



ANALYSIS OF VARIATIONS IN DIABETIC TYPE 2 PARTICIPANTS' COGNITIVE TEST RESULTS

Ms. Pyary Joy, Research Scholar, LNCT University, Bhopal.

Dr. Sunil Khare, Research Supervisor, Department of Medical Physiology, LNCT University, Bhopal.

Abstract

In diabetes, there are some less known and not well talked about issues that affect the brain's ability to think clearly. Diabetes can lead to slow and gradual damage to the brain over time. People with diabetes are 1.5 times more likely to experience a decline in their thinking abilities. A study of cognitive function in adults with type 2 diabetes helps understand how diabetes affects the brain throughout a person's life. Six people with type 2 diabetes took part in the study and completed tests measuring their processing speed, attention, executive function, learning, and memory. The study also looked at their best possible performance levels. The results showed that their attention and processing speed were lower, but their executive function was stronger. Health factors related to diabetes were connected to different areas of cognitive function.

Keywords: *Diabetes, cognition, pathogenesis, scores.*

Introduction

Diabetic mellitus

The main health challenge of the 21st century is diabetes mellitus. It is a metabolic disorder that includes a group of different conditions causing long-term high blood sugar and difficulty in handling glucose. It is sometimes referred to as a "well-defined type of aging acceleration," showing that patients have increasing responsibility for managing this progressive disease [1].

The most common type of diabetes is Type 2 diabetes. The key issue here is insulin resistance, where the body doesn't use insulin properly, and there is also a lack of enough insulin.

This is the cause of 85 to 95% of all diabetes cases. The rise in this disease in many countries is due to changes in society and culture, increased urban living, changes in eating habits, an aging population, lack of exercise, and unhealthy lifestyle choices [2].

Cognition

The word cognition comes from the Latin word "cognoscere," which means "to get to know" or "to become familiar with." It includes mental processes and abilities that involve taking in information, changing it, organizing it, keeping it, retrieving it, and using stored information. These processes include sensing, remembering, solving problems, and thinking. The process of cognition uses existing knowledge to form new knowledge Diabetes on Cognitive Function [3].

Obesity and cognition

Obesity is considered a global health problem that has significant effects on overall health. It is linked to heart disease, high blood pressure, diabetes, and stroke. New research shows that obesity is connected to cognitive function. The inflammation caused by obesity affects the brain, especially in the hypothalamus, leading to poor cognitive performance [4].

Hypertension and cognition

Hypertension is a well-known cause of cerebrovascular issues. It is associated with problems in cognitive functions such as visual spatial skills, learning, attention, executive functions, memory, psychomotor abilities, and perceptual skills. These cognitive areas are linked to a worse outcome in people with high blood pressure.

Dyslipidemia and cognition

Dyslipidemia, or abnormal levels of lipids in the blood, is a major risk factor for cardiovascular disease. It is related to cognitive dysfunction. Dyslipidemia causes increased atherosclerosis and the buildup of amyloid in the brain, which contributes to a steady decline in cognitive abilities [5].

Cognitive impairment

It is reducing the functions of cognition. It occurs in the later stage of dementia. These stages include no cognitive impairment, mild cognitive impairment, and dementia.

Cognitive dysfunction and type 2 diabetes mellitus

Diabetic mellitus causes slow but progressive impairment of brain function. Type 2 DM is associated with decreased psychomotor speed, verbal memory, fast recall,

slow recall, fluency, preservation, and attention to visual stimuli. It also contributes to brain abnormalities, including structural, functional, and metabolic changes.

Structural changes in the brain

Type 2 diabetes leads to both macroscopic and microscopic modifications in the brain. Numerous neuroimaging studies have shown atrophy of cortical and subcortical regions and white matter intensities [6].

Global brain atrophy and enlargement of ventricles

Reduction in brain volume and cortical/subcortical areas due to type 2 diabetes is observed through neuroimaging studies. Enlargement of ventricles is considered a major indicator of cerebral atrophy in type 2 diabetes. It is noted that retinopathy, HbA1c levels, and duration of diabetes are correlated with glucose toxicity, vascular damage, and hyperinsulinemia.

