein cholesterol, LDL-C: Low density lipoprotein cholesterol, VLDL-C: Very low density lipoprotein cholesterol, SCRT: Serum creatinine

Table 2: Gender characteristics of the entire population distributions

Parameters	Males (n = 33)	Females (n = 101)	p-value
Age (year)	49.52±11.99	51.00±11.21	0.5172
Wt (kg)	64.76±14.69	67.53±13.72	0.3231
BMI (kg m^{-2})	22.58±5.37	25.13±4.86	0.012
WC (cm)	82.73±21.13	92.55±14.88	0.0038
Thigh circumference (cm)	48.12±12.68	51.45±10.07	0.1258
WTR	1.735±0.26	1.85±0.45	0.176
FBS (mmol L^{-1})	12.47±3.00	12.95±4.38	0.5536
TC (mmol L^{-1})	3.43±1.30	3.93±1.21	0.0449
TG (mmol L^{-1})	1.30±0.85	1.20±1.01	0.628
HDL-C (mmol L^{-1})	1.82±1.83	2.42±2.70	0.2336
LDL-C (mmol L^{-1})	1.66±0.99	2.06±0.96	0.0409
VLDL-C (mmol L^{-1})	2.15±8.96	1.07±5.63	0.414
SCRT (µmol L^{-1})	119.60±9.86	113.00±10.40	0.5964

Data are presented as Mean±SD, Wt: Weight, BMI: Body mass index, WC: Waist circumference, WTR: Waist-to-thigh ratio, FBS: Fasting blood sugar, TC: Total cholesterol, TG: Triglyceride, HDL-C: High density lipoprotein cholesterol, LDL-C: Low density lipoprotein cholesterol, VLDL-C: Very low density lipoprotein cholesterol, SCRT: Serum creatinine

Table 3: Classification of diabetic subjects into obese and non-obese using the BMI, WC and WTR

	BMI≥30 kg m^{-2}			WC (IDF criteria)			WTR≥1.95		
Parameters	Obese (n = 14)	Non obese (n = 120)	p-value	Obese (n = 69)	Non obese (n = 65)	p-value	Obese (n = 33)	Non obese (n = 101)	p-value
Age (year)	49.36±13.92	50.78±11.11	<0.6589	52.42±10.25	48.74±12.26	0.061	50.42±9.17	48.74±11.43	0.0632
C (cm)	110.30±22.19	87.7±14.81	<0.0001	***	***	***	99.73±8.68	87.00±18.00	0.0001
Thigh circumference (cm)	61.79±22.40	49.33±7.72	<0.0001	53.88±11.42	47.17±9.00	0.0002	47.06±8.36	51.79±11.30	0.0286
WTR	2.01±0.94	1.80±0.30	0.0649	1.95±0.43	1.69±0.35	0.0002	***	***	***
BMI (kg m^{-2})	***	***	***	27.56±4.32	21.25±3.61	0.0001	26.89±3.71	23.72±5.25	0.0017
FBS at diagnosis (mmol L^{-1})	8.84±3.70	12.27±5.51	0.0249	13.01±4.18	12.65±4.00	0.6104	11.23±5.95	12.13±5.27	0.4131
TOTAL-C (mmol L^{-1})	4.12±1.20	3.77±1.25	0.3313	4.06±1.19	3.54±1.26	0.0152	4.21±1.20	3.68±1.24	0.0308
TG (mmol L^{-1})	1.13±0.80	1.24±0.99	0.6934	1.30±1.00	1.15±0.94	0.3831	1.34±1.01	1.19±0.95	0.4212
HDL-C (mmol L^{-1})	2.63±2.62	2.23±2.52	0.5699	2.60±2.82	1.92±2.12	0.1209	2.68±2.74	2.14±2.44	0.2895
LDL-C (mmol L^{-1})	2.08±0.86	1.95±0.99	0.639	2.03±0.91	1.89±1.05	0.4034	1.98±1.00	1.95±0.98	0.8886
VLDL-C (mmol L^{-1})	0.51±0.36	1.43±6.96	0.6243	0.56±0.40	2.15±9.42	0.1648	0.61±0.46	1.57±7.58	0.4706
SCRT (µmol L^{-1})	122.50±4.5	109.60±6.8	0.0449	113.52±9.3	106.0±4.03	0.649	98.08±5.74	120.21±4.67	0.0149

