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Original Article **Open Access**

Prevalence of Cognitive Impairment and its Associated Risk Factors among Subjects with Type-2 Diabetes Mellitus Attending Referral Hospitals in Katsina State

Ismail Abdullahi[1], Murdakai Tanko[1], Uduak E. Umana[1], Musa Mustapha[1], Hafsat L. Sabo[1], Aliyu I. Aliyu[1], Aisha H. Babankanwa[1], Yassar I. Sulaiman[1], Ahmad S. Umar[1], Emem C. Umoh[1], Muhammad Abdulmalik[2], Abbas Nasidi[3], Sani A. Bello[4], Rasaq A. Oyewo[5]

[1]Department of Human Anatomy, Faculty of Basic Medical Sciences, Ahmadu Bello University, Zaria, Nigeria; [2]Department of Human Physiology, Faculty of Basic Medical Sciences, Ahmadu Bello University, Zaria, Nigeria; [3]Department of Human Anatomy, Faculty of Basic Medical Sciences, Bauchi State University, Gadau, Nigeria; [4]Department of Human Anatomy, Faculty of Basic Sciences, Abubakar Tafawa Balewa University, Bauchi, Nigeria [5]Department of Human Anatomy, Faculty of Basic Medical Sciences, Federal University of Health Science, Azare, Nigeria.

ABSTRACT

Type-2 diabetes mellitus (T2DM) is known to increase the risk of cognitive impairment (CI). There is a dearth of research addressing the growing concern of CI among individuals with T2DM in Nigeria, specifically in Katsina State. The present study determined the prevalence of CI and its associated risk factors among T2DM in Katsina State. This cross-sectional study employed a systematic random sampling technique to select and recruit 193 and 167 confirmed T2DM subjects with CI and normal cognition, respectively, who met the study inclusion criteria. A mini-mental state examination questionnaire was used to determine CI. The data collected include socio-demographics, medical, nutritional, and adiposity characteristics. The prevalence of CI in T2DM was 53.6%. Binary logistic regression revealed that age ≥ 60 years (AOR 1.08), female gender (AOR 1.03), non-formal education (AOR 1.23), cigarette smoking (AOR 4.55), duration of T2DM >10 years (AOR 3.73), hypertension (AOR 1.22), abnormal glycaemic control (AOR 2.23), abnormal body mass index (AOR 1.12), abnormal body adiposity index (AOR 0.12), abnormal waist-to-hips ratio (AOR 1.48), and abnormal waist-to-height ratio (AOR 3.91) were significantly associated with increased risk of CI among T2DM patients. The study concludes that CI among T2DM patients is significantly associated with older age, female gender, non-formal education, smoking, longer T2DM duration, hypertension, poor glycaemic control, and various abnormal adiposity indices, highlighting the need for targeted interventions in these high-risk groups.

Keywords

Cognitive impairment, Katsina state, Type-2 diabetes mellitus

Correspondence: Ismail Abdullahi, PhD. Department of Human Anatomy, Faculty of Basic Medical Sciences, Ahmadu Bello University, PMB 12003, Zaria, Nigeria. E-mail: isdanmaliki@gmail.com; Phone Number: +2347068308276; ORCID: 0000-0002-9589-1277; Murdakai Tanko- 0000-0002-0727-5299, mutanko63@gmail.com; Uduak Umana- 0000-0003-2096-7238, ueumana@gmail.com; Musa Mustapha- 0000-0002-9280-8482, ibnelmustapha35@gmail.com; Hafsat Sabo- 0000-0003-1777-5569, hafsatlsabo@gmail.com; Aliyu Aliyu- 0000-0001-9393-2496, draliyuisahaliyu@gmail.com; Aisha Babankanwa- 0000-0002-0940-6467, aishamalyk1@gmail.com; Yassar Sulaiman- 0000-0002-5690-2762, sulaimanyassar@gmail.com, Ahmad Umar- 0000-0002-0008-6647, drdikko@gmail.com, Emem Umoh - 0009-0007-9342-1996, ememyarns@yahoo.com; Muhammad Abdulmalik- 0000-0003-3308-6923, drmodee8@gmail.com; Abbas Nasidi- 0000-0002-7176-7671, abbasnasidi@basug.edu.ng; Sani Bell- 0009-0009-9895-1245, sabello@atbu.edu.ng; Rasaq Oyewo-oyeworasaki@gmail.com

