International Journal of Research in Medical Sciences
Chaudhari S et al. Int J Res Med Sci. 2023 Nov;11(11):4131-4135
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20233387

Original Research Article

Assessment of executive functions in type II diabetes patients with focus on duration of diabetes: preliminary findings of an analytical cross-sectional study

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Received: 08 September 2023
Revised: 06 October 2023
Accepted: 20 October 2023

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ABSTRACT

Background: Executive functions have been defined as one's ability to plan, initiate, sequence, monitor, and inhibit complex behaviour. Executive functions are purportedly affected significantly in diabetes population; duration of diabetes having particularly negative impact. Present study was undertaken to determine whether executive functions are affected more in diabetic patients as compared to non-diabetics and to further assess the role duration of diabetes.
Methods: In this analytical, cross-sectional study being conducted over 18 months period at a tertiary-care private teaching hospital in Central India, 148 participants (74 in diabetic & 74 in non-diabetic group) between the age of 30-60 years are enrolled. Preliminary data of 50 patients is presented here. The executive functions were assessed by using Delis-Kaplan Executive function system and participants was subjected to Trail making test, Design fluency test, Tower test and DKEF sorting test and the scores were compared between the two groups.
Results: Statistically significant differences were observed for Trail making test (median value diabetic-7 vs. non-diabetic-10), Design fluency test (median value diabetic-10 vs. non-diabetic-10, the range varied significantly), Tower test (median value diabetic-5 vs. non-diabetic-9), DKEF sorting test (median value diabetic-7 vs. non-diabetic-8) and Sort recognition test (median value- diabetic-6 vs. non-diabetic-8). The duration of diabetes exhibited strong, statistically significant negative correlation with the four studied parameters and had weak, insignificant positive correlation with sort recognition DS.
Conclusions: Executive functions are significantly affected in adult diabetes patients as compared to non-diabetic population and duration of diabetes has major contributory role in this affection.

Keywords: Executive functions, Diabetes mellitus, Duration

INTRODUCTION

Executive functions (EF), simply put, are the high-level cognitive processes that facilitate ways of behaving and optimise one's approach to unfamiliar circumstances.[1] Although they have been defined variously over years; these problem-solving and goal-directed behaviours indeed are the capacities that make us unique as humans. EF involves a comprehensive series of advanced cognitive activities that are defined as "one's ability to plan, initiate, sequence, monitor, and inhibit complex behaviour" in the diagnostic and statistical manual of mental disorders, 4th edition (DSM-IV).[2] The range of illnesses, conditions and medications that can potentially impact executive performance in the aged is more extensive than that seen in the younger people, which have important implications. Executive function decline that signifies the onset of pathological brain changes, or reflect a potentially treatable illness, must be distinguished from those that occur as part of the aging; as it will have diagnostic as well

as prognostic value. As noted earlier, many of the conditions that can impact cognitive performance in the aged can result in impairments in EF.[3] Appropriate assessment of EF, therefore, can be crucial for the accurate diagnosis of a range of cognitive disorders. The assessment of executive functioning can also be central to the assessment of an older person's capacity to drive, and to make informed financial, legal, medical and lifestyle decisions.[4] The devastating impact of type 2 diabetes mellitus (T2DM) on vascular, renal, retinal and peripheral nerve functions has been well documented. Beyond that; the impact of long standing T2DM on cognition has also been purported to be significant and appears to extend across broad range of related functions.[5-7] Disturbances in the executive function, particularly within the dimension of time sharing, may contribute to the gait abnormalities and increased risk for falls, functional impairments and disabilities associated with type 2 DM. However, the relationships between executive function and ensued disabilities remain poorly understood in this population. The complexity of both executive function and the diabetic disease process makes interpretation of these deficits and their functional consequences difficult. With this research gap in mind, the present study was planned with the objective of determining whether executive functions are affected more in diabetic patients as compared to non-diabetic population; and to determine whether duration of diabetes is a factor affecting this.