Data are presented as Mean±SD, Wt: Weight, BMI: Body mass index, WC: Waist circumference, WTR: Waist-to-thigh ratio, FBS: Fasting blood sugar, TC: Total cholesterol, TG: Triglyceride, HDL-C: High density lipoprotein cholesterol, LDL-C: Low density lipoprotein cholesterol, VLDL-C: Very low density lipoprotein cholesterol, SCRT: Serum creatinine

cholesterol than male diabetics. However, the lipid levels were all within the physiological range: (Men with lipid levels greater than 5.82, 3.88 mmol L^{-1} and lower than 0.91 mmol L^{-1} for TC, LDL and HDL, respectively and women with lipid levels greater than 6.21, 4.40 mmo L^{-1} and lower than 1.00 mmol L^{-1} for TC, LDL and HDL, respectively, according to the Framingham study, constitutes a cardiovascular risk (Kannel, 1995).

Obesity has been described by several criteria: The BMI, WC and WTR by the WHO and IDF. The WHO defines obesity as BMI>30 kg m^{-2}, WHR>1 in men and >0.85 in women (WHO., 2000) and WC>94 cm for men and >80 cm for women agreed by both IDF and WHO (Alberti *et al*., 2009). Based on the BMI, only 10.4% of the diabetics were obese and these in addition had significantly high WC and thigh circumference but surprisingly, this was associated with a significantly low fasting blood glucose. However, 51.5% of the subjects under the IDF criteria were obese. Thigh circumference, WTR, BMI and total cholesterol were significantly higher in these diabetics. Based on the WTR criteria, 25% of the diabetics were obese. The BMI, thigh circumference, waist circumference and total cholesterol were significantly higher in these obese subjects than in than non obese (Table 3).

A linear regression model was used to determine the significance and independence of the variables in predicting the fasting blood sugar level in the subjects as well as the male and female subjects exclusively. Men and women differ in body-fat distribution; hence gender was considered in the analysis. Waist Circumference (WC) and Waist-to-Thigh Circumference Ratio (WTR) were significant predictors of fasting blood glucose level in the study population ($p = 0.0019$, $p = 0.0038$, respectively) and in the male. Total body weight, Body mass index and thigh circumference and creatinine were not significant predictors ($p = 0.8599$, $p = 0.6433$, $p = 0.6327$, $p = 0.5804$, respectively). Triglyceride was a significant predictor of fasting blood glucose level in the total study population ($p = <0.0001$). On the contrary, total cholesterol, high density lipoprotein cholesterol, low density lipoprotein cholesterol, very low density lipoprotein were not significant predictors of fasting blood glucose level in the study population. The females population had triglyceride as the only lipid significant predictor of fasting blood glucose level ($p = 0.0006$), whereas the males had triglyceride and HDL-cholesterol as significant predictors of fasting blood glucose level ($p = 0.0146$, $p = 0.006$, respectively). The regression coefficient of male triglyceride was slightly higher than that of the female population ($\beta = 0.069 \pm 0.027$ v $\beta = 0.045 \pm 0.013$, respectively), whilst the body mass index, waist circumference and waist-to-thigh ratio of the female population were not significant predictors of fasting blood glucose level ($p = 0.2217$, $p = 0.1536$, $p = 0.0639$, respectively) but in the males they were significant predictors ($p = 0.0315$, $p = 0.0056$, $p = 0.0079$, respectively).

