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Glycosylated Hemoglobin: Prospective Study of Its Determinants and Metabolic Correlates Among Type 2 Diabetes Mellitus Patients of Ogbomosho, South-West Nigeria

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Article history: Received 21 March 2025, Reviewed 23 May 2025, Accepted for publication 02 June 2025

Abstract

Background: The reliability of the glycosylated hemoglobin (HbA1c), documented to be the gold standard in the diagnosis and monitoring of diabetes mellitus, could be related to some medical conditions. The study determined the associates of the HbA1c in the diagnosis and monitoring of diabetes mellitus.

Methods: Data from 213 participants were analyzed in this prospective study to assess the determinants and correlates of HbA1c in a type 2 diabetic mellitus (T2DM) population. Independent associates of HbA1c were determined using regression analysis.

Results: The mean age of the 213 (50.23% females) participants was 66.9 ± 8.7 years. Majority were middle aged (60.10%), 158 (74.18%) were taking metformin. The mean HbA1c was $5.89 \pm 1.56\%$, it was higher in females, reduced with aging ($p=0.08$) but was positively related to the educational status, body mass index, waist hip ratio, waist circumference, and the blood pressure. Poor diabetes control was found in 25.82% of the participants, it was less common in men ($p=0.09$), elderly ($p=0.001$) and kidney dysfunction ($p<0.001$). The HbA1c was positively associated with the left ventricular hypertrophy (LVH), $p=0.001$, fasting insulin ($p=0.003$), insulin resistance ($p=0.004$) and was independently associated with LVH, hyperhomocysteinemia, insulin resistance and kidney function.

Conclusion: The control of diabetes mellitus was poor in women, in non-elderly, obesity, subclinical atherosclerosis and LVH. Using the HbA1c, early screening for at-risk population, and effective monitoring of diabetes patients is imperative to avert or minimize the deleterious effect of T2DM on the population, particularly the productive age group.

Keywords: Hyperglycemia, poor diabetic control, glycosylated hemoglobin, insulin resistance, subclinical atherosclerosis



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How to cite this article

Ala OA, Uduagbamen PK, Oni O, Olanrewaju O. Glycosylated Hemoglobin: Prospective Study of Its Determinants and Metabolic Correlates Among Type 2 Diabetes Mellitus Patients of Ogbomosho, South-West Nigeria. The Nigerian Health Journal 2025; 25(2):626 – 636. <https://doi.org/10.71637/tnhj.v25i2.1058>



Introduction

The prevalence and burden of type 2 diabetes mellitus (T2DM) continue to rise worldwide, particularly in developing nations in Africa and Asia. This increasing trend is attributed to various factors, including the adoption of a westernized-lifestyle characterized by low physical activity, increased consumption of refined sugar and fatty meals.¹ Improved access to screening and diagnostic tools resulting from rising socioeconomic and educational attainments, has also contributed to the increasing prevalence.² In resource-challenged settings, such as sub-Sahara Africa (SSA), glycosylated hemoglobin (HbA1c) and the plasma glucose (PG) remain the most readily available tools for screening, diagnosis and prognosis. Although HbA1c is preferred over the plasma glucose, it is less accessible and more expensive than the plasma glucose.³

For over three decades, since the landmark Diabetes Control and Complications Trial, HbA1c has played a crucial role in diabetes management despite some known limitations.⁴ The properties of the red blood cells (RBCs) can affect HbA1c results by altering the HbA1c-average glucose relationship.⁵ Enzymopathies, membranopathies and other clinicopathologic conditions that affect the RBC life span can reduce the reliability of the HbA1c in diabetes management. These conditions can lead to under- or over-estimation of the glucose exposure which determines the HbA1c value.⁶ Consequently, this can result in under and over-diagnosis as well as suboptimal and over-treatment, leading to poor management outcomes, some of which can be fatal or result in permanent tissue/organ damage.

The significance of these associations is further underscored in Africans, Asians and African Americans where hemoglobinopathies are more prevalent.^{2,5,6} Population-based variations in the association between glucose levels and HbA1c can lead to disparities in screening and management practices and outcome.⁷ Moreover, different physiologic and pathologic processes can alter the conditions affecting glucose exposure of the RBCs in an individual.⁸ Therefore it is essential to identify measures that minimize individual and population-based variations. Correlating the HbA1c with other metabolic measures that are less affected by individual or group-based variations could provide an alternative platform for more reliable assessments of the HbA1c in population groups significantly affected by hemoglobinopathies such as

Africans, Asians and African Americans.⁹ This could result in more reliable findings in HbA1c-based population screening and management of diabetes mellitus in these hemoglobinopathy plagued groups.¹⁰ Consequently, this can eliminate or minimize the individual, race, and ethnic-based disparities associated with HbA1c use leading to improved diabetes screening and management outcomes.

