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Original Research Article

Impact of Chronic Diabetes Mellitus on Cognitive Health in Aging Populations

Amrendra Prasad Singh[1], Shiv Shankar Prasad[2], Abhay Kumar Sinha[3]

[1]Assistant Professor, Department of Geriatric Medicine, Patna Medical College and Hospital, Patna, Bihar, India.

[2]Assistant Professor, Department of Geriatric Medicine, Patna Medical College and Hospital, Patna, Bihar, India.

[3]Assistant Professor and HOD, Department of Geriatric Medicine, Patna Medical College and Hospital, Patna, Bihar, India.

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Corresponding Author: Dr. Shiv Shankar Prasad

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Abstract:

Background: Diabetes mellitus (DM) is a chronic metabolic disorder increasingly prevalent among the elderly, with evidence suggesting its association with cognitive decline. Cognitive impairment in older adults adversely affects memory, executive function, and quality of life.

Aim: To assess the prevalence of cognitive impairment in elderly diabetic patients and identify associated risk factors.

Methodology: A hospital-based cross-sectional study was conducted among 90 diabetic patients aged ≥60 years at the Department of Geriatric Medicine, Patna Medical College and Hospital, India. Cognitive function was assessed using the Hindi Mental State Examination (HMSE). Socio-demographic, clinical, and glycemic data were collected. Statistical analysis included Chi-square tests and logistic regression.

Results: Cognitive impairment was observed in 53.3% of participants, with mild impairment being most common (31.1%). Age ≥70 years (AOR = 2.1, p = 0.02) and uncontrolled glycemia (AOR = 2.5, p = 0.01) were significant predictors. Gender, BMI, and diabetes duration were not significantly associated, whereas low literacy correlated with poorer cognitive performance.

Conclusion: Elderly diabetic patients, particularly those with advanced age and poor glycemic control, are at heightened risk of cognitive decline. Early cognitive screening, optimal glycemic management, and educational interventions are recommended to preserve cognitive and metabolic health.

Keywords: Diabetes Mellitus, Cognitive Impairment, Elderly, HMSE, Glycemic Control.

Introduction

Diabetes mellitus (DM) is a persistent metabolic disorder primarily characterized by chronic hyperglycemia due to defects in insulin production, insulin action, or both [1]. Over the past few decades, the incidence of diabetes has risen globally, particularly in older adults, and is now considered a significant public health concern. The International Diabetes Federation estimates that 1 in 10 adults worldwide have diabetes, a percentage which represents many adults over the age of 60 [2]. The aging process itself predisposes individuals to broad changes both physiologically and neurologically, and when the presence of diabetes is registered, these changes will affect the cognitive health of the individual as well. Cognitive decline in elderly adults typically presents as a decline in memory, executive functioning, attention, as well as slower processing speed, which may progress to a more extreme condition corresponding to a neurodegenerative disorder (e.g., mild cognitive impairment (MCI), dementia). There is increasing evidence that diabetes mellitus may be a risk factor for accelerated decline of cognition in adults, mainly linking metabolic disturbances with processes of neurodegeneration.

The pathophysiological mechanisms linking diabetes to cognitive impairment are complex and multifaceted. Chronic hyperglycemia results in microvascular and macrovascular complications of cerebral perfusion, as well as ischemic injury and white matter lesions [3]. Insulin resistance, a normal physiological feature of type 2 diabetes, negatively impacts neuronal function and synaptic plasticity, which inhibit learning and memory. Moreover, hyperglycemia may contribute to the generation of oxidative stress and inflammation that promote neuronal degeneration and amyloid-β deposition, all of which are involved in Alzheimer's disease pathology [4].

Advanced glycation end-products (AGEs) and chronic low-grade inflammation have been implicated in mediating cognitive impairment based on observational studies of diabetic subjects. The interaction of vascular, metabolic, and inflammatory pathways explains the complexity of the association between diabetes and subsequent cognitive decline.

Epidemiological studies have all shown a higher prevalence of cognitive impairment in elderly diabetic subjects than in their non-diabetic controls [5]. Longitudinal cohort studies have shown diabetic subjects to have higher rates of global cognitive decline, decline in episodic memory, and decline in executive function. Significantly, the risk of developing dementia has been found to be roughly twice that of elderly type 2 diabetic patients, emphasizing the clinical importance of assessing the cognitive status of this population [6]. Cognitive decline in diabetic patients impacts the quality of life but also creates a problem in the self-management of diabetes that perpetuates a bidirectional cycle where poor glycemic control further hastens the decline of cognition. It is therefore crucial to identify early cognitive alterations in elderly diabetic patients so that appropriate interventions are instituted early to maintain the level of cognition as far as possible and to optimize the metabolic control.

