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Oxidative Stress, Antioxidant Enzymes and Risk of Hypertension in Obese Type 2 Diabetic Subjects in Osogbo, Osun State, Nigeria

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ABSTRACT: Obesity is a chronic disease often associated with type 2 diabetes mellitus (T2DM) and metabolic syndrome. Coexistence of diabetes and hypertension have adverse clinical outcomes with micro and macrovascular complications. This study investigates the relationship of oxidative stress markers and antioxidants with occurrence of hypertension in obese type 2 diabetic subjects in Osun State, Nigeria. Four hundred and forty-five participants made up of 138 non-obese diabetics, 107 obese diabetic subjects attending two tertiary Hospitals in Osogbo in addition to 100 obese non-diabetes (positive controls) and 100 non-obese non-diabetes (negative controls) were enrolled in this study. FBS (9.55±0.13 mmol/l) and HbA1c (9.51±0.15 %) showed highest significant increase in obese diabetic subjects compared to other groups. Mean serum MDA was highest among obese diabetics ($p<0.05$) while least values of superoxide dismutase (121.09±3.10 µ/ml) and catalase (24.97±0.66 pg/ml) were recorded in non-obese diabetics ($p<0.05$). 21.0% of non-obese diabetics (n=29), 54.2% of obese diabetics (n=58), 45.0% of obese non-diabetic (n=45) and 21% of non-obese non-diabetics (n=21) were hypertensive. Age, sex, marital status, religion and occupation (χ^2=9.856, 8.405, 22.701, 12.066 and 14.468) respectively were all significantly associated with occurrence of hypertension among obese diabetics. Receiver operating characteristics (ROC) and area under the curve (AUC) showed MDA having the highest cut off point among obese diabetes subject: 0.529 (0.42-0.64 95% CI) with a steep increase in LDL: 0.505(0.40-0.62 95% CI). This study revealed that increased oxidative stress and reduced antioxidant defense enzymes are strongly associated with dyslipidemia among obese diabetic subject.

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Obesity, defined as excessive accumulation of fat is associated with increased risk of developing insulin resistance and type 2 diabetes (Webber *et al*., 2014). Excessive accumulation of fat is a consequence of positive energy balance resulting from high intake of energy-rich food (Korita *et al.*, 2013), decreased physical activity (sedentary lifestyle), genetic, environmental, cultural and economic factors (Bego *et al*., 2019). Obesity is associated with an increased risk of developing metabolic syndrome which is a complex disorder represented by a cluster of cardiovascular risk factors associated with central fat deposition, abnormal plasma lipid levels, elevated blood pressure, low-grade inflammatory state and oxidative stress (Wildman, 2011). Data from previous reports showed that among 1.9 billion adults that were overweight, over 650 million were obese (WHO, 2016) while Diabetes mellitus affects an estimated 5%–10% of adults worldwide (Mohammed, 2019). In Nigeria the prevalence of obesity and diabetes ranges from 3.0 to 22.2% respectively (Adeloye *et al.*, 2021). Co-morbidity of obesity and type 2 diabetes contributes to occurrence of metabolic syndrome, coronary heart disease and hypertension (Lobato *et al.*, 2012; Pap *et al*., 2013 and Čolak, and Pap, 2021). Hypertension is the most frequently diagnosed cardiovascular disease risk equivalent in Nigeria with high rise in the population's mean blood pressure (Adeloye *et al.*,

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2021). Increasing urbanization and its associated lifestyle changes contributes to occurrence of hypertension in Nigeria (Adeloye *et al.,* 2021). Obese Individuals with T2DM are at high risk of increased production of ROS and decreased antioxidant capacity suggesting that oxidative stress can be one of the underlying mechanisms of dysfunctional metabolism in obese and type 2 diabetic subjects (Besler *et al.,* 2011). In addition, high levels of circulating glucose and lipids can result in an excessive supply of energy substrates to metabolic pathways in adipose and non-adipose cells, which in turn may increase the production of ROS which are essential signaling molecules, if not well controlled they can result in lipid peroxidation (Čolak and Pap, 2021; Lobato *et al.,* 2012). Therefore, it is of great importance to establish strategies for combating the pathological effect.

The aim of this study was to assess the relationship between dyslipidemia, oxidative stress and risk of hypertension in obese, non-obese type 2 diabetic subjects and controls in Osun State, Nigeria.

MATERIAL AND METHODS

Study Area: This study was carried out at UNIOSUN Teaching Hospital and State Specialist Hospital Asubiaro, Osogbo, Osun State, Nigeria

Study Design: This was a hospital based case control study, spanning the period of October 2019 to March 2020

Study Population: Individuals attending the Family Health Clinic of UNIOSUN Teaching Hospital and State Specialist Hospital Asubiaro, Osogbo, Osun State were enrolled in the study. Type 2 diabetes mellitus was diagnosed by the attending physician based on the American Diabetes Association Criteria (WHO 2019). All subjects completed structured questionnaire capturing their demographic information. Informed consent was sought for and obtained from each subject.

