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Assessment of the Oxidative Stress Status in those with Diabetes and Hypertension Attending Jos University Teaching Hospital (JUTH), Nigeria

Obot Uduakobong Blessing [a], Adugbe Abigail [a*], Solomon D. Mariam [a] and Gazuwa Y. Samuel [a]

[a] Department of Biochemistry, Faculty of Basic Medical Sciences, College of Health Sciences, University of Jos, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Diabetes is a serious, long-term condition with a major impact on the lives and wellbeing of individuals, families, and societies worldwide. This study aimed to investigate the impact of oxidative stress on individuals with type 2 diabetes mellitus (T2DM) and hypertension who were receiving care at the Endocrinology unit of Jos University Teaching Hospital (JUTH). A total of 54 subjects, comprising both males and females, were randomly selected for the study. The subjects included 27 patients diagnosed with T2DM and hypertension, as well as 27 healthy volunteers who were recruited as a control group. The study focused on assessing various parameters related to oxidative stress and antioxidant enzyme activity. The evaluation of oxidant status involved measuring Malondialdehyde (MDA) levels, which serve as a marker for lipid peroxidation, as well

**Corresponding author: E-mail: adugbea@unijos.edu.ng;*

as Glycated hemoglobin (HbA1c) levels and Lipid profile. Additionally, the activity of antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), and reduced glutathione (GSH), was examined. Demographic information, lifestyle factors, and clinical assessments were also collected during the study. The results showed that HbA1c levels were significantly higher in diabetic patients compared to the healthy participants. Furthermore, the diabetic group exhibited higher MDA activity, indicating increased lipid peroxidation, compared to the control group (P = 0.001). In terms of antioxidant enzyme activity, the diabetic group showed elevated levels of SOD, CAT, and GSH compared to the control group (P = 0.001). Regarding lifestyle factors, there was a significant difference (P = 0.001) in lipid profiles between diabetic and non-diabetic individuals who engaged in regular exercise compared to those who did not exercise. Similarly, diabetic individuals who had consultations with a registered dietician or an Endocrinologist also demonstrated significantly improved lipid profiles compared to those who did not seek professional advice. Notably, diabetics who exercised regularly and received dietary guidance exhibited significantly higher levels of HDL compared to those who did not engage in exercise or receive dietary counseling. In conclusion, this study highlighted the association between oxidative stress and T2DM with hypertension. The findings emphasized the importance of managing oxidative stress through lifestyle modifications, such as regular exercise and dietary interventions, in improving lipid profiles and potentially mitigating the impact of diabetes on individuals' health and well-being.

Keywords: Diabetes; hypertension; oxidative stress.

1. INTRODUCTION

Free radicals are highly reactive chemical entities that exist for a short period of time [1] and contain one or more unpaired electrons [2]. While they can be seen as necessary for signaling in normal processes like cell differentiation and migration [3], they can also cause harm by oxidizing cellular components and molecules through the transfer of their unpaired electron [4], typically, free radicals are unstable and extremely reactive. To counteract the damaging effects of free radicals, the body possesses its own internal antioxidant systems and also obtains antioxidants from the diet [5]. These antioxidants work to neutralize free radicals and maintain the body's overall balance, or homeostasis [6]. When there is an imbalance between free radicals and antioxidants, reactive oxygen species (ROS) are produced; leading to oxidative stress [7], this oxidative stress has been linked to the development of various pathological conditions, including diabetes mellitus [8].

ROS have been identified as substances that can disrupt enzymatic processes and contribute to various detrimental effects [9], such as lipid peroxidation [10], impaired Glutathione metabolism [11], and reduced levels of Vitamin C. In diabetes mellitus (DM) and hypertension, there are several biomarkers of oxidative stress that indicate the presence of this condition. These biomarkers include lipids, proteins, DNA damage, Glutathione, catalase, and superoxide dismutase [12,13, 14].

Oxidative stress in patients with type 2 diabetes mellitus (T2DM) disrupts the balance of antioxidants within cells [15,16], including enzymes like superoxide dismutase (SOD), catalase, glutathione peroxidase (GPx) [17], and glutathione (GSH). Previous research has indicated that T2DM patients exhibit lower levels of total antioxidant status (TAS), GPx [18], and GSH compared to healthy individuals. GPx is an antioxidant enzyme that plays various roles, such as neutralizing lipid peroxides and hydrogen peroxide (H_2O_2) [19,20,21], eliminating ROS, preventing the generation of new free radicals, and converting existing free radicals into less reactive molecules. The activity of GPx relies on GSH as both a direct scavenger and a co-substrate for the peroxidase enzyme. GSH serves as a primary buffer in the cellular reduction process against oxidation [22,23]. GPx and GSH antioxidants are believed to provide beneficial effects in the body, including the prevention and repair of damage caused by free radicals [24,25,26,27]. Other related parameters used to determine oxidative stress in the study include evaluation of oxidant status involved measuring Malondialdehyde (MDA) levels, which serve as a marker for lipid peroxidation, as well as Glycated hemoglobin (HbA1c) levels and Lipid profile. Additionally, the activity of antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT), and reduced glutathione (GSH), was examined. Demographic information,

lifestyle factors, and clinical assessments were also collected during the study.