DISCUSSION

Overweight and or obesity have been shown to be predisposing factors for the development of type 2 diabetes mellitus in several studies (Kahn *et al*., 2006; McTernan *et al*., 2002). In recent times concern has been, not only the amount of fat associated with obesity but its distribution. Waist circumference, waist-to-hip ratio and waist-to-thigh ratio; indicators of visceral adiposity have been implicated as makers of diabetes in several studies (Snijder *et al*., 2003). The subjects in this study presented with a significantly increased body weight, BMI, waist circumference and higher waist-to-thigh ratio compared to the controls. The higher risk of type 2 diabetes in persons with a high Waist-to-Hip Ratio (WHR) (WHR>1 in men and >0.85 in women (WHO., 2000) or Waist-to-Thigh Ratio (WTR) has been attributed to increased visceral fat, however, smaller hip or thigh circumference may also explain the predictive value of the WHR or WTR for type 2 diabetes (Seidell *et al*., 1997). It was observed in the Hoorn Study that the waist-to-hip ratio and not Body Mass Index (BMI) is an independent predictor of diabetes in the elderly (De Vegt *et al*., 2001). The exact mechanism remains unclear. Several other studies have established a low waist-to-hip ratio as a strong predictor of type 2 diabetes associated with visceral fat adiposity (Bjorntorp, 1991). In recent times attention has now been shifted to the waist circumference and waist-to-thigh ratio (Pouliot *et al*., 1994; Dobbelsteyn *et al*., 2001). The waist-to-thigh ratio represents an index of fatty acid disposal and has been used to predict the occurrence of diabetes (Ohlson *et al*., 1985). A high WTR is an expression of a larger skeletal mass and an increased capacity for fatty acid and glucose disposal and is therefore associated with low plasma glucose. The waist-to-thigh ratio in particular also gives a better prediction of the accumulation of visceral fat (Ohlson *et al*., 1985; Carey *et al*., 1997; Chan *et al*., 1994; Lundgren *et al*., 1989), which is assumed to play an important role in the aetiology of diabetes, because the accumulation of free fatty acids in the liver, results in insulin resistance and hyper insulinaemia (Despres *et al*., 1995). The predictive value of the WTR for type 2 diabetes is not only due to abdominal fat accumulation (as indicated by waist circumference) but its distribution (Snijder *et al*., 2003).

The thigh circumference of the subjects were non significantly higher than in the control and did not significantly correlate with plasma blood glucose levels. The thigh is potentially a good indicator of the occurrence of diabetes; people with narrow thighs are more likely to develop diabetes and heart diseases (Snijder *et al*., 2003), because of decreased ability to utilize glucose and fatty acid, the accumulation of which can result in insulin resistance, a marker of diabetes and cardiovascular diseases (Van Pelt *et al*., 2002; Despres *et al*., 1995).

With respect to the gender effect, the females had lager thigh circumference although not significant. A similar trend but significant results were obtained in the Hoorn Study for both hip and thigh circumferences (Snijder *et al*., 2003). Though, the thigh circumference of the females were higher than in the male (non significantly), which should have expressed a corresponding improved glucose handling over the male, considering the thigh circumference as an independent diabetes risk factor. Probably, the associated higher WC, LDL and total cholesterol (known to be diabetogenic) over the male value seems to offset the better glucose handling in the females in the Ghanaian population contrary to what has been observed in the Caucasian women (Snijder *et al*., 2003). Ghanaian women have a higher WC than their male counterparts (Owiredu *et al*., 2008). This however, may also be due to the fact that measurement of hip circumference may differ between men and women. Whereas, gluteal fat mass and pelvic width may be the main determinants of hip circumference in women, pelvic width and muscle mass may be the main determinants in men (Snijder *et al*., 2003).

Creatinine levels, is also an expression of skeletal mass, in subjects with normal renal function (Bonsnes and Taussky, 1945). Creatinine levels in the diabetics were similarly not significantly increased over the controls and between the male and female (Table 1). Furthermore, creatinine did not also predict fasting blood glucose levels, suggesting that these parameters did not directly influence the observed significant plasma glucose difference between the normal and the diabetic subjects (Table 4). In a study in Japan, skeletal muscle mass was similarly found not to be associated with either glucose tolerance or insulin sensitivity in overweight and obese men and women (Kuk *et al*., 2008). However, the rate of fatty acid oxidation in another study was found to be reduced in obese and type 2 diabetes (Kelley and Simoneau, 1994; Mandarino *et al*., 1993) subjects, who had lower creatinine compared to the controls. It therefore seems that ethnicity or some genetic factors may predispose skeletal muscle to glucose utilization. In a study in rodents, skeletal muscle in obese mice were shown to have reduced number of mitochondria and therefore

Table 4: Gender and measures of fat distribution to predict the glucose level when used singly in a linear regression model

