1 ***Original Research Article***
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3 # CORRELATION BETWEEN OXIDATIVE STRESS MARKERS AND ATHEROGENIC INDICES
4 # IN TYPE 2 DIABETES MELLITUS
5
6 ## ABSTRACT

7 Worldwide, approximately 200 million individuals are currently suffering from Type 2 diabetes mellitus
8 (DM). Diabetes mellitus is associated with hyperglycemia; which induces oxidative stress that is
9 responsible for the various complications associated with the disease. This study was designed to know
10 the relationship between oxidative stress and atherogenic indices of plasma in Type 2 diabetic and non-
11 diabetic subjects. A total number of eighty (80) subjects comprising of 58 diabetic subjects with mean age
12 (62.91±10.57) years and 22 non-diabetic subjects with mean age (55.27±16.62) years were studied.
13 Estimation of enzymatic and non-enzymatic oxidative stress markers (which included MDA, SOD, GPx,
14 CAT, Uric acid and Albumin) and atherogenic indices (TCHOL, TG, HDL, LDL) were done respectively
15 using standard spectrophotometric techniques. The mean plasma of SOD, GPx, CAT and albumin were
16 significantly lower in diabetic subjects compared with control group. However, TChol, HDL, MDA and uric
17 acid were significantly higher in diabetic subjects compared with controls. The findings of this study
18 showed significant differences in dyslipidemia, lipid peroxidation and increase of oxidative stress markers
19 from naïve type 2 diabetic subjects through controls. Thus, early diagnosis and management of this
20 condition is necessary in order to incorporate antioxidant supplement as a supportive therapy for
21 adequate glycaemic control.

22 **Keywords:** Diabetes mellitus, Oxidative stress, antioxidant, CVD, atherogenic indices

23

24 ## 1.0 INTRODUCTION

25 Diabetes mellitus (DM), commonly referred to as diabetes, is a group of metabolic diseases characterized
26 by chronic hyperglycaemia over a prolonged period. Diabetes is either due to the pancreas inability to
27 produce adequate insulin or insulin resistance to the cells of the body [1]. As of 2014, 387 million diabetes

28 cases were reported worldwide [2] and type 2 DM made up about 90% of the case [3]. This represents
29 8.3% of the adult population with equal rates in both women and men [4]. From 2012 to 2014, diabetes
30 was estimated to have resulted in 1.5 to 4.9 million deaths each year and the number of individuals with
31 diabetes are expected to rise to 592 million by 2035 [5]. Diabetes has been at least reported to double an
32 individuals' risk of death [6].
33 There are three main types of diabetes mellitus as reported by Picot *et al.* [7] which are the Type 1 DM,
34 type 2 DM and gestational diabetes. Inability of the pancreas to produce enough insulin is the main cause
35 of type 1 DM and this type was previously referred to as "insulin-dependent diabetes mellitus" (IDDM) or
36 "juvenile diabetes" [4]. Type 2 DM is initiated by insulin resistance; a condition in which cells fail to
37 respond to insulin properly [4]. As the disease progresses, a lack of insulin may also develop [8]. This
38 form was previously referred to as "non-insulin-dependent diabetes mellitus" (NIDDM) or "adult-onset
39 diabetes". The primary cause is excessive body weight and inadequate exercises [4]. Gestational
40 diabetes is the third main type and occurs when pregnant women without a previous history of diabetes
41 develop hyperglycaemic condition [4]. Type 2 diabetes is typically a chronic disease associated with a
42 ten-year-shorter life expectancy. Long-term complications from this condition includes heart disease,
43 stroke, diabetic retinopathy, kidney failure, and poor blood flow in the limbs leading to amputations [1].
44 Free radicals are atoms or group of atoms with an unpaired number of electron(s) in their outer most shell
45 and can be possibly formed when oxygen interacts with certain biomolecules [9]. Once formed, these
46 highly reactive species can start a chain reaction. Their chief danger comes from the damage they can do
47 when they react with important cellular component such as DNA, or the cell membrane [9]. Cells might
48 function poorly or die if this eventually occurs and is not arrested on time. To prevent free radical effect(s),
49 the body has a defense mechanism system of antioxidants [10]. An antioxidant is a molecule that inhibits
50 the oxidation of other molecules, while oxidation is a chemical reaction that can produce free radicals,
51 leading to chain reaction that may damage cells. Thus antioxidants such as thiols or ascorbic acid
52 terminate this chain reaction [11]. To balance the oxidative state, plant and animal maintain complex
53 systems of overlapping antioxidants, such as glutathione and enzymes (such as catalase) produced
54 internally or Vitamin C, Vitamin A, and Vitamin E obtained by ingestion [12]. Antioxidants are widely used

in dietary supplements and have been investigated to be highly effective for the prevention of diseases such as cancer and coronary heart diseases [13].