Despite the known limitation associated with the use of the HbA1c for screening, diagnostic and management purposes, literature is scarce in many hemoglobinopathy-plagued settings. To bridge the knowledge gap, this hospital-based prospective study assessed glycosylated hemoglobin and determined its correlations with cardiorenal and metabolic measures in Nigeria.

Materials and methods

Study Area: The study was conducted at Bowen University Teaching Hospital (BUTH) in Ogbomosho, Nigeria, a facility that primarily serves rural communities. As a leading teaching hospital in the region, BUTH provides comprehensive clinical services, including specialized diabetes care through its Adult Diabetes Clinic. Established in 1907 and elevated to teaching hospital status in 2009, BUTH boasts a 400-bed capacity and functions as a referral hub for five local governments in Ogbomosho and neighboring regions.

Study Design and Sampling Technique: This study utilized a cross-sectional analytical design, based on hospital data. Systematic random sampling was employed to select participants, ensuring a representative sample. The data collection process spanned six months.

Sampling Methodology: A systematic sampling approach was used to recruit participants from the diabetes clinics. The study's sampling frame consisted of all adults diagnosed with T2DM who visited the clinics during a six-month period. Participants were selected at predetermined intervals from the clinic registry until the targeted sample size was reached.

Study population: This study recruited 213 patients with T2DM comprising 106 men and 107 women, following approval from the institutional ethics

committee and receipt of written informed consent from all participants

Eligibility Criteria: The study population consisted of individuals aged 40 years and above, diagnosed with T2DM after the age of 40, and having received treatment for at least six months. Informed consent, either written or verbal, was a prerequisite for participation.

Exclusion Criteria: The study excluded individuals with gestational diabetes, pregnant or breastfeeding women with tailored glycemic goals, and those hospitalized for acute diabetes complications or concurrent chronic conditions (such as malignancies or autoimmune disorders), to ensure sample homogeneity.

Sample size determination: The study minimum sample size was determined using Fisher's formula: $N = (Z^2 \times P \times Q) / d^2$, where: N is the minimum sample size; Z is the standard normal distribution value corresponding to a 95% confidence level (1.96); P is the national prevalence of diabetes mellitus in Nigeria (7.0% or 0.07); ^[11] Q is the complementary probability (1-P), equal to 0.93; d is the specified tolerance for absolute accuracy (3.5% or 0.035).

Substituting these values into the formula yields $N = (1.96)^2 \times 0.07 \times 0.93 / (0.035)^2 = 204.2$.

To account for incomplete questionnaires and missing test results, a 4% allowance was factored into the sample size calculation, yielding an additional 9 participants. This adjustment brought the total desired sample size to 213.

Data collection: A structured questionnaire was utilized to collect comprehensive data, including demographic information, physical examination results, and laboratory findings. The demographic characteristics assessed included age, gender, education level, occupation, and marital status. Furthermore, data on diabetes duration, antidiabetic medications, other medications, history of peripheral vascular disease, and intermittent claudication were also collected.

Physical measurements were taken using standardized protocols to ensure accuracy. Height and weight were recorded without shoes or headwear. Body Mass Index (BMI) was calculated using the Quetelet index.^[12] Blood pressure was measured according to established guidelines. Waist circumference was assessed using a flexible tape measure, carefully positioned at the

midpoint between the 5th lowest palpable rib and iliac crest. The waist-hip ratio was calculated by dividing the waist measurement by the hip measurement, taken at the widest region below the waistline.^[12]

To ensure precision, all anthropometric measurements were conducted after a 12-hour fasting period. Additionally, blood pressure measurements were taken twice, with the average value recorded for analysis.

