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Serum Malondialdehyde and C-Reactive Protein Levels in Type 2 Diabetic Non-Hypertensive and Hypertensive Non-Diabetic Patients in Kogi State, Nigeria.

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Abstract

Background: Oxidative stress and chronic low-grade inflammation are key mechanisms linking Type 2 Diabetes Mellitus (T2DM) and hypertension. Biomarkers such as malondialdehyde (MDA) and C-reactive protein (CRP) provide insight into lipid peroxidation and systemic inflammation, yet data from Kogi State are limited. This study assessed serum levels of MDA and CRP among individuals with T2DM and hypertension and examined possible gender differences. **Methods:** A cross-sectional study involving 150 age-matched adults was conducted, comprising 50 T2DM patients, 50 hypertensive patients, and 50 apparently healthy controls. Each group included 25 males and 25 females. Participants were aged 40–50 years with overweight/obese BMI, while smokers and alcohol users were excluded. Serum MDA, CRP, total cholesterol (TC), and fasting blood sugar (FBS) were analysed photometrically. **Results:** Serum MDA and CRP levels were significantly higher among T2DM and hypertensive subjects compared to healthy controls ($p < 0.05$). Female participants exhibited higher oxidative stress levels than males. These findings underscore the role of oxidative stress and inflammation in the pathophysiology of both conditions. **Conclusion:** Elevated oxidative stress and inflammation in T2DM and hypertension may accelerate ageing and increase morbidity. Lifestyle interventions—including weight reduction, healthy diet, and regular physical activity, are essential to improve cardiometabolic outcomes. Further studies are needed to determine how these biomarkers influence disease progression.

Keywords: C-reactive protein, malondialdehyde, Hypertension, T2DM, Oxidative-stress, Inflammatory reaction

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Introduction

Hypertension and Type 2 Diabetes Mellitus (T2DM) are major risk factors for atherosclerosis and its complications, including myocardial infarction and stroke. Both conditions share several pathogenic mechanisms such as obesity, inflammation, oxidative stress, insulin resistance, and psychosocial stress, and commonly occur as co-morbidities Cheung, 2010. Their overlap is well documented: a study in Hong Kong found that only 42% of individuals with diabetes had normal blood pressure, while just 56% of hypertensive individuals had normal glucose tolerance Cheung, 2010. In the United States, hypertension occurs in 30% of patients with type 1 diabetes and in 50–80% of those with T2DM Landsberg & Molitch, 2004.

In Nigeria, diabetes prevalence ranges from 0.65% in rural Mangu to 11% in urban Lagos, with over 3.85 million people living with impaired glucose tolerance Africa Region of International Diabetes Federation (IDF), 2023. Hypertension preva-

lence is estimated at 32.8%, with more than 90% classified as essential hypertension (EH) Johnson et al., 2002 Rosendorf, 2005; Ulasi et al., 2010. Good glycaemic control and management of cardiovascular risk factors reduce morbidity and mortality in diabetic patients Nathan et al., 2005, highlighting shared environmental and genetic determinants.

Oxidative stress and chronic inflammation are major contributors to the development of both hypertension and T2DM Kotur-Stevuljevic et al., 2007. Excess free-radical production or reduced antioxidant capacity leads to endothelial dysfunction and vascular injury Ogita & Liao, 2004. Oxidative stress has been proposed as a central driver of insulin resistance, β-cell dysfunction, and hypertension Ceriello & Motz, 2004. Multiple inflammatory mediators, including TNF-α, IL-1β, IL-6, IL-18, and various chemokines, play important roles in the pathogenesis of T2DM Stern et al., 1992. Inflammatory biomarkers such as high-sensitivity C-reactive protein (CRP) predict both diabetes risk and cardiovascular events Pradhal, 2007, and inflammation has also been implicated in hypertension Nagano et al., 2005. Atherosclerosis itself is now recognized as an inflammatory disease Blake & Ridker, 2001; Ross, 1999.

CRP and malondialdehyde (MDA) are among the most widely studied biomarkers of inflammation and oxidative stress. MDA, a lipid peroxidation product, reflects oxidative damage and is elevated in diabetes and cardiovascular disease Ayaz et al., 2011; Kim et al., 2009. CRP, produced by the liver in response to IL-6 and IL-1, is stable, has a long half-life, and is a strong predictor of cardiometabolic risk Boos & Lip, 2005; Pu et al., 2006Pu et al., 2006. Elevated CRP levels reflect systemic inflammation in T2DM and correlate with obesity, insulin resistance, and worsening cardiovascular risk Salomaa et al., 2010. Obesity, particularly visceral fat accumulation, contributes to cytokine secretion and insulin resistance Al-Shukaili et al., 2013; Garcia et al., 2010; Goldfine et al., 2011. Lifestyle modification—including weight loss, dietary improvements, and physical activity—remains essential for preventing and managing T2DM and hypertension Colberg et al., 2010; Cornelissen & Smart, 2013; Duclos et al., 2013; Selvin et al., 2007.