Oxidative stress reflects an imbalance between the systemic manifestation of reactive oxygen species (ROS) and a biological system's ability to readily detoxify the reactive intermediates or to repair the resulting damage. Disturbances in the normal redox state of cells could possibly cause toxic effects through the production of peroxides and free radicals that damage the body's biomolecules, including proteins, lipids, and DNA [14]. Oxidative stress from oxidative metabolism had been reported to cause base damage, as well as break strand in DNA [15]. In humans, oxidative stress is thought to be involved in the development of atherosclerosis and had been cited to be of etiological importance in cardiovascular diseases [16], which could be related to diet and also metabolic disorders with abnormal lipid metabolism [17]. In either of the case, it results in atherosclerotic endothelial dysfunction from arterial diseases and this has been reported to be responsible for about 30% of deaths worldwide [16]. Diabetes mellitus is characterized by hyperglycemia, which may induce oxidative stress that is responsible for the various complications associated with the disease [18] that affects the heart, the nerves and the retina resulting into heart disorders [19]. The characteristics of diabetic mellitus such as hyperglycemia, dyslipidemia, inflammation and oxidative stress affect the vascular wall and thus accelerating atherosclerosis and its clinical complications [10]. Atheroslerotic disorder of the coronary arteries usually result in partial or complete occlusion of vascular lumen and this is of pathological significance in determining the morbidity and mortality pattern of ischemic heart disease (IHD) [10]. Coronary artery disease (CAD) is initially symptomless with normal basic activities but as the disease progresses, the degree of lumen narrowing is sufficiently great and this limits an increase in blood flow during exercises and thus producing symptoms of angina pectoris which can lead to heart attack [20].

Oxidative stress is associated with increased production of oxidizing species or a significant decrease in the effectiveness of antioxidant defenses, such as glutathione [21]. The effects of oxidative stress depend upon the size of these changes, with a cell being able to overcome small perturbations and regain its original state. However, more severe oxidative stress can cause cell death and even moderate oxidation can trigger apoptosis, while more intense stress may cause necrosis [22]. Generally, approximately 200

82 million individuals are currently suffering from type 2 diabetes mellitus (DM) in the entire world [2]. Some
83 studies have shown that Type 2 DM subjects generally carry a number of risk factors for coronary
84 vascular disease (CVD), which is found to be characterized by hyperglycemia, abnormal lipid profiles
85 pattern and alterations in inflammatory mediators [20]. Thus, diabetes mellitus associated with
86 cardiovascular diseases tends to be one of the highest causes of death worldwide. This study therefore
87 aimed at knowing the relationship between oxidative stress biomarkers and atherogenic indices of plasma
88 in type 2 diabetes mellitus, which may contribute to the incidence of CVD in this condition if it is not
89 ameliorated on time.

90 2.0 MATERIALS AND METHODS

91 2.1 Study population

92 This study was conducted at Federal Medical Centre, Owo in Ondo State. Owo is a town in Ondo State
93 situated at south-western Nigeria, with latitude 710'59.998''N and longitude 534'59.988''E at an average
94 altitude of 348 meters. It is at the southern edge of the Yoruba hills and at the intersections of roads from
95 Akure and Benin City. The community has a population of 276, 593 according to national population in
96 the year 2006 census [23].