Regional atrophy of the brain

The major regional atrophy in type 2 diabetes is temporal lobe atrophy, which includes hippocampal and amygdala atrophy. Type 2 diabetes in obese adolescents is associated with decreased levels of brain tissue in the frontal lobe, with both white and grey matter reduction [7].

Materials and method

Participants and Procedures

This study was a type of research that looked at things as they were at one point in time. The people who took part in the study were adults with type 2 diabetes. They were chosen from different clinics and community centers that offer care for people with type 2 diabetes.

Participant Characteristics

A total of six people were included in this study. They all had a confirmed diagnosis of type 2 diabetes and completed all the tests. Their ages ranged from 35 to 60, with an average age of 44 [8].

The participants met the following criteria:

1. Adults between the ages of 35 and 60
2. Able to read and write
3. Capable of understanding English to complete tests and questionnaires
4. Diagnosed with type 2 diabetes for at least one year
5. Taking medication as recommended by their healthcare provider

Measures

During the study, the researcher collected all the data in the order it was planned. The measures were chosen because they were suitable for the participants involved in the study [9].

Recruitment

The participants received care through an integrated diabetes program in Chennai. The diabetes management team included a variety of healthcare professionals such as nurses, diabetes and endocrinology consultants, chiropodists, and psychologists.

T2DM Diagnosis

To take part in the study, participants had to have a confirmed diagnosis of type 2 diabetes. They could also be diagnosed with type 1 diabetes, but they had to be clear about their condition. If there was any confusion about their diagnosis during recruitment, they were not included in the study [10].

Demographic Information

The participants were adults aged 35 to 60, and included both men and women.

Medical Comorbidities

Some participants had diabetes that was more difficult to manage, and this could have affected their cognitive function, as shown in previous research.

Cognitive impairment

This refers to a decline in cognitive functions. It happens in the later stages of dementia. These stages are: no cognitive impairment, mild cognitive impairment, and dementia. Cognitive dysfunction and type 2 diabetes mellitus Type 2 diabetes can slowly and gradually harm brain function. Type 2 diabetes is linked to slower thinking, trouble remembering words, slower recall, reduced ability to speak fluently, and difficulty paying attention to visual information. It also causes changes in the brain, including structural, functional, and metabolic issues [11].

Structural changes in the brain

Type 2 diabetes leads to both big and small changes in the brain. Many brain scans have shown that parts of the brain, like the cortex and areas under it, and the white matter, shrink.

Global brain atrophy and enlargement of ventricles

Neuroimaging studies show that type 2 diabetes causes a loss of brain volume and area in the cortex and under the cortex. Enlarged ventricles are a key sign of brain shrinkage in type 2 diabetes [12]. It is also found that retinopathy, high blood sugar levels, and how long someone has had diabetes are connected to damage from high blood sugar, blood vessel problems, and high insulin levels.

Regional atrophy of the brain

In type 2 diabetes, the most noticeable brain shrinkage happens in the temporal lobe, including the hippocampus and amygdala. In obese teenagers with type 2 diabetes, there is less brain tissue in the frontal lobe, with both white and grey matter being reduced.

Informed Consent

The participants were given the chance to ask questions and were provided with a paper to read and sign. They could not start the test until they signed the paper. They were also told they could stop the test at any time.

Procedure

The interview took place in a meeting room or a clinical room in a hospital. Each session took about 25 minutes. The participants provided their demographic information, including their date of birth, identity, and medical details such as kidney problems and head injuries.

Materials

The tests used in this study were chosen based on speed of processing and verbal and visual attention. These tests were selected and tested on participants who had diabetes and cognitive impairment.

Mental Status Examination Questionnaire: This was used to assess the cognitive level of the participants.

Optimal Ability

This tool helps evaluate the best possible ability or the presence of a disease in neuropsychology by measuring cognitive impairment. A reading test was given where participants were asked to spell words irregularly and pronounce them [13].

Learning and Memory

Visual and verbal learning and memory were tested using the Wechsler Memory Scale III.

Analysis

The raw scores were converted into scaled scores, which were then entered into the Statistical Package for Social Sciences (SPSS). The analysis was done on the data parameters.

