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Anthropometric indices as novel markers of risk in type 2 diabetes mellitus (T2DM) among Nigerian adults in Zamfara State

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Abstract

Body mass index (BMI) has traditionally been used as an indicator of body size measure and composition. Although, other measures of adiposity of the abdomen such as waist circumference (WC), waist-hip ratio (WHR), neck circumference (NC) have been suggested as being superior to BMI in predicting disease outcome. This study was designed to compare different anthropometric variables in term of their ability to predict type 2 diabetes mellitus (T2DM). This was a case-control study in 240 participants involving 120 verified T2DM cases and 120 non-diabetics as control. Age, gender and anthropometric data were collected from each participant. Logistic regression models were used with areas under the receiver operating characteristic (AROC) curve to compare the variables predictive statistics. The AROC of WHR to identify T2DM patients was 0.678 ($P<0.05$), with sensitivity 62.5% of and specificity of 60.8%. The AROC for average arm circumference (AAC) model is 0.649 with sensitivity of 55.8% followed by BMI model (AROC 0.635) and WC model (AROC 0.600) ($P<0.05$). Hip circumference (HC) (AROC 0.508) and NC (AROC 0.492) models were not significant predictors of T2DM. Subjects of ≥ 60 years, AAC value ≥ 32.6 cm, BMI value ≥ 30 kg/m², and WHR value ≥ 0.93 were at significantly ($P<0.05$) higher odds of developing T2DM than lower subjects with lower values. There were no significant differences ($P>0.05$) in the mean HC and NC values between the diabetic and non-diabetic subjects. The non-diabetic subjects have significantly ($P>0.05$) higher mean height value than the diabetic subjects. Measures of generalized and central obesity were significantly associated with increased risk of developing T2DM. This study revealed that WHR can predict type 2 diabetes mellitus risk more accurately than other anthropometric measures and can thus be helpful in predicting patients with future occurrence of diabetes and providing necessary interventions.

Keywords: Type 2 Diabetes Mellitus, Waist-hip Ratio, AROC, Case control study, Nigeria

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INTRODUCTION

Diabetes is a chronic disease that occurs as a result of inability of the pancreatic islet cells to produce sufficient insulin or the failure of the body to effectively utilize secreted insulin. Insulin is a hormone that plays important role in regulating the amount of glucose in the blood stream. Type 2 diabetes results from the body's ineffective use of insulin. Majority of the diabetes cases across the globe have type 2 diabetes accounting for around 90% of all cases, and are largely as result of sedentary lifestyle, obesity and overweight (WHO, 2018). Prediabetes is a condition in which a person has blood glucose level higher than normal but lower than the diagnostic range for diabetes (Tuso, 2014). Lifestyle modifications such as healthy diet and exercise have been proven to delay or prevent the development of diabetes mellitus (Kerrison *et al.*, 2017). The quantification of the body composition by measures such weight, height and waist circumference could serve as estimate of a patient's risk for obesity-related co-morbidities as cardiovascular disease and type 2 diabetes mellitus (Purnell, 2018). Overweight and obesity are defined as accumulation of fat in excess of the body need that it portends trouble to health. Body mass index (BMI) is widely used to quantify obesity in a populace and is a measure of a person's weight (in kilograms) divided by the square of his or her height (in meters). So many observational studies have used BMI to measure general or overall adiposity. BMI is commonly employed as the measure of general or overall adiposity in most observational studies but there is increasing evidence supporting central (abdominal) fat pattern of distribution measured by waist circumference (WC) or waist-to-hip ratio (WHR) as a better estimator of health risk than elevated body weight majorly among older adults (Huxley *et al.*, 2010; Must and McKeown, 2012).

Anthropometry studies human body measurement with regards to proportions of body tissues such muscle, bone and adipose (fat) (NHANES III, 1988). Assessments of subcutaneous fat tissues are very important at identifying individuals at greater risks for cardiovascular disease, hypertension, gallstones, arthritis, diabetes mellitus and other illnesses (NHANES III, 1988).

Epidemiological studies on obesity have utilized measures of body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), hip circumference (HC) and waist-to-stature ratio (WSR). Although, there is contention as to which

anthropometric measures more accurately describe obesity and signify the greatest risk for type 2 diabetes and hypertension (Wei *et al.*, 1997; Folsom *et al.*, 2000; Tulloch-Reid *et al.*, 2003; Hayashi *et al.*, 2004; Menke *et al.*, 2007; Zhou *et al.*, 2009).