In addition to biological mechanisms, the contribution of the role of lifestyle factors and the highly prevalent comorbid conditions of elderly diabetic patients, such as hypertension, dyslipidemia, obesity, and physical inactivity, contributes to the cumulative risk of cognitive decline [7]. Social factors of health, for instance, educational attainment, socioeconomic position, and access to healthcare also impact the risk of elderly individuals to the complications related to diabetes and neurocognitive decline [8]. New clinical practice measures are giving increased importance to a multidisciplinary intervention that includes glycemic control, the management of cardiovascular risk factors, neuropsychological testing, and change in lifestyle in a move to avert the progression of cognitive impairments [9]. Additionally, biomarkers and studies using neuroimaging are providing increased understanding of the structural and functional modifications in the brain associated with diabetes and are promising for the early detection and specific therapeutic intervention.

Despite the aggregate evidence base for the connection between diabetes and cognitive decline, several research gaps remain. Heterogeneity of the study population, variation in diagnostic criteria for cognitive impairment, and variation in glycemia control parameters hinder the establishment of rigid causal relationships. Further research also is required for the temporal relationship between the onset of diabetes and the decrease in cognition and variable effects of type 1 versus type 2 diabetes. Clarifying these specifics is relevant for the establishment of individualized plans for management and prevention measures that are suitable for elderly diabetic patients. In aggregate, the establishment of diabetes mellitus as a modifiable risk factor for the decline in cognition has broad population health, clinical, and intervention testing implications for 'the promotion of healthy aging and cognitive resilience for the elderly population globally.

Methodology

Study Design: This was a hospital-based descriptive cross-sectional study conducted to assess the correlation between diabetes mellitus and cognitive decline in elderly patients. The study aimed to identify the prevalence of cognitive impairment among elderly diabetic patients and explore factors associated with cognitive decline.

Study Area: The study was conducted in the Department of Geriatric Medicine, Patna Medical College and Hospital, Patna, Bihar, India from January 2023 to December 2023

Inclusion and Exclusion Criteria

Inclusion Criteria: Patients of either gender, aged 60 years and above, diagnosed with diabetes mellitus (type 1 or type 2) and attending the outpatient or inpatient services of the Department of Geriatric Medicine were included in the study.

Exclusion Criteria: Patients with a known history of neuropsychiatric disorders, major depressive illness, or dementia prior to the diagnosis of diabetes were excluded. Additionally, individuals unable to communicate or follow the investigator's instructions, and those on chronic psychoactive medications, were excluded to ensure accurate cognitive assessment.

Sample Size: The sample size was calculated as 90 participants based on previous prevalence data of cognitive impairment among elderly diabetics and considering feasibility within the study period.

Procedure: Eligible participants were consecutively selected from the outpatient and inpatient registers of the Department of Geriatric Medicine. After obtaining written informed consent, participants were interviewed using a pre-tested semi-structured questionnaire to collect socio-demographic information, clinical history, duration of diabetes, glycemic control, comorbidities, and lifestyle factors. Cognitive function was assessed using the Hindi Mental State Examination (HMSE), a culturally adapted tool validated for use in elderly Indian populations. The HMSE evaluates orientation, attention, memory, language, and visuospatial abilities, with a maximum score of 30. Participants scoring below 26 were considered to have cognitive impairment and further classified as mild (21–25), moderate (11–20), or severe (≤10). Glycemic control was assessed

based on recent fasting and post-prandial blood sugar levels from hospital records, while body mass index (BMI) was calculated to assess nutritional status. Participants with significant cognitive impairment were referred to neurology or psychiatry services for further evaluation.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 27.0. Categorical variables were presented as frequency and percentage, whereas continuous variables were expressed as mean ± standard deviation. The association between diabetes-related factors and cognitive impairment was examined using the Chi-square test. Variables with significant associations were further analyzed using logistic regression to identify predictors of cognitive decline. A p-value of <0.05 was considered statistically significant, and results were reported as adjusted odds ratios with 95% confidence intervals.

Result

Table 1 also gives the socio-demographic details of the 90 participants. Most participants were between the ages of 60–64 years (31.1%), followed by those aged 65–69 years (28.9%), 70–74 years (22.2%), and ≥75 years (17.8%). Male participants also outnumbered females (57.8% vs. 42.2%). For educational status, a third of the participants were illiterate (33.3%), 31.1% had primary education, 22.2% secondary education, and 13.4% graduates or higher. Most participants were also occupied by being retired (55.6%), while homemakers constituted 33.3% and the remainder were occupied in other fields (11.1%). Analysis for socioeconomic status showed that half of the participants came from the middle class (50%), 38.9% came from the lower class, and 11.1% from the upper class. Generally, the table indicates a predominantly male population of predominantly retired persons of the middle-aged to elderly group with diversified educational background and socioeconomic status.