Inclusion Criteria: Subjects, aged between 30 and 60 years, Obese subject, as defined by BMI $\geq$ 30Kg/m^2 and above, All subjects that meet diagnostic criteria for type II diabetes and obesity.

Exclusion Criteria: Individuals with history of hepatitis, chronic alcoholics and pregnant women

Ethical Consideration: Ethical clearance (HREC/27/04/2015/SSO/42) was obtained from the research ethical review committee of State Hospital Asubiaro, Osogbo, Osun State, Nigeria.

Sample Collection: Participants were grouped into Obese type 2 diabetic subjects, Non Obese diabetic subjects, Obese non-diabetics (positive controls) and Non Obese non-diabetics (negative controls). Blood samples were collected after a minimum 12-h fast for biochemical measurements. Eight ml peripheral venous blood was collected from each participant and aliquot into plain, EDTA and fluoride oxalate bottles respectively. The samples were allowed to clot, retracted and centrifuged at 3000 rpm for 10 minutes to obtain serum. Plasma sample was spun at 1500 r pm at 4 ˚C for 30 min, separated and stored frozen.

Anthropometric Measurements: Participants' height without shoe on was measured to the nearest inch using a stadiometer. Weight was measured to the nearest kilogram using a digital scale (SECA North America, Chino, CA). Height was converted to meters and weight was converted to kilograms for analysis. Self-reported and measured BMI were classified into WHO categories: underweight (<18.5 kg/m^2), normal (18.5 - <25 kg/m^2), overweight (25 - <30 kg/m^2) and obese ($\geq$30 kg/m^2) (13).

Blood Pressure Measurement: Blood pressure (BP) measurements were measured twice to the nearest 2 mmHg with a mercury sphygmomanometer. Two readings were taken on the left and right arms of each subject in a sitting position after a 5-min rest between readings, and systolic and diastolic BPs were determined as their average.

Biochemical Analysis: Fasting levels of blood glucose, total cholesterol, HDL cholesterol, and TG were determined by enzymatic hydrolysis and oxidation as previously described (Trinder, 1969). LDL cholesterol was calculated using the Friedewald equation (Friedewald *et al.,* 1972), Serum Malondyhydehyde (MDA), Catalase, superoxide dismutase (SOD) was performed using ELISA kits (Cloud-Clone Corp, Houston, USA).

Statistical analysis: Statistical analysis was done using IBM SPSS version 25.0 software package and graph pad prism 5.0 to determine the means, standard error of mean, correlations and one-way analysis of variance (ANOVA) among study groups, while least square difference or post hoc test was employed to determine the differences between the means. $P<0.05$ was considered as significant.

RESULTS AND DISCUSSION

Table 1 showed that a larger proportion of the participants were aged 31-50 years with a female preponderance, civil servants and attained tertiary education. The highest values for body mass index

(BMI), waist circumference (WC), systolic blood pressure (SBP), waist hip ratio (WHR) and hip circumference (HC) were recorded among obese diabetics while mean DBP was observed in obese non-diabetics. (Table 2). From Table 3, the mean Fasting blood sugar and glycated hemoglobin were significantly increased in obese diabetics compared to other study groups. There were no significant differences in mean values of plasma lipid profile, atherogenic indices of plasma, cardiac risk ratio, non-high density lipoprotein and atherogenic coefficient among the study subjects (P<0.05).

Figures 1 and 2 present lipid peroxidation marker, MDA, and antioxidant enzymes SOD and Catalase levels among the study subjects. Mean MDA value was increased while SOD and Catalase were decreased in obese diabetics than others groups (p<0.05).

Table 1: Socio demographic characteristic of respondents

Variable	Categories	Frequency	Percent
Age	≤ 30 years	63	14.2
	31-50 years	288	64.7
	51 years and above	94	21.1
Sex	Female	341	76.6
	Male	104	23.4
Marital status	Divorced	26	5.8
	Married	315	70.8
	Single	54	12.1
	Widow	50	11.2
Religion	Christianity	75	16.9
	Islam	345	77.5
	Traditional	25	5.6
Occupation	Artisans	111	24.9
	Civil servant	265	59.6
	Traders	69	15.5
Educational	Primary	20	4.5
	Secondary	70	15.7
	Tertiary	355	79.8