97 2.2 Study design

98 This is a case-control study and it was conducted at Federal Medical Centre, (FMC) Owo, which is a
99 Tertiary health institution in Ondo State. The research was conducted between January and July, 2016. A
100 total number of eighty (80) subjects comprising of fifty eight (58) type 2 diabetes mellitus subjects (both
101 males and females) aged between 30 – 80 years, were sub-divided into diabetic mellitus subjects under
102 treatment, DMUT and naïve diabetic subjects (which are newly diagnosed type 2 diabetes mellitus)
103 attending diabetic clinic at Federal Medical Centre, Owo were randomly selected for this study. Type 2
104 diabetes mellitus subjects in this study were diagnosed according to guideline of WHO [24]. Their medical
105 history and personal data were obtained via short structured questionnaire after due approval from the
106 ethical committee of the hospital. The Control group had twenty-two (22) ages and sex matched
107 apparently healthy subjects with no history of diabetes mellitus enrolled into the study. Informed consent
108 was thus obtained from all the participants.

109 **2.3 Ethical clearance and consent**

110 Subjects participating in this study were fully briefed on the research protocols in the clinic after which
111 they were required to sign a written consent. After that, a pre-designed structural questionnaire was
112 utilized to collect bio-data, and socio-demographic characteristics of the patients. Approval for this study
113 was obtained from the Federal Medical Centre, Owo and Ethical Clearance
114 (FMC/OW/380/VOL.XXIX/197) was issued by Ethical Committee Federal Medical Centre, Owo.

115 **2.4 Collection and Storage of Samples**

116 Blood samples were obtained from each subject by applying a tourniquet around the arm above elbow.
117 The ante-cubital forsa was disinfected with a 70% alcohol soaked swab. Six (6) milliliter (ml) of venous
118 blood was collected from each subject using aseptic procedure after 12 hours fast. Four (4) ml of venous
119 blood was dispensed into 5 ml sterile vacutainer bottle containing lithium heparin anticoagulant and gently
120 mixed by inverting the container severally for the determination of lipids profile and oxidative stress
121 markers. The remaining (2 ml) of the venous blood was dispensed into 3 ml vacutainer bottle containing
122 fluoride oxalate anticoagulant which was also mixed gently by inverting the container severally for the
123 determination of plasma glucose. Plasma was separated from the blood by centrifugation for 5 minutes at
124 4000rpm, into plain bottles and stored at -20℃ unt il time of analysis.

125 **2.5 Analytical Methods**

126 Height (m) was taken using a Stadiometer while body weight (kg) was measured using a body weight
127 weighing scale with the subject wearing light clothing and without shoes. Body mass Index (BMI) was
128 calculated as the ratio of weight (kg) to the square of height (m^2). Blood pressure and pulse rate were
129 taken simultaneously using a sphygmomanometer. Blood levels of fasting blood sugar and lipids profile
130 were determined using standard spectrophotometric method [25] and standard methods were employed
131 for the determination of SOD, CAT and GPx plasma activities [26, 27] and plasma levels of MDA, Uric
132 acid and albumin [28, 29, 30].

133 **2.6 Statistical analysis of data**

134 A statistical package for social science (SPSS) 17.0 was used for the analysis of the data appropriately.
135 All values were expressed as Mean ± Standard deviation (SD). Analysis of variance (ANOVA) was used

136 to determine significant differences among groups while Spearman correlation was used to test the
137 association between variables. The level of significance was taken at 95% confidence interval and P
138 value less than 0.05 was considered significant.

139 3.0 RESULTS AND DISCUSSION

140 3.1 Results

141 A total number of eighty (80) subjects comprising 58 diabetic subjects with mean age (62.91±10.57) years
142 and 22 non-diabetic subjects (control) with mean age (55.27±16.62) years were studied. Twenty three
143 (23) out of the diabetic subjects were naïve (i.e. not yet placed on diabetic drugs) while the remaining 35
144 were already undergoing treatment.

145 Table 1 shows the age and sex distribution of all participants. Participants were aged between 30 and 80
146 years. There were 34 females and 24 males, and 13 females and 9 males in diabetic and non-diabetic
147 groups respectively. Thus, females constituted 58.75% while males constituted 41.25% in overall.

148 Table 2 shows the anthropometric indices and biochemical parameters in naïve diabetic subjects (naïve
149 DM), diabetic subjects under treatment (DMUT) and controls using One way analysis of variance
150 (ANOVA). The mean BMI, Pulse, SBP, DBP, FBS, TChl, TAG, HDL, MDA and Uric acid were significantly
151 higher in naïve DM than controls while the mean plasma of albumin and plasma activities of SOD, GPx
152 and CAT were significantly lower. Also, the mean BMI, Pulse, SBP, DBP, FBS and HDL were significantly
153 higher, whereas plasma activities of SOD, GPx and CAT were significantly lower in DMUT than controls.
154 However, the mean Pulse, SBP, DBP and FBS were significantly lower, whereas mean plasma of
155 albumin was significantly higher in DMUT compared with naïve DM.