METHODS

The present study is an analytical, cross-sectional study being conducted over 18 months period (November 2022 to May 2023) in the department of Medicine at Dr. Panjabrao Deshmukh Alias Memorial Medical College, Amravati (a tertiary care private teaching hospital in Central India). All the known type II diabetic patients between the age of 30-60 years coming to the OPD at the study centre and diabetic clinic constituted the 'study group' and members of the general non-diabetic populations of similar age and socio-demographic profile in the society constituted the 'control group'. Those with comorbid medical illness, psychological or psychiatric illness, morbidly sick diabetic patients and those with history of excessive and abnormal consumption of psychotropic substances or drugs were excluded from the study. Participants were enrolled only after explaining the aim of the study and eliciting written consent from them. Following operational definitions were adopted for the study: Executive function, EF involves a comprehensive series of advanced cognitive activities that are defined as one's ability to plan, initiate, sequence, monitor and inhibit complex behaviour.[2] Type II Diabetes Mellitus- Patient is considered diabetic if any one of following is present: Fasting blood glucose >126 mg/dl, 2 hour plasma glucose >200 mg/dl (after OGTT). HbA1c >6.5%, Symptoms of diabetes and random blood glucose >200 mg/dl. The sample size was estimated using OpenEpi (Version 3) by referring to a previously similar Indian study.[9] (Mythili V. Assessment of Executive Function in Type 2 Diabetes Mellitus).[8] By considering two-sided confidence level of 95%, accepting power of the study at 90%, with ratio of controls to cases at 1:1 and mean difference of 1.98 in EF Scaled score in diabetic and non-diabetic populations in the quoted previous study using EF test (Trail Making test-A), the minimum calculated sample size was 148, i.e., 74 in each group. Preliminary data of 50 participants is being presented here.

All the participants were enrolled for the study after taking due consent by following convenience sampling method. The data were collected using a semi structured questionnaire; which includes detailed record of history followed by detailed clinical examination of patients and reviewing their medical records. The Executive Functions were assessed by using Delis-Kaplan Executive function system (D-KEFS), which is a conglomeration of specific EF functions.[10] Each participant in the study and control group was subjected to following tests in D-KEFS: Trail making test, Design fluency test, Tower test, DKEF sorting test. EF dysfunction was assessed as per the guiding manual. Crude and mean scores were calculated. Mean score of each of the above-mentioned test was 10 with an SD of 3. Those with the score of <7 were considered as abnormal.

Statistical analysis

Data were analysed using SPSS (version 20). Mean and SD were calculated for continuous variable and percentage for categorical variable. To estimate prevalence of executive dysfunction in type 2 diabetic population, frequency and percentage were calculated. To test statistical significance of association between executive dysfunction and diabetes, Chi-Square Test was used. To test significance of executive dysfunction with duration of diabetes, Pearson Correlation was used. A p value of <0.05 was considered statistically significant.

RESULTS

In the present study, there were 11 individuals without diabetes and 12 individuals with diabetes in the age group of 40-50 years, constituting a total of 23 participants. Likewise, in the 51-60 years age category, there were 12 non-diabetic and 10 diabetic individuals, amounting to 22 participants. In the age group above 60 years, there were 2 non-diabetic and 3 diabetic individuals, making a total of 5 participants. The difference for age in the two groups was statistically insignificant. As for the gender, in the "No diabetic" group, there were 12 females and 13 males, totaling to 25 participants. Similarly, in the "Diabetic" group, there were 14 females and 11 males, also totaling to 25 participants; the difference between the group being statistically insignificant (Table 1).

The executive functions were assessed as part of the study by using Delis-Kaplan Executive function system and all the participants in the study ('diabetic') and control ('non-diabetic') groups were subjected to following tests in D-

KEFS: Trail making test (TMT), Design fluency test (DFT), Tower test and DKEF sorting test. Contrast scaled score (CSS) was calculated for trail making test and design fluency test. Total achievement score (TAS) was calculated for Tower test. Free sorting description score (DS) and Sort Recognition Description Score were calculated for DKEF Sorting Test.

Table 1: Age group distribution.

Category	No diabetic	Diabetic	P value
Age (years)			
40-50	11	12	0.80
51-60	12	10	
>60	2	3	
Total	25	25	
Gender			0.57
Female	12	14	0.57
Male	13	11	
Total	25	25	

Table 2: Comparison of TMT-CSS between diabetic and non-diabetic patients.

TMT-CSS	Median (Q1-Q3)	U value	P value
Non-Diabetic	10 (9-11)	126.5	0.003
Diabetic	7 (5-9)		

The preliminary data of 50 participants (25 in each group) has been analysed and is presented here. The results of the four tests are being reported as median scores along with the Q1-Q3 range for each group. Further, Mann-Whitney U test was performed to check for statistical significance. In this study, the TMT-CSS test was administered to two groups: Non-Diabetic and Diabetic. The results were reported as median (Q1-Q3) values for each group. The Non-Diabetic group had a median score of 10 (range: 9-11), while the Diabetic group had a median score of 7 (range: 5-9). To assess the statistical significance of the group difference, the Mann-Whitney U test was performed. The calculated U value was 126.5, indicating a significant difference between the two groups. Furthermore, the obtained p value of 0.003, assuming a significance level of 0.05, suggests that this observed difference is statistically significant (Table 2).