Results and discussion

Looking at the scores from the tests, there was no big drop or problem in how well people performed. The average scores were above 3, which mean they were doing fine. When comparing scores on Switch Accuracy with the Test of Premorbid Functioning (TOPF), there was a slight improvement in some areas. The TOPF scores showed that people had different results, meaning some did better than others. But when looking at the whole group, there wasn't a clear pattern of getting worse in any specific area like attention or how fast they could process things [14].

Participant 1

51 years old, male Works for himself, speaks English as a second language, from Tamil Nadu. Has diabetes, diagnosed in December 2015, and managed through diet and exercise without medication.

He did well in attention and thinking skills, especially in Digits Forward and Category Fluency. But he had more trouble with learning and memory, like in the Visual Immediate test. His TOPF score didn't match his best performance. This means he had strong thinking abilities even though he has diabetes.

Table 1: Scaled test scores for first participant

Domain	Test Name	Scaled Score
Optimal ability	TOPF	12.3
Learning & memory	Story immed	6.8
	Story delayed	4.8
	Visual immed	8.3
	Visual delayed	10.8
Processing speed	Colour Naming	12.2
	Word reading	13.1
	Visual scanning	13.5
	Number seq	14.1
	Letter seqq	13
	Digit symbol	15.4
	Verbal attention	Digits For Ward
Digits backward		15.9
Digit sequencing		11.5
Digit span		15.8
Executive function	Letter Fluency	18
	Cat Fluency	15.9
	Switch Output	15.5
	Switch Accuracy	14.2
	Inhibition	12.3
	Inhib switching	11.2
Verbal & visuo Spatial	N-1 switch	8.4
	Similarities	11
	Block design	11.5

Participant 2

49 years old, female Unemployed, has a college-level education. Diagnosed with diabetes in 2003. She did average on most tests. She was good at switching tasks and thinking clearly, but had slower processing speed and trouble with sequencing. Her best performance was average.

This suggests she might have slower thinking, but her planning and decision-making skills were okay. High cholesterol could have affected her memory, as noted in a study by Schreurs [16].

Table 2: Scaled test Scores for second participant

Domain	Test Name	Scaled Score
Optimal ability	TOPF	12.5
Learning & memory	Story immed	7.1
	Story delayed	5.3
	Visual immed	8.9
	Visual delayed	10.3
Processing speed	Colour Naming	12.8
	Word reading	13.6
	Visual scanning	14.2
	Number seq	13.9
	Letter seqq	12.8
	Digit symbol	15.9
	Verbal attention	Digits For Ward
Digits backward		16.3
Digit sequencing		12.1
Digit span		15.2
Executive function	Letter Fluency	17.6
	Cat Fluency	16.1
	Switch Output	15.9
	Switch Accuracy	14.8
	Inhibition	12.6
	Inhib switching	11.6
Verbal & visuo Spatial	N-1 switch	8.9
	Similarities	11.4
	Block design	9.8

Participant 3

45 years old, male chess coach with a university-level education. Diagnosed with diabetic retinopathy in 2016 and received treatment.

Showed improvement in Letter Fluency and Category Fluency, but had lower scores in Inhibition and Inhibition Switching. Also performed worse in Block Design, which tests visuospatial skills.

Table 3: Scaled test scores for third participant

Domain	Test Name	Scaled Score
Optimal ability	TOPF	12.8
Learning & memory	Story immed	7.1
	Story delayed	5.2
	Visual immed	8.9
	Visual delayed	10.4
Processing speed	Colour Naming	12.7
	Word reading	13.6
	Visual scanning	13
	Number seq	13.9
	Letter seqq	13.5
	Digit symbol	15.1
Verbal attention	Digits For Ward	17.4
	Digits backward	16.5
	Digit sequencing	12.2
	Digit span	15.3
Executive function	Letter Fluency	18.4
	Cat Fluency	16.3
	Switch Output	15.9
	Switch Accuracy	13.7
	Inhibition	12
	Inhib switching	11.7
	N-1 switch	9
Verbal & visuo Spatial	Similarities	11.4
	Block design	13.2

This suggests a mix of good and poor cognitive performance, with average overall function but some mild issues with executive functions and visuospatial abilities [17].