	Total (n = 204)			Female (n = 142)			Male (n = 62)		
Parameters	β	p-value	R^2	β	p-value	R^2	β	p-value	R^2
Wt (kg)	-0.030±0.171	0.8599	0.0002	-0.204±0.190	0.2832	0.0082	0.807±0.464	0.0871	0.0480
BMI	0.030±0.064	0.6433	0.001	-0.084±0.069	0.2217	0.0107	0.363±0.165	0.0315	0.0748
WC (cm)	0.645±0.205	0.0019	0.0465	0.309±0.216	0.1536	0.0145	1.652±0.575	0.0056	0.1210
Thigh circumference (cm)	-0.060±0.124	0.6327	0.0011	-0.203±0.132	0.1257	0.0167	0.379±0.362	0.3	0.0179
WTR	0.014±0.005	0.0038	0.0406	0.012±0.006	0.0639	0.0243	0.022±0.008	0.0079	0.1119
TC (mmol L^{-1})	0.020±0.015	0.1827	0.0088	0.012±0.016	0.4539	0.0040	0.002±0.041	0.9577	4.73E-05
TG (mmol L^{-1})	0.047±0.011	<0.0001	0.0783	0.045±0.013	0.0006	0.0808	0.069±0.027	0.0146	0.0954
HDL-C (mmol L^{-1})	-0.040±0.033	0.2398	0.0068	-0.027±0.040	0.5038	0.0032	-0.203±0.071	0.006	0.119
LDL-C (mmol L^{-1})	-0.008±0.016	0.6001	0.0014	-0.011±0.016	0.5219	0.0029	-0.033±0.049	0.5113	0.0072
VLDL-C (mmol L^{-1})	0.075±0.070	0.2896	0.0056	0.033±0.069	0.6311	0.0017	0.446±0.238	0.0652	0.0555
SCRT (μmol L^{-1})	0.072±0.391	0.5804	0.0037	0.655±2.228	0.7703	0.0023	0.841±1.76	0.6369	0.0051

Data are presented as Mean±Standard deviation, Wt: Weight, BMI: Body mass index, WC: Waist circumference, WTR: Waist to thigh ratio, TC: Total cholesterol, TG: Triglyceride, HDL-C: High density lipoprotein cholesterol, LDL-C: Low density lipoprotein cholesterol, VLDL-C: Very low density lipoprotein cholesterol, SCRT: Serum creatinine . β: Regression gradient, R^2: Square of the univariate coefficient of regression, p-value significance of the association of the variable with the fasting blood sugar level

reduced skeletal muscle utilization of glucose and lipids (Bonnard *et al*., 2008) which was partly responsible for the observed insulin resistance in obese subjects. Similar results have also been observed in a human study (Kelley *et al*., 2002). In obese subjects the skeletal mass is proportionally lower compared to the total body mass and subjects predisposed to diabetes than in lean individual who tend to have a higher skeletal mass ratio to the total body mass, in which case the skeletal mass is protective against metabolic dysregulation of glucose and fatty acids (Park *et al*., 2009).

The mean BMI of the subjects (Table 1) though significantly higher than the control level, was within the normal range. Even, when the obese diabetic subjects were classified based on WC or WTR (IDF) criteria (Table 3), the mean BMI of the obese was 27.56±4.32 kg m^{-2}, more of overweight than obese by the WHO definition of obesity (BMI≥30 kg m^{-2}) (WHO., 2000). It was not surprising therefore that BMI was not correlated to the fasting blood glucose as has been reported in several studies. This also asserts the fact that the distribution of the fat plays a major role in its effect as well as the actual quantity. The WC and the WTR were significantly higher in the obese, hence the waist circumference and the WTR correlated with the plasma blood glucose. However, BMI, significantly predicts blood glucose levels in the obese male subject ($p = 0.0315$) (Table 4). The ability of these obesity indicators to predict diabetes may differ with ethnicity, age and sex (Resnick *et al*., 1998; Nakagami *et al*., 2003).