Table 2: Anthropometric parameters among study subjects

Subject/ parameters	Obese diabetic (n=107)	Non obese diabetic (n=138)	Obese non-diabetic (n=100)	Non obese non-diabetic (n=100)	P-value
Age	45.69±1.17	40.94±0.97	41.96±1.24	43.14±1.10	0.015*
BMI (kg/m^2)	34.06±0.29	24.13±0.19	33.22±0.25	23.59±0.28	0.000*
SBP (mmHg)	142.48±2.69	125.82±1.69	133.58±2.27	128.61±2.46	0.000*
DBP(mmHg)	84.80±1.19	81.72±0.93	85.46±1.01	77.20±0.89	0.000*
WC(cm)	98.52±0.86	79.72±0.64	93.86±0.71	76.78±0.91	0.000*
HC (cm)	108.08±0.86	87.27±0.64	105.42±0.71	89.34±0.91	0.000*
WHR	0.91±0.00	0.91±0.00	0.89±0.00	0.86±0.00	0.000*

**significant at p<0.05, BMI= Body mass index, SBP=Systolic blood pressure, DBP= Diastolic BP, WC=Waist Circumference, HC= Height Circumference, WHR= Waist Hip Ratio*

Table 3: Biochemical profile and atherogenic indices among all subjects

Subject	Obese diabetic (n=107)	Non obese diabetic (n=138)	Obese non-diabetic (n=100)	Non obese non-diabetic (n=100)	P-value
FBS(mmol/l)	9.55±0.13	9.20±0.13	5.41±0.09	5.25±0.12	0.000*
HbA1c(mmol/l)	9.51±0.15	7.33±0.17	8.40±0.22	8.40±0.19	0.001*
TC (mmol/l)	5.36±0.09	4.94±0.07	4.99±0.10	4.32±0.08	0.566
TG (mmol/l)	1.62±0.05	1.61±0.03	1.13±0.06	0.82±0.06	0.913
HDL-C (mmol/L)	0.94±0.02	1.18±0.02	1.15±0.03	1.08±0.03	0.369
LDL-C (mmol/L)	3.69±0.08	3.03±0.06	3.32±0.10	2.87±0.08	0.711
LDL:HDL	4.24±0.15	2.72±0.09	3.09±0.13	2.91±0.12	0.715
AIP	0.24±0.02	0.14±0.01	0.04±0.02	0.19±0.03	0. 358
CRR	6.12±0.19	4.37±0.10	4.56±0.14	4.30±0.14	0.000
Non HDL	4.42±0.08	3.76±0.07	3.83±0.10	3.24±0.08	0.373
AC	5.12±0.19	3.37±0.10	3.56±0.14	3.30±0.14	0.035

TC =Total Cholesterol, TG = Triacylglycerol, HDL-C = High Density Lipoprotein, LDL-C = Low Density Lipoprotein, AIP = Atherogenic index of plasma, CRR = Cardiac risk ratio, AC = Atherogenic coefficient

Correlation Results: Among obese diabetic subjects, positive associations were recorded for Fasting blood sugar versus catalase (r=0.245, p=0.011), SOD with total cholesterol (r=0.419, p=0.000), MDA (r=0.232, p=0.016) and HDL (r=0.286, p=0.003) respectively. Also HDL was positively associated with total cholesterol (r=0.593, p=0.000) but inversely correlated with DBP (r=-0.304, p=0.001), AIP (r=-0.786, p=0.000) and MDA (r=-0.236, p=0.003). Catalase (r=0.309, p=0.000). SOD shows an inverse association with FBS (r=-0.264, p=0.002), total cholesterol (r=-0.177, p=0.038), HDL (r=-0.248, p=0.003) and catalase (r=-0.348, p=0.000). MDA was inversely associated with TG (r=-0.311, p=0.000) and AIP (r=-0.211, p=0.013). In obese non-diabetics, FBS was associated with catalase (r=0.225, p=0.024), likewise HDL with LDL (r=-0.205, p=0.040) and SOD (r=0.245, p=0.011).

A positive association of total cholesterol with TG (r=0.275, p=0.006) and catalase (r=0.313, p=0.002) was recorded while HDL was inversely associated

with SBP (r=-0.263, p=0.008) and LDL (r=-0.300, p=0.002). LDL showed positive association with total cholesterol (r=-0.889, p=0.000) and catalase (r=-0.301, p=0.002). a similar result was obtained for MDA and HbA1c (r=0.315, p=0.001) in non-obese non-diabetics