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INTRODUCTION

Diabetes is a major global health problem that the world is facing today. The world prevalence of diabetes among adults (aged 20–79 years) was 6.4%, affecting 285 million adults in 2010, and likely to increase to 7.7% or 439 million adults by 2030 (Alanazi *et al.*, 2017). The rapidly growing number of people who have diabetes has made the Center for Disease Control (CDC) declare it an epidemic. Nigeria is regarded as the diabetic capital of the world (Iregbu *et al*., 2022). A recent meta-analysis reported that approximately 5.8% (about 6 million) of adult Nigerians live with type-2 diabetes mellitus (T2DM) (Uloko *et al*., 2018). This figure has been likened to the tip of the iceberg, as it is estimated that two-thirds of T2DM cases in Nigeria are yet undiagnosed (Adeloye *et al*., 2017). The increasingly sedentary lifestyle has played a crucial role in the spread of type-2 diabetes, which is the more prevalent form of diabetes in developed nations by a considerable margin (Alanazi *et al*., 2017).

T2DM has been consistently associated with a higher risk of cognitive decline, especially in older persons (Spartano *et al*., 2019). Cognitive decline may be partly due to an array of tissue responses to chronic hyperglycemia, postprandial glucose fluctuations, advanced glycation end products, and altered insulin action (Gowd *et al*., 2021). Some mechanisms explaining the relationship between diabetes and cognitive decline remain to be elucidated. A T2DM patient with memory problems may forget to take insulin doses, take medications on time, or forget to eat on time. Other comorbidities like hypertension, poor glycaemic control, cigarette smoking, and fat tissue distribution, among others associated with ageing and diabetes, also add to the burden of cognitive impairment (CI) and its impact on self-care abilities (Shapira *et al*., 2022). Thus, the clinical presentation of T2DM patients with cognitive dysfunction and associated comorbidities is frequently subtle but has an enormous impact on overall diabetes management.

Alongside the physical health challenges posed by diabetes, CI has emerged as a significant yet underexplored issue affecting individuals with this condition (Zafari *et al*., 2018). CI impacts the quality of life of those affected and poses substantial challenges to healthcare systems and families providing care (Anand *et al*., 2022). Despite global recognition of the diabetes-cognitive impairment link (Eze *et al*., 2015; Yarube and Mukhtar, 2018; Karvani *et al*., 2019; Tianyi *et al*., 2019; Wang *et al*., 2019; Williams *et al*., 2020; Izquierdo *et al*., 2021; Adebayo *et al*., 2022; Bashir and Yarube, 2022; Chiba *et al*., 2020; Rizzo *et al*., 2022), there is a notable absence of localised research conducted in Katsina State to comprehensively understand the prevalence and associated risk factors of CI in individuals with T2DM. This research gap is crucial because it hinders the development of targeted healthcare interventions, policy recommendations, and educational initiatives urgently needed to address the unique needs of individuals with T2DM in Katsina State. Furthermore, Katsina State's cultural, socioeconomic, and healthcare landscape differs significantly from other regions (Peters *et al*., 2014; Musa *et al*., 2024), and this necessitated a context-specific investigation into CI's prevalence and risk factors in the state.

To address this critical gap in knowledge, this study assessed the prevalence of CI and identified the specific risk factors associated with CI among individuals diagnosed with T2DM in Katsina State.

MATERIALS AND METHODS

Study Design, Setting, and Ethical Statement

This cross-sectional study was conducted from April 2021 to March 2022 at three selected hospitals in Katsina State located within two geopolitical zones of the state, namely, General Hospitals Funtua and Malumfashi located in the Funtua geopolitical zone and General Hospital Katsina in the Katsina central geopolitical zone. The selected hospitals serve as the primary referral centres for the two regions, hence the rationale behind choosing these hospitals.

All participants provided written informed consent, and the Health Research Ethics Committee of Ahmadu Bello University Zaria (Ref: ABU/HREC/G13/2020) and Katsina State Hospital Management Board (Ref: MOH/ADM/SUB/1152/1/462) approved the study protocol before data collection. STROBE guidelines for the cross-sectional study were strictly followed. Also, detailed explanations of the study protocol were given to the study participants, and anonymity and confidentiality of the study data were guaranteed.