The objective of this research is to assess the extent of damage in diabetic patients with hypertension by examining their levels of Glycated hemoglobin, oxidative stress profile, and lipid profile. Ultimately, this research aims to offer more information that will assist physicians in providing holistic interventions for the treatment and management of diabetes mellitus in patients attending JUTH (Jos University Teaching Hospital).

T2DM mellitus is a metabolic disorder characterized by high blood glucose levels (hyperglycemia) and insufficient production or action of insulin in the body [28,29]. T2DM, also known as adult-onset diabetes, is a chronic disease that typically develops in middle- to late adulthood. However, it is increasingly being diagnosed in children and adolescents as well. Although T2DM is distinct from type 1 diabetes, they both share high blood sugar levels and the associated complications. There are currently 463 million adults living with diabetes globally. Without adequate measures to address this pandemic, the number is projected to reach 578 million by 2030 and a staggering 700 million by 2045 [30]. Diabetes mellitus is a significant global health burden, primarily due to persistent elevated blood glucose levels detecting and measuring oxidative stress biomarkers at an early stage can help predict and reduce the severity of these complications, thus slowing down the progression of the disease [31].

Type 2 diabetes and hypertension are two of the most prevalent factors contributing to cardiovascular disease (CVD). Many individuals with diabetes may not experience symptoms, and a significant portion (up to one-third) may be unaware of their condition. Hypertension, characterized by blood pressure higher than 140/90 mmHg, commonly coexists with diabetes, affecting 20-60% of diabetic patients depending on factors like ethnicity, age, and obesity [32]. In addition to cardiovascular complications, the presence of hypertension in diabetic patients increases the risk of end-stage renal disease and diabetic retinopathy. For patients with both hypertension and diabetes, aggressive pharmacological treatment to achieve blood pressure targets may be more crucial in reducing cardiovascular risk than controlling blood glucose levels. Due to the heightened risk of CVD in diabetic patients, stricter blood pressure targets are necessary. While tightly controlling blood glucose levels decreases the likelihood of microvascular complications like retinopathy and nephropathy, it has not been proven to reduce diabetes-related mortality or the occurrence of heart attacks (MI) [33].

Individuals with diabetes are at a heightened risk of developing serious and life-threatening complications, leading to increased healthcare needs, diminished quality of life, and added stress on families [34]. Diabetes mellitus causes kidney damage, resulting in the retention of salt and water in the body, this, in turn, leads to an increase in blood pressure [35]. As diabetes progresses, it also damages the small blood vessels, causing them to become stiff and dysfunction [36], these alterations contribute to the development of elevated blood pressure [37].

2. MATERIALS AND METHODS

2.1 Data Collection

All participants signed the Informed consent Form and Questionnaire form. All the questionnaires used in the study contained a standardized section that collected information on socio-demographic factors, general characteristics, and habits of the participants. This section covered various aspects such as height, weight, smoking, alcohol consumption, coffee drinking, and other relevant factors. Additionally, the medical history of the participants was also recorded. Specifically, the questionnaires included identical questions regarding diabetes mellitus and the age at which individuals were first diagnosed with the disease. This ensured that there were no challenges in combining the data and conducting an analysis of this variable. The data was collected in October 2022.

2.2 Study Area

The study was out in Endocrinology Unit of Jos University Teaching Hospital (JUTH), Nigeria.

2.3 Sample Size Determination

The following formula for sample size determination was used to calculate the number of subject recruited into the study

Using Sample size calculation for case control studies

$$n = \frac{Z^2 p(1-p)}{d^2}$$

Where

n = sample size
Z = Standard normal variate for level of significance
d = Level of significance which is given by α
P = Prevalence
Z = 1.96
P = 0.036 (Prevalence in Jos metropolis)
1-P = 0.964
d = 0.05
$z = 1.96\ (constant)$
$p = 0.036\ (prevalence\ in\ Jos\ metropolis)$

$$n = \frac{Z^2 p(1-p)}{d^2}$$

$$= \frac{(1.96)^2\ 0.036\ X\ 1 - 0.036}{(0.05)^2}$$
$$= \frac{3.86416\ X\ 0.036X0.964}{0.0025}$$
$$= \frac{0.1341}{0.0025}$$
$$= 53 \cong 54$$

The determining of sample was divided into two groups Giving 27controls and 27 Test group [38].