Sample collection and analysis: Venous blood samples, measuring 5 mL, were obtained from participants via aseptic venipuncture, following a strictly verified overnight fasting regimen. Subsequent laboratory analysis of these samples focused on determining critical biochemical markers, including fasting glucose (FBG),^[13] serum creatinine (SCr),^[14] total cholesterol (TC),^[15] triglycerides (TG),^[15] high-density lipoprotein cholesterol (HDL),^[15] and HbA1c,^[13] fasting insulin,^[16] homocysteine (Hcy)^[17] and uric acid.^[18] The glomerular filtration rate (GFR) was estimated using the Modification of Diet in Renal Disease (MDRD) study equation, which incorporate serum creatinine levels, age, sex, and ethnicity.^[14]

Creatinine clearance (mL/min) was calculated as $(140 - \text{age}) \times \text{weight (kg)} \times (0.85 \text{ if female}) / 72 \times \text{serum creatinine (mg/dL)}$.^[14]

Insulin resistance was assessed using the Homeostatic Model Assessment (HOMA-IR)^[16]

Additional calculations were performed to determine the atherogenic index and lipid ratios.^[19,20]

The triglyceride glycemic index (TGI) was determined as $\text{TG} \times \text{FBG} / 2$.

The atherogenic index of plasma (AIP) was estimated as $\text{Log}_{10} (\text{TG} / \text{HDL-C})$.

The atherogenic coefficient (AQ) was determined as $(\text{TC} - \text{HDL-C}) / \text{HDL}$

The cardiac risk ratio (CRR) was calculated as $\text{TC} / \text{HDL-C}$

Data Analysis: The SPSS version 26 was utilized for data analysis. Means with standard deviation presented as continuous variables were compared using Student's t-test but when there were more than two groups, a one-way ANOVA was used. Proportions and frequencies, presented as categorical variables were compared using Chi-square or Fisher's exact test when the number of variables is less than five. The unadjusted odds ratios (ORs) from logistic regression analysis was used to

determine correlations of the outcome variables. Adjustment variables with $p < 0.025$ entered from the univariate analysis into the multivariate model was used to determine independent correlates of the glycosylated hemoglobin. This study was approved by the Bowen University Teaching Hospital, Ogbomosho Human Ethics Committee (BUTH/REC-726).

Definition of terms: The cut-off values were used to define various metabolic and anthropometric parameters:

For central obesity, a waist-to-hip ratio (WHR) of ≥ 0.90 for males and ≥ 0.85 for females was considered abnormal. Elevated HbA1c was defined as $\geq 7.0\%$. Hypertriglyceridemia was indicated by triglyceride (TG) levels ≥ 150 mg/dL

Obesity was defined as a body mass index (BMI) > 25.0 kg/m². An AIP ≥ 0.1 , AQ ≥ 3.0 and a CRR ≥ 3.5 were considered abnormal.

Reduced high-density lipoprotein cholesterol (HDL-C) was defined as ≤ 40 mg/dL

Fasting hyperglycemia was indicated by a fasting glucose (FG) ≥ 126 mg/dL. Impaired kidney function was defined as a glomerular filtration rate (GFR) < 60 mL/min/1.73m² or a serum creatinine (SCr) ≥ 1.2 mg/dL. Central obesity was also assessed using waist circumference (WC) cut-offs of > 94 cm for males and ≥ 80 cm for females. Insulin resistance was defined as a homeostatic model assessment-insulin resistance (HOMA-IR) ≥ 2.5 .

Hypercholesterolemia was indicated by total cholesterol (TC) levels ≥ 200 mg/dL.

A TGI ≥ 3.5 were considered abnormal.

Elevated homocysteine levels were defined as ≥ 15 μ mol/L for males and ≥ 13 μ mol/L for females. Elevated fasting insulin levels were indicated by ≥ 20 μ U/mL for males and ≥ 17 μ U/mL for females.

Hyperuricemia was defined as uric acid levels ≥ 7.0 mg/dL (males) and ≥ 6.0 mg/dL (females).

Results

The mean age of the 213 (50.23% females) participants was 66.93 ± 8.74 years, with (5.63%) in the young age group, 60.10% in the middle-aged group and 34.27% in the elderly group. All participants received antiplatelet therapy, with 74.65% received low dose aspirin (ASA) (Table 1). One hundred and seventy-one (80.28%) participants received OHAs, of this, 158 (92.40%) received metformin. T2DM was more prevalent as the

educational status increased: none (11.27%), primary (22.06%), secondary (30.52%) and tertiary (36.15%). The prevalence of T2DM reduces with longer disease duration, < 5 years (53.52%), 5-9 years (22.07%), 10-14 years (10.80%) and those 15 years old or more (7.51%). One hundred and eighty (84.5%) participants were receiving a statin therapy. Weight circumference-based obesity was more common than the WHR- and BMI-based obesities (56.34%), (51.64%) and (38.97%) respectively. Seventy-five (35.21%) participants had hypertension.