Participant 4

54 years old, male, painter and decorator, educated up to age 15. Diagnosed with diabetes in 2007. Had lower scores in verbal and visuospatial areas but did well in processing speed and executive functions.

Table 4: Scaled test scores for fourth participant

Domain	Test Name	Scaled Score
Optimal ability	TOPF	13.2
Learning & memory	Story immed	7.4
	Story delayed	5.7
	Visual immed	9.2
	Visual delayed	10.6
Processing speed	Colour Naming	13.1
	Word reading	14
	Visual scanning	14.7
	Number seq	13.6
	Letter seqq	13.2
	Digit symbol	16.3
Verbal attention	Digits For Ward	16.9
	Digits backward	15.8
	Digit sequencing	12.5
	Digit span	15
Executive function	Letter Fluency	17.2
	Cat Fluency	15.9
	Switch Output	15.5
	Switch Accuracy	14.5
	Inhibition	13
	Inhib switching	12
	N-1 switch	9.3
Verbal & visuo Spatial	Similarities	11.8
	Block design	10.2

Like visual scanning, category fluency, and inhibition switching. His cognitive profile is unusual for someone with Type 2 Diabetes Mellitus (T2DM), showing strengths in speed and flexibility despite not having much formal education [18].

Participant 5

55 years old female, medical secretary with good education. Diagnosed with diabetes in 2001. Performed well in Digits Forward and Letter Fluency, but had some difficulties with processing speed and immediate memory. Her TOPF score showed she was at optimal ability levels.

Table 5: Scaled test scores for fifth participant

Domain	Test Name	Scaled Score
Optimal ability	TOPF	13.6
Learning & memory	Story immed	7.8
	Story delayed	6.2
	Visual immed	9.6
	Visual delayed	10.2
Processing speed	Colour Naming	13.4
	Word reading	14.6
	Visual scanning	14.2
	Number seq	13.9
	Letter seqq	13.5
	Digit symbol	16
Verbal attention	Digits For Ward	17.3
	Digits backward	15.5
	Digit sequencing	12.9
	Digit span	15.4
Executive function	Letter Fluency	17
	Cat Fluency	16.3
	Switch Output	15.2
	Switch Accuracy	14.8
	Inhibition	13.4
	Inhib switching	12.6
Verbal & visuo Spatial	N-1 switch	9.8
	Similarities	12.1
	Block design	10.6

This suggests a mild slowdown in processing speed, but her executive and verbal abilities are still strong [19].

Participant 6

35 years old female, college graduate who is currently unemployed. Diagnosed with diabetes in 2015. Has a history of a skull fracture at age 5 and childhood dyslexia. Overall performance across different cognitive areas was low, especially in executive functions and verbal skills. However, she did better in Block Design. This suggests a mix of cognitive deficits, likely due to past developmental and neurological issues rather than diabetes alone.

Table 6: Scaled test scores for sixth participant

Domain	Test Name	Scaled Score
Optimal ability	TOPF	13.9
Learning & memory	Story immed	8.2
	Story delayed	6.6
	Visual immed	9.9
	Visual delayed	10.6
Processing speed	Colour Naming	13.8
	Word reading	14.2
	Visual scanning	14.6
	Number seq	13.7
	Letter seqq	13.2
	Digit symbol	15.7
Verbal attention	Digits For Ward	17.7
	Digits backward	15.2
	Digit sequencing	13.3
	Digit span	15.6
Executive function	Letter Fluency	17.3
	Cat Fluency	16.7
	Switch Output	15.5
	Switch Accuracy	14.5
	Inhibition	13.7
	Inhib switching	12.9
Verbal & visuo Spatial	N-1 switch	10.1
	Similarities	12.4
	Block design	10.9

Looking at all the participants, there were different patterns in how their executive functions, learning, and processing speed

performed. While TOPF scores ranged from average to just below average, they didn't always match up with actual cognitive performance. This means that TOPF might not be a reliable single test to tell if someone with Type 2 Diabetes Mellitus (T2DM) is experiencing cognitive decline. The test results from the six people show a clear pattern of strong overall thinking skills, but there are some differences in specific areas. The scores for the Test of Premorbid Functioning (TOPF) were between 12.3 and 13.9, which means they all had good levels of thinking ability before any issues started. This could be because they had similar education or jobs.