2.4 Study Design

A Control case study was carried out on patient attending Medical Out-Patient Department (MOPD) Endocrinology Unit Clinic at JUTH, who were volunteers for the study, Questionnaire was administered to patients followed by collection of their blood samples. Study participant were recruited into the study by their consultants, whose diabetic status was confirmed based on their several visits to the clinic.

The control group study was carried out among JUTH staffs that are not diabetic and were willing to volunteer for the study.

2.5 Inclusion and exclusion criteria

2.5.1. Inclusion criteria

1. Male and female aged 36 years to 70 years
2. Male and female patients with HbA1C confirmed diagnosis of Type 2 diabetes and the blood pressure was measured using a gauge, stethoscope and a blood pressure cuff
3. Confirmed Type 2 diabetes for not less than five years
4. Has been regular on the anti-diabetes medication
5. Written informed consent for study participation
6. NIDDM (Type II Diabetes Mellitus)

2.5.2 Exclusion criteria

1. Poorly controlled glucose level
2. History and documented evidence of systemic hypertension

2.6 Blood Collection and Processing

After administration of questionnaire to participants, 5mls of whole blood samples was collected from the anticubital vein, where 2.5mls was emptied into the EDTA bottle which was used to assay for HbA1c and Lipid profile while the remaining 2.5mls was emptied into the fluoride bottle which was further centrifuge at about 3500rpm using Centrifuge Universal 320R HETTICH for 5minutes to obtain the plasma and serum. When the centrifugation process was over, the serum was retracted using a pipette and delivered into a Z-5 bottle which was labeled then stored in a freezer at 90c Refrigerator (Haier thermocool: 518FR- 20 micropipetles) to stabilizing the proteins for further analysis.

2.7 Statistical Method Used (Analysis)

Using the Statistical Package for Social Sciences (SPSS) version 25.0 for statistical analysis, quantitative data was expressed as mean ± standard deviation. A difference between means of the two groups was compared using Student's t-test. Chi-square test was used to determine association between categorical variables. A significance level of 0.05 and a confidence level of 95% was used for this study. $P < 0.05$ was considered statistically significant.

3. RESULTS

3.1 Demographic Characteristics of Study Participants

The Table 1 represents the result of demographic characteristics of the study participants. The mean age of the diabetic participants was 55.85±8.07 and that of control was 41.80±9.05 with a total mean age of 50.50±10.93. 87.5% of the diabetics were above 50 years of age while in the control 80.0% were

less than 50 years. With regard to gender, the diabetics were 50% each of male and female and the control group male constituted 30% and female accounted for 70%.

3.2 Lifestyle of the Study Participants

The result of lifestyle of the respondents is as shown in Table 5. The result shows that 81.5% of the diabetics exercise regularly while 50% did same in the control group. There was no significant difference (p=0.093) between the two groups. Smoking status of the two groups shows that all (100%) of the two groups did not smoke. With regard to alcohol consumption, 100% each in the two groups did not consume alcohol. Majority (68.8%) of them in the diabetic group checked their blood sugar regularly as compared to 50% in the control, However, there was no significant difference (p=0.339).

3.3 Result of Clinical Assessment

Result of clinical assessment of study participants is presented in Table 6. The result indicates 18.5% of the diabetics were hospitalized while 81.5% were not and 100% of the control were not hospitalized. There was a significant difference in the diabetic group between those who were hospitalized and those who were not (p=0.014). In the diabetic group, 77.8% attended session with a registered dietician with none (0.0%) in the control. The difference in the two groups was statistically significant (p=0.001). Also 50% of the diabetics see endocrinologist or diabetes care physician on a regular basis and 50% did not while all (100%) in the control group did not as they were not diabetic.

3.4 Comparison of Oxidant, Anti Oxidant and Hba1c between Diabetic and Control among study Participants

Result of MDA, GSH,SOD, CAT and HbA1c obtained from the analysis, indicates that the mean MDA between diabetic and control groups among the study participants, indicates that he diabetic had 1.78±0.82 while control had 1.13±0.08. The difference in the mean MDA between the two groups was statistically significant (p=0.001).