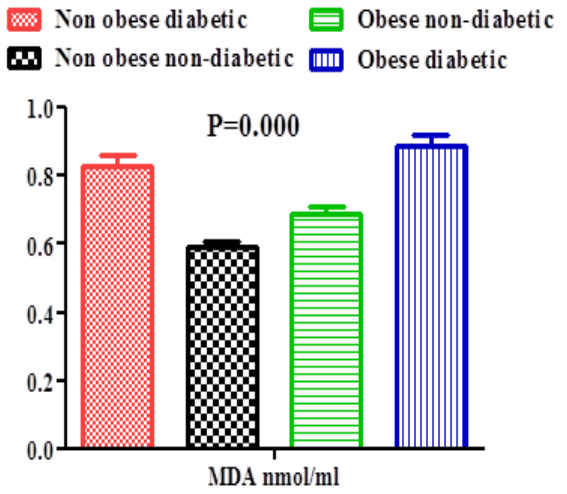

Fig 1: Serum MDA levels in all study subjects

Table 4 presents the plasma lipid profile and atherogenic indices based on gender of the subjects. No significant differences were observed in the mean lipid profile and atherogenic indices when comparisons were made in both male and female subjects (p>0.05). Tables 5-8 showed Pearson Chi-Square analysis results of association between socio demographic characteristics and occurrence of hypertension among all study subjects. Age, sex, religion, occupation and marital status were associated with hypertension in obese diabetics (p<0.05). Among non-obese diabetic and non-obese non-diabetic subjects, religion and marital status showed significant associations with occurrence of hypertension.

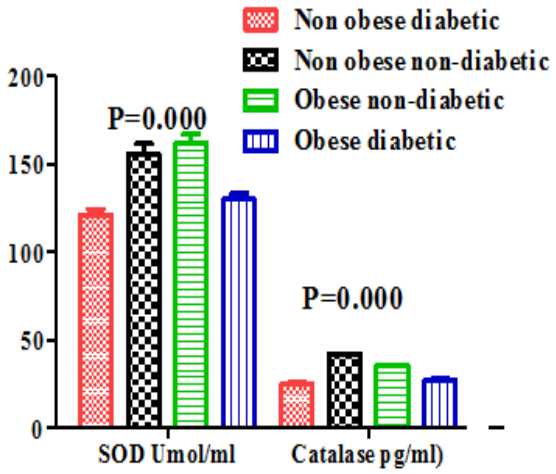

Fig 2: Serum SOD (Umol/ml) and Catalase levels in all subjects

Table 4: Lipid profile and atherogenic indices based on gender of the subjects

	Female (n=341)					Male (n=104)				
Variable / Group	OD (n=87)	NOD (n=103)	OND (n=78)	NOND (n=73)	P-value	OD (n=20)	NOD (n=35)	OND (n=22)	NOND (n=27)	p-value
TC (mmol/L)	5.11±0.13	5.18±0.13	5.01±0.16	4.94±0.14	0.647	5.17±0.24	5.15±0.23	5.37±0.23	4.96±0.13	0.611
TG(mmol/L)	1.44±0.08	1.39±0.05	1.43±0.08	1.39±0.08	0.937	1.23±0.10	1.22±0.10	1.29±0.07	1.48±0.20	0.497
HDL-C (mmol/L)	1.01±0.04	1.00±0.04	1.12±0.04	1.06±0.05	0.176	1.06±0.06	1.07±0.07	1.00±0.06	1.05±0.08	0.912
LDL-C (mmol/L)	1.30±0.05	1.30±0.03	1.27±0.04	1.25±0.04	0.723	1.35±0.06	1.18±0.06	1.33±0.07	1.29±0.06	0.264
LDL-C:HDL-C	1.41±0.12	1.37±0.08	1.24±0.08	1.28±0.07	0.514	1.31±0.08	1.18±0.17	1.39±0.14	1.35±0.15	0.757
AIP	0.15±0.03	0.13±0.02	0.10±0.03	0.12±0.04	0.691	0.06±0.06	0.04±0.07	0.11±0.03	0.14±0.07	0.679
CRR	5.41±0.28	5.68±0.35	4.80±0.27	5.09±0.30	0.175	5.01±0.29	5.10±0.50	5.52±0.41	5.26±0.64	0.906
Non- HDL	4.10±0.12	4.19±0.13	3.89±0.17	3.89±0.15	0.338	4.11±0.21	4.08±0.23	4.37±0.21	3.91±0.18	0.492
Atherogenic coefficient	4.41±0.28	4.68±0.35	3.80±0.27	4.09±0.30	0.175	4.01±0.29	4.10±0.50	4.52±0.41	4.26±0.64	0.906

OD - Obese diabetic, NOD - Non- obese diabetic, OND - Obese non-diabetic, NOND - Non obese non-diabetic

To determine the most effective indices in predicting the incidence of developing hypertension, analysis of the receiver-operating characteristic (ROC) curve and the area under the curve (AUC) for lipid profile, glucose and markers of lipid peroxidation in relation to the incidence of hypertension as shown in Table 9and the figure 3. MDA has the highest AUC among the nine indices (MDA, SOD, catalase, FBS, HbA1c, total cholesterol, TG, HDL and LDL) among the diabetic groups. Compared to non-diabetic participants with a steep increase in LDL among the obese diabetes participants

Table 5: Socio-demographic variables and risk of hypertension in obese diabetic subjects (n=107)