In a cross-sectional study undertaken in Jinan, China, Wang *et al.* (2016) reported that among adults aged 50 years and above, the best indicator of the relationship between obesity and type 2 diabetes is waist-to-stature ratio (WSR) for men and BMI for women. Adejumo *et al.* (2018) in their study in southwest Nigeria compared the ability of anthropometric parameters to predict Metabolic Syndrome (MetS) and concluded that the WC was the best at predicting MetS in both men and women. Waist hip ratio (WHR) in both sexes had significant association with essential hypertension and type 2 diabetes mellitus while WC in males correlated strongly with BMI compared to WHR (Asuku *et al.*, 2017).

Overweight and particularly obesity, majorly at younger ages, considerably increases lifetime risk of diagnosed diabetes, while their impact on diabetes risk, life expectancy, and diabetes duration diminishes with age (Narayan *et al.*, 2007). Weight gain and body mass are very important to the formation and increasing type 1 and type 2 diabetes incidences (Al-Goblan *et al.*, 2014). Siddiqui (2018) reported that type 2 diabetes can be prevented to a large extent by increasing physical activities and maintaining a healthy weight. Studies by Fasanmade *et al.* (2013) did not find routine anthropometric indices as reliable surrogates for atherogenicity measured by abnormalities in total cholesterol, low density lipoprotein and high-density lipoprotein cholesterol in Nigerians with type 2 diabetes and/or hypertension.

The connection between obesity and type 2 diabetes mellitus has been evaluated using several approaches. Imaging techniques such as computed tomography and magnetic resonance directly quantify the abdominal and subcutaneous fat tissues (Pescatori *et al.*, 2019). These procedures are more expensive and intrusive making anthropometric assessments more regularly used. The majority of previous studies were carried out in other part of the world with few reporting available from Africa region most especially Nigeria. This study aims to compare wide ranging anthropometric measures as regards to their ability to predict type 2 diabetes mellitus (T2DM) in Nigerian adults.

MATERIALS AND METHODS

Study design and selection criteria

This was a case control study comprising one hundred and twenty (120) diabetic cases recruited from Federal Medical Centre (FMC), Gusau, Zamfara State, Nigeria. One hundred and twenty (120) non-diabetics recruited from the local community were used as control. Inclusion criteria for cases were those aged ≥ 30 years of either sex diagnosed with T2DM and who consented to participate. Patients of T2DM having other medical conditions like stroke, chronic renal diseases and chronic lung diseases or bedridden at the time of the study recruitment and pregnant females were excluded from the study. Diabetes was ruled out in the non-diabetic control by screening the participants at the time of enrolment into the study by random blood glucose (RBS) estimation using a glucometer (Accu-Chek Active Blood Glucose Monitoring System, Roche Diagnostics Corporation, Mannheim, Germany). Subjects with random blood sugar level (RBS) of less than 7.8 mmol/l were eligible to be included as controls. Institutional ethical committee clearance was obtained from Federal Medical Center, Gusau with approval no IEC 123/2014 before the initiation of the study. Written informed consent was obtained from all the study subjects.

Measurement protocol

The measurement protocol approved by World Health Organization (WHO, 2011) was used for all standardized measurements. Measurements such as neck, waist, and hip circumferences, right and left arm circumferences were made with a stretch-resistant tape that is wrapped snugly around the subject's body part of interest, but not to the point that the tape is constricting. Subjects were asked to stand upright during the measurement, with arms relaxed at the side, feet evenly spread apart and body weight evenly distributed and the reading taken to the nearest 0.1 cm. The height was taken as the perpendicular distance between the top of the head (the vertex) and the bottom of the feet. Readings for subjects' height were taken to the nearest 0.1 cm using a stadiometer and later converted to meter. Weight defined as the force the matter in the body exerts in a standard gravitational field was taken using weighing scales. The subjects were asked to stand on the centre of the scale without support, with their arms loosely by their sides, head facing forward and with their weight distributed evenly on both

feet and reading to the nearest 0.1 kg was recorded for each subject. Body mass index (BMI) is defined as a person's weight in kilograms divided by the square of the person's height in metres (kg/m^2). The following indices were computed: WHR: waist circumference (cm)/hip circumference (cm); BMI: weight (kg)/height² (m^2); AAC: right arm circumference + left arm circumference/2. The following criteria was used for defining weight status using BMI: BMI <18.5 kg/m^2 —Underweight, BMI 18.5- 24.9 kg/m^2 Normal weight, BMI 25.0-29.9 kg/m^2 Overweight and BMI ≥ 30 kg/m^2 Obese (WHO, 2004).