156 Table 3 indicates correlation of plasma levels of enzymatic antioxidant biomarkers with atherogenic
157 indices and other parameters in diabetic subjects. CAT had positive correlation with FBS, TChol, TAG
158 and LDL, but inverse correlation with HDL. Also, SOD showed statistically negative correlation with
159 TChol, TAG, HDL and LDL, while GPx only had positive correlation with HDL, TChol:HDL and LDL:HDL.
160 Finally, table 4 shows plasma levels of MDA had significant positive correlation with FBS, TChl and LDL.
161 Uric acid showed statistical positive significant correlation with blood pressure (SBP and DBP), while
162 albumin only had significant inverse correlation with pulse.

163

164

165 **Table 1: Age and Sex distribution of the Subject population in percentage (%)**

Age group (Years)	Diabetic Subjects		Non-diabetic subjects		Total
	Male	Female	Male	Female	
31-40	-	1 (1.25)	4 (5)	3 (2.75)	8 (10)
41-50	8 (10)	2 (2.5)	-	3 (3.75)	13 (16.25)
51-60	2 (2.5)	8 (10)	1 (1.25)	2 (2.5)	13 (16.25)
61-70	10 (12.5)	15 (18.75)	1 (1.25)	3 (2.75)	29 (36.25)
71-80	4 (5)	8 (10)	3 (3.75)	2 (2.5)	17 (21.25)
Total	24 (30)	34 (42.5)	9 (11.25)	13 (16.25)	80 (100)

166

167 **Table 2: Anthropometric indices and biochemical parameters in naïve diabetic subjects,**

168 **diabetic subjects under treatment (DMUT) and controls**

169

Parameters	Naïve DM (n=23)	DMUT (n=35)	Control (n=22)
BMI (Kg/m^2)	30.44±6.28[a]	27.94±8.42	24.88±5.11
Pulse (b/m)	78.04±4.65 [a]	72.51±4.13 [a, b]	69.09±3.04
SBP (mmHg)	135.00±12.61 [a]	125.31±12.38 [a, b]	115.73±8.69
DBP (mmHg)	85.43±7.22 [a]	81.57±7.65 [a, b]	75.64±5.38
FBS (mmol/l)	13.50±4.95 [a]	8.47±3.45 [a, b]	4.57±0.61
TChl (mmol/l)	5.38±1.37 [a]	4.82±1.31	4.26±1.01
TAG (mmol/l)	2.21±0.86 [a]	1.53±0.62	1.46±0.74
HDL (mmol/l)	1.44±0.38 [a]	1.40±0.53 [a]	1.04±0.27
LDL (mmol/l)	2.93±0.93	2.72±0.90	2.56±0.62
TChl:HDL	3.95±1.64	3.70±1.12	4.20±0.74
LDL:HDL	2.21±1.29	2.18±0.94	2.57±0.68
SOD (U/ml)	2.12±0.47 [a]	1.96±0.81 [a]	3.19±1.39

MDA (µmol/l)	3.44±1.07 [a]	3.12±1.66	2.51±0.96
GPx (U/ml)	2.10±0.68 [a]	1.99±0.79 [a]	2.90±0.90
CAT (U/L)	19.76±5.71 [a]	21.23±7.11 [a]	27.91±6.87
Uric Acid (mmol/l)	437.30±155.11 [a]	363.41±182.41	287.99±125.75
Albumin (mg/dl)	33.56±5.07 [a]	38.35±5.07 [b]	38.39±4.10

170 [a] = significantly different from controls, [b] = significantly different from Naïve DM,

171 Key: BMI= body mass index, SBP= systolic blood pressure, DBP= diastolic blood pressure, FBS= fasting
172 blood sugar, TChl = Total cholesterol, TAG = triglycerides, HDL = High density lipoprotein, LDL = Low
173 density lipoprotein, SOD = Superoxide dismutase, MDA= Malondialdehyde, GP_X = Glutathione
174 peroxidase, CAT= Catalase