Table 1: Socio-demographic Characteristics of Study Participants (n = 90)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	60–64	28	31.1
	65–69	26	28.9
	70–74	20	22.2
	≥75	16	17.8
Gender	Male	52	57.8
	Female	38	42.2
Education	Illiterate	30	33.3
	Primary	28	31.1
	Secondary	20	22.2
	Graduate and above	12	13.4
Occupation	Retired	50	55.6
	Homemaker	30	33.3
	Others	10	11.1
Socioeconomic Status	Lower	35	38.9
	Middle	45	50
	Upper	10	11.1

Table 2 provides the clinical characteristics of the participants. For the duration of the diabetes, the majority of the participants (44.4%) experienced it for 5–10 years while 24.4% experienced it for fewer than 5 years while 31.1% experienced it for more than 10 years. For the type of diabetes experienced by the participants, the majority of the participants (91.1%) experienced type 2 diabetes while a negligible 8.9% experienced type 1 diabetes. Glycemic control evaluation showed that 42.2% of the participants experienced normalized blood glucose levels while 57.8% experienced uncontrolled levels. For the body mass index (BMI) distribution, the finding showed that 44.4% of the participants were of normal weight while 22.2% were overweight while another 22.2% were obese while 11.1% were underweight representing a significant number of participants having weight disturbances that may affect the management of their diabetes.

Table 2: Clinical Characteristics of Participants

Variable	Category	Frequency (n)	Percentage (%)
Duration of Diabetes	<5 years	22	24.4
	5–10 years	40	44.4
	>10 years	28	31.1
Type of Diabetes	Type 1	8	8.9

	Type 2	82	91.1
Glycemic Control	Controlled (FBS ≤125 mg/dl & PPBS ≤200 mg/dl)	38	42.2
	Uncontrolled (FBS >125 mg/dl or PPBS >200 mg/dl)	52	57.8
BMI (kg/m²)	Underweight (<18.5)	10	11.1
	Normal (18.5–22.9)	40	44.4
	Overweight (23–24.9)	20	22.2
	Obese (≥25)	20	22.2

Table 3 explains the research participants' cognitive performance using their HMSE scores. A majority of the participants, that is 42 participants (46.7%), showed the normal level of cognitive performance denoted by a score between 26 and 30. Mild impairment of the cognition, represented by the score between 21 and 25, characterized 28 participants (31.1%), while a moderate level of impairment represented by the score between 11 and 20 accounted for 16 participants (17.8%). A serious level of impairment represented by the score of 10 and below accounted for 4 participants (4.4%). Together, over half of the participants (48 participants, 53.3%) scored below 26 using the HMSE test, indicating a level of cognitive impairment.

Table 3: Cognitive Function Based on HMSE Scores

HMSE Score	Cognitive Status	Frequency (n)	Percentage (%)
26–30	Normal	42	46.7
21–25	Mild Impairment	28	31.1
11–20	Moderate Impairment	16	17.8
≤10	Severe Impairment	4	4.4
<26	Overall Cognitive Impairment	48	53.3