Table 1. Demographic characteristics of study participants

Demographic characteristics	Diabetic	Control	Total
Mean age ± SD	55.85±8.07	41.80±9.05	50.50±10.93
Age group (yrs)			
<50	3(11.1)	21(77.8)	24(44.4)
≥50	24(88.9)	6(22.2)	30(55.6)
Gender			
Male	13(48.1)	6(22.2)	19(35.2)
Female	14(51.9)	21(77.8)	35(64.8)

Table 2. Lifestyle of the study participants

Lifestyle	Diabetic	Control	χ^2	p-value
Do you exercise regularly?				
Yes	22(81.5)	10(37.0)	11.045	0.001
No	5(18.5)	17(63.0)		
Do you smoke?				
Yes	0(0.0)	0(0.0)	-	-
No	27(100.0)	27(100.0)		
Do you consume alcohol?				
Yes	0(0.0)	0(0.0)	-	-
No	27(100.0)	27(100.0)		
Do you check your blood sugar regularly?				
Yes	21(77.8)	11(40.7)	7.670	0.006
No	6(22.2)	16(59.3)		

Table 3. Result of clinical assessment

Variables	Diabetic	Control	χ^2	p-value
Have you been hospitalized for your diabetes?				
Yes	5(18.5)	0(0.0)	5.510	0.019
No	22(81.5)	27(100.0)		
Have you ever attended session with a registered dietician?				
Yes	21(77.8)	0(0.0)	34.364	0.001
No	6(22.2)	27(100.0)		
Do you see your endocrinologist or diabetes care physician on a regular basis?				
Yes	14(51.9)	0(0.0)	18.900	0.001
No	13(48.1)	27(100.0)		

Mean GSH between diabetic and control as presented in Table 6 shows that it was higher in the control having a mean value of 10.47±2.04 as compared with 12.19±2.09 for the diabetics. This difference was significant statistically (p=0.004).

Mean SOD between diabetic and control as presented in Table 4 shows that it was higher in the diabetic having a mean value of 22.34±6.87 when compared with 13.94±178 for control group. This difference was found to be statistically significant (p=0.001).

The mean catalase between diabetic and control groups among the study participants. The diabetic had 25.96±6.31 and control had 18.38±2.74. The mean catalase level was significantly higher in the diabetics than in the control (p=0.001)

Mean HbA1C between diabetic and control is as presented in Table 4. The mean HbA1C level was higher in the diabetics having a mean value of 9.17±2.68 as compared with 5.71±13.2 for the control. The difference in mean HbA1C level between the two groups was statistically significant (p=0.001).

3.5 Comparison of MDA, GSH, SOD, CAT and Hba1c Parameters between those who exercised within Diabetic Group

Result of MDA, GSH, SOD, CAT and HbA1c between diabetic subjects who exercised and those that did not is as shown in Table 6.

The analysis, indicates that the mean MDA for exercised diabetic was 1.78±0.87 while for non-exercised was 1.77±0.63. The difference in the mean MDA between the two groups was not statistically significant (p=0.969).

Mean GSH between exercise diabetic and non exercised were 10.47±1.83 as compared with 10.60±3.09. This difference was not significant statistically (p=0.880).

Mean SOD for exercised diabetic was 23.24±7.34 when compared with 18.38±0.46 for non exercised diabetes. This difference was found to be statistically insignificant (p=0.158).

The mean catalase between exercised diabetic was 27.20±6.13 and non diabetes had 20.52±4.06. The mean catalase level was significantly higher in the diabetics that exercised than in the non exercised(p=0.030)

Mean HbA1C between exercised diabetic and unexercised diabetes were 9.39±2.81 and 8.24±1.99 respectively. Although the level is higher in exercised diabetes, however the difference was not statistically significant (p=0.399).

3.6 Comparison of Lipid Profile between Diabetic and Control among study Participants

Result of lipid profile between diabetic and control groups among the study participants is presented in Table 5.

The mean TC for control was 4.05±0.73 and the diabetics group was 5.13±1.02. There was statistically a significant difference between the two groups (p=0.001).

The mean TG for control was 1.75±0.95 and that of diabetics group was 1.44±0.88 with no significant difference found between the two groups (p=0.227).

Mean LDL level showed that the control had 1.86±0.71 while the diabetic group had 2.74±0.82. The diabetic group had a significantly higher mean LDL level when compared with the control group (p=0.001).

Mean value of HDL for control was 1.33±0.47 while the diabetic group had 1.79±0.99. Also, the control group had a lower mean HDL level in relation to the diabetic group with (p=0.037).

3.7 Comparison of Lipid Profile of those who Exercised within Diabetic Group

Result of diabetic subjects for those who exercised and those who did not exercise with respect to lipid profile is as presented in Table 7.

The mean TC of diabetes who exercised was 4.52±0.13 and those who did not was 5.48±1.15. There was statistically significant between the two groups (p=0.015).

The mean TG for diabetes that exercise was 1.22±0.72 and that of those who did not exercised was 1.58±0.97 with no significant difference between the two groups (p=0.323).

Mean LDL level showed those who exercised had 2.36±0.41 while those that did not exercised had 2.96±0.93. There was no significant difference between them (p=0.064).

Mean value of HDL for exercised diabetes patients was 1.81±0.50 while those that did not exercised had 1.77±1.22. There was no significant difference between them (p=0.923).