Sample size determination and sampling procedure

The sample size for this study was obtained using the formula:

$[n = z^2pq/d^2]$ (Naing *et al*., 2006)

Where:

n= the desired sample size, z= the standard normal deviation, usually set at 1.96 (≈2.0), p= the prevalence of CI among T2DM in a previous study in Southern Nigeria is 14.7% (0.147) (Williams *et al*., 2020), q = 1.0-p = 0.951, d = degree of accuracy desired, usually set at 0.05.

Therefore, $n = (1.96)^2(0.147)\ (0.853)/(0.05)^2 = 192$.

Out of the 360 confirmed cases of T2DM recruited for the study, 193 subjects were screened for impaired cognition, while 167 had normal cognitive function.

A multistage sampling method was employed to divide the geopolitical zones into three strata: Katsina Central, Funtua, and Daura. However, two political zones were used for data collection due to regional security instability, excluding the Daura zone. The two selected strata (zones) have referral centres for T2DM management. Some T2DM patients of the excluded third zone (Daura zone) also attend Katsina central zone referral centres, accounting for some of their percentages. From each selected geopolitical zone, 95 to 98 confirmed T2DM with CI after the screening, and 87 to 80 T2DM subjects with normal cognition were selected using systematic random sampling, i.e., every second T2DM patient, to avoid bias. The recruitment was done during the patient's visit for routine check-ups in the endocrine outpatient clinics of the selected hospitals. All participants enrolled were on treatment with either oral hypoglycaemic drugs, diet, or both, with disease duration of not less than two years and a controlled disease state (record glycated haemoglobin less than 6.5 g/dL) at the time of the study. Three months before the study, patients admitted to a hospital or with any apparent deformity (amputated or deformed limbs) that could compromise the anthropological profile were excluded. Pregnant and lactating mothers and T2DM with severe comorbidities like stroke, chronic renal failure, psychiatric disorders such as depression, alcohol or drug dependence, and those using antidepressant or antipsychotic medications, insulin injections, or a history of chronic lung disease (defined from patient records) were also excluded from the study.

Anthropometric Measurements

Anthropometric measurements, including height, weight, waist circumference (WC), and hip circumference (HC), were taken according to the standard protocols reported by the International Society for the Advancement of Kinanthropometry (ISAK) (Silva and Vieira, 2020). Briefly, the measurements were taken as follows:

1. Height (Ht) (m): Standing with bare feet, vertically in the midline from heel to vertex (the topmost position of the head) to the nearest 0.1 cm using a stadiometer (Holtain Harpenden, UK).
2. Weight (Wt) (kg): The subjects were barefooted and lightly dressed. Weight was taken to the nearest 0.1 kg using a digital weighing balance (EBSA-20, Kolgon Industrial Limited, China).
3. Waist Circumference (WC) (cm): Distance at the level of the narrowest point between the lower costal (rib) border and the iliac crest. It was measured perpendicular to the long axis of the trunk (cm) using flexible inelastic tape (Luftkin W606PM, NutriActiva Limited, USA).
4. Hip Circumference (HC) (cm): the distance at the level of the greatest posterior protuberance of the buttocks and perpendicular to the long axis of the trunk.

Body adiposity index (BAI), body mass index (BMI), waist-to-hip ratio (WC/HC), and waist-to-height ratio (WC/Ht) were evaluated from the measured anthropometric variables, viz.

1. Body Mass Index (BMI): $Wt(kg)/H(m)^2$ (Nihiser *et al*., 2007).
2. Waist-to-Hip Ratio: WC/HC (Lear *et al*., 2010).
3. Waist-to-Height Ratio: WC/Ht (Savva *et al*., 2013).
4. $BAI = [HC/(Ht)^5] - 18$. Where HC is in centimetres and Ht is in metres (Bennasar--Veny *et al*., 2013).

Intra- and inter-Observer Measurement Errors Assessment

This study employed precision measures to assess intra- and inter-observer measurement errors as outlined (Gwani *et al*., 2017). The precision estimate measures of error used include absolute technical error of measurement (aTEM), relative technical error of measurement (rTEM), coefficient of reliability (Rr), and coefficient of variation (CV).

To calculate aTEM, the following formula was applied:

$aTEM = \sqrt{\Sigma(m_1 - m_2)^2/2n}$

Here, ‘n’ represents the number of participants being measured, while ‘m_1’ and ‘m_2’ correspond to the first and second measurements.