The Non-Diabetic group achieved a median score of 10 (range: 9-11), while the Diabetic group had a median score of 10 (range: 10-11) on the DFT-CSS test. The calculated U value from the Mann-Whitney U test was 204.5, indicating no significant difference between the two groups. The obtained p value of 0.03 supports this finding, indicating a statistically significant distinction between the groups in terms of their performance on the DFT-CSS test (Table 3). The Tower test was administered to two groups: Non-Diabetic and Diabetic. Median scores and Q1-Q3 ranges were reported. The Non-Diabetic group had a median score of 9, while the Diabetic group had a median score of 5. To assess the statistical significance of the group difference, the Mann-Whitney U test was applied. The calculated U value of 18 reveals a significant distinction between the groups. Additionally, the obtained p value was less than 0.001, indicating high statistical significance (Table 4).

Table 3: Comparison of DFT.CSS between diabetic and non-diabetic patients.

DFT-CSS	Median (Q1-Q3)	U value	P value
Non-Diabetic	10 (9-11)	204.5	0.03
Diabetic	10 (8-10)		

Table 4: Comparison of Tower test between diabetic and non-diabetic patients.

TAS	Median (Q1-Q3)	U value	P value
Non-Diabetic	9 (7-9)	18	<0.001
Diabetic	5 (4-6)		

In a study comparing Non-Diabetic and Diabetic groups, the Free Sorting Test was administered, and the results were reported as median scores with Q1-Q3 ranges. The Non-Diabetic group had a median score of 8, while the Diabetic group had a median score of 7. To determine the statistical significance of the group difference, the Mann-Whitney U test was employed. The calculated U value of 74 indicates a significant distinction between the two groups. Moreover, the obtained p value was found to be less than 0.001, which is below the commonly used threshold of 0.05 for statistical significance. This suggests that the observed difference in the Free Sorting Description scores between the non-diabetic and diabetic groups is highly statistically significant (Table 5).

Table 5: Comparison of free sorting DS between diabetic and non-diabetic patients.

Free sorting DS	Median (Q1-Q3)	U value	P value
Non-Diabetic	8 (7-10)	95.5	<0.001
Diabetic	7 (6-8)		

Table 6: Comparison of sort recognition DS between diabetic and non-Diabetic patients.

Sort recognition DS	Median (Q1-Q3)	U value	P value
Non-Diabetic	8 (5-10)	55	<0.001
Diabetic	6 (4-6)		

In a study comparing two groups, Non-Diabetic and Diabetic, participants underwent the Sort Recognition test, and their results were reported as median scores along with the Q1-Q3 range for each group. The Non-Diabetic group

achieved a median score of 8, while the Diabetic group obtained a median score of 6. To determine the statistical significance of the difference between the two groups, the Mann-Whitney U test was conducted. The calculated U value was 55, indicating a significant difference between the Non-Diabetic and Diabetic groups. Moreover, the obtained p value was less than 0.001, suggesting that this observed difference between the groups is highly statistically significant (Table 6).

Table 7: Correlation of duration of diabetics with various scores.

Correlation coefficient	Duration of diabetics	P value
TMT-CSS	-0.5821	0.002
DFT-CSS	-0.5178	0.009
TAS	-0.4075	0.04
Free sorting DS	-0.4908	0.01
Sort recognition DS	0.23	0.26

The duration of diabetes was studied for correlation with the various Delis-Kaplan Executive function system test parameters; as a proxy for the Executive Functions. Firstly, in the Trail Making Test-CSS, a moderate negative correlation of -0.5821 (p=0.002) emerged. This implies that as the duration of diabetes increases, there is a tendency for a decrease in TMT-CSS performance. Secondly, the Design Fluency Test-CSS displayed a significant negative correlation of -0.5178 (p=0.009). This finding suggests that a longer duration of diabetes is linked with lower scores in DFT.CSS. Additionally, the Tower Test exhibited a correlation coefficient of -0.4075 (p=0.04), indicating a negative relationship between diabetes duration and performance in this task. This suggests that a lengthier diabetes duration is associated with relatively diminished performance in the Tower Test. Furthermore, the Free Sorting Test - D.S. demonstrated a substantial negative correlation of -0.4908 (p=0.01). This implies that an extended duration of diabetes corresponds to reduced performance in this specific task. Lastly, the Sort Recognition Test-DS displayed a correlation coefficient of 0.23 (p=0.26). This suggests a relatively weak and non-significant positive relationship between diabetes duration and performance in this task, indicating that diabetes duration may not significantly influence performance in Sort Recognition (Table 7).