Variables/subgroups		Normal (n=27)	Pre hypertensive (n=22)	Hypertensive (n=58)	Total	χ^2	P-value
Age	≤ 30 years	1(0.9%)	0(0.0%)	7(6.5%)	8(7.5%)	9.856	0.043
	31-50 years	21(19.6%)	16(15.0%)	28(26.2%)	65(60.7%)		
	≥ 51 years	5(4.7%)	6(5.6%)	23(21.5%)	34(31.8%)		
Sex	Female	27(25.2%)	17(15.9%)	43(40.2%)	87(81.3%)	8.405	0.015
	Male	0(0.0%)	5(4.7%)	15(14.0%)	20(18.7%)		
Marital status	Divorced	0(0.0%)	1(0.9%)	8(7.5%)	9(8.4%)	22.701	0.001
	Married	24(22.4%)	15(14.0%)	42(39.3%)	81(75.7%)		
	Single	0(0.0%)	0(0.0%)	7(6.5%)	7(6.5%)		
	Widow	3(2.8%)	6(5.6%)	1(0.9%)	10(9.3%)		
Religion	Christianity	3(2.8%)	3(2.8%)	5(4.7%)	11(10.3%)	12.066	0.017
	Islam	19(17.8%)	19(17.8%)	52(48.6%)	90(84.1%)		
	Traditional	5(4.7%)	0(0.0%)	1(0.9%)	6(5.6%)		
Occupation	Artisans	6(5.6%)	7(6.5%)	19(17.8%)	32(29.9%)	14.468	0.006
	Civil servant	20(18.7%)	6(5.6%)	27(25.2%)	53(49.5%)		
	Traders	1(0.9%)	9(8.4%)	12(11.2%)	22(20.6%)		
Education	Primary	0(0.0%)	5(4.7%)	5(4.7%)	10(9.3%)	8.963	0.062
	Secondary	4(3.7%)	5(4.7%)	9(8.4%)	18(16.8%)		
	Tertiary	23(21.5%)	12(11.2%)	44(41.1%)	79(73.8%)		

Table 6: Socio demographic variables and risk of hypertension in non-obese diabetic subjects (n=138)

Variables/subgroups		Normal (n=65)	Pre hypertensive (n=44)	Hypertensive (n=29)	Total	χ^2	P-value
Age	≤ 30 years	7(5.1%)	8(5.8%)	8(5.8%)	23(16.7%)	8.673	0.070
	31-50 years	43(31.2%)	33(23.9%)	17(12.3%)	93(67.4%)		
	51 years and above	15(10.9%)	3(2.2%)	4(2.9%)	22(15.9%)		
Sex	Female	48(34.8%)	34(24.6%)	21(15.2%)	103(74.6%)	0.259	0.879
	Male	17(12.3%)	10(7.2%)	8(5.8%)	35(25.4%)		
Marital status	Divorced	0(0.0%)	4(2.9%)	0(0.0%)	4(2.9%)	19.402	0.004
	Married	43(31.2%)	27(19.6%)	21(15.2%)	91(65.9%)		
	Single	7(5.1%)	6(4.3%)	8(5.8%)	21(15.2%)		
	Widow	15(10.9%)	7(5.1%)	0(0.0%)	22(15.9%)		
Religion	Christianity	29(21.0%)	13(9.4%)	3(2.2%)	45(32.6%)	20.038	0.000
	Islam	35(25.4%)	31(22.5%)	22(15.9%)	88(63.8%)		
	Traditional	1(0.7%)	0(0.0%)	4(2.9%)	5(3.6%)		
Occupation	Artisans	19(13.8%)	14(10.1%)	15(10.9%)	48(34.8%)	7.505	0.112
	Civil servant	38(27.5%)	20(14.5%)	10(7.2%)	68(49.3%)		
	Traders	8(5.8%)	10(7.2%)	4(2.9%)	22(15.9%)		
Educational	Primary	2(1.4%)	2(1.4%)	4(2.9%)	8(5.8%)	6.530	0.163
	Secondary	0(0.0%)	1(0.7%)	0(0.0%)	1(0.7%)		
	Tertiary	63(45.7%)	41(29.7%)	25(18.1%)	129(93.5%)		

Obesity is a major potential modifiable risk factor for type 2 diabetes due to insulin resistance constituting a high burden of cardiovascular disease and hypertension.

Demographic changes, rising income, urbanization, unhealthy lifestyle and dietary habits are driving forces for obesity epidemic in this community. About 12million people were reported to be obese in 2020 with a female preponderance. Worldwide, more than 3 million deaths were overweight and obesity-related **(**Adeloye *et al.,* 2021**).** The need for urgent action in understanding and tackling predictable biochemical parameters for quick intervention cannot be overemphasized, thus necessitating this study.

Increased LDL-C and non-HDL-C as well as low HDL cholesterol levels were reported to be associated with increased cardiovascular disease risk in patients with diabetes (WHO, 2016 and Martin-Timo *et al.,* 2014). This was similar to the results recorded in the present study although the increase in LDL-C was not statistically significant.