Table 1: Demographic, clinical and laboratory characteristics of participants

Variables	Freq	%
Sex		
Male	106	49.77
Female	107	50.23
Smoking		
No	190	89.20
Yes	23	10.80
Antiplatelet therapy		
Acetylsalicylate	159	74.65
Clopidogrel	54	25.35
BP lowering drugs		
None	30	14.08
Diuretics	160	75.12
Non-diuretics	23	10.80
Hypoglycemic agents		
Oral	171	80.28
Insulin	14	6.57
Oral agents and insulin	28	13.15
Activity/exercise		
Moderate-significant	80	37.56
None-mild	133	62.44

BP – Blood Pressure

The mean HbA1c) was $5.89 \pm 1.56\%$, it was elevated in 55 (25.82%) participants, more so with women than men. Hypertension was associated with higher HbA1c ($p < 0.001$). Eleven (5%), 3 (1%) and 8 (4%) participants had elevated AIP, AQ and CRR, and these were positively related to the HbA1c, $p = 0.05$, $p = 0.03$ and $p = 0.04$ respectively). Eight participants (3.76%) had kidney dysfunction (GFR < 60 mL/min), 68 (31.92%) had GFR between 60 and 89 mL/min, and 137 (64.32%) had GFR ≥ 90 mL/min. The HbA1c was directly proportional to GFR ($p = 0.04$) but was negatively related to the age, $p = 0.08$. Fifty-one (23.94%) participants had elevated fasting plasma glucose (Table 2). Using the WHR, the mean HbA1c for the non-obese males was lower than

the non-obese females ($p=0.09$), whereas the mean HbA1c was higher in the obese males than the obese females, $p=0.04$. Subclinical atherosclerosis was more positively related with the fasting blood glucose than the HbA1c, AIP ($p=0.003$ versus $p=0.05$), AQ ($p=0.09$

versus $p=0.9$) and CRR ($p=0.05$ versus $p=0.06$). The fasting insulin was more positively related to HbA1c than the HOMA, ($p=0.004$ versus $p<0.001$) and ($p=0.03$ versus $p=0.003$) respectively.

Table 2: Sociodemographic and clinical correlates of HbA1c- and FBS-based glycemic control

Variables	HbA1c <7.0	HbA1c ≥ 7.0	P-value	FBS <7.2	FBS ≥ 7.2	P-value
Sex	158	55		162	51	
Male	82 (51.90)	24 (43.64)	0.09	80 (49.38)	26 (50.98)	0.43
Female	76 (48.10)	31 (56.36)		82 (50.62)	(49.02)	
Age						
18-64, (n, %)	93 (58.86)	47 (85.45)	0.001	104 (64.20)	15 (70.59)	0.05
≥ 65 , (n, %)	65 (41.14)	8 (14.55)		58 (36.80)	15 (29.41)	
BMI mean (SD)	26.92 (7.31)	32.64 (6.27)	0.02	31.73 (8.93)	27.71 (8.42)	0.04
WHR mean (SD)	1.04 (1.03)	1.36 (1.74)	0.04	1.14 (0.67)	1.19 (1.01)	0.26
WC, cm mean (SD)	88.23 (15.73)	97.89 (31.42)	<0.001	89.49 (18.85)	93.8 (21.79)	0.005
Hypertension, (n, %)	41 (25.95)	34 (61.81)	0.04	44 (27.16)	31 (60.78)	0.04
AIP, (n, %)	17 (10.76)	11 (20.00)	0.05	21 (12.96)	7 (4.32)	0.003
AQ, (n, %)	5 (3.16)	3 (5.45)	0.02	5 (3.13)	3 (5.88)	0.09
CRR, (n, %)	12 (7.59)	8 (14.54)	0.06	14 (8.64)	6 (11.76)	0.05
LVH, (n, %)	21 (13.29)	34 (61.81)	0.001	28 (17.28)	27 (52.94)	<0.001
HOMA, (n, %)	15 99.09)	17 (30.91)	0.003	18 (11.11)	14 (27.45)	0.001
Fasting insulin, (n, %)	12 (7.59)	12 (21.81)	0.004	11 (.80)	13 (25.49)	<0.001
Hcy, mean (SD)	15.34 (10.14)	27.46 (12.84)	<0.001	15.93 (12.64)	25.8 (12.05)	0.001
UA, mean (SD)	4.14 (2.13)	7.82 (3.36)	<0.001	3.18 (1.37)	4.78 (1.94)	0.03
KD, (n, %)	21 (13.29)	7 (12.72)	0.52	23 (14.20)	5 (9.80)	0.08
Microalbuminuria, (n, %)	24 (15.19)	19 (34.54)	0.01	29 (17.90)	14 (27.45)	0.06