Lipid profile and insulin resistance: As expected, triglycerides were also raised in the diabetic subjects due to increased lipolysis (Table 1) probably due to increased dependence on fatty acid as an alternative energy source (Mooradian, 2009). This is a common phenomenon particularly in poorly controlled diabetes. In the absence of glucose cells utilize triglycerides from the adipose tissue as a source of energy (Goldberg, 2001). The HDL, the reverse transport cholesterol lipoprotein was significantly reduced in the subjects. When the results were subjected to univariate analysis to predict the effect of these parameters in glyaceamic control (Table 4), triglyceride was a significant predictor of fasting blood sugar level in the total study population ($p = <0.0001$). Contrarily, total cholesterol, high density lipoprotein cholesterol, low density lipoprotein cholesterol, very low density lipoprotein were not significant predictors of fasting blood sugar level in the study population. This observation may be credible, because even though some of the lipid parameters were statistically significantly different between the subjects and the controls, however these were all within the physiological range and therefore have very minimal diabetogenic effect.

CONCLUSION

Waist circumference and waist-to-thigh circumference ratio were better markers of type 2 diabetics, than BMI. The WC and WTR were significantly increased in the diabetic subjects and were predictors of plasma glucose as shown from the regression analysis. Plasma creatinine was a poor predictor of fasting blood glucose possibly because of the low prevalence obese subjects in Bolgatanga.

ACKNOWLEDGMENTS

Martin A. Awe and Edwin Die Doodah were supported by the Ghana Education Trust Fund through the Kwame Nkrumah University of Science and Technology, Kumasi. The authors are also grateful to the laboratory and administrative staff of the Bolgatanga Regional Hospital, for assisting in sample collection.

REFERENCES

Alberti, K.G., R.H. Eckel S.M. Grundy, P.Z. Zimmet and J.I. Cleeman *et al*., 2009. 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: 1640-1645.

Amoah, A.G.B., S.K. Owusu and S. Adjei, 2002. Diabetes in Ghana: A community based prevalence study in Greater Accra. Diabetes Res. Clin. Pract., 56: 197-205.

Bjorntorp, P., 1991. Metabolic implications of body fat distribution. Diabetes Care, 14: 1132-1143.

Bonnard, C., A. Durand, S. Peyrol, E. Chanseaume and M.A. Chauvin *et al*., 2008. Mitochondrial dysfunction results from oxidative stress in the skeletal muscle of diet-induced insulin-resistant mice. J. Clin. Invest., 118: 789-800.

Bonsnes, R.W. and H.H. Taussky, 1945. On the colorimetric determination of creatinine by the Jaffe reaction. J. Biol. Chem., 158: 581-591.

Bray, G.A., S.R. Smith, L. de Jonge, H. Xie and J. Rood *et al*., 2012. Effect of dietary protein content on weight gain, energy expenditure and body composition during overeating: A randomized controlled trial. J. Am. Med. Aassoc., 307: 47-55.

Carey, V.J., E.E. Walters, G.A. Colditz, C.G. Solomon and W.C. Willett *et al*., 1997. Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women the nurses' health study. Am. J. Epidemiol., 145: 614-619.

Chan, M.J., E.B. Rimm, G.A. Colditz, M.J. Stampfer and W.C. Willett, 1994. Obesity, fat distribution and weight gain as risk factors for clinical diabetes in men. Diabetes Care, 17: 961-966.

De Vegt, F., J.M. Dekker, A. Jager, E. Hienkens, P.J. Kostense *et al*., 2001. Relation of impaired fasting and postload glucose with incident type 2 diabetes in a dutch population: The hoorn study. J. Am. Med. Assoc., 285: 2109-2013.

Despres, J.P., S. Lemieux, B. Lamarche, D. Prud'homme and S. Moorjani *et al*., 1995. The insulin resistance-dyslipidemic syndrome: Contribution of visceral obesity and therapeutic implications. Int. J. Obesity Related Metab. Disorders, 19: S76-S86.

Dobbelsteyn, C.J., M.R. Joffres, D.R. MacLean and G. Flowerdew, 2001. A comparative evaluation of waist circumference, waist-to-hip ratio and body mass index as indicators of cardiovascular risk factors. The Canadian heart health surveys. Int. J. Obesity, 25: 652-661.

Ferrannini, E., J.D. Smith, C. Cobelli, G. Toffolo, A. Pilo and R.A. DeFronzo, 1985. Effect of insulin on the distribution and disposition of glucose in man. J. Clin. Invest., 76: 357-364.

Goldberg, I.J., 2001. Diabetic dyslipidemia: Causes and consequences. J. Clin. Endocrinol. Metab., 86: 965-971.

