

Correlates of Insulin Resistance in Northern Nigeria

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Abstract

Insulin resistance is a key pathophysiological defect in type 2 diabetes mellitus (T2DM) and understanding its correlates in diverse populations can inform prevention strategies. This Nigerian study explored insulin resistance patterns among 150 people- apparently healthy individuals and persons with prediabetes and type 2 diabetes. Insulin resistance was assessed using Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) index. The study found significant differences in insulin resistance between the groups ($p < 0.001$). Abnormal waist-to-hip ratio (WHR) increased the odds of prediabetes (adjusted odds ratio, AOR: 3.99) and type 2 diabetes (AOR: 5.28). Abnormal total cholesterol to high density lipoprotein cholesterol (HDL-C) ratio was linked to higher odds of developing type 2 diabetes (AOR: 4.94). Elevated HOMA-IR increased the odds of prediabetes (AOR: 9.20) and type 2 diabetes (AOR: 13.15). The findings support evidence-based policies for diabetes prevention and management in Nigeria to prevent disease progression and cardiovascular complications.

Introduction

Diabetes mellitus is a group of metabolic disorders marked by improper carbohydrate metabolism, where glucose is underutilized as energy and overproduced due to inappropriate gluconeogenesis and glycogenolysis, resulting in hyperglycaemia.¹ In 2021, global diabetes prevalence was estimated at 10.5%, affecting 537 million adults aged 20–79, and projected to rise to 643 million by 2030 and 783 million by 2045.² In Nigeria, a meta-analysis by Uloko et al. reported a prevalence of 5.7%.³

Insulin resistance (IR), defined as a reduced response to normal insulin levels, results in decreased peripheral glucose uptake and failure to suppress hepatic glucose production and lipolysis.⁴ IR is a hallmark of type 2 diabetes mellitus (T2DM), with manifestations ranging from predominant insulin resistance with relative insulin deficiency to primary insulin secretory defects.^{5–6} These dysfunctions are typically present by the time T2DM is diagnosed.⁷

Beyond diabetes and impaired fasting glucose, elevated insulin resistance itself constitutes a significant metabolic concern. It is an independent risk factor for congestive heart failure, cardiovascular events, coronary vasomotor abnormalities, colorectal adenomas, and several cancers.^{8–11} However, national estimates on the prevalence and trends of IR in normoglycemic or hyperglycaemic individuals are limited.

This study aims to examine insulin resistance patterns and associated factors across three groups: apparently healthy individuals, those with prediabetes, and individuals with T2DM. By analyzing variations within and between these groups, the study seeks to identify key risk factors and provide insights to guide targeted prevention and management strategies in the region.

Materials and Methods

This cross-sectional study was conducted in the diabetes clinic of a tertiary hospital in Northwestern Nigeria. Participants were recruited from August to October 2020. We studied 150 participants; 50 subjects with T2DM, 50 subjects with prediabetes, and 50 apparently healthy subjects. The diagnosis of diabetes was made based on the 2019 WHO diagnostic criteria.¹² Prediabetes was defined as a fasting blood glucose level of 100–125 mg/dL (5.6–6.9 mmol/L) and diabetes was defined as fasting blood glucose level of 126 mg/dL (7.0 mmol/L) or higher on two separate tests.^{12,13}

The inclusion criteria for the study subjects were as follows: 1) patients aged 40 years and above, who had been diagnosed with T2DM within the last six months, not requiring insulin and never having been treated with insulin. 2) Prediabetic individuals aged 40 years and above, and 3) Apparently healthy individuals aged 40 years and above without a personal or family history of T2DM. We excluded subjects with Type 1 DM, those on insulin, and pregnant women from the study.

Study Protocol:

Diabetic and pre-diabetic patients were recruited via simple random sampling from the Diabetes clinic. Apparently healthy individuals were recruited using the same sampling method from the General Out-Patient Clinic (GOPC).