Subsequently, rTEM was computed using the formula:

$rTEM = (aTEM/VAV) \times 100$

Where ‘VAV’ signifies the variable average value, essentially the mean of the two measurements.

The calculation of Rr involved the following formula:

$Rr = 1 - (aTEM^2/SD^2)$

In this equation, ‘SD’ is the standard deviation of all measurements.

Finally, CV was determined using the formula:

$CV = (SD \times 100)/X$

Where ‘X’ represents the mean of all measurements.

Assessment of Cognitive Impairment

The cognitive assessment test used a mini-mental state examination (MMSE) questionnaire with a Cronbach’s alpha of 0.99 (Sanford, 2017). It contains 24 items to measure several dimensions of cognitive function, including the test of calculation, language, orientation, and recall ability. The scoring range was from 0 to 30 points, with scores from 0 to 23 CI and 24 to 30 normal cognition. CI was categorised as severe cognitive impairment or dementia, having scores from 0 to 18 and mild cognitive impairment with a score from 19 to 23 (Sanford, 2017). The patients were seated and allowed to rest for about ten minutes after their routine medical check-up before the cognitive assessment to get the utmost attention from the subjects during the assessment.

Data Analyses

The Kolmogorov-Smirnov test was used to determine the data normality. Using descriptive statistics, data were expressed as mean ± standard deviation (continuous variables) or percentages (categorical variables). A Pearson’s chi-square test was used to compare baseline characteristics between type-2 diabetics with normal and impaired cognition and between sexes in the type-2 diabetics with impaired cognition. An independent t-test was used to compare sex differences in the prevalence of cognitive impairment among subjects with impaired cognition. A binary logistic regression was used to determine the factors [socio-demographic (age, sex, marital status, smoking status, and level of education), medical (duration of diabetes, hypertension, and glycaemic control), nutritional (BMI), and body adiposity characteristics (BAI, WC/HC, WC/Ht)] (independent variables) associated with the risk of developing CI (dependent variable) among T2DM patients. Before running the binary logistic regression, all possible 2-way interactions, multicollinearity, model assumptions (normality, linearity, and homoscedasticity), and outliers were checked using plots of residuals. Data were analysed using SPSS (Statistical Product for Service Solution) version 28 software (IBM, New York, USA), and $P < 0.05$ was set as the level of significance.

RESULTS

The intra- and inter-observer absolute TEM, relative TEM (<1.5%), coefficient of reliability (0.98), and coefficient of variation (<5.0%) for the measured digit lengths were within the acceptable limits.

The results of various socio-demographic, medical, adiposity, and nutritional characteristics of type-2 diabetics compared with normal and impaired cognition is shown in Table 1. There were significant differences between the normal and impaired cognition groups in age, gender, level of education, smoking status, duration of diabetes, hypertension, HbA levels, body adiposity index, waist-to-hip ratio, waist-to-height ratio, and body mass index. These variables were more associated with cognitive impairment. However, marital status did not show a significant difference between the groups.

0.359, p = 0.001). Female gender was a significant risk factor for CI compared to male (AOR: 1.032, 95% CI: 0.257 - 4.139, p = 0.014). Similarly, patients with no formal education have a nearly two times higher risk of developing CI than those with formal education (AOR: 1.234, 95% CI: 0.431 - 4.111, p = 0.001). The same goes for patients smoking. A 4.459 times risk of contracting CI was observed compared to non-smokers (AOR: 4.549; 95% CI: 0.104 - 5.886, p = 0.001). Further, the following factors were also significant risk factors for CI: duration of disease greater than ten years (AOR: 3.728, 95% CI: 0.164 - 3.240, p = 0.001), hypertension (AOR 1.217; 95% CI: 0.289 - 5.118, p = 0.019), poor glycaemic level (AOR 18.398; 95% CI: 3.101 - 109.159, p = 0.001), abnormal nutritional characteristics (AOR: 1.116, 95% CI: 0.018 - 2.751, p = 0.024), abnormal waist-to-hip circumference (AOR: 1.478, 95% CI: 0.075 - 3.049, p = 0.035), abnormal waist-to-height circumference (AOR: 3.908; 95% CI: 0.119 - 6.933, p = 0.026), and abnormal body adiposity index (AOR: 2.124; 95% CI: 0.019 - 0.815, p = 0.030) as presented in Table 3.