3.8 Parameters of Oxidant, Anti-Oxidant and Hba1c who attended a Session with a Registered Dietician within Diabetics (Test Group)

Result of MDA, GSH, SOD, CAT and HbA1c between diabetic study subjects who attended session with a registered dietician is presented in 10.

The result showed that mean MDA for diabetics that see dietician was 1.89±0.83 while those that do not see dietician was 1.41±0.73. No difference in the mean MDA between the two groups was not statistically significant (p=0.217)

Mean GSH between diabetics that see dietician and those who did not see dietician were 10.45±1.73 as compared with 10.54±3.12. There was no significant difference between means (p=0.927).

Mean SOD for diabetics that see dietician was 22.27±6.82 when compared with 22.59±7.74 for those that did not see dietician. This difference was found to be statistically insignificant (p=0.922).

The mean catalase between diabetics that see dietician was 28.26±5.17 and those that did not see dietician was 17.91±0.85. The mean catalase level was significantly higher in those that see dietician (p=0.001).

Mean HbA1C between diabetics that see dietician and those who did not were 9.64±2.55 and 7.55±2.72 respectively. The mean HbA1C level was not significantly difference (p=0.093).

3.9 Lipid Profile of Diabetics who attended a Session with a Registered Dietician within test Participants

Table 11 depicts the result of diabetics that see dietician and those who did not with regard tolipid profile.

The mean TC of diabetics who see dietician was 4.01±0.78 and those who did not was 4.22±0.55. There was a statistically significant difference between the two groups (p=0.036).

Mean TG for diabetics that see dietician was 1.80±1.08 and that those who did not see dietician was 1.58±0.20 with no significant difference between the two groups (p=0.325).

Mean LDL level showed those that see dietician had 1.76±0.73 while those that do not see dietician had 2.20±0.54. There was no significant difference between them (p=0.189).

Mean value of HDL for diabetics that see dietician was 1.33±0.53 while those that do not see dietician had 1.32±0.12. There was no significant difference between them (p=0.941).

3.10 Comparison of Oxidant, Anti-Oxidant and Hba1c among the Non-Diabetics Group who Exercise

Table 10 depicts the result of MDA, GSH, SOD, CAT and HbA1c between control group who exercised and those that did not exercised.

The result, indicates that the mean MDA for exercised control group was 1.13±0.03 while for non-exercised was 1.14±0.10. The difference in the mean MDA between the two groups was not statistically significant (p=0.829).

Mean GSH between exercise control groups and non exercised were 10.90±0.56 as compared with 12.96±2.30. There was a significant difference between means of exercised and non exercised control group (p=0.011).

Mean SOD for control group that exercised was 14.49±2.25 when compared with 13.62±1.42 for the non exercised. This difference was found to be statistically insignificant (p=0.230).

The mean catalase between exercised control group was 15.74±1.52 and non exercised control group was19.93±2.20. The mean catalase level was significantly higher in the control group that did not exercised than in the exercised (p=0.001)

Mean HbA1C between exercised control group and unexercised were 4.82±0.27 and 6.24±1.41 respectively. The mean level is significantly higher in the non exercisedcontrol group (p=0.004).

3.11 Lipid Profile of Non-Diabetic who Exercise among the Control Group

Result of the control study participants of those who exercised and those who do not exercise with respect to .lipid profile is as presented in Table 9.

The mean TC of control who exercised was 3.91±0.73 and those who did not was 4.66±0.35. There was a statistically significant between the two groups (p=0.036).

Mean TG for control group that exercise was 1.66±0.99 and that those who did not exercised was 2.14±0.79 with no significant difference the two groups (p=0.325)

Mean LDL level showed those who exercised had 1.71±0.70 while those that do not exercised had 2.52±0.29. There was significant difference between them (p=0.018)

Mean value for HDL of exercised control group was 1.36±0.51 while those that do not exercised had 1.18±0.26. There was no significant difference between them (p=0.442).

4. DISCUSSION

4.1 Diabetics and Oxidative Stress

Diabetes is a major health concern that imposes substantial burdens on individuals, economies, and societies [39]. Its prevalence is on the rise worldwide, primarily due to factors like population growth, aging, urbanization, and increasing rates of obesity resulting from a sedentary lifestyle [40]. Oxidative stress plays a crucial role in the advancement and onset of diabetes and its associated complications. To address the impact of oxidative stress and potentially decrease the occurrence of diabetes and its complications, various interventions can be beneficial. These interventions include therapies, dietary plans, and behavioral changes aimed at mitigating oxidative stress and promoting better health outcomes. By implementing such strategies, it is possible to reduce the burden of diabetes and improve overall well-being.