Sociodemographic data from each group were collected (Table 1). The weight of the study participants was measured in kilograms (kg) to the nearest 0.5 kg using a scale (Soehnle-Waagen GmbH & Co. Germany) positioned on a firm horizontal surface, with the subjects clad in minimal clothing and without shoes. Height (in meters) was recorded to the nearest 0.1 m using a stadiometer (Seca GmbH & Co., KG Germany) with the subjects standing erect, without shoes and headgears, on a flat surface with their heels and occiput in contact with the stadiometer. Body mass index (BMI) was calculated by dividing the weight (kg) by the square of the height in meters (m^2). Waist circumference was measured to the nearest 0.1 cm using a non-stretchable dress maker's tape at a point mid-way between the margin of the lowest rib and the iliac crest. Hip circumference was measured at the horizontal level of maximum circumference around the buttocks and the pubis symphysis to the nearest 0.1 cm. Waist-to-hip ratio was calculated by dividing the waist circumference (cm) by the hip circumference (cm).

Table 1
Sociodemographic characteristics and clinical characteristics of respondents.

Variables	Total N = 150	Apparently Healthy n = 50	Pre-Diabetes n = 50	Type 2 DM n = 50	P-value
Age (years)					
40–50	124 (82.7%)	44 (88.0%)	45 (90.0%)	35 (70.0%)	0.01*
51–60	26 (17.3%)	6 (12.0%)	5 (10.0%)	15 (30.0%)	
Sex					
Male	63 (42.0%)	25 (50.0%)	21 (42.0%)	17 (34.0%)	0.27
Female	87 (58.0%)	25 (50.0%)	29 (58.0%)	33 (66.0%)	
Marital status					
Unmarried	37 (24.7%)	14 (28%)	14 (28.0%)	9 (18.0%)	0.41
Married	113 (75.3%)	36 (72%)	36(72.0%)	41 (82.0%)	
Occupation					
Civil servants	90 (60.0%)	36 (72.0%)	36 (72.0%)	18 (36.0%)	< 0.001*
Traders	55 (36.7%)	14 (28.0%)	14 (28.0%)	27 (54.0%)	
Artisan	5 (3.3%)	0 (0.0%)	0 (0.0%)	5 (10.0%)	
Educational status					
Informal	14 (9.3%)	5 (10.0%)	5 (10.0%)	4 (8.0%)	0.50
Primary	10 (6.7%)	2 (4.0%)	2 (4.0%)	6 (12.0%)	
Secondary	65 (43.3%)	24 (48.0%)	24 (48.0%)	17 (34.0%)	
Tertiary	61 (40.7%)	19 (38.0%)	19 (38.0%)	23 (46.0%)	
SBP					
Normal	114 (76.0%)	42(84.0%)	38 (76.0%)	34 (68.0%)	0.17
Abnormal	36(24.0%)	8 (16.0%)	12 (24.0%)	16 (32.0%)	
DBP					
Normal	114 (76.0%)	41 (82.0%)	38 (76.0%)	35 (70.0%)	0.37
*Statistically significant at P value of < 0.05, BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; WHR: Waist-Hip Ratio. Abnormal SBP > 140mmHg, Anormal DBP > 90mmHg.					

Variables	Total N = 150	Apparently Healthy n = 50	Pre-Diabetes n = 50	Type 2 DM n = 50	P-value
Age (years)					
Abnormal	36 (24.0%)	9 (18.0%)	12 (24.0%)	15 (30.0%)	
BMI					
Normal	40 (26.7%)	16 (32.0%)	15 (30.0%)	9(18.0%)	0.42
Overweight	49 (32.7%)	17 (34.0%)	16(32.0%)	16 (32.0%)	
Obese	61 (40.6%)	17 (34.0%)	19 (38.0%)	25 (50.0%)	
WHR					0.02*
Normal	39 (26.0%)	18(36.0%)	15(30.0%)	6(12%)	
Abnormal	111 (74.0%)	32(64.0%)	35(70.0%)	44(88%)	
*Statistically significant at P value of < 0.05, BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; WHR: Waist-Hip Ratio. Abnormal SBP > 140mmHg, Anormal DBP > 90mmHg.					