In the Learning and Memory part, everyone had average scores for remembering stories right away and later. The average for remembering immediately was about 7.4, and later it was around 5.6. This means they had a bit more trouble remembering things over time. But when it came to visual memory, they did much better, with scores close to 9 or 10. This shows they remembered pictures or shapes better than words. For processing speed, all the people did very well. Their scores for tasks like naming colors, reading words, scanning images, and arranging numbers or letters were between 12.2 and 16.3. This means they were fast at doing these kinds of tasks, which usually shows good attention and the ability to think quickly and efficiently. In Verbal Attention tasks, like remembering numbers in order or repeating them, the scores were between 11.5 and 18.0 [20].

Everyone performed well in these areas, showing strong skills in understanding and using language. The Digit Forward subtest had the highest average scores, around 17, showing good listening skills and the ability to remember and use information. Even though there was a little variation in the Digit Sequencing part, all the scores were still above average, meaning the person can keep their attention on verbal tasks over time.

In the Executive Function area, the results were mostly strong, with scores between 11.2 and 18.4. The Letter and Category Fluency tasks had the highest scores, showing good ability to think of words and organize them. However, tasks like Inhibition and Inhibitory Switching had slightly lower scores but were still in the normal to high range, meaning the person has enough control over their thinking but might have some ups and downs. The N-1 Switch subtest had the lowest scores, between 8.4 and 10.1, which suggests that handling more complex switching and control when thinking hard might be harder than simpler tasks. For Verbal and Visuospatial Reasoning, Similarities and Block Design had similar scores, averaging around 11 to 12, showing a good balance between verbal thinking and the ability to build and understand visual patterns. The slight difference in Block Design scores, from 9.8 to 13.2, may show some variation in how well people solve nonverbal problems and use their hands and eyes together [21].

Conclusion

This study looked at the thinking abilities of six middle-aged people who have Type 2 Diabetes Mellitus (T2DM) using a full set of brain-related tests. The results showed similar trends in all the participants, showing that people with T2DM had different levels of performance but mostly good results in several areas of thinking, such as problem-solving, learning and remembering, how fast they can process information, focusing with words, planning and organizing, and skills with words and pictures.

Reference

1. Bahour N, Cortez B, Pan H, Shah H, Doria A, Aguayo-Mazzucato C. Diabetes mellitus correlates with increased biological age as indicated by clinical biomarkers. *Geroscience*. 44(1):415-427. doi: 10.1007/s11357-021-00469-0