Greenfield, T.K. and W.C. Kerr, 2008. Alcohol measurement methodology in epidemiology: Recent advances and opportunities. Addiction, 103: 1082-1099.

Haffner, S.M., M.P. Stern, J. Dunn, M. Mobley, J. Blackwell and R.N. Bergman, 1990. Diminished insulin sensitivity and increased insulin response in nonobese, nondiabetic Mexican Americans. Metabolism, 39: 842-847.

Harita, N., T. Hayashi, K.K. Sato, Y. Nakamura, T. Yoneda, G. Endo and H. Kambe, 2009. Lower serum creatinine is a new risk factor of type 2 diabetes: The Kansai healthcare study. Diabetes Care, 32: 424-426.

Hofso, D., T. Jenssen, J. Bollerslev, J. Roislien, H. Hager and J. Hjelmesaeth, 2009. Anthropometric characteristics and type 2 diabetes in extremely obese Caucasian subjects: A cross-sectional study. Diabetes Res. Clin. Pract., 86: e9-e11.

Kahn, S.E., R.L. Hull and K.M. Utzschneider, 2006. Mechanisms linking obesity to insulin resistance and type 2 diabetes. Nature, 44: 840-846.

Kannel, W.B., 1995. Range of serum cholesterol values in the population developing coronary artery disease. Am. J. Cardiol., 76: 69C-77C.

Kelley, D.E. and J.A. Simoneau, 1994. Impaired free fatty acid utilization by skeletal muscle in non-insulin-dependent diabetes mellitus. J. Clin. Invest., 94: 2349-2356.

Kelley, D.E., B. Goodpaster, R.R. Wing and J.A. Simoneau, 1999. Skeletal muscle fatty acid metabolism in association with insulin resistance, obesity and weight loss. Am. J. Physiol. Endocrinol. Metab., 277: E1130-E1141.

Kelley, D.E., J. He, E.V. Menshikova and V.B. Ritov, 2002. Dysfunction of mitochondria in human skeletal muscle in type 2 diabetes. Diabetes, 51: 2944-2950.

Kuk, J.L., K. Kilpatrick, L.E. Davidson, R. Hudson and R. Ross, 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.

Lithell, H., F. Lindgarde, K. Hellsing, G. Lundqvist, E. Nygaard, B. Vessby and B. Saltin, 1981. Body weight, skeletal muscle morphology and enzyme activities in relation to fasting serum insulin concentration and glucose tolerance in 48-year-old men. Diabetes, 30: 19-25.

Lundgren, H., C. Bengtsson, G. Blohme, L. Lapidus and L. Sjostrom, 1989. Adiposity and adipose tissue distribution in relation to incidence of diabetes in women: Results from a prospective population study in Gothenburg, Sweden. Int. J. Obesity, 13: 413-423.

Mandarino, I.J., A. Consoli, A. Jain and D.E. Kelley, 1993. Differential regulation of intracellular glucose metabolism by glucose and insulin in human muscle. Am. J. Physiol., 265: E898-E905.

Mazess, R.B., H.S. Barden, J.P. Bisek and J. Hanson, 1990. Dual-energy x-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. Am. J. Clin. Nutr., 51: 1106-1112.

McTernan, C.L., P.G. McTernan, A.L. Harte, P.L. Levick, A.H. Barnett and S. Kumar, 2002. Resistin, central obesity and type 2 diabetes. Lancet, 359: 46-47.

Mooradian, A.D., 2009. Dyslipidemia in type 2 diabetes mellitus. Nat. Rev. Endocrinol., 5: 150-159.

Nakagami, T., Q. Qiao, B. Carstensen, C. Nhr-Hansen and G. Hu *et al*., 2003. Age, body mass index and type 2 diabetes-associations modified by ethnicity. Diabetologia, 46: 1063-1070.

National Heart Lung and Blood Institute, 1988. Current status of blood cholesterol measurement in clinical laboratories in the United States: A report from the laboratory standardization panel of the national cholesterol education program. Clin. Chem., 34: 193-201.

Ohlson, L.O., B. Larsson, K. Svardsudd, L. Welin and H. Eriksson *et al*., 1985. The influence of body fat distribution on the incidence of diabetes mellitus: 13.5 years of follow-up of the participants in the study of men born in 1913. Diabetes, 34: 1055-1058.