Blood samples for biochemical tests were drawn in the morning, after 8–12 hours fast, by puncturing an antecubital vein. The tests included glycated hemoglobin (HbA1c), Fasting Plasma Glucose (FPG), 2-hour Post Prandial (2HrPP) and a plasma lipid assay. HbA1c level was measured using high performance liquid chromatography (HPLC) technique.¹⁴ Plasma glucose levels were determined using a glucose-oxidase/Trinder's enzymatic calorimetric method with an end-point reaction.¹⁵ Total cholesterols, triglycerides and high-density lipoprotein cholesterol (HDL-C) were assayed using an enzymatic reagent with an automated analyzer. Low density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation.¹⁶ If triglycerides exceeded 4.5 mmol/L, then direct LDL-C measurement was performed. Insulin resistance was calculated using the HOMA-IR method.¹⁷

We determined fasting plasma glucose levels after participants underwent an overnight fast of 8–12 hours, during which they abstained from food and cigarette smoking.¹⁸ We measured postprandial glucose levels 120 minutes after participants consumed a 75g glucose load, following the overnight fast. We adopted the International Diabetes Federation criterion for postprandial hyperglycemia, defining it as a plasma glucose level ≥ 7.8 mmol/L.¹⁸

We defined prediabetes in accordance with ADA 2022 guidelines, that is participants with fasting plasma glucose levels between 5.6–6.9 mmol/L, 2-hour postprandial glucose levels between 7.8–11.0 mmol/L, or hemoglobin A1c values between 5.7–6.4%.¹⁹ Hypertension was defined as blood pressure of $\geq 140/90$ mmHg or history of hypertension.²⁰ Insulin resistance was defined as a HOMA-IR value of ≥ 2.0 .¹⁷

The data obtained were entered into a Microsoft Excel spreadsheet and analyzed using STATA version 18.0 (STATA-Corp LLC, College Station, TX, USA). Categorical variables were presented as frequencies and percentages and compared across glycemic levels using Pearson's chi-square or Fisher's exact test, as appropriate. Fasting plasma glucose (FPG), 2HrPP, HbA1c, and HOMA-IR were summarized using means and standard deviation (SD). We used ANOVA test to compare continuous variables across the three categories of glycemia. We used multinomial regression analysis to identify risk factors for prediabetes and T2DM and considered age and sex as a priori confounding variables in all models. We employed a backward stepwise regression, including all independent variables with $p < 0.10$ at the bivariate level. We derived the reported p values from the likelihood ratio test and presented adjusted odds ratios (aORs) and their 95% confidence intervals (CIs) for all factors associated with prediabetes and T2DM. Type I error was fixed at 5% for all statistical tests.

Results

The ages of participants ranged from 40–60 years with mean age $\pm$ standard deviation (SD) of 44.9 ± 4.9 years. Most participants were female (58%), married (75.3%) and employed in civil service (60%) (Table 1). Approximately 76% of participants had normal blood pressure readings ($< 140/90$). One-half of participants with T2DM were obese. An abnormal waist-to-hip ratio was commonly observed across all 3 groups, ranging from 64% in apparently healthy subjects to 88% in those with T2DM. One-third of participants had abnormal HOMA-IR (Table 2). The proportion of participants with abnormal TChol, HDL-C, triglycerides, LDL-C and HOMA-IR was greater in patients with T2DM compared to apparently healthy individuals and respondents with pre-diabetes. The mean values of HbA1C, FPG, 2HrPP, and HOMA-IR were lowest among apparently health participants and highest in persons with T2DM (Table 3).