BMI- body mass index, WHR-waist hip ratio, WC-waist circumference, AIP-, atherogenic index of plasma, AQ-atherogenic coefficient, CRR-cardiac risk ratio, LVH-left ventricular hypertrophy, HOMA-insulin resistance, Ins-insulin, Hcy-homocysteine, UA-uric acid, KD-kidney dysfunction

The positive correlation between the HbA1c and the fasting insulin was stronger in males than the women (Figure 1) and was very strong in the elderly, strong in the middle aged and very weak in the young.

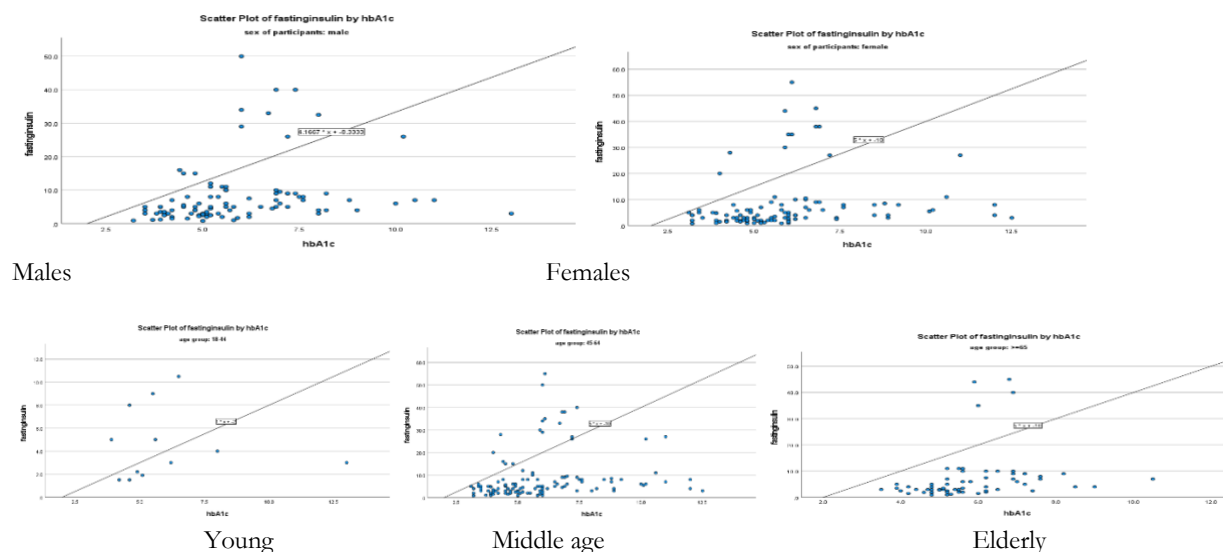


Figure 1: Correlation between the HbA1c and fasting insulin in (a) in males and females, and in (b) in the young, middle age and elderly

The positive correlation between the HbA1c and HOMA was stronger in women than the men (Figure 2) and was strong in the elderly, weakly strong in the middle aged, and weak in the young.