Table 1: Comparison of baseline characteristics between type 2 diabetics with normal and impaired cognition

Variables		Normal cognition (n = 167)	Cognitive impairment (n = 193)	χ^2 (df)	*P* – value
Socio-demographic characteristics					
Age (Years)	20 - 50	94	22		
	51 - 64	90	146		
	65 - 70	3	25	57.16 (1)	0.001
Gender	Male/Female	92/75	81/112	6.17 (1)	0.013
Marital status	Married/Unmarried	124/43	130/63	2.05 (1)	0.152
Level of education	No formal education	14	16		
	Primary education	29	14		
	Secondary education	31	20		
	Tertiary education	93	143	16.54 (1)	0.001
Cigarette smoking	Yes/No	42/125	23/170	10.59 (1)	0.001
Medical characteristics					
Duration of T2DM	<10 years	92	57		
	>10 years	95	137	24.10 (1)	0.001
Hypertension	Yes/No	126/41	141/52	11.21 (1)	0.033
HbA	Normal/Abnormal	151/16	0/193	19.35 (1)	0.001
Adiposity characteristics					
Body adiposity index	Normal/Abnormal	42/122	49/144	6.23 (1)	0.013
Waist-to-hip ratio	Normal/Abnormal	75/92	56/137	9.77 (1)	0.002
Waist-to-height ratio	Normal/Abnormal	77/90	54/139	12.71 (1)	0.001
Nutritional characteristics					
Body mass index	Normal/Abnormal	109/58	70/123	8.93 (1)	0.011

HbA: Glycosylated Haemoglobin A

The chi-square analysis of type-2 diabetics with CI highlights notable sex-related associations across several characteristics (Table 2). Significant associations were observed between CI and marital status, level of education, smoking status, and hypertension status. On the other hand, variables such as age, duration of diabetes, and HbA levels did not show significant associations with CI.

The results of sex-related associations between adiposity characteristics and nutritional status among type-2 diabetics with CI are highlighted in Table 3. Significant associations were observed between CI and body adiposity index, waist-to-height ratio, and body mass index. The waist-to-hip ratio showed no significant sex-related associations with CI.

The prevalence of CI in the overall population (A) is 53.4%, and based on gender (B), 25.5% (male) and 31.1% (female), as presented in Figure 1.

The risk factors for CI are highlighted in Table 4. After adjustment in the multiple logistic regression, patients aged 60 years and above were a significant risk factor for CI compared to those below 60 (AOR: 1.083, 95% CI: 0.19 -

Note: In simple (SLR) and multiple (MLR) logistic regression analysis, both crude odds ratios (COR) and adjusted odds ratios (AOR) are reported to provide a comprehensive understanding of the relationship between independent variables and the outcome. The COR (SLR) measures the relationship without considering other variables. At the same time, the AOR (MLR) accounts for the influence of other relevant variables in the model, thereby controlling for potential confounding factors. Reporting both ratios is essential for assessing the independent effect of each predictor (SLR), identifying confounding (MLR), ensuring transparency in results, and facilitating comparative analysis to understand how controlling for other variables impacts the associations, ultimately enhancing the credibility and interpretability of the findings.

Table 2: Distribution and comparison of socio-demographic and medical characteristics of male and female T2DM with CI

Variables		Total (n = 193) n (%)	Male (n = 81) n (%)	Female (n = 112) n (%)	χ^2 (df)	*P*-value
Socio-demographic characteristics						
Age	20-50 years	22 (11.4)	10 (12.3)	12(10.7)		
	51-64 years	146 (75.6)	65 (80.2)	81 (72.3)		
	65-70 years	25 (13.0)	6 (7.4)	19 (17.0)	3.82 (2)	0.148
Marital status	Non married	130 (67.4)	73 (90.1)	57 (50.9)		
	Married	63 (32.6)	8 (9.9)	55 (49.1)	32.90 (1)	0.001
Level of education	No formal education	36 (18.8)	16 (19.8)	20 (17.8)		
	Primary education	42 (21.7)	14 (17.3)	28 (25.0)		
	Secondary education	55 (28.4)	20 (24.7)	35 (31.3)		
	Tertiary education	60 (31.1)	31 (38.3)	29 (25.9)	93.31 (3)	0.001
Smoking status	Non-smokers	170 (88.1)	78 (96.3)	92 (82.1)		
	Smokers	23 (11.9)	3 (3.7)	20 (17.9)	8.97 (1)	0.003
Medical characteristics						
Duration of T2DM	<10 years	57 (29.5)	24 (29.6)	33 (29.5)		
	>10 years	136 (70.5)	57 (70.4)	79 (70.5)	0.01 (1)	0.98
Hypertension	Normotensive	141 (73.1)	65 (80.2)	76 (67.9)		
	Hypertensive	52 (26.9)	16 (19.8)	36 (32.1)	3.67 (1)	0.04
HbA	Normal	72 (37.3)	28 (34.6)	44 (39.3)		
	Abnormal	121 (62.7)	53 (65.4)	68 (60.7)	1.32 (1)	0.34