Despite rising obesity, sedentary behaviour, and calorie-dense dietary patterns among residents of Kogi State, Nigeria, data remain limited on oxidative stress and inflammatory biomarkers in individuals with T2DM and hypertension. This study therefore aims to determine serum levels of MDA, CRP, cholesterol, and glucose in patients with T2DM and hypertension, compare these values with healthy controls, and assess gender differences in oxidative and inflammatory responses.

Methods

Study Design and Setting

This experimental study included 50 patients with Type 2 Diabetes Mellitus (T2DM), 50 patients with essential hypertension, and 50 apparently healthy controls. All participants were aged 40–50 years and were sex-matched, with each group comprising 25 males and 25 females. Subjects were recruited from the Federal Medical Centre (FMC), Lokoja, through clinical history, physical examination, and relevant laboratory investigations.

A structured questionnaire was administered to obtain lifestyle and medical information and to confirm eligibility. Inclusion criteria were: overweight or obese Body Mass Index (BMI), normal systolic and diastolic blood pressure (SBP and DBP) for T2DM subjects not on antihypertensive medication, normal glucose profile for hypertensive subjects not on antidiabetic therapy, age 40–50 years, male or female sex, and absence of smoking or alcohol intake. Smoking, alcoholism, and bisexual individuals were excluded.

Sample Collection and Laboratory Analysis

Fasting venous blood samples were collected into EDTA, fluoride oxalate, and plain tubes. Plasma from EDTA tubes was used for C-reactive protein (CRP) assay, serum from plain tubes for malondialdehyde (MDA) and total cholesterol measurement, and plasma from fluoride oxalate tubes for fasting blood glucose estimation. Serum MDA, CRP, total cholesterol, and fasting glucose were analysed using standard ELISA and enzymatic methods Tietz, 2006.

Statistical Analysis

Data were analysed using SPSS version 20. Differences between groups were assessed using Student's *t*-test, and statistical significance was set at

$p \leq 0.05$.

Ethical Approval

Ethical clearance was obtained from the Federal Medical Centre (FMC), Lokoja, after which permission was granted to access patient folders and recruit participants.

Results

Serum malondialdehyde (MDA) and C-reactive protein (CRP) levels were significantly higher among male and female subjects with type 2 diabetes mellitus (T2DM) and essential hypertension compared with age- and sex-matched controls ($p < 0.05$), as shown in Tables 1 and 2.

Table 1: **Comparison of male apparently healthy controls (AHS), male essential hypertensive (MEH), and male T2DM (MT2DM) subjects for all parameters analyzed.**

Parameter	Group	Mean	SD	P-value
BMI (kg/m^2)	AHS	21.65	1.44	–
	MEH	25.76	0.52	0.000*
	MT2DM	26.03	0.60	0.000*
SBP (mmHg)	AHS	117.2	6.78	–
	MEH	136.6	7.46	0.668
	MT2DM	120.8	4.00	0.000*
DBP (mmHg)	AHS	79.2	4.93	–
	MEH	90.8	8.62	0.006*
	MT2DM	81.6	5.54	0.318
FG (mmol/L)	AHS	4.45	0.33	–
	MEH	4.95	0.37	0.727
	MT2DM	6.01	0.85	0.001*
TC (mmol/L)	AHS	4.36	0.56	–
	MEH	6.28	0.74	0.045*
	MT2DM	5.39	0.88	0.035*
CRP (mg/L)	AHS	1.58	0.43	–
	MEH	3.22	0.14	0.000*
	MT2DM	4.72	0.58	0.003*
MDA (nmol/mL)	AHS	2.13	0.28	–
	MEH	4.02	0.13	0.000*
	MT2DM	3.35	0.48	0.002*

Note: * indicates statistical significance at $p \leq 0.05$.

Females exhibited consistently higher MDA values across both disease groups, suggesting greater susceptibility to oxidative stress. This pattern corresponded with their higher total cholesterol levels shown in Table 3.

Table 2: **Comparison of female apparently healthy controls (FAHS), female essential hypertensive (FEH), and female T2DM (FT2DM) subjects for all parameters analyzed.**

Parameter	Group	Mean	SD	P-value
BMI (kg/m^2)	FAHS	21.54	1.34	–
	FEH	27.56	0.89	0.120
	FT2DM	25.74	1.73	0.655
SBP (mmHg)	FAHS	116.4	4.90	–
	FEH	141.6	6.88	0.823
	FT2DM	141.6	6.88	0.981
DBP (mmHg)	FAHS	80.8	4.93	–
	FEH	95.2	7.70	0.002*
	FT2DM	81.6	5.54	0.444
FG (mmol/L)	FAHS	4.33	0.36	–
	FEH	5.09	0.15	0.000*
	FT2DM	6.35	1.12	0.022*
TC (mmol/L)	FAHS	4.87	0.33	–
	FEH	6.94	0.52	0.071
	FT2DM	5.10	0.47	0.521
CRP (mg/L)	FAHS	1.28	0.51	–
	FEH	3.52	0.17	0.000*
	FT2DM	4.92	0.25	0.066
MDA (nmol/mL)	FAHS	1.95	0.14	–
	FEH	4.59	0.39	0.000*
	FT2DM	3.20	0.23	0.020*

Note: * indicates statistical significance at $p \leq 0.05$.