175

176 **Table 3: Correlation of plasma levels of enzymatic antioxidant biomarkers with**
177 **atherogenic indices and other parameters in diabetic subjects**

	SOD		GPx		CAT	
	r-value	p-value	r-value	p-value	r-value	p-value
BMI (Kg/m^2)	-0.151	0.259	0.040	0.765	-0.096	0.474
Pulse (b/m)	0.130	0.332	0.108	0.419	0.015	0.910
SBP (mmHg)	-0.033	0.807	-0.063	0.638	- 0.159	0.234
DBP (mmHg)	-0.112	0.404	-0.127	0.342	-0.253	0.056
FBS (mmol/l)	-0.064	0.635	-0.250	0.059	-0.373	0.004*
TChl (mmol/l)	-0.474	0.000*	-0.235	0.076	-0.447	0.000*
TAG (mmol/l)	-0.279	0.034*	- 0.104	0.439	-0.387	0.003*
HDL (mmol/l)	-0.308	0.019*	0.286	0.029*	0.303	0.021*
LDL (mmol/l)	-0.418	0.001*	0.070	0.603	-0.293	0.026*
TChl:HDL	-0.010	0.938	0.297	0.024*	0.096	0.474
LDL:HDL	0.001	0.994	0.287	0.029*	0.132	0.324

178 * Correlation is significant at the 0.05 level (2-tailed)

179

180 **Table 4: Correlation of plasma levels of non-enzymatic biomarkers of oxidative stress**
181 **with atherogenic indices and other parameters in diabetic subjects**
182

	MDA		Uric Acid		Albumin	
	r-value	p-value	r-value	p-value	r-value	p-value
BMI (Kg/m^2)	0.230	0.083	0.025	0.852	-0.155	0.244
Pulse (b/m)	0.121	0.366	0.184	0.166	-0.307	0.019*
SBP (mmHg)	0.101	0.450	0.312	0.017*	-0.121	0.366
DBP (mmHg)	0.231	0.081	0.291	0.027*	0.096	0.472
FBS (mmol/l)	0.382	0.003*	0.251	0.057	-0.321	0.014
TChl (mmol/l)	0.512	0.000*	-0.031	0.818	-0.036	0.790
TAG (mmol/l)	-0.336	0.010*	- 0.052	0.697	-0.192	0.149
HDL (mmol/l)	0.168	0.206	-0.073	0.587	-0.113	0.398
LDL (mmol/l)	0.460	0.000*	- 0.048	0.718	0.010	0.938
TChl:HDL	0.147	0.272	-0.057	0.674	0.034	0.798
LDL:HDL	0.113	0.400	- 0.072	0.591	0.068	0.613

183 * Correlation is significant at the 0.05 level (2-tailed)
184

185 **3.2 Discussion**

186 Diabetes mellitus is associated with hyperglycemia which induces oxidative stress that is responsible for
187 the various complications associated with the disease [18], affecting the heart, the nerves and the retina
188 resulting to heart disorders [19]. The characteristics of diabetic mellitus such as hyperglycemia,
189 dyslipidemia, inflammation, and oxidative stress affect the vascular wall and thus accelerating
190 atherosclerosis and its clinical complications [10].

191 Oxidative stress reflects an imbalance between the systemic manifestation of reactive oxygen species
192 and a biological system's ability to readily detoxify the reactive intermediates or to repair the resulting
193 damage. Oxidative stress depicts the existence of products called free radicals and reactive oxygen
194 species (ROS) which are formed under normal physiological conditions but become deleterious when
195 they are unable to be quenched by the antioxidant systems [31]. There are convincing experimental and
196 clinical evidences that the generation of reactive oxygen species is increased in both types of diabetes

197 and that the onset of diabetes is closely associated with oxidative stress [32]. Free radicals are formed
198 disproportionately in diabetes by glucose autoxidation, polyol pathway and non-enzymatic glycation of
199 proteins [33]. Abnormally high levels of free radicals and simultaneous decline of antioxidant defense
200 systems can lead to the damage of cellular organelles and enzymes, increase lipid peroxidation and
201 development of complications of diabetes mellitus [34].