n (%): Frequency (percentage)**;** HbA: glycosylated haemoglobin A; CI: cognitive impairment

DISCUSSION

This is the first cross-sectional study to determine the risk factors for CI among T2DM patients in Katsina State. The finding of a 53.6% prevalence of CI among individuals with type-2 diabetes in Katsina State is alarming and highlights a substantial burden of cognitive dysfunction in this population. Interestingly, the study also reveals a notable gender difference, with a higher proportion of females (31.5%) experiencing CI than males (22.5%). This gender discrepancy might suggest that females with type-2 diabetes in Katsina State are at a higher risk of CI, potentially due to hormonal, lifestyle, or socioeconomic factors (Subramaniapillai *et al*., 2021; Volgman *et al*., 2019; Wang *et al*., 2020). It is essential to note that these findings should be interpreted in the context of the local population and healthcare system, as the prevalence of CI in individuals with type-2 diabetes can vary widely across regions and ethnicities (Wang *et al*. 2020). Compared with other studies in different geographic areas and populations, these results revealed inconsistencies (Adebayo *et al*., 2022;

Table 3: Distribution and comparison of adiposity and nutritional characteristics between male and female T2DM subjects with CI

Variables		Total (n = 193) n (%)	Male (n = 81) n (%)	Female (n = 112) n (%)	χ^2 (df)	*P*-value
Adiposity Characteristics						
Body adiposity index	Normal	49 (25.4)	25 (30.9)	24 (21.4)		
	Abnormal	144 (74.6)	56 (69.1)	88 (78.6)	6.20 (1)	0.030
Waist-to-hip ratio	Normal	56 (29.0)	21 (25.9)	35 (31.3)		
	Abnormal	137 (71.0)	60 (74.1)	77 (68.8)	0.67 (1)	0.421
Waist-to-height ratio	Normal	54 (28.0)	21 (25.9)	33 (29.5)		
	Abnormal	139 (72.0)	60 (74.1)	79 (70.5)	6.86 (1)	0.013
Nutritional Characteristics						
Body mass index	Normal	70 (36.3)	27 (33.3)	43 (38.4)		
	Abnormal	123 (63.7)	54 (66.7)	69 (61.6)	4.48 (1)	0.034

n (%): Frequency (percentage)

Bashir and Yarube, 2022; Chiba *et al*., 2020; Eze *et al*., 2015; Izquierdo *et al*., 2021; Karvani *et al*., 2019; Rizzo *et al*., 2022; Tianyi *et al*., 2019; Wang *et al*., 2019; Williams *et zal*., 2020; Yarube and Mukhtar, 2018; Delgado-Saborit *et al*., 2021; Jia *et al*., 2020; Mohamed *et al*., 2023; Zhen *et al*., 2019). The reasons for the discrepancies in findings observed could be the potential influence of cultural, genetic, or healthcare-related factors on CI in diabetes. Further research and targeted interventions are necessary to understand and address this significant public health issue. The results of this study indicate several significant risks of CI in patients with type-2 diabetes in Katsina State. First, the results of this study indicate that age is a significant risk factor for CI among individuals with type-2 diabetes in Katsina State, with patients aged 60 years and above having a higher likelihood of experiencing CI compared to those below 60 years of age. This finding aligns with the well-established notion that age is a significant risk factor for cognitive decline and dementia, and it is consistent with tive changes in the brain, which can exacerbate cognitive dysfunction in individuals with diabetes (Rundek *et al*., 2022). It underscores the importance of regular cognitive assessments and tailored interventions for elderly individuals with type-2 diabetes to mitigate the risk of CI and its associated complications.