Table 2
Biochemical characteristics of respondents

Variables	Total N = 150	Apparently Healthy n = 50	Pre-DM n = 50	T2DM n = 50	P-value
Total Cholesterol					
Normal	67 (44.7%)	28(56.0%)	26(52.0%)	13(26.0%)	0.005*
Abnormal	83(55.3%)	22(44.0%)	24(48.0%)	37(74.0%)	
HDL-C					
Normal	55(36.7%)	22(44.0%)	19(38.0%)	15(30.0%)	0.28
Abnormal	95(63.3%)	28(56.0%)	31(62.0%)	35(70.0%)	
TRIG					
Normal	86(57.3%)	36(72.0%)	32(64.0%)	18(36.0%)	0.001*
Abnormal	64(42.7%)	14(28.0%)	18(36.0%)	32(64.0%)	
LDLC					
Normal	45(30.0%)	19(38.0%)	18(36.0%)	8(16.0%)	0.03*
Abnormal	105(70.0%)	31(62.0%)	32(64.0%)	42(84.0%)	
TC/HDL-C					
Normal	75(50.0%)	35(70.0%)	27(54.0%)	13(26.0%)	< 0.001*
Abnormal	75(50.0%)	15(30.0%)	23(46.0%)	37(74.0%)	
HOMA-IR					
Normal	101 (67.3%)	42(84.0%)	40(80.0%)	19(38.0%)	< 0.001*
Abnormal	49 (32.7%)	8(16.0%)	10(20.0%)	31(62.0%)	
*Statistically significant at P value of < 0.05; HbA1c: glycated haemoglobin; FPG: fasting plasma glucose; 2hPPG: 2hour post-prandial glucose; TC: total cholesterol; HDL: high density lipoprotein; TG: triglycerides; LDL: low density lipoprotein; TC/HDL: atherogenic index, HOMA-IR: homeostatic model assessment Insulin resistance. (define all abnormal values in footnote)					
* Abnormal TC > 200mg/dl					
Abnormal HDL-C < 50mg/dl in Females and < 45mg/dl in Males					
Abnormal TG>150mg/dl					
Abnormal LDL-C > 100mg/dl					

Table 3
Mean values of biochemical variables of respondents, Kano, Nigeria

Variables	Apparently Healthy Mean±SD	Pre-DM Mean±SD	T2DM Mean±SD	F-test	P-value
HbA1c	4.79±0.30	5.99±0.25	8.51±1.01	462.67	< 0.001*
FPG	4.90±0.35	5.64±0.51	14.83±4.88	189.75	< 0.001*
2HrPP	6.63 ±0.49	8.37±0.96	20.49±5.50	272.69	< 0.001*
HOMA-IR	1.86±0.37	2.00±0.61	3.31±0.55	25.77	< 0.001*
*Statistically significant at P value of < 0.05; HbA1c: glycated haemoglobin; FPG: fasting plasma glucose; 2hPPG: 2 hour post-prandial glucose; HOMA-IR: homeostatic model assessment Insulin resistance.					

Table 4 shows that after adjusting for potential confounders, the total cholesterol to high-density lipoprotein cholesterol ratio (TC/HDL-C), HOMA-IR, and waist-to-hip ratio (WHR) emerged as independent risk factors for development of pre-diabetes and T2DM. Participants with an abnormal WHR were four and five times as likely to develop prediabetes (AOR: 3.99; 95% CI: 1.31–14.99) and type 2 diabetes (AOR: 5.28; 95% CI: 1.37–20.31) respectively, compared to those with a normal WHR. Similarly, individuals with an abnormal TC/HDL-C ratio were nearly five times more likely to develop T2DM (AOR: 4.94; 95% CI: 1.11–21.81) than apparently healthy individuals with normal values. HOMA-IR also significantly increased the odds of prediabetes (AOR: 9.20; 95% CI: 3.22–26.21) and type 2 diabetes (AOR: 13.15; 95% CI: 4.17–41.49).