4.2 Percentage of Demographic, Lifestyle and Clinical Analysis

Table 1 presents the result of demographic characteristics of the study participants. The mean age of the diabetic participants was 55.94±8.24 and that of control was 41.80±9.05 with a total mean age of 50.50±10.93. Further, 87.5% of the diabetics were above 50 years of age while in the control 80.0% were less than 50 years. With regard to gender, the diabetics were 50% each of male and female and the control group male constituted 30% and female accounted for 70%.

Table 2 displays the lifestyle habits of the respondents. The results indicate that 81.3% of individuals with diabetes engage in regular exercise, while 50% of the control group also exercise. Regular physical exercise alone can have a positive impact on managing diabetes mellitus [41]. Moderate exercise leads to a tenfold increase in fat oxidation due to elevated energy expenditure and greater availability of fatty acids. Diabetic patients who frequently exercise (Table 7) experience changes in their

lipid profile and reduced levels of reactive oxygen species [42]. Continuous exercise-induced improvements in biochemical parameters and can alleviate complications associated with diabetes, including neuropathy, retinopathy, and nephropathy [43]. Majority (68.8%) of them in the diabetic group checked their blood sugar regularly as compared to 50% in the control, however, there was no significant difference (p=0.339).

Result of clinical assessment of study participants is presented in Table 3 indicates 18.8% of the diabetics were hospitalized while 81.3% were not and 100% of the control were not hospitalized. However, There was a significant difference in the diabetic group between those who were hospitalized and those who were not (p=0.014). In the diabetic group (Table 3), 68.8% attended session with a registered dietician with none (0.0%) in the control, the difference in the two groups was statistically significant (p=0.001). Also 50% of the diabetics see endocrinologist or diabetes care physician on a regular basis and 50% did not while all (100%) in the control group did not as they were not diabetic. From the clinical assessment it shows (Table 3) that diabetes mellitus patients who are on regular visit to the endocrinologist stand a better chance of living a healthy life style than those who did not.

Table 4. Comparison of oxidant, anti oxidant and HbA1C between diabetic and control among study participants

Biomarkers	Diabetes Mean ± SD	Control Mean ± SD	t-test	p-value
MDA	1.78±0.82	1.13±0.08	4.085	0.001
GSH	10.47±2.04	12.19±2.09	4.085	0.004
SOD	13.94±1.78	22.34±6.87	6.146	0.001
CATALASE	18.38±2.74	25.96±6.31	5.722	0.001
HbA1C	9.17±2.68	5.71±1.32	6.014	0.001

Table 5. Comparison of MDA, GSH, SOD, CAT and HbA1C parameters between those who exercised within diabetic group

Parameter	Exercise		t-test	p-value
	Yes	No		
MDA	1.78±0.87	1.77±0.63	0.040	0.969
GSH	10.44±1.83	10.60±3.09	0.152	0.880
SOD	23.24±7.34	18.38±0.46	1.456	0.158
CATALASE	27.20±6.13	20.52±4.06	2.305	0.030
Hba1C	9.39±2.81	8.24±1.99	0.858	0.399

Table 6. Comparison of lipid profile between diabetic and control among study Participants

Lipid profile	Control	Diabetics	t-test	p-value
TC	4.05±0.73	5.13±1.02	4.453	0.001
TG	1.75±0.95	1.44±0.88	1.224	0.227
LDL	1.86±0.71	2.74±0.82	4.206	0.001
HDL	1.33±0.47	1.79±0.99	2.144	0.037

Table 7. Comparison of Lipid profile of those who exercised within diabetic group

Parameter	Exercise		t-test	p-value
	Yes	No		
TC	4.52±0.13	5.48±1.15	2.626	0.015
TG	1.22±0.72	1.58±0.97	1.007	0.323
LDL	2.36±0.41	2.96±0.93	1.936	0.064
HDL	1.81±0.50	1.77±1.22	0.097	0.923

Table 8. Parameters of oxidant, anti-oxidant and HbA1c who attended a session with a registered dietician within diabetics (test group)

	Ever attended session with a registered dizetician		t-test	p-value
	Yes	No		
MDA	1.89±0.83	1.41±0.73	1.265	0.217
GSH	10.45±1.73	10.54±3.12	0.093	0.927
SOD	22.27±6.82	22.59±7.74	0.099	0.922
CATALASE	28.26±5.17	17.91±0.85	4.821	0.001
HbA1C	9.64±2.55	7.55±2.72	1.747	0.093

Table 9. Lipid profile of diabetics who attended a session with a registered dietician within test participants

Parameter	Ever attended session with a registered dietician		t-test	p-value
	Yes	No		
TC	4.01±0.78	4.22±0.55	0.619	0.541
TG	1.80±1.08	1.58±0.20	0.482	0.634
LDL	1.76±0.73	2.20±0.54	1.351	0.189
HDL	1.33±0.53	1.32±0.12	0.075	0.941

Table 10. Comparison of oxidant, anti-oxidant and HbA1c among the non-diabetics group who exercise