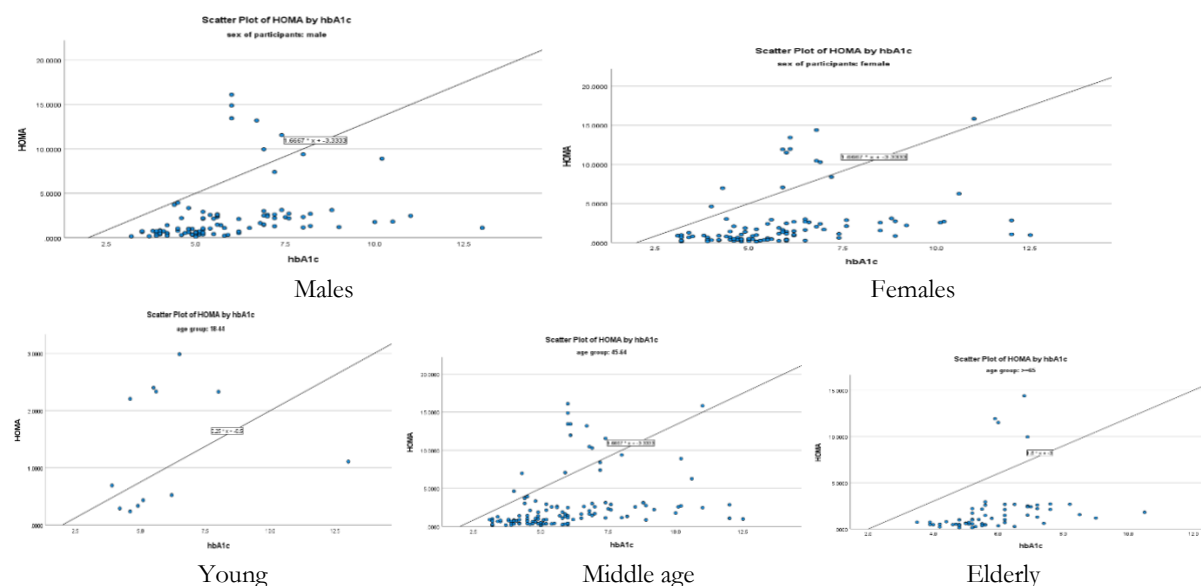


Figure 2: Correlation between the HbA1c and HOMA in (a) in males and females, and in (b) in the young, middle age and elderly

The negative correlation between the HbA1c and the GFR was stronger in men than the women (Figure 3) and was very strong in the middle aged, strong in the elderly and very weak in the young.

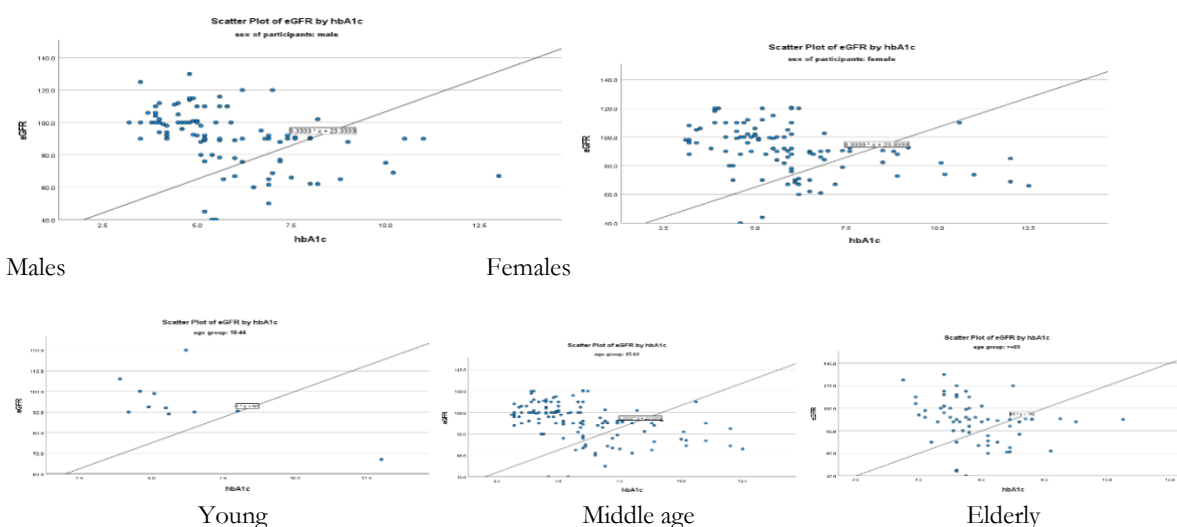


Figure 3: Correlation between the HbA1c and the glomerular filtration rate in (a) in males and females, and in (b) in the young, middle age and elderly

Diabetes control was better in men than women, it improved with age ($p=0.01$) and declining kidney function ($p<0.001$) (Table 3). Diabetes control was worse with hypertension ($p=0.01$), increasing cardiac risk ratio ($p=0.01$) and left ventricular hypertrophy ($p<0.001$).