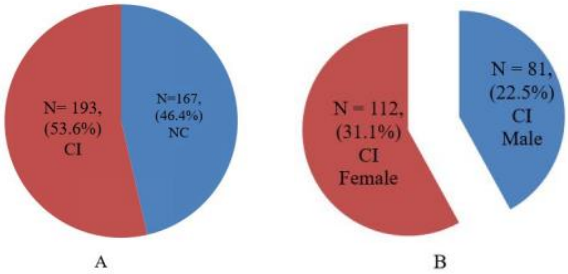

Fig. 1: Prevalence of cognitive impairment in the (A) overall study population and (B) based on sex [t(193) = 2.24, p = 0.02]. CI: cognitive impairment; NC: normal cognition.

Table 4: Risk factors for CI in T2DM

Variables		Simple logistic regression COR (95% CI)	*P*-value	Multiple logistic regression AOR (95% CI)	*P*-value
Socio-demographic characteristics					
Age	<60 years	Reference			
	≥60 years	0.115 (0.032-0.413)	0.001*	1.083 (0.19-0.359)	0.001*
Gender	Male	Reference			
	Female	0.635 (0.215-1.869)	0.409	1.032 (0.257-4.139)	0.014*
Marital status	Married	Reference			
	Unmarried	1.17 (0.430-3.181)	0.758	1.056 (0.304-3.666)	0.932
Level of education	Formal education	Reference			
	Non-formal education	0.113 (0.023-0.431)	0.001*	1.234 (0.431-4.111)	0.001*
Smoking status	Non-smokers	Reference			
	Smokers	1.392 (0.115-1.334)	0.034*	4.549 (0.104-5.886)	0.040*
Medical characteristics					
Duration of T2DM	<10 years	Reference			
	>10 years	2.507 (0.140-4.835)	0.031*	3.728 (0.164-3.240)	0.007*
Hypertension	Normotensive	Reference			
	Hypertensive	1.026 (0.346-3.045)	0.033*	1.217 (0.289-5.118)	0.019*
HbA	Normal	Reference			
	Abnormal	0.113 (0.013-0.512)	0.001*	2.234 (0.413-13.234)	0.001*
Nutritional characteristics					
Body mass index	Normal	Reference			
	Abnormal	0.190 (0.042-0.857)	0.031*	1.116 (0.018-2.751)	0.024*
Adiposity characteristics					
Waist-to-hip ratio	Normal	Reference			
	Abnormal	0.265 (0.059-1.195)	0.014*	1.478 (0.075-3.049)	0.035*
Waist-to-height ratio	Normal	Reference			
	Abnormal	1.273 (0.060-2.231)	0.041*	3.908 (0.119-6.933)	0.026*
Body adiposity index	Normal	Reference			
	Abnormal	0.360 (0.079-1.632)	0.185	0.124 (0.019-0.815)	0.03*

COR: Crude odd ratio; AOR: Adjusted odd ratio; CI: Confidence interval; HbA: Glycosylated haemoglobin; *significant at P < 0.05

findings from various global studies on diabetes-related CI (Connell *et al*., 2022; Meiner *et al*., 2020; Mohamed *et al*., 2023; Yarube and Mukhtar, 2018). Older age is associated with a greater likelihood of vascular and neurodegenera-

Second, in this study, female gender is a significant risk factor for CI in T2DM compared to males. This finding is intriguing and somewhat divergent from previous studies (Janghorbani *et al*., 2012; Johansson *et al*., 2015).

While evidence suggests that women may be more susceptible to CI in general (Belrose and Noppens, 2019), diabetes-related CI has often been linked to the male gender in some studies due to potential hormonal and metabolic differences (Dutta *et al*., 2022). Therefore, this result warrants further investigation and may highlight the need for gender-specific approaches in managing cognitive health among individuals with T2DM in Katsina State. To draw more definitive conclusions and gain a broader perspective, it would be beneficial to compare these findings with other studies conducted in different regions and populations, taking into account potential cultural and healthcare system variations that could influence the relationship between gender and CI in T2DM.

Third, patients with no formal education have nearly a two-times higher risk of developing CI than those with formal education. This finding underscores the importance of education as a protective factor against CI, which has been observed in other studies as well (Muhammad *et al*., 2022; Wang *et al*., 2020). Low education levels may limit individuals' access to information, healthcare, and cognitive stimulation, potentially increasing their vulnerability to CI.