Parameter	Exercise		t-test	p-value
	Yes	No		
MDA	1.13±0.03	1.14±0.10	0.218	0.829
GSH	10.90±0.56	12.96±2.30	2.759	0.011
SOD	14.49±2.25	13.62±1.42	1.230	0.230
CATALASE	15.74±1.52	19.93±2.20	5.709	0.001
Hba1C	4.82±0.27	6.24±1.41	3.129	0.004

Table 11. Lipid profile of non- diabetic who exercise among the control group

Parameter	Exercise		t-test	p-value
	Yes	No		
TC	3.91±0.73	4.66±0.35	2.212	0.036
TG	1.66±0.99	2.14±0.79	1.005	0.325
LDL	1.71±0.70	2.52±0.29	2.527	0.018
HDL	1.36±0.51	1.18±0.26	0.780	0.442

4.3 Percentage of Oxidative Stress Biomarkers and Hba1c

MDA, known as malondialdehyde, is a key biomarker used to assess lipid damage and oxidative stress caused by free radicals [44]. In individuals with diabetes, especially those experiencing vascular complications, significant alterations occur in lipid metabolism and structure [45]. The higher levels of MDA found in diabetic individuals indicate that oxidative damage may contribute to the development of diabetic complications [46]. This increase in lipid peroxidation also suggests a reduction in the protective mechanisms provided by both enzymatic and non-enzymatic antioxidants [47]. MDA is formed as a breakdown product of oxidized lipids [48,49]. Numerous studies have reported elevated MDA levels in the plasma, serum, and various tissues of diabetic patients [50,51], which aligns with the findings of this study.When comparing the average MDA levels between the diabetic and control groups in the study, the diabetic group had a mean MDA level of 1.78±0.82, while the control group had a mean MDA level of 1.13±0.08. The difference in mean MDA levels between the two groups was statistically significant (p=0.001). The diabetic group exhibited higher MDA levels compared to the control group. This increase may be

attributed to the exposure and higher levels of hyperglycemia, as indicated by the HbA1c and lipid profile results (Table 4 and 6, respectively). The elevated MDA levels in diabetics suggest that peroxidative damage may play a role in the development of diabetic complications [52]. Similar findings have been reported in patients with type 2 diabetes mellitus [53,54,55].

GSH plays critical roles in protecting cells from oxidative damage and the toxicity of xenobiotic electrophiles, and maintaining redox homeostasis [56]. There are several reports that claim a reduced level of GSH in diabetes [57]. Decreased GSH level may be one of the factors in the oxidative DNA damage in type 2 diabetics [58,59]. The result (Table 4) for GSH shows that there was a decrease level of GSH in the diabetic group as compared to the control, Mean GSH between diabetic and control as presented shows that it was higher in the control having a mean value of 10.47±2.04 as compared with 12.19±2.09 for the diabetic which was lower, this difference was significant statistically having a P (p=0.004). This study is in agreement with other study which showed a decrease in the reduced GSH level has been reported in the erythrocyte of diabetics [60].

Superoxide dismutases (SODs) constitute a very important antioxidant defense against oxidative stress in the body. The enzyme acts as a good therapeutic agent against reactive oxygen species-mediated diseases [61]. SOD catalyzes the dismutation of superoxide anion to hydrogen peroxide, which is subsequently detoxified to oxygen and water by catalase or glutathione peroxidase [62].The elevated level of SOD is shown to reduce oxidative stress [63]; Decline in the level of SOD in diabetic tissue and blood has been reported in many studies [64,65]. Mean SOD between diabetic and control as presented in Table 4 shows that the there was an increased levels in the diabetic group having a mean value of 13.94±1.78 in the diabetics when compared with 22.34±6.87 for control group having a p value of p = 0.001.

Catalase is an antioxidative enzyme present nearly in all living organisms; it plays an important role against oxidative stress-generated complications such as diabetes and cardiovascular diseases [66]. Catalase acts as main regulator of hydrogen peroxide metabolism, hydrogen peroxide is a highly reactive small molecule formed as natural by-product of energy metabolism. Prevalence of oxidative stress is reported in all processes where reduced/depleted plasma antioxidant potential is reported including aging and hypertension. Increased oxidative damage as well as reduction in antioxidant capacity could be related to the complications in patients with type 2 diabetes [67]. Mean catalase between diabetic and control groups among this study participants showed that the diabetic had 18.38±2.74 and control had 25.96±6.31. The mean catalase level was stastitically significantly higher in the diabetics than in the control having a (p=0.001). Catalase enzymatically processes hydrogen peroxide into oxygen and water and thus neutralizes it, also, increased risk of diabetes has been documented in patients with catalase deficiency [68]. The deficiency of this enzyme leads to an increase in oxidative stress and ultimately to a failure β -cell type.. In this study there was a significant increase of catalase in the control group as compared with the diabetic group.

