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 (9.5±0.13 mmol/l) and HbA1c (9.5±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 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 - 0.64 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). Comorbidity 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 contribute 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 (Çolak and Papp, 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 ≥ 30Kg/m² 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/m²), normal (18.5 - <25 kg/m²), overweight (25 - <30 kg/m²) and obese (≥30 kg/m²) (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).

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

| 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                  |                 |                 |                          |
| 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 status              |                 |                 |                          |
| Primary                         | 20              | 4.5             |
| Secondary                       | 70              | 15.7            |
| Tertiary                        | 355             | 79.8            |

| Table 2: Anthropometric parameters among study subjects |
|---------------------------------|-----------------|-----------------|--------------------------|
| Subject/ Age                    | Obese diabetic | Non obese diabetic | Obese non diabetic | Non obese non-diabetic | P-value |
| (n=107)                         | (n=138)         | (n=100)          | (n=100)              |
| Age (years)                     | 45.69±0.17      | 40.94±0.97      | 41.96±0.24          | 43.14±1.90          | 0.015*   |
| BMI (kg/m²)                     | 34.06±0.29      | 24.13±0.19      | 33.22±0.25          | 23.59±0.28          | 0.000*   |
| WC (cm)                         | 125.82±0.69     | 81.72±0.93      | 83.58±2.27          | 128.61±2.46         | 0.000*   |
| WC (cm)                         | 98.52±0.86      | 79.72±0.64      | 83.68±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           | 0.85±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/ Age                    | Obese diabetic | Non obese diabetic | Obese non diabetic | Non obese non-diabetic | P-value |
| (n=107)                         | (n=138)         | (n=100)          | (n=100)              |
| FBS (mmol/l)                    | 9.54±1.13       | 9.20±0.13       | 5.41±0.09            | 5.25±0.12           | 0.000*   |
| HbA1c (mmol/l)                  | 9.1±0.15        | 7.33±1.17       | 8.40±0.22            | 8.40±0.19           | 0.001*   |
| TC (mmol/l)                     | 4.94±0.07       | 4.99±0.10       | 4.32±0.08            | 0.566              |
| TG (mmol/l)                     | 1.61±0.03       | 1.15±0.06       | 0.82±0.06            | 0.913              |
| HDL (C mmol/L)                  | 1.18±0.02       | 1.15±0.03       | 1.04±0.03            | 0.369              |
| LDL-C (C mmol/L)                | 3.03±0.06       | 3.22±0.10       | 2.87±0.08            | 0.711              |
| LDL-HDL                         | 2.72±0.09       | 3.09±0.13       | 2.91±0.12            | 0.715              |
| AIP                             | 0.14±0.01       | 0.04±0.02       | 0.19±0.03            | 0.358              |
| CRR                             | 1.14±0.10       | 3.63±0.14       | 4.30±0.14            | 0.000              |
| Non HDL                         | 3.76±0.07       | 3.83±0.10       | 3.24±0.08            | 0.373              |
| AC                              | 3.74±0.19       | 3.73±0.10       | 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
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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 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.

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). 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.
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 12 million 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 et al., 2001).
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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 | χ² | 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%)           | 65(65.0%) |       |        |
| 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%)      | 1(1.0%)                | 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 | χ² | P-value |
|---------------------|-------------|-----------------------|--------------------|-------|----|--------|
| Age                 |             |                       |                    |       |    |        |
| ≤ 30 years          | 2(2.0%)     | 8(8.0%)               | 5(5.0%)            | 15(15.0%) | 12.297 | 0.015  |
| 31-50 years         | 4(4.0%)     | 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%)          | 55(55.0%) |       |        |

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 (StepieńStepień, Wlazel, 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, Stepień 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 (Klopf, Jukema, Rabelink, Castro Cabezas, 2012). Cholesterol ratio is used as a monitoring tool for determining the risk of

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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 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).

**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)   | 0.50(0.40-0.62) |

The text 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.

**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.
Some studies (Ozata et al., 2002 and Amirkhiz 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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