Discussion

This study demonstrates elevated oxidative stress among hypertensive subjects (male SBP: 136.6 ± 7.41 mmHg; female SBP: 141.6 ± 6.88 mmHg) and T2DM subjects (male FBG: 6.01 ± 0.85 mmol/L; female: 6.35 ± 1.12 mmol/L). Serum MDA levels were significantly higher in both sexes in both disease groups ($p \leq 0.05$), indicating increased lipid peroxidation.

These findings align with previous reports showing elevated erythrocyte membrane MDA levels and their positive correlation with glycated hemoglobin Ayaz et al., 2011. Persistent hyperglycaemia induces auto-oxidation of glucose, generating reactive oxygen species (ROS) that drive diabetic complications Paravicini & Touyz, 2006; Tietz, 2006. Similarly, increased MDA levels have been documented in essential hypertension Kędziora-Kornatowska et al., 2007, with intracellular fatty-acid oxidation activating ROS-related pathways Di Napoli et al., 2005.

CRP levels were significantly elevated in all groups except female T2DM subjects, although their mean CRP remained higher than that of controls. Elevated basal CRP is a known risk factor for diabetes, hypertension, and cardiovascular disease Bandeira et al., 2013.

Women exhibited higher oxidative stress, likely

Table 3: Comparison of T2DM and EH Subjects by Sex

2*Parameter	T2DM Subjects				EH Subjects			
	V	Mean	SD	*p*-value	V	Mean	SD	*p*-value
BMI	MT2DM	26.032	0.60119	*0.000	MEH	25.764	0.51711	*0.001
	FT2DM	25.744	1.72629		FEH	27.556	0.89026	
SBP	MT2DM	120.8	4.00000	*0.023	MEH	136.6	7.46101	0.273
	FT2DM	118.0	5.77350		FEH	141.6	6.87992	
DBP	MT2DM	81.6	5.53775	1.000	MEH	90.8	8.62168	0.941
	FT2DM	81.6	5.53775		FEH	95.2	7.70281	
FG	MT2DM	6.0096	0.84829	0.218	MEH	4.9472	0.36523	*0.015
	FT2DM	6.3484	1.11882		FEH	5.0908	0.15305	
TC	MT2DM	5.3876	0.88293	*0.002	MEH	6.2784	0.73896	*0.004
	FT2DM	5.0952	0.47078		FEH	6.9372	0.51515	
CRP	MT2DM	4.7160	0.57747	*0.000	MEH	3.2216	0.14488	0.695
	FT2DM	4.9192	0.25288		FEH	3.5212	0.17331	
SMDA	MT2DM	3.3548	0.48142	*0.000	MEH	4.0200	0.12712	*0.000
	FT2DM	3.1996	0.22932		FEH	4.5888	0.38603	

Note. * indicates statistical significance at $p \leq 0.05$.

Abbreviations: MT2DM = Male Type 2 Diabetes Mellitus; FT2DM = Female Type 2 Diabetes Mellitus; MEH = Male Essential Hypertension; FEH = Female Essential Hypertension.

linked to higher BMI and total cholesterol. Increased plasma cholesterol promotes lipid peroxidation and contributes to atherogenesis (Ross, 1999). These findings echo global trends indicating that urbanization, poor diet, and physical inactivity heighten risks of hypertension and T2DM (IDF, 2023).

Limitation: The small sample size, single-center setting, and lack of confounder adjustment limit generalizability.

Conclusion

Oxidative stress and inflammation are markedly elevated in hypertensive and T2DM subjects, accelerating ageing and increasing morbidity. Lifestyle modification—weight reduction, dietary improvement, and regular physical activity—is essential for improving glycaemic and blood pressure control and reducing complications. The findings underscore the importance of monitoring oxidative stress and inflammatory markers in managing non-communicable diseases in Nigeria.

Recommendation

Further studies should explore how oxidative stress and inflammation contribute to disease progression toward complications such as coronary heart disease, stroke, nephropathy, retinopathy, neuropathy, and cardiomyopathy. The utility of MDA and CRP as routine biomarkers for early detection and risk stratification should also be evaluated.

Known Facts

- Elevated SMDA and CRP indicate oxidative stress and inflammation.
- Higher SMDA and CRP levels correlate with disease severity in T2DM and hypertension.
- Both markers are potential predictors of complications such as atherosclerosis, nephropathy, and cardiovascular disease.

Authors' Contributions

SHS: Conceived the study and drafted the manuscript. **AS**: Reviewed the manuscript. **AHS, AAS**: Conducted literature review.

Conflict of Interest

The authors declare no conflict of interest and received no external funding.

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