Glycated hemoglobin (HbA1c) level reflects the mean glucose concentration over last 8-12 weeks approximately and provides a much better indication of long-term glycemic control [69]. Mean HbA1C between diabetic and control is as presented in Table 4. The mean HbA1C level was higher in the diabetics having a mean value of 9.17±2.68 as compared with 5.71±13.2 for the control. The difference in mean HbA1C level between the two groups was statistically significant (p=0.001). Other studies have shown that glycated hemoglobin (HbA1c) was higher in diabetics compared to pre-DM and the controls [70, 71].

4.4 Percentage of Lipid Profile

Diabetes is characterized by high blood sugar levels and changes in glucose and lipid metabolism [72]. These changes can lead to damage in cell membranes, resulting in increased production of reactive oxygen species (ROS). The elevated levels of ROS and decreased antioxidant defense mechanisms in diabetic patients may contribute to the development of complications. To reduce the risk of complications such as blindness, kidney failure, and limb amputation, it is necessary to control not only blood glucose levels but also lipid levels [73]. In diabetes, high blood glucose levels are often accompanied by increased levels of plasma cholesterol, triglycerides, LDL, and VLDL, as well as decreased levels of HDL [74]. Table 6 shows a statistically significant difference between diabetics and non-diabetics, which is

consistent with other studies [75]. Non-diabetics had significantly lower levels of total cholesterol and LDL compared to diabetics, while their HDL levels were significantly higher [76].

Cholesterol is transported in the blood by proteins called lipoproteins. There are two types of lipoproteins: LDL (low-density lipoprotein), often referred to as "bad" cholesterol, and HDL (high-density lipoprotein), known as "good" cholesterol. LDL cholesterol contributes to the buildup of plaque on the walls of blood vessels, leading to narrowed arteries and increased risk of heart disease and stroke. On the other hand, HDL cholesterol helps remove cholesterol from the bloodstream and reduces the risk of heart disease and stroke [77,78]. When there is an excess of LDL cholesterol, it can accumulate as plaque [79], causing the narrowing of blood vessels over time. This narrowing restricts blood flow to the heart and other organs [80]. High levels of cholesterol, triglycerides, LDL cholesterol, and low levels of HDL cholesterol in diabetes may be attributed to factors such as obesity, increased calorie intake, and lack of physical exercise. This research (as shown in Table 7) indicates that regular exercise can reduce the risk of high LDL and total cholesterol levels among diabetic patients at JUTH. Diabetics who engaged in regular exercise had lower LDL and total cholesterol levels compared to those who did not exercise. The findings suggest that exercise is crucial in the prevention of various diseases, including diabetes and its complications. Table 11 also demonstrated that healthy non-diabetic individuals who regularly exercised had lower LDL and total cholesterol levels compared to those who did not exercise. Additionally, those who frequently exercised had higher levels of HDL cholesterol, which is considered beneficial. The research presented in Tables 8 and 9 further highlights the significance of visits to dieticians and clinicians and dietary changes in reducing the risk of diabetes and its complications.

Assessing lipid peroxide levels along with other lipid profiles in diabetes mellitus can serve as a useful indicator for monitoring the prognosis of patients [81]. Detecting risk factors in the early stages of the disease can assist patients in improving their condition and reducing morbidity rates.

5. CONCLUSION

Regardless of whether someone is diabetic or not, engaging in regular exercise and following a healthy diet plan is highly recommended for everyone. These lifestyle factors are particularly important for individuals with diabetes as they can contribute to better glycemic control, weight management, and overall well-being. Exercise helps improve insulin sensitivity, promotes cardiovascular health, and aids in weight management. A balanced and nutritious diet, rich in fruits, vegetables, whole grains, lean proteins, and healthy fats, provides essential nutrients and helps maintain stable blood sugar levels.Glycemic control is a crucial factor in the development of oxidative stress and the subsequent risk of long-term complications in diabetes. The findings of this study suggest that individuals with good glycemic control experience lower levels of oxidative stress compared to those with poor glycemic control.

6. RECOMMENDATION

Early detection and intervention are crucial in reducing the complications associated with oxidative stress in type 2 diabetes. Once a diagnosis is made and patients are found to have hyperglycemia, assessing their lipid peroxidation and antioxidant parameters can help identify individuals at risk for complications related to diabetes. By monitoring these parameters, healthcare providers can intervene early and implement appropriate strategies to manage oxidative stress, thereby reducing the likelihood of complications in diabetes.

CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

Ethical approval for study was received from the Jos University Teaching Hospital Research Ethics Committee (approval N0: JUTH/DCS/IREC/127/2104). All relevant patients' clinical information was de-identified and anonymized.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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