The increase in plasma concentration of non HDL-C could be associated with increase in serum triglyceride levels, increased VLDL and IDL, and decreased HDL cholesterol levels (Ginsberg, 2009; Wu *et al*., 2014).

Rise in serum low density lipoprotein could be as a result of decrease in its clearance in the blood vessels by high density lipoprotein or increased synthesis of low density lipoprotein or increase in low density lipoprotein receptors within the cells (Bhatti, Akbri and Shakoor, 2001).

Table 7: Socio-demographic variables and risk of hypertension in obese non-diabetic subjects (n=100)

Variables/subgroups		Normal (n=30)	Pre hypertensive (n=25)	Hypertensive (n=45)	Total	χ^2	P-value
Age	≤ 30 years	1(1.0%)	9(9.0%)	7(7.0%)	17(17.0%)	13.237	0.010
	31-50 years	25(25.0%)	11(11.0%)	27(27.0%)	63(63.0%)		
	51 years and above	4(4.0%)	5(5.0%)	11(11.0%)	20(20.0%)		
Sex	Female	23(23.0%)	17(17.0%)	38(38.0%)	78(78.0%)	2.577	0.276
	Male	7(7.0%)	8(8.0%)	7(7.0%)	22(22.0%)		
Marital status	Divorced	0(0.0%)	4(4.0%)	3(3.0%)	7(7.0%)	18.317	0.005
	Married	25(25.0%)	11(11.0%)	33(33.0%)	69(69.0%)		
	Single	1(1.0%)	8(8.0%)	4(4.0%)	13(13.0%)		
	Widow	4(4.0%)	2(2.0%)	5(5.0%)	11(11.0%)		
Religion	Christianity	1(1.0%)	2(2.0%)	5(5.0%)	8(8.0%)	4.611	0.330
	Islam	25(25.0%)	21(21.0%)	39(39.0%)	85(85.0%)		
	Traditional	4(4.0%)	2(2.0%)	1(1.0%)	7(7.0%)		
Occupation	Artisans	2(2.0%)	2(2.0%)	6(6.0%)	10(10.0%)	3.802	0.433
	Civil servant	25(25.0%)	18(18.0%)	36(36.0%)	79(79.0%)		
	Traders	3(3.0%)	5(5.0%)	3(3.0%)	11(11.0%)		
Education	Secondary	7(7.0%)	14(14.0%)	7(7.0%)	28(28.0%)	0.430	0.807
	Tertiary	23(23.0%)	11(11.0%)	38(38.0%)	72(72.0%)		

Table 8: Socio-demographic variables and risk of hypertension in obese non-diabetic subjects (n=100)

Variables/subgroups		Normal n=52	Pre hypertensive n=27	Hypertensive n=21	Total	χ^2	P-value
Age	≤ 30 years	2(2.0%)	8(8.0%)	5(5.0%)	15(15.0%)	12.297	0.015
	31-50 years	41(41.0%)	13(13.0%)	13(13.0%)	67(67.0%)		
	51 years and above	9(9.0%)	6(6.0%)	3(3.0%)	18(18.0%)		
Sex	Female	38(38.0%)	19(19.0%)	16(16.0%)	73(73.0%)	0.203	0.903
	Male	14(14.0%)	8(8.0%)	5(5.0%)	27(27.0%)		
Marital status	Divorced	3(3.0%)	0(0.0%)	3(3.0%)	6(6.0%)	12.775	0.047
	Married	43(43.0%)	18(18.0%)	13(13.0%)	74(74.0%)		
	Single	2(2.0%)	7(7.0%)	4(4.0%)	13(13.0%)		
	Widow	4(4.0%)	2(2.0%)	1(1.0%)	7(7.0%)		
Religion	Christianity	6(6.0%)	4(4.0%)	1(1.0%)	11(11.0%)	28.779	0.000
	Islam	46(46.0%)	23(23.0%)	13(13.0%)	82(82.0%)		
	Traditional	0(0.0%)	0(0.0%)	7(7.0%)	7(7.0%)		
Occupation	Artisans	12(12.0%)	7(7.0%)	2(2.0%)	21(21.0%)	5.152	0.272
	Civil servant	30(30.0%)	18(18.0%)	17(17.0%)	65(65.0%)		
	Traders	10(10.0%)	2(2.0%)	2(2.0%)	14(14.0%)		
Education	Primary	0(0.0%)	0(0.0%)	2(2.0%)	2(2.0%)	13.093	0.011
	Secondary	8(8.0%)	7(7.0%)	8(8.0%)	23(23.0%)		
	Tertiary	44(44.0%)	20(20.0%)	11(11.0%)	75(75.0%)		

High density lipoprotein promotes afflux and uptake of cholesterol from peripheral tissues by facilitating the conversion of cholesterol ester and subsequent delivery to the liver (Winfred and Gerald, 2017)). Similar studies (Bhatti, Akbri and Shakoor, 2001, Szczygielska *et al*., 2003 and Vergès, 2009) reported a significant decrease in serum concentration of high density lipoprotein in obese, type II diabetes mellitus subjects compared to non- obese. The observation of a non-significant reduction in plasma high density lipoprotein from this study could be attributed to the effect of anti-diabetic regimen administered to the obese diabetics.