202 From the results obtained in this study, it is evident that the diabetic patients had much higher glucose
203 and lipids levels (TChol and TAG) when compared with non-diabetic subjects. An increase of the indices
204 in this study is consistent with Whiting et al. [35] who they reported that chronic hyperglycemia could
205 influence the generation of free radicals, which may eventually result in an increase in lipid peroxidation
206 and depletion of antioxidants. Significant lipid peroxidation, higher levels of lipids and lipid risk factors
207 (such as increase in BMI, SBP & DBP) in diabetic subjects in this study are indicators for atherogenic
208 changes [36]. The products of lipid peroxidation are harmful to most cells in the body and are associated
209 with a variety of diseases, such as atherosclerosis and brain damage [37].

210 The major finding of this study was that antioxidant levels, both enzymatic and non-enzymatic, were
211 either significantly reduced or increased in diabetic subjects. Significant decrease in albumin levels and
212 elevated levels of uric acid in the diabetic subjects when compared with the corresponding control groups
213 are reflective of the acute phase response. Acute-phase reactants are plasma proteins that alter in
214 concentration sequel to an inflammatory stimulus [38]. Thus, decrease in plasma levels of albumin may
215 be used as a marker of negative acute phase proteins in type 2 diabetic subjects.

216 Significant increase in the mean levels of plasma Uric acid in naïve diabetic cases when compared to
217 controls is associated with the cause of type 2 diabetes, independent of obesity, dyslipidemia and high
218 blood pressure as reported by Dhengan et al. [39]. In humans, uric acid is the main plasma antioxidant
219 followed by vitamin C and thus, it stabilizes vitamin C in plasma and protects it from oxidation [40, 41].
220 Besides that hyperuricaemia was presumed to be consequence of insulin resistant [39], Uric acid in the
221 blood had also been documented to scavenge superoxide radicals, hydroxyl radicals, singlet oxygen and
222 could chelate transition metals [42]. Thus increase in plasma levels of Uric acid in cases compared to

223 controls might be a compensatory mechanism in order to mop up free radicals generated in diabetic
224 condition.

225 This study shows a significant increase in plasma MDA levels in type 2 diabetics when compared to
226 controls indicating increase in lipid peroxidation. Malondialdehyde (MDA) is a product of lipid peroxidation
227 and provides a means of assessing the extent of lipid peroxidation. Our data showed plasma levels of
228 MDA had significant positive correlation with FBS and TChol. This finding is in agreement with previous
229 report by Suchitra et al. [36]. They also reported significant positive correlation of MDA with FBS and
230 TChol in diabetic subjects. This correlation analysis also suggests that hyperglycemia per se is greatly
231 involved in oxidative stress resulting in increased lipid peroxidation.

232 The significant reduction in activity of serum antioxidant enzymes such as SOD, CAT and GPx was
233 recorded in this work among diabetic subjects when compared to controls. This observation is consistent
234 with most invivo and invitro studies which demonstrated that the levels of antioxidant enzymes are altered
235 in chronic conditions [43]. Catalase catalyzes the decomposition of hydrogen peroxide to water and
236 oxygen. It is a very important enzyme in protecting the cell from oxidative damage by reactive oxygen
237 species (ROS) [44]. Superoxide dismutases are important antioxidant defense systems in nearly all cells
238 exposed to oxygen. They are proteins co-factored with copper and zinc, or manganese, iron, or nickel,
239 while GPx is a selenium dependent enzyme with peroxidase activity whose main biological role is to
240 protect the organism from oxidative damage. The biochemical function of glutathione peroxidase is to
241 reduce lipid hydroperoxides to their corresponding alcohols and to reduce free hydrogen peroxide to
242 water [45]. Oxidative stress results when there is increase in production of free radicals or decrease in
243 activity of counter-actors, antioxidants or both in a combination [36]. These observations provide evidence
244 for the increase in the oxidative stress among type 2 diabetes.

245 **4.0 Conclusion and recommendations**

246 The findings of this study show significant differences in dyslipidemia, lipid peroxidation and increasing of
247 oxidative stress markers from naïve type 2 diabetic subjects through controls. Thus, early diagnosis and
248 management of this condition is necessary in order to incorporate antioxidant supplement as a supportive

249 therapy for adequate glycaemic control. This would go far in preventing development of oxidative stress-
250 associated diabetic complications.

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