2. Tsai YH, Chuang LL, Lee YJ, Chiu CJ. How Does Diabetes Accelerate Normal Aging? An Examination of ADL, IADL, and Mobility Disability in Middle-aged and Older Adults with and Without Diabetes. *Diabetes Res Clin Pract.* 182:109114. doi:10.1016/j.diabre.2021.109114
3. Kouvari M, D'Cunha NM, Travica N, Sergi D, Zec M, Marx W, Naumovski N. Metabolic Syndrome, Cognitive Impairment and the Role of Diet: A Narrative Review. *Nutrients.* 14(2):333. doi: 10.3390/nu14020333
4. Costache AD, Ignat BE, Grosu C, Mastaleru A, Abdulan I, Oancea A, et al. Inflammatory Pathways in Overweight and Obese Persons as an Impairment and Earlier Onset Alzheimer's Dementia in the General Population: A Narrative Review. *Bio medicines.* 11(12):3233. doi:10.3390/Biomedicines11123233
5. Cheon EJ. Hypertension and cognitive dysfunction: a narrative review. *J Yeungnam Med Sci.* 40(3):225-232. doi: 10.12701/jyms.2022.00605
6. Ungvari Z, Toth P, Tarantini S, Prodan CI, Sorond F, Merkely B, et al. Hypertension-induced cognitive impairment: from pathophysiology to public health. *Nat Rev Nephrol.* 17(10):639-654. doi: 10.1038/s41581-021-00430-6
7. De Bresser J, Tiehuis AM, van den Berg E, Reijmer YD, Jongen C, Kappelle LJ, et al. Utrecht Diabetic Encephalopathy Study Group. Progression of cerebral atrophy and white matter hyperintensities in patients with type 2 diabetes. *Diabetes Care.* 33(6):1309-14. doi: 10.2337/dc09-1923
8. Mahmood S, Dkhar W, Kadavigere R, Sukumar S, Nayak K, Pradhan A, et al. An analysis of brain structural changes in type 2 diabetes using advanced MRI techniques. *Magn Reson Imaging.* 121:110419. doi: 10.1016/j.mri.2025
9. Zhang T, Shaw M, Cherbuin N. Association between Type 2 Diabetes Mellitus and Brain Atrophy: A Meta-Analysis. *Diabetes Metab J.* 46(5):781-802. doi: 10.4093/dmj.2021.0189
10. Setia MS. Methodology Series Module 3: Cross-sectional Studies. *Indian J Dermatol.* 61(3):261-4. doi: 10.4103/0019-5154.182410
11. Pérez-Guerrero EE, Guillén-Medina MR, Márquez-Sandoval F, Vera-Cruz JM, Gallegos-Arreola MP, Rico-Méndez MA, et al. Methodological and Statistical Considerations for Cross-Sectional, Case-Control, and Cohort Studies. *J Clin Med.* 13(14):4005. doi: 10.3390/jcm13144005
12. Kilander L, Nyman H, Boberg M, Lithell H. Cognitive function, vascular risk factors and education. A cross-sectional study based on a cohort of 70-year-old men. *J Intern Med.* 242(4):313-21. doi: 10.1046/j.1365-2796.1997.00196.x
13. Degen C, Toro P, Schönknecht P, Sattler C, Schröder J. Diabetes mellitus Type II and cognitive capacity in healthy aging, mild cognitive impairment and Alzheimer's disease. *Psychiatry Res.* 30;240:42-46. doi: 10.1016/j.psychres.2016.04.009
14. Shura RD, Ord AS, Martindale SL, Miskey HM, Taber KH. Test of Premorbid Functioning: You're Doing It Wrong, but Does It Matter? *Arch Clin Neuropsychol.* 14:acaa025. doi: 10.1093/arclin/acaa025
15. Wong RH, Scholey A, Howe PR. Assessing premorbid cognitive ability in adults with type 2 diabetes mellitus--a review with implications for future intervention studies. *Curr Diab Rep.* 14(11):547. doi: 10.1007/s11892-014-0547-4
16. Schreurs BG. The effects of cholesterol on learning and memory. *Neurosci Biobehav Rev.* 34(8):1366-79. doi: 10.1016/j.neubiorev.2010.04.010

17. De Almeida Faria ACR, Dall'Agnol JF, Gouveia AM, De Paiva CI, Segalla VC, Ogata FE, et al. Cognitive Performance and Diabetic Retinopathy: What Your Eyes Can Reveal About Your Brain. *curr diabetes Rev.*19(9):e05822207323. doi:10.2174/1573399819666220805154638
18. Spauwen PJ, Köhler S, Verhey FR, Stehouwer CD, van Boxtel MP. Effects of type 2 diabetes on 12-year cognitive change: results from the Maastricht Aging Study. *Diabetes Care.* 36(6):1554-61. doi: 10.2337/dc12-0746
19. Wong RH, Scholey A, Howe PR. Assessing premorbid cognitive ability in adults with type 2 diabetes mellitus--a review with implications for future intervention studies. *Curr Diab Rep.* 14(11):547. doi: 10.1007/s11892-014-0547-4
20. Bozanic A, Toro P, Bello-Lepe S, Hurtado-Oliva J, Beyle C, Valdés C, et al. Cognitive impairment with Type 2 Diabetes Mellitus among community-dwelling older adults in Chile: Prevalence, risk factors and cognitive characteristics. *Front Hum Neurosci.* 16:1070611. doi:10.3389/fnhum.2022.1070611
21. Sola T, Sola FM, Jehkonen M. The Effects of Type 2 Diabetes on Cognitive Performance: A Review of Reviews. *Int J Behav Med.* 31(6):944-958. doi: 10.1007/s12529-024-10274-6