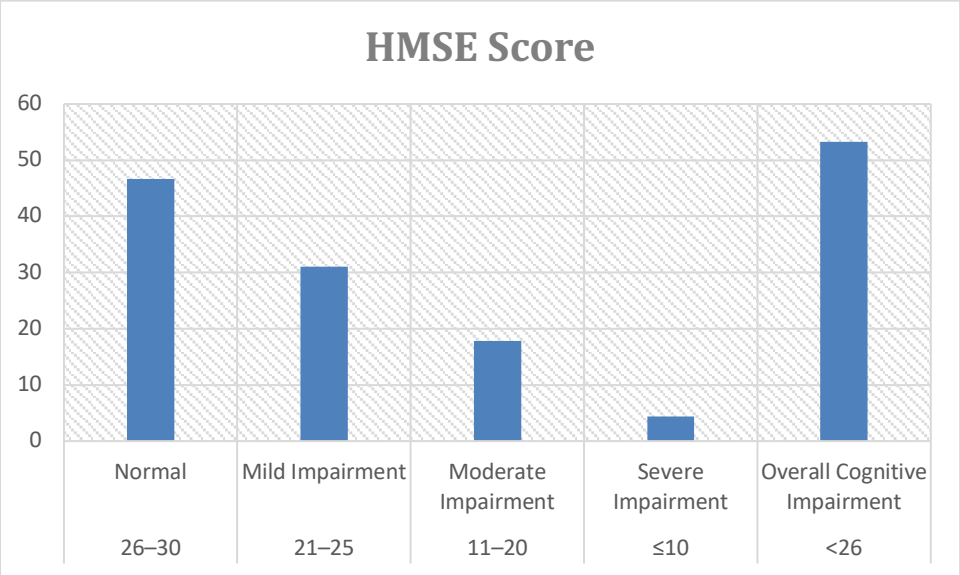

Figure 3: Cognitive Function Based on HMSE Scores

Table 4 also establishes the connection between glycemic control and the presence of cognitive impairment in participants in this study. Of the 38 participants that preserved controlled glycemic levels, 16 (42.1%) revealed evidence of cognitive impairment while 22 (57.9%) revealed no such impairment. Of the 52 participants that revealed uncontrolled glycemic levels, 32 (61.5%) revealed evidence of cognitive impairment while 20 (38.5%) revealed none. The overall sample consisted of 90 participants where 48 (53.3%) revealed evidence of cognitive impairment while the other 42 (46.7%) revealed none. The relationship established showed statistical significance ($p = 0.03$), a fact that indicates that poor glycemic control significantly corresponds to increased cognitive impairment prevalence for this population.

Table 4: Association Between Glycemic Control and Cognitive Impairment				
Glycemic Control	**Cognitive Impairment Present**	**Cognitive Impairment Absent**	**Total**	**P-value**
Controlled	16	22	38	0.03*
Uncontrolled	32	20	52	
Total	48	42	90	

Table 5 determines the result of logistic regression analysis that establishes factors associated with cognitive impairment for participants under study. Specifically, participants aged over 70 years significantly exhibited higher odds of having cognitive impairment (AOR = 2.1, 95% CI: 1.1–4.2, p = 0.02), thereby establishing that aged adults are over twice as likely to experience cognitive decline than their youthful counterparts. Second, poor glycemic control emerged as another significant predictor (AOR = 2.5, 95% CI: 1.2–5.1, p = 0.01), translating to poorly controlled diabetes significantly elevating the risk of cognitive impairment. Conversely, a history of diabetes that extended beyond 10 years revealed a tendency towards a higher risk (AOR = 1.8, 95% CI: 0.9–3.5); however, the association failed to reach statistical significance (p = 0.07). Further, gender and body mass index (BMI) failed to indicate significant association for cognitive impairment with p-values of 0.35 and 0.32 for gender and BMI respectively, which indicates the absence of perceived influence from these factors by the studied population.

Table 5: Logistic Regression Analysis for Predictors of Cognitive Impairment			
Variable	**Adjusted Odds Ratio (AOR)**	**95% Confidence Interval (CI)**	**P-value**
Age (≥70 years vs <70)	2.1	1.1–4.2	0.02
Gender (Female vs Male)	1.3	0.7–2.5	0.35
Duration of Diabetes (>10 years vs <10 years)	1.8	0.9–3.5	0.07
Glycemic Control (Uncontrolled vs Controlled)	2.5	1.2–5.1	0.01
BMI (Overweight/Obese vs Normal)	1.4	0.7–2.8	0.32

Discussion

This study assessed the cognitive impairment of older patients with diabetes mellitus, and the prevalence rate was 53.3%, with mild cognitive impairment being the most prevalent. This prevalence is fairly consistent with Khullar et al. (2017) [10], which reported a prevalence rate of 33.7% in populations of type 2 diabetes in Punjab, India, and Mukherjee et al. (2012) [11], which reported cognitive impairment in 42% of diabetic elderly participants. However, our prevalence rate is higher than that of Tiwari et al. (2012) [12] and Krishnamoorthy et al. (2019) [13], which had prevalence rates of 9.6% and 10.8%, respectively, in rural and urban Indian populations. Differences in study population, use of cognitive testing measures and cut-off scores for impairment, and inclusion of older individuals or those with more advanced disease or poor glycemic control would potentially contribute to disparities in cognitive impairment prevalence rates. Similarly, Pednekar et al. (2016) [14] reported a much higher prevalence rate of 74%, perhaps due to the use of more sensitive cognitive testing batteries or inclusion of studies that focus on diabetes duration in chronically poor glycemic control in cohorts. These examples also illustrate how methodological differences can influence findings related to cognitive impairment rates.