Data from this study showed a significant increase in the total cholesterol in obese diabetic subjects when compared to obese non diabetes participants, this finding is at variance with a previous work (StępieńStępień, Wlazeł, Paradowski, Banach and Rysz, 2014) that reported a significant decrease in serum concentration of cholesterol among obese diabetic subject, but is in agreement with another report (Bhatti, Akbri and Shakoor, 2001). Our observation could be as a result of increased de-novo synthesis or decrease in utilization of total cholesterol in the body or as a result of genetic predisposition of an individual. (Bhatti, Akbri and Shakoor, 2001)

Serum triglyceride showed a significant increase among obese diabetes subjects. However, Stępień *et al.,* (2014) reported a significant decrease in serum triglyceride concentration of obese diabetes subjects compared to obese non diabetics. This finding could be as a result of reduction in lipolysis of triglyceride-rich lipoproteins which may be impaired in obesity due to reduced mRNA expression levels of lipoprotein lipase in adipose tissue (Klop, Jukema, Rabelink, Castro Cabezas, 2012). Cholesterol ratio is used as a monitoring tool for determining the risk of

cardiovascular disease. Atherogenic index of plasma is a useful diagnostic tool for dyslipidemia and possible prediction of cardiovascular disease risk as well as for effective therapeutic monitoring. In this study the mean atherogenic index of plasma and cardiac risk ratio showed a significant increase among obese diabetic than obese non diabetes subjects suggesting obesity e is a risk factor for cardiovascular disorders in diabetes. This is in contrast with the findings of another work (Salwe *et al*., 2012) which reported a decrease in the cardiac risk ratio in obese diabetic subjects but in agreement with another research that recorded a significant increase in atherogenic index of plasma of obese diabetic subjects (Ozata, 2002). This observation could be due to acute myocardial infarction related to increased oxidative stress, inflammation or endothelial cell dysfunction (Singh *et al*., 2015).

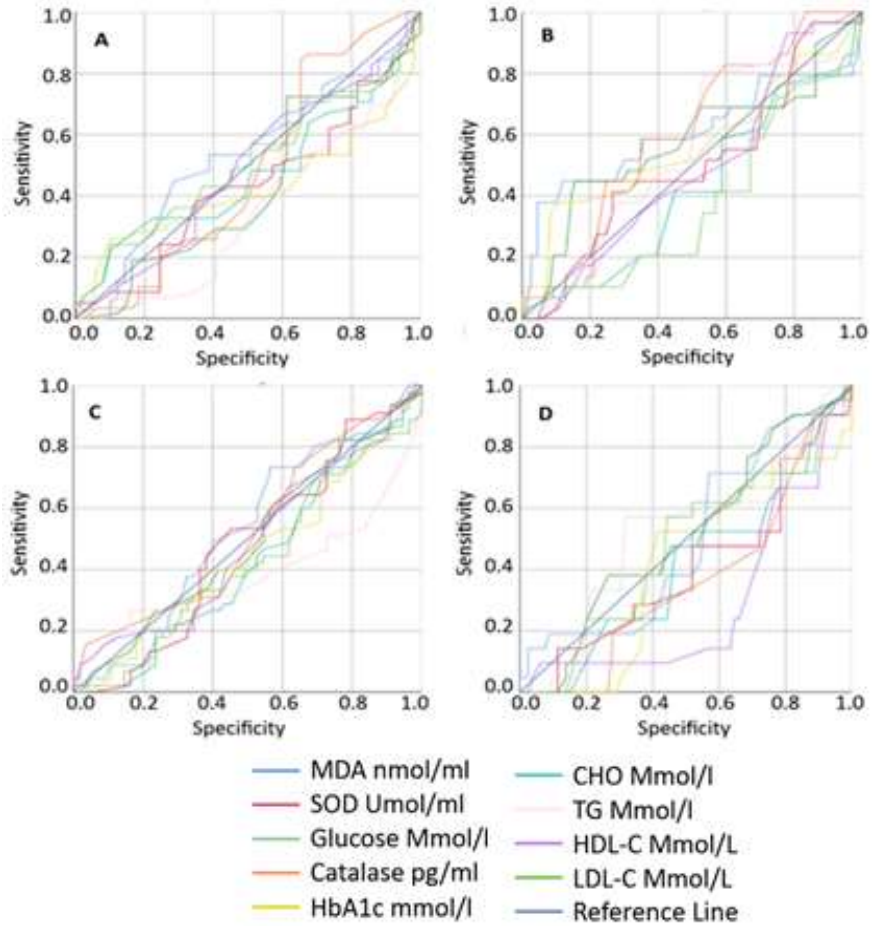

Fig 3: Diagrammatic representation of ROC curves in relation to incidence of hypertension among the study participants A: obese diabetic subjects, B: non-obese diabetic subjects, C: obese non-diabetic subjects, D: non-obese non-diabetic subjects