Fourth, smoking is associated with a significantly higher risk of CI, with smokers having a 4.5 times higher risk compared to non-smokers. This result aligns with extensive research linking smoking to various health issues, including cognitive decline (Choi *et al*., 2018; Beydoun *et al*., 2014). Smoking is known to have detrimental effects on vascular health. It has been associated with increased oxidative stress, which can contribute to CI (Deal *et al*., 2020).

Fifth, the study identifies several other factors as significant risk factors for CI, including a disease duration greater than ten years, hypertension, poor glycaemic control, abnormal nutritional characteristics, abnormal waist-to-hip circumference, abnormal waist-to-height circumference, and abnormal body adiposity index. These findings are consistent with the existing literature, which highlights the role of diabetes-related factors, such as long disease duration (Pal *et al*., 2018), poor glycaemic control (Koh *et al*., 2022), and comorbid conditions like hypertension (Ungvari *et al*., 2021), in increasing the risk of CI in individuals with T2DM. Abnormal anthropometric measurements, such as waist-to-hip and waist-to-height ratios, can also indicate metabolic disturbances associated with cognitive decline (Xu *et al*., 2021).

Lastly, the study's finding of no significant association between marital status and CI suggests that in this particular population of individuals with type-2 diabetes, marital status does not appear to be a significant risk factor for CI. However, it is crucial to interpret these results cautiously, as the relationship between marital status and cognitive function can be influenced by various factors, including social support, lifestyle, and mental health (Shi *et al*., 2023). Comparing these findings with other studies is essential, as different populations may exhibit varying associations between marital status and CI. Some studies have reported that being married or in a committed relationship can have a protective effect on cognitive function, possibly due to increased social engagement and emotional support (Rutter, 2013), while others have found no significant relationship (Najar *et al*., 2021), similar to this study. Therefore, it is essential to consider the context and potential confounding variables when interpreting these results and to conduct further research to understand the complex interplay between marital status and cognitive health in individuals with type-2 diabetes.

While these findings are valuable, it is essential to acknowledge the limitations of this study, such as the relatively small sample size and the need for further research to confirm these associations. Additionally, the reported odds ratios indicate risks, but causation cannot be inferred from this cross-sectional study.

To gain a broader perspective and validate these findings, comparing them with results from other studies conducted in different regions and populations is crucial. Such comparative analyses could help identify common risk factors across diverse populations and highlight the potential influence of regional and cultural factors. Furthermore, longitudinal studies are needed to establish causal relationships and explore potential mechanisms underlying the observed associations between these risk factors and CI in individuals with type-2 diabetes. This can provide more robust evidence for developing targeted interventions and strategies to prevent or mitigate cognitive decline in this patient population.

By conducting a comprehensive investigation tailored to this specific region, this research has provided essential insights that will inform healthcare strategies, improve the quality of care, and enhance the overall well-being of individuals with T2DM in Katsina State.

Conclusion

Overall, the prevalence of CI is 53.6%. The results suggest that age ≥ 60 years, female gender, lack of formal education, smoking, longer disease duration, hypertension, poor glycaemic control, and abnormal nutritional and body adiposity characteristics are important factors associated with the risk of CI. These findings provide valuable insights into the potential risk factors for CI and highlight the importance of considering these factors in clinical assessments and interventions to prevent or manage CI. Henceforth, interventions such as health education and regular medical screening are required to enhance CI control programs in the state.

DECLARATION

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Conflict of Interest
None declared.

Ethical Approval
Ethical approval for the study was by the Health Research Ethics Committee of Ahmadu Bello University Zaria (Ref: ABU/HREC/G13/2020) and Katsina State Hospital Management Board (Ref: MOH/ADM/SUB/1152/1/462).

Consent to Participate and Publish Data
Informed consent was obtained from all individual participants included in the study and they also provided informed consent for publication.

Authors' Contribution
AI wrote the original manuscript draft. MT, UEU, and MM conceptualise the research idea and methodology. AI, HLS, AIA, AHB, YIS, ASU, ECU, MA, AN, SAB, and RAO did a literature search, data collection, and analysis and prepared the bibliography. MT, UEU, and MM review and modify the final draft of the manuscript. All authors have read and agreed to the published version of the manuscript.

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