In our study, age was an important predictor, with participants aged ≥70 years having more than twice the risk of cognitive impairment (AOR = 2.1). This finding aligns with earlier findings from Murman (2015) [15] that advancing age is strongly associated with structural and functional brain changes, including white matter degeneration and reduced hippocampal volume, that negatively impact cognitive function. In these previous studies, Khullar et al. (2017) [10] and Mukherjee et al. (2012) [11] reported increasing rates of cognitive deficits with older age, allowing for an understanding of the interaction between age-related neurodegeneration and diabetes-related neurotoxic metabolic disorders that led to cognitive impairment. Our study additionally indicated that the rate of cognitive impairment was also significant in the 60–69-year-old group of participants (33.5%), meaning cognitive vulnerability may, indeed, begin prior to the elderly diabetic's age.

Glycemic control proved to be another important factor in our study, with 61.5% of participants with uncontrolled diabetes showing cognitive deficits, compared to those who had controlled glycemia (42.1%, p = 0.03). Through logistic regression, we found uncontrolled diabetes to be a 2.5-fold independent predictor of cognitive impairment. These results correspond with the reports from Munshi

(2017) [16] and Sheen and Sheu (2016) [17] that chronic hyperglycemia and recurrent hypoglycemic episodes lead to hippocampal dysfunction, oxidative stress and cerebrovascular damage, which are all associated with neurocognitive decline. The significant relationship between dysregulated glycemia and cognitive impairment found in our study highlights the importance of achieving strong metabolic control in reducing cognitive risk in older diabetics.

In terms of gender, we did not find a statistically significant relationship, although some previous studies suggest that females are more susceptible because of genetic and hormonal factors (Yaffe et al., 2004 [18]; Lin et al., 2015) [19]. Female carriers of the apolipoprotein E4 allele or brain-derived neurotrophic factor variants, for example, have been shown in some prior studies to experience accelerated cognitive decline in the presence of impaired glucose metabolism. This suggests that gender effects may depend on the characteristics of the population studied and the sample size. Larger study samples are needed to understand sex-specific vulnerabilities to cognitive impairment in adults with diabetes.

In our population, education and literacy have a strong correlation with cognitive functioning. A third of the participants were illiterate, and this condition is associated with lower HMSE scores. Such findings are consistent with the evidence provided by Sengupta et al. (2014) [20], where lower education has been shown to reduce cognitive reserve and neuropsychological test adaptation, thereby increasing the risk for dementia. Also, poor literacy may impede health literacy in such persons, which may hinder appropriate self-management of their diabetes and consequently impact their cognitive functions. These findings emphasize the need for appropriate educational programs and cognitive activity plans for elderly diabetic patients having poor levels of literacy.

The current study failed to find a significant correlation between the duration of diabetes or body mass index (BMI) and cognitive impairment that is in contrast to various previous studies that have indicated that long disease duration and obesity are risk factors for the decline in cognition (Khullar et al., 2017). On the other hand, our findings are in agreement with Mukherjee et al. (2012) that glycemic control has a shorter-term impact on the cognitive function of elderly patients than the total duration of the condition or body composition measures. This indicates a complicated relationship between the regulation of metabolism and the measures of cognition, rather than static constructs that are dependent solely upon demographic and anthropometric measures.

Thirdly, the concomitancy between possible hypoglycemic episodes and the decline in cognition observed in the current sample is supported by existing evidence for a bidirectional association between hypoglycemia and dementia (Sheen & Sheu, 2016). Incident or recurrent hypoglycemia may cause damage to neurons and hasten neurodegenerative processes and hence the importance of careful glycemic control measures in the elderly.

Overall, our findings indicate that elevated age and poorly controlled diabetes are the strongest predictors of decline in cognition in the elderly diabetic population, supported by previous studies (Munshi, 2017; Khullar et al., 2017; Mukherjee et al., 2012). Literacy and glycemic control emerged as modifiable factors for intervention although gender, body mass index (BMI), and disease duration showed erratic relations. With emphasis on the need for continuous evaluation of cognition, patient education, and improved control of the diabetic patient's condition, our study adds depth to the literature on the decline in cognition in the elderly.

Conclusion

The present study reports a significant prevalence of cognitive impairment (53.3%) in older adults with diabetes mellitus, with most cases of mild impairment. Older age (≥70 years) and poor glycemic control were strong and significant predictors of cognitive impairment, which suggests that older adults and those with uncontrolled diabetes have a high risk for cognitive decline. Although gender, BMI and duration of diabetes were not predictive, literacy level and educational status were all significant contributors to cognitive performance. Literacy represents a type of cognitive reserve, and educational status is a marker of health literacy, both of which promote disease management and cognitive health. Considering these results, early cognitive screening, strict glycemic control, and educational interventions may promote improved cognitive function. In summary, modifying external factors may promote metabolic and cognitive health among older adults with diabetes.

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