Table 4

Multinomial logistic regression showing independent predictors for developing prediabetes and Type 2 diabetes mellitus, Kano, Nigeria

Variable	Pre-DM	T2DM	P-value
	Adjusted OR (95% CI)	Adjusted OR (95% CI)	
Age (years)			
40–50	Reference	Reference	0.11
51–60	3.33 (0.91–12.06)	2.95 (0.78–11.14)	
Sex			
Male	Reference	Reference	0.68
Female	1.25 (0.44–3.58)	1.54 (0.52–4.61)	
WHR			
Normal	Reference	Reference	0.01*
Abnormal	3.99 (1.31–14.99)	5.28 (1.37–20.31)	
Tchol			
Normal	Reference	Reference	0.80
Abnormal	1.20 (0.26–5.57)	1.01(0.21–4.76)	
TRIG			
Normal	Reference	Reference	0.82
Abnormal	1.73 (0.50-6.00)	1.74 (0.46–6.56)	
LDLC			
Normal	Reference	Reference	0.96
Abnormal	1.19 (0.27–5.23)	1.0 (0.21–4.36)	
TC/HDL-C			
Normal	Reference	Reference	0.04*
Abnormal	2.06 (0.49–8.60)	4.94 (1.11–21.81)	
HOMA-IR			
Normal	Reference	Reference	< 0.001*
*Statistically significant at P value of < 0.05, WHR: Waist-Hip Ratio, TC: total cholesterol; HDL: high density lipoprotein; TG: triglycerides; LDL: low density lipoprotein; TC/HDL: atherogenic index.			

Variable	Pre-DM	T2DM	P-value
	Adjusted OR (95% CI)	Adjusted OR (95% CI)	
Age (years)			
Abnormal	9.20(3.22–26.21)	13.15(4.17–41.49)	
*Statistically significant at P value of < 0.05, WHR: Waist-Hip Ratio, TC: total cholesterol; HDL: high density lipoprotein; TG: triglycerides; LDL: low density lipoprotein; TC/HDL: atherogenic index.			

Discussion

We found associations between sociodemographic factors and development of prediabetes and T2DM. There was age-related disparity with a higher prevalence of prediabetes and apparently healthy individuals in the 40–50 age group, contrasting with increased Type 2 Diabetes Mellitus (T2DM) cases in older populations. This aligns with existing literature, emphasizing the escalating risk of diabetes with advancing age.^{21–23} Additionally, gender disparities were observed, with females comprising a larger proportion of T2DM subjects, consistent with prior research, potentially due to biological, lifestyle, and socioeconomic factors.²⁴ Occupational differences also emerged, with civil servants showing higher rates of prediabetes and healthy individuals, while traders were disproportionately represented in the diabetic group, emphasizing the role of vocational factors in diabetes risk.²⁵

Most participants exhibited normal systolic blood pressure (SBP), with a higher proportion among apparently healthy individuals. Conversely, abnormal SBP was more prevalent among T2DM subjects; these findings suggest a trend towards increased blood pressure with deteriorating glucose metabolism.

Body mass index (BMI) and waist-to-hip ratio (WHR) also demonstrated significant associations with glucose metabolism. A substantial proportion of participants were overweight or obese, predominantly in the T2DM group, indicating a strong obesity-diabetes link. Central obesity, measured by WHR, disproportionately affected T2DM subjects, emphasizing its critical role in glucose homeostasis. These findings emphasize the importance of addressing obesity and central obesity in prevention and management of diabetes.

The lipid profile and insulin resistance analysis revealed significant associations with blood glucose regulation. Total cholesterol levels exhibited a notable disparity across the glycemic groups. A substantial proportion of T2DM subjects had abnormal total cholesterol levels, whereas healthy individuals predominantly displayed normal levels. This finding solidifies the link between dyslipidemia and diabetes risk. High-density lipoprotein cholesterol (HDL-C) levels showed a trend towards abnormality in T2DM subjects, although the difference did not achieve statistical significance. However, the preponderance of abnormal HDL-C levels among T2DM individuals hints at impaired lipid metabolism. Triglyceride levels showed a strong association with blood glucose regulation. T2DM

subjects exhibited significantly higher abnormal triglyceride levels, which is in agreement with reports by Betteridge (1999), which emphasized the role of triglycerides in diabetes pathophysiology.²⁶