Data analysis

The mean values of anthropometric measures were compared between diabetic and non-diabetic subjects using the *t* test. Relationship between anthropometric variables among diabetic and non-diabetic subjects was determined using chi-square test. Logistic regression analysis was used to evaluate the association between measures of obesity and diabetes and also to compute the odds ratio (OR) and 95% confidence intervals (CI) for diabetes risks associated with the anthropometric measures. The area under the receiver operating characteristic (AROC) curve (c-statistic) for each model was calculated and used as the primary criterion upon which to judge a model's discriminative ability (Pepe *et al.*, 2004). All data analysis was done using the IBM SPSS® V21.0 software for windows (IBM Corporation, Armonk, New York, United States).

RESULTS

The results of this study revealed that subjects who were diabetic had significantly ($p < 0.05$, $p = 0.000$) higher mean age, waist circumference (WC), weight (W), random blood sugar level (RBSL), average arm circumference (AAC), body mass index (BMI) and waist hip ratio (WHR) than the non-diabetic subjects (Table 1). There were no significant differences ($p > 0.05$, $p = 0.94$ and 0.29 respectively) in the mean hip (HC) and neck circumferences (NC) between the diabetic and non-diabetic subjects (Table 1). The non-diabetic subjects were significantly ($P < 0.05$, $p = 0.04$) taller than the diabetic subjects (Table 1). There was increasing prevalence rate of diabetes with increasing BMI values. The prevalence rates were 33.1, 49.3 and 62.9% in the normal, overweight and obese subjects respectively (Table 2). The odds for diabetes in the obese subjects are about 3.143 times higher than in the normal weight subjects (Table 2). The prevalence

of diabetes increases with increasing age. The prevalence rate for subjects between ages 30 and 39 years was 3.0% and increased to as high as 84.8% in diabetic subjects aged 60 years and above. Subjects of ≥ 60 years old were more likely (OR=178.29) to develop diabetes than the younger subjects of 30–39-year-old (Table 2). Subjects with average arm circumference (AAC) of ≥ 32.6 cm were 3.8 times more likely developing diabetes when compared with subjects with AAC of ≤ 29.0 cm. (Table 2). The prevalence of diabetes increased with increasing WHR (Table 2). Subjects with WHR of greater than 0.92 were at 3.95 times increased odds of

being diabetic when compared to those with WHR of less than or equals 0.88 (Table 2).

Analysis of data revealed that Waist-hip ratio (WHR) was the most significant predictor of diabetes with AROC of 0.678 and OR of 1.27E4 (95% CI = 1.79E4–9.02E5), followed by AAC (AROC= 0.649, OR= 1.12, 95% CI = 1.05–1.19), BMI (AROC= 0.635, OR= 1.09, 95% CI= 1.04-1.44) and WC (AROC= 0.600, OR= 1.03 95% CI= 1.01-1.05) (Table 3). The results of the study also showed that Hip circumference (HC) and NC were not significant predictors of diabetes (Table 3).

Table 1: Mean anthropometric measures in the diabetic and non-diabetic subjects

Anthropometrics	Diabetic	Non-diabetic	P-value
Age (year)	55.38 \pm 1.01 ^a	39.89 \pm 0.86 ^b	0.000**
HC	100.3 \pm 1.22 ^a	100.5 \pm 0.97 ^a	0.936ns
WC (cm)	92.6 \pm 1.19 ^a	88.3 \pm 1.15 ^b	0.009*
W (kg)	74.9 \pm 1.38 ^a	69.5 \pm 1.17 ^b	0.003**
NC (cm)	35.3 \pm 0.36 ^a	34.8 \pm 0.35 ^a	0.288ns
H (m)	1.60 \pm 0.007 ^b	1.62 \pm 0.008 ^a	0.040*
AAC (cm)	31.9 \pm 0.41 ^a	29.8 \pm 0.38 ^b	0.000**
BMI (kgm ⁻²)	29.5 \pm 0.58 ^a	26.7 \pm 0.47	0.000**
WHR	0.93 \pm 0.01 ^a	0.88 \pm 0.01 ^b	0.000**