Table 3: Univariate analysis of factors associated with glycated haemoglobin

Variables	HbA1c <7.0	HbA1c ≥7.0	P-value
Sex			
Male	82 (77.36)	24 (22.64)	0.07
Female	76 (71.03)	31 (28.97)	
Age, years			
<65	93 (66.43)	47 (33.57)	0.01
≥65	65 (89.04)	8 (10.96)	
Obesity WC, (n, %)	70 (44.30)	50 (90.91)	0.02
Obesity WHR, (n, %)	68 (43.04)	42 (76.36)	0.04
Obesity BMI, (n, %)	47 (29.75)	36 (65.45)	0.01
Hypertension, (n, %)	41 (25.95)	34 (61.81)	0.01
AIP, (n, %)	17 (10.76)	11 (20.00)	0.04
AQ, (n, %)	5 (3.16)	3 (5.35)	0.05
CRR, (n, %)	12 (7.59)	8 (14.54)	0.04
LVH, (n, %)	21 (13.29)	34 (61.81)	<0.001
Hyperhomocysteinemia, (n, %)	49 (31.01)	39 (70.91)	<0.001
Hyperuricemia, mmol/L (n, %)	47 (29.75)	32 (56.36)	0.001
Fasting insulin, mean (SD)	7.53 (3.84)	9.58 (5.51)	0.03
HOMA-IR, mean (SD)	2.07 (1.45)	3.34 (2.00)	0.04
Urine ACR, mg/g, mean (SD)	15.56 (8.16)	28.6 (8.79)	<0.001
GFR, mL/min, mean (SD)	76.59 (17.55)	52.73 (9.42)	<0.001

WC-waist circumference, WHR-waist hip ratio, BMI-body mass index, AIP-atherogenic index of plasma, HOMA-IR-insulin resistance, ACR-albumin creatinine ratio, GFR-glomerular filtration rate.

Using backward elimination to adjust for confounders, variables with $p<0.025$ in the univariate model were entered into the multiple regression analysis (Table 4) to determine independent associates of elevated HbA1c which were hypertension, LVH, hyperhomocysteinemia, fasting insulin, insulin resistance, urine albumin creatinine ratio and kidney function.

Table 4: Multiple logistic regression of independent associates of glycated haemoglobin

Variables	OR	95% CI	P-value
Age	1.2	1.173-1.939	0.06
Waist circumference	1.3	0.946-1.855	0.06
Body mass index	1.4	1.352-2.105	0.05
Hypertension	1.8	1.892-3.663	0.04
Left ventricular hypertrophy	5.7	2.384-8.503	<0.001
Hyperhomocysteinemia	4.8	2.716-7.094	<0.001
Hyperuricemia	3.9	1.747-5.033	0.02
Fasting insulin	1.6	0.672-2.045	0.05
Insulin resistance	1.5	1.172-2.326	0.06
Urine albumin creatinine ratio	5.5	4.821-9.588	<0.001
Glomerular filtration rate, mL/min	6.8	2.967-9.023	<0.001

Discussion

The study evaluated T2DM control using the HbA1c and the fasting plasma glucose concentration in a typical resource-challenged setting. The risk of developing cardiorenal and metabolic complications of diabetes is closely associated with chronic hyperglycemia and its severity.²¹ The HbA1c has gained universal acceptance as the gold standard for assessing glycemic controls in diabetes and, even prediabetes.^{4, 22} As a reflection of glycemic control over the preceding 2-3 months, HbA1c is preferred over plasma glucose, which can fluctuate widely (at times unpredictable and unexplainable). The prevailing glucose concentration determines HbA1c levels through posttranslational modification of hemoglobin by glucose.²³ The generation of the advanced glycation end-products (AGEs) from chronic hyperglycemia further highlights the superiority of the HbA1c over the plasma glucose.^{4,22} The associated inflammatory changes resulting from chronic hyperglycemia, in synergy with deranged plasma lipids have been documented as the basis for the higher risk of cardiorenal and metabolic disease. HbA1c has been found to predict cardiovascular disease and also cardiovascular events.²⁴

Despite the recommendation by the American diabetes association's recommendation to use HbA1c for the diagnosing diabetes and prediabetes, some inconsistencies have been reported in the relationship between HbA1c levels and other measures of glycemic control.^{5,6,24} These contrary findings were evident in this study, as worsening HbA1c-based diabetes control was more with closely associated with socio-demographic and anthropometric parameters than with fasting hyperglycemia. However, the relationship between HbA1c-based diabetes control and other metabolic markers and subclinical atherosclerosis markers was reversed. This confirms the limited reliability of HbA1c in assessing glycemic control, consistent with findings by Aepfelbacher et al., which showed that improvements in HbA1c-based diabetes control in patients with myocardial infarction on glycemic control regimens were associated with reductions in left ventricular septal mass but had no effect on other cardiac parameters.²⁵ Diabetic control in early disease is more closely related to cardiovascular risk than in advanced disease and, high normal levels of HbA1c are more closely related to sub-clinical atherosclerosis than elevated levels of HbA1c.²⁵⁻²⁷ Moreover, glycated albumin is more closely correlated with diabetes control than HbA1c.²⁸ It is worth noting