The distribution of low-density lipoprotein cholesterol (LDL-C) levels by diabetes status revealed a significant disparity, with T2DM subjects predominantly displaying abnormal levels. This finding resonates with established literature highlighting the role of LDL-C in cardiovascular and diabetes risk.^{27,28} The atherogenic index (TC/HDL-C ratio) also proved a robust predictor of glucose metabolism disorders. T2DM subjects exhibited significantly higher abnormal atherogenic index values, underscoring the utility of the index in identifying diabetes risk.

HOMA-IR values demonstrated a profound association with blood glucose regulation. T2DM subjects displayed significantly higher abnormal HOMA-IR levels, reinforcing insulin resistance's central role in diabetes pathophysiology, and this agrees with Thevenod and Petersen et al.^{28,29}

Glycemic profiles showed significant variation across apparently healthy, prediabetes, and T2DM groups. HbA1c, FPG, and 2HrPP levels progressively increased from healthy to T2DM individuals, indicating glucose metabolism deterioration. HOMA-IR values also demonstrated a notable gradient, with T2DM subjects exhibiting higher insulin resistance. These findings stress the importance of comprehensive glycemic assessments for diagnosing and monitoring glucose metabolism disorders. Significant differences in glycemic parameters support early intervention strategies.

Multivariate analysis identified WHR, atherogenic index and HOMA-IR as critical predictors of glucose metabolism disorders.^{30–33} Abnormal WHR significantly increased the odds of development of prediabetes and T2DM, highlighting central obesity's detrimental effects on insulin sensitivity. Elevated atherogenic index also heightened odds of developing T2DM, emphasizing the importance of lipid profile management in preventing diabetes. HOMA-IR predicted both prediabetes and T2DM, reinforcing the central role of insulin resistance in the etiology of T2DM. Taken together, these findings corroborate the interplay between anthropometric, lipidemic, and insulin resistance factors.^{34–36} Targeted interventions addressing central obesity, dyslipidemia and insulin resistance can mitigate diabetes risk, and integrating WHR, atherogenic index and HOMA-IR into clinical screening protocols can facilitate early identification of at-risk individuals.³⁷

While this study contributes valuable insights, some limitations include the small sample size and single-center recruitment. In addition, the cross-sectional study design limits our ability to infer causality or temporal relationships. There is therefore the need for larger, multi-center, longitudinal investigations to confirm and extend our findings. The strengths of the study include the use of validated assessments, and multivariate regression analysis to determine the independent association between selected variables and the odds of developing prediabetes and T2DM.

Conclusion

In conclusion, this study highlights WHR, TC/HDL-C ratio and HOMA-IR as important predictors of prediabetes and T2DM. These findings underscore the importance of comprehensive risk assessment and targeted interventions addressing central obesity, dyslipidemia and insulin resistance.

Declarations

Information if the manuscript was presented as part at a meeting, the organization, place, and exact date on which it was read: N/A

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Author contributions: UFA, IDG, AEU and ABG conceived and designed the study. UMT, FMD, AAJ, ALO and UAA conducted the literature search. UFA, JMI, KSS and ZAH supervised the collection of data. UFA, MAS and FIT analyzed the data. All authors drafted and revised the manuscript. JMI, FMD, ATA and MHA proofread the manuscript. All authors approved the final version of the manuscript.

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Data availability statement: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate: All participants provided their written informed consent to participate in this study. The study was approved by the AKTH Human Research Ethics Committee, under protocol number: NHREC/21/08/2008/AKTH/EC/2580 and was conducted in accordance with the principles of the Helsinki Declaration.

This manuscript has been read and approved by all the authors. The requirements for authorship have been met. All authors believe that this manuscript represents our honest work.

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