Table 9: ROC curves in relation to incidence of hypertension among the study participants; Area Under the Curve (95% Confidence Interval)

Test Result Variable(s)	Non obese diabetes	Non obese non-diabetes	Obese non-diabetes	Obese diabetes
MDA nmol/ml	0.602(0.46-0.74)	0.498(0.36-0.64)	0.520(0.41-0.64)	0.529(0.42-0.64)
SOD Umol/ml	0.504(0.39-0.62)	0.404(0.27-0.54)	0.479(0.37-0.59)	0.432(0.32-0.54)
Catalase pg/ml)	0.607(0.50-0.71)	0.364(0.24-0.49)	0.523(0.41-0.64)	0.484(0.37-0.60)
F.B.S	0.573(0.44-0.70)	0.511(0.38-0.65)	0.493(0.38-0.61)	0.427(0.32-0.54)
HbA1c mmol/l	0.566(0.43-0.70)	0.417(0.28-0.55)	0.447(0.33-0.56)	0.423(0.31-0.53)
CHO Mmol/l	0.424(0.31-0.54	0.416(0.28-0.55)	0.425(0.31-0.54)	0.468(0.36-0.58)
TG Mmol/l	0.54(0.42-0.66)	0.525(0.38-0.67)	0.386(0.27-0.50)	0.352(0.25-0.46)
HDL-C Mmol/L	0.49(0.38-0.60)	0.294(0.17-0.42)	0.486(0.37-0.60)	0.49(0.38-0.60)
LDL-C Mmol/L	0.375(0.26-0.49)	0.471(0.33-0.61)	0.426(0.31-0.54)	0.505(0.40-0.62)

The test result variable(s): MDA nmol/ml, SOD Umol/ml, F.B.S, Catalase pg/ml), HbA1c mmol/l, CHO Mmol/l, TG Mmol/l, HDL-C Mmol/L, LDL-C Mmol/L has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased

Some studies (Ozata *et al*., 2002 and Amirkhizi *et al.*, 2007) have reported that obesity could lead to alteration in the antioxidant capacity when it persists for a long time leading to depletion of antioxidant enzymes such as superoxide dismutase. However, plasma concentration of superoxide dismutase increased significantly among obese diabetic subjects in comparison with non-obese and non-diabetics in this study. Alba *et al* (2011) made a contradictory observation of a significantly lower SOD activity in obese individuals compared with healthy controls, having implications for the development of obesity-related disorders. The increased superoxide dismutase among our obese diabetic subjects could be due to reduced endothelial dysfunction, characterized by a reduction in the bioavailability of vasodilators, particularly nitric oxide (NO), and an increase in endothelium-derived contractile factors that favor atherosclerotic disease since more than two third of the subjects were on at least one form of treatment (Alba, 2011).Plasma MDA showed a significant increase among obese diabetic subject compared to the control group. This finding is in line with the submission of others (Kumawat, 2013) that reported significantly increased MDA levels among diabetic subjects. These observations suggested that generation of free radicals from increased lipid peroxidation is associated with comorbidity of type 2 diabetes and obesity (Kumawat *et al*., 2013), Hence, it can be hypothesized that the extent of oxidative stress and occurrence of Type 2 diabetes complications are dependent on metabolic control of diabetes since elevated MDA was reported in diabetics with poor glycemic control (Ghosh *et al*., 2018). Conflicting reports exist suggesting that dyslipidemia; high BMI (Ghosh *et al*., 2011) and WHR (Midha, Krishna, Nath, 2014) are good predictors for the development of hypertension. In the present study, analysis of the receiver-operating characteristic (ROC) curve and the area under the curve (AUC) for lipid profile, glucose and markers of lipid peroxidation in relation to the incidence of hypertension shows that MDA has the highest AUC among the nine indices (MDA, SOD, catalase, FBS, HbA1c, total cholesterol, TG, HDL and LDL) among the diabetic groups compared with non-diabetes participants with a steeper increase in LDL among the obese diabetes participants. Suggesting MDA and LDL can be utilized as predictive indices for the development of hypertension in obese individuals.

Conclusion: The pathophysiology of typical dyslipidemia observed in obesity is multifactorial and may be due to hepatic alteration in lipid profile synthesis, which could have resulted in the significant reduction in changes observed in mean concentration of SOD among study subjects. Diabetes patients should strive for weight loss, weight maintenance, and a reduction in disease risk factors, particularly cardiovascular risk. To manage diabetes risk factors, health interventions and education programs must be properly planned and implemented on a national scale.

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