DISCUSSION

Executive function, an important component of cognitive function, has been the focus of much research only in recent years, given its close relationship with chronic non-infectious diseases, which are on rise off late.[11] Complex interaction of multiple factors results in the balance of mental faculties required for good executive function. They are known to decrease with aging and are impaired in the early stages of dementia and Alzheimer disease.[12] The association with diabetes however is not so clear, especially in this population, and hence was the objective of present research; which is an early exploration of a larger study. The Executive Functions were assessed in the study by Delis-Kaplan Executive function system. As a part of this, the TMT-CSS score is supposed to assess cognitive flexibility of examinee. DFT-CSS is supposed to asses response inhibition and design fluency. Tower-TAS is expected to asses spatial planning, rule learning strategies and establishment and maintenance of cognitive set. DKEF sorting test assesses initiation of problem-solving behavior, concept formation skills, ability to explain concept abstraction, ability to transfer sorting concept into action and cognitive flexibility. Free sorting-DS reflects the examinee's ability to perceive and form conceptual relationships in both the verbal and nonverbal modalities. Sort recognition DS reflects examinee's ability to initiate problem-solving and concept-formations skills and to inhibit the pull to repeat the same behavioral (sorting) response. However, no one-to-one specific skill-test relationship exists and substantial evidence is not available in this regard.

The comparison of TMT-CSS score between diabetic and non-Diabetic patients in the present study indicated significant difference between the groups. This is inline with the study by Teixeire et al which indicated co-relation between TMT-B test and diabetes. It inferred significant co-relation to exist between decrease executive memory and language.[13] A metanalytical review by Vincent et al also concluded significant decline in the diabetic group for the TMT-CSS.[14] Other parametric tests assessed in the current study as part of the Delis-Kaplan Executive function system also indicated significant results similar to the one observed for TMT. Impaired performance on variety of executive tasks had been previously reported in older adults with T2DM and significantly increased risk of executive decline has also been observed in longitudinal investigations of T2DM and cognition.[13] Mansur et al in their meta-analysis, had also concluded the same; corroborating the observations of the present study further.[15] Perhaps the strongest evidence of diabetes-related executive dysfunction stems from an analysis by Yeung et al of a multidimensional executive battery administered to 465 older adults, 41 of whom had type 2 DM. Those with diabetes scored approximately 12% and 14% lower than their peers without diabetes on executive measures of inhibition and shifting, respectively.[16] The implications of these affections can be profound, especially in older age group. It seems likely that disease-related changes in executive function adversely affect daily functional abilities in older adults with type 2 DM; although this couldn't be validated as a part of current exploration owing to small sample. But the correlation of decline in the EF with the duration of diabetes was significant in the present study. Clinicians should be prepared to recognize possible impairments in executive function in older people with diabetes and should understand that these changes may directly or indirectly affect even the most basic activities. Periaira et al concludes that executive dysfunctions and decline in general of cognitive functioning are associated with a

lower ability to undertake the activities of daily living.[17] Hood Thabit in his theoretical review mentions that, clinicians and healthcare workers managing patients with DM should be aware of potential of impaired EF in their patients; as specific behavior and educational intervention may be needed to help to manage patient with DM and impaired EF.[18]

Limitations

The obvious limitations of the study are the fact that the patients are receiving oral hypoglycemic agents, which may affect the outcomes to some extent; and even though we have excluded moderate & severely diabetic patients, unknown comorbidities and variations in severity within the chosen diabetic category may have some effect on the outcome.

CONCLUSION

Executive functions are seen to be significantly affected in adult diabetes patients as compared to non-diabetic population and duration of diabetes has major contributory role in this affection. It is advisable to the clinicians to take proactive cognizance of the association while evaluating diabetic patients for secondary complications. Further studies are recommended to elucidate the pathophysiological mechanisms of diabetes-related EF decline and to develop novel strategies for breaking this cycle.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Chaudhari S, Somvanshi P. Assessment of executive functions in type II diabetes patients with focus on duration of diabetes: preliminary findings of an analytical cross-sectional study. Int J Res Med Sci 2023;11:4131-5.