that the fasting plasma glucose contributes more to assessing poorly controlled diabetes, with a reversal in post-prandial assessment.²⁹ The hallmark of T2DM is insulin resistance which is more closely related to post-prandial hyperglycemia than fasting blood glucose. These affiliations could contribute to the discordancy associated with HbA1c-based diabetes controls.²⁶⁻²⁸

In resource-challenged settings, where HbA1c may be less commonly used due to cost, the reliability of the plasma glucose levels becomes imperative.³ post-prandial glucose determination commonly follows the fasting glucose checks. The relatively higher positive relationship between fasting glucose levels and other metabolic and atherogenic markers further restates its usefulness, particularly in resource-challenged settings.³⁰ Findings that showed lesser correlation between HbA1c and subclinical atherosclerosis and other metabolic markers, than fasting hyperglycemia, is suggestive of lesser reliability in predicting cardiovascular disease and events, compared to fasting hyperglycemia. Our findings are contrary to several studies that found HbA1c to be of predictive value in the occurrence of cardiovascular diseases and events.^{4,21,22}

Baseline advanced glycated end-products have been found to be strongly correlated with fasting insulin, and insulin resistance. Notably, restricting high AGEs containing diets for 4-months has been observed to improve insulin sensitivity.³¹ The positive association between worsening insulin resistance, higher fasting insulin and fasting hyperglycemia further highlights the reliability of fasting hyperglycemia in assessing diabetes control.

Biguanides are known not to lower the fasting plasma glucose levels unlike insulin and the sulphonylureas which lower the HbA1c, fasting- and post-prandial glycemic levels. Given that a majority of participants received metformin (alone or in combination with insulin or other OHAs) the reliability of biguanides can further be taken seriously.³²

Limitations were encountered in this study included: the data collection technique was by self-administration, making its reliance to be dependent on respondents' memory and honesty. Fat deposition in visceral (ectopic) tissues and organs in addition to some inflammatory and cardiovascular markers were not assessed. Using only the fasting glucose samples limited the generalization

and applicability of results, which could be of value in view of gender-based variations in fasting and postprandial glycemic excursions. The strength of the study is in its relatively large sample size and the many metabolic markers that were analyzed.

Implications of the study

The fact that hemoglobinopathy are more common in our clime coupled with cost-dependent higher availability of the FBG, tend to limit the reliability of the HbA1c. Furthermore, knowing the relative strength of associations between the glycosylated hemoglobin and the FBG in assessing diabetes control in resource-challenged climes, coupled with the relatively higher frequency of hemoglobinopathy would enhance the outcome of treatment and monitoring. This is so as a more focused assessment program can be undertaken knowing the differential correlation that exist between a measure and cardiometabolic, and renal functional derangements.

Conclusion

The glycosylated hemoglobin remains a reliable measure in the diagnosis and monitoring of diabetes mellitus. The HbA1c had a higher sensitivity in determining poor diabetes control, more so in women. Subclinical atherosclerosis, left ventricular hypertrophy, HOMA-IR and fasting insulin were more correlated with fasting hyperglycemia than elevated HbA1c. In contrast, obesity, hypertension, hyperhomocysteinemia and hyperuricemia were more closely associated with elevated HbA1c than fasting hyperglycemia. Glycosylated hemoglobin was independent associated with hypertension, hyperhomocysteinemia, hyperuricemia and declining kidney function. In resource-challenged settings, fasting plasma glucose remains a valuable tool impact in diabetes management, not only due to its lower cost but its stronger association with markers of subclinical atherosclerosis and other metabolic parameters compared with the HbA1c.

Declarations

Ethical Consideration: The approval for this study was given by the Committee on Human Ethics of Bowen University Teaching Hospital, Ogbomosho, (BUTH/REC-726).

Authors' Contribution: All authors contributed equally to the study.

Conflict of interest: The authors declare no conflict of interest.

Funding: There was no funding for this study.

Acknowledgement: We acknowledge the support of the nursing and support staffs of the endocrine unit and the medical outpatient clinics of Bowen University Teaching Hospital, Ogbomosho.

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