Key: WC=Waist circumference, W=Weight, H=Height, AAC=Average arm circumference, BMI=Body mass index, WHR=Waist-hip ratio, *=Significant, **= Very significant. Values are expressed as mean \pm standard error of the mean (SEM). Values with different superscripted alphabets across rows are significantly different at $P < 0.05$. N = 120 for diabetic and non-diabetic participants

DISCUSSION

Anthropometric measurements quantitatively assess the composition of the body as regards to the muscle, bone, and adipose tissue and are critical diagnostic criteria for obesity (Casadei and Kiel, 2020). Obesity is linked to raised blood pressure, blood lipids, and blood glucose and those that are obese are significantly at higher risk for disease state such as cardiovascular disease, hypertension, diabetes mellitus, and

several other conditions (Din-Dzietham *et al*, 2007). Our results from this case-control study in Nigerian adults showed that mean BMI, WC, WHR and AAC values were significantly elevated in the diabetic as compared to the non-diabetic subjects. These results suggest a stronger association between these markers of adiposity and type 2 diabetes mellitus (T2DM). Studies have shown that visceral and subcutaneous fat cause the release of 'pro-inflammatory' chemicals by fat cells, which makes the body

resistant to insulin action thus disrupting insulin-responsive-cells function through alteration of their response to insulin (Lebovitz and Banerji, 2005; Global Diabetes Community, 2019). Visceral adiposity is also associated with build-up of surplus lipid in liver, resulting in the impairment of cell autonomous which is involved in insulin signaling (Hardy *et al.*, 2012). Our studies reveal that ageing has a significantly larger area under the ROC curve implying a positive association between older age and increasing prevalence of diabetic cases. This is in agreement with the studies carried out by Suastika *et al.* (2011) in some selected villages of Bali in Indonesia which showed that impaired fasting glycemia and type 2

diabetes mellitus were more prevalent in the aged than in the younger persons. The positive association obtained among the older age and the increasing prevalence of diabetic cases may be as a result of aging which causes an increase in insulin resistance and alteration in the beta cell compensatory effects and functions despite decreasing insulin responsiveness (Chang and Halter, 2003; De Tata, 2014). The first- and second-phase insulin secretions usually decrease at the rate of approximately 0.7% per year with aging (Szoke *et al.*, 2008). More so, aging is related with decrease in beta cell proliferation capability and upgraded susceptibility to apoptosis (Maedler *et al.*, 2006).

Table 2: Relationship between anthropometric variables among diabetic and non-diabetic subjects

Anthropometry variable	N	Diabetic subject n (%)	Non-diabetic subject n (%)	P-Value	OR	95%CI
Weight status (BMI) (Kgm⁻²)						
Normal ^b	77	27 (35.1)	50 (64.9)	0.002	0.32	0.17-0.60
Overweight	69	34 (49.3)	35 (50.7)		1.80	0.92-3.50
Obesity ^c	89	56 (62.9)	33 (37.1)		3.14	1.66-5.93
Age group (years)						
30-39 ^b	66	2 (3.0)	64 (97.0)	0.000	0.006	0.00-0.03
40-49	64	27 (42.2)	37 (57.8)		23.35	5.25-103.85
50-59	59	47 (79.7)	2 (20.3)		125.33	26.77-586.72
≥60 ^c	46	39 (84.8)	7 (15.2)		178.29	35.24-901.90
AAC(cm)						
≤29.0 ^b	90	33 (36.7)	57 (63.3)	0.000	0.26	0.14-0.50
29.1-32.5	70	32 (45.7)	38 (54.3)		1.46	0.77-2.75
32.6 ^c +	80	55 (68.8)	25 (31.2)		3.80	2.01-7.19
WHR						
≤0.88 ^b	82	24 (29.3)	58 (70.7)	0.000	0.25	0.13-0.50
0.89-0.92	79	47 (59.5)	32 (40.5)		3.55	1.85-6.83
0.93 ^c +	79	49(62.0)	30 (38.0)		3.95	2.05-7.62