Owiredu, W.K.B.A., M.S. Adamu, N. Amidu, E. Woode, V. Bam, J. Planger-Rhule and C. Opoku-Okrah, 2008. Obesity and cardiovascular risk factors in a pentecostal population in Kumasi-Ghana. J. Med. Sci., 8: 682-690.

Park, S.W., B.H. Goodpaster, J.S. Lee, L.H. Kuller and R. Boudreau *et al*., 2009. Excessive loss of skeletal muscle mass in older adults with type 2 diabetes. Diabetes Care, 32: 1993-1997.

Pouliot, M.C., J.P. Despres, S. Lemieux, S. Moorjani and C. Bouchard *et al*., 1994. Waist circumference and abdominal sagittal diameter: Best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. Am. J. Cardiol., 73: 460-468.

Ravussin, E., S. Lillioja, T.E. Anderson, L. Christin and C. Bogardus, 1986. Determinants of 24-hour energy expenditure in man. Methods and results using a respiratory chamber. J. Clin. Invest., 78: 1568-1578.

Resnick, H.E., P. Valsania, J.B. Halter and X. Lin, 1998. Differential effects of BMI on diabetes risk among black and white Americans. Diabetes Care, 21: 1828-1835.

Ryden, L., P.J. Grant, S.D. Anker, C. Berne and F. Cosentino *et al*., 2013. ESC guidelines on diabetes, pre-diabetes and cardiovascular diseases developed in collaboration with the EASD. Eur. Heart J., 34: 3035-3087.

Seidell, J.C., T.S. Han, E.J.M. Feskens and M.E.J. Lean, 1997. Narrow hips and broad waist circumferences independently contribute to increased risk of non-insulin-dependent diabetes mellitus. J. Internal Med., 242: 401-406.

Simoneau, J.A., J.H. Veerkamp, L.P. Turcotte and D.E. Kelley, 1999. Markers of capacity to utilize fatty acids in human skeletal muscle: Relation to insulin resistance and obesity and effects of weight loss. FASEB J., 13: 2051-2060.

Snijder, M.B., J.M. Dekker, M. Visser, L.M. Bouter and C.D.A. Stehouwer *et al*., 2003. Associations of hip and thigh circumferences independent of waist circumference with the incidence of type 2 diabetes: The Hoorn study. Am. J. Clin. Nutr., 77: 1192-1197.

Sobngwi, E., F. Mauvais-Jarvis, P. Vexiau, J.C. Mbanya and J.F. Gautier, 2001. Diabetes in Africans. Part 1: Epidemiology and clinical specificities. Diabetes Metab., 27: 628-634.

Tataranni, P.A. and E. Ravussin, 1995. Variability in metabolic rate: Biological sites of regulation. Int. J. Obesity, 19: S102-S106.

Taylor, R.W., D. Keil, E.J. Gold, S.M. Williams and A. Goulding, 1998. Body mass index, waist girth and waist-to-hip ratio as indexes of total and regional adiposity in women: Evaluation using receiver operating characteristic curves. Am. J. Clin. Nutr., 67: 44-49.

Van Pelt, R.E., E.M. Evans, K.B. Schechtman, A.A. Ehsani and W.M. Kohrt, 2002. Contributions of total and regional fat mass to risk for cardiovascular disease in older women. Am. J. Physiol. Endocrinol. Metab., 282: E1023-E1028.

WHO., 2000. The problem of overweight and obesity. World Health Organization, Geneva, Switzerland. http://whqlibdoc.who.int/trs/WHO_TRS_894_%28part1%29.pdf.

WHO., 2009. Physical status: The use and interpretation of anthropometry. Report of a WHO Expert Committee, Technical Report Series No. 854, World Health Organization, Geneva, Switzerland.

Witt, K.A. and E.A. Bush, 2005. College athletes with an elevated body mass index often have a high upper arm muscle area, but not elevated triceps and subscapular skinfolds. J. Am. Dietetic Assoc., 105: 599-602.

Zurlo, F., K. Larson, C. Bogardus and E. Ravussin, 1990. Skeletal muscle metabolism is a major determinant of resting energy expenditure. J. Clin. Invest., 86: 1423-1427.