Note: For the odds ratios (OR), the "b" labeled tertiles are the baseline for each stated OR, the bold-faced OR were compared the highest tertiles labeled "c"

Table 3: Values for Sensitivity, Specificity, Overall Percentage and area under the receiver operating characteristic (AROC) curve, Odds ratio (OR) and 95% confidence interval (95%CI) for predictor variables using the 0.5 cut off

Characteristics	Age	WHR	AAC	BMI	WC	NC	HC
Sensitivity	76.5	62.5	55.8	59.2	50.0	40.8	55.8
Specificity	80.8	60.8	62.5	66.7	59.2	62.5	42.5
Overall Percentage	78.7	61.7	59.2	62.9	54.6	51.7	49.2
AROC	0.869	0.678	0.649	0.635	0.600	0.552	0.492
P-value	0.000	0.000	0.000	0.000	0.008	0.172	0.825
OR	1.16	1.27E4	1.12	1.09	1.03	1.04	1.00
Lower 95% CI	1.12	1.79E2	1.05	1.04	1.01	0.97	0.98
Upper 95% CI	1.21	9.02E5	1.19	1.44	1.05	1.11	1.02

Key: Sensitivity=percentage of disease occurrences correctly predicted, Specificity=Percentage of disease non occurrences correctly predicted, AROC =Area under the receiver operating characteristic curve

Our study identified WHR as the best predictor of diabetes when compared to other measures such as AAC, BMI and WC. In another study by Jia *et al.* (2011), WHR with area under curve of 0.63 was the best predictor of diabetes in Chinese men over a 2 years follow-up period. Ta *et al.*, (2010) also reported waist-to-hip ratio (WHR) and systolic blood pressure can identify persons that are more associated with higher risk of type 2 diabetes in Vietnamese population. Study conducted by Asuku *et al.* (2017) on relationships of anthropometric indices of centripetal adiposity with essential hypertension and type 2 diabetes mellitus in Kano metropolis showed WHR had significant association with essential hypertension and type 2 diabetes mellitus in both males and females while WC in males correlated strongly with BMI compared to WHR. However, this contradicts the earlier reports of Khader *et al.* (2019), who reported the higher ability for waist-to-height ratio (WHR) to predict diabetes and hypertension among Jordanian adult men and women compared to other measures of anthropometry. Furthermore, study by Ting *et al.* (2018) suggested neck circumference (NC) as an indicator providing an early prediction of developing type 2 diabetes mellitus. In our study BMI performed better than WC in predicting type 2 diabetes mellitus. This finding is consistent with the findings of Haghghatdoost *et al.*, (2017) that showed BMI being a better predictor compared to other measures among men and women from a population-based cohort study. On the other hand, other studies showed that WC had better predictive powers for the risk of type 2 diabetes than the BMI. Waist circumference gives a better prediction of diabetes risk than does BMI. This is

the conclusion drawn by Feller and her colleagues from the German Institute for Nutritional Research in Potsdam-Rehbrücke in 2010. Our results suggest that excess weight and obesity are major contributing factor to type 2 diabetes mellitus and keeping a healthy body weight may serve as important preventive strategy for type 2 diabetes mellitus onset. Several current weight-loss plans, including diet programs, physical activity and lifestyle modifications have helped in long-term weight reduction and significantly reduced the incidence of diabetes (Tate *et al.*, 2003; Norris *et al.*, 2005; Appel *et al.*, 2011).

CONCLUSION

The findings of this study revealed that high adiposity is associated with a substantially increased risk of type 2 diabetes mellitus. Amongst the measures of adiposity assessed in this study, WHR Waist-to-hip ratio was better identifying diabetes. Keeping a healthy weight, not living a sedentary life with good dieting can help reduce your chances of being type 2 diabetes patient.

Study limitations

We acknowledge the study limitations. Most importantly, the sample size was not large enough and we could not estimate the cut-off points for the anthropometric measures. More so, the duration of the disease in each patient and also the drug used by each of the patient was not taken into account during the period of study.

Conflict of interest

Authors have no conflict of interest to declare.

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