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A Review on Executive Dysfunction in Type 2 Diabetes Mellitus Assessment and Management

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ABSTRACT

Type 2 diabetes mellitus is metabolic disorder which is associated with executive function. Executive function is the important to carry out initiation, inhibition memory and planning. There is an association of executive function impairment and Type 2 Diabetes mellitus. There are many factors such as age, gender, fitness, sleep etc. which affects executive functioning. Assessment tool such as Digit symbol substitution test, Trail making test, Stoop test, clock drawing test, Verbal Fluency Test and Wisconsin card sorting test. We can manage Type 2 Diabetes Mellitus which associate with executive function impairment by physiotherapy treatment and self-care management and remainder.

Keywords: Type 2 Diabetes Mellitus, Executive function, Cognition, Stoop Test, Trail making test, Digit Symbol Substitution test

INTRODUCTION

Type 2 Diabetes mellitus: Diabetes is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. [1] Type 2 Diabetes Mellitus (T2DM) is characterized by different combinations of insulin resistance and insulin deficiency. Type 2 Diabetes Mellitus is the most common form of diabetes, accounting for 90% of cases, affecting over 460 million worldwide with projections expecting this number to rise to over 700 million in just 25 years. [2] Type 2 Diabetes Mellitus is associated with an array of debilitating clinical sequelae, including visual loss, renal dysfunction, wound formation, limb amputation, neuropathy, and cardiovascular and cerebrovascular diseases. In addition to these traditional complications, Type 2 Diabetes Mellitus also has been identified as a significant risk factor for falls and disability, as well as for cognitive impairments and dementia.[3] Type 2 Diabetes Mellitus affects cognitive subdomains served by the fronto-temporal lobe, resulting in a decline in memory, executive function and processing abilities.[4]

Executive functions: Executive functions (EFs) are a collection of top-down control processes used when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible. [5] Executive functions are built such as reasoning, problem solving, and planning. There is general agreement that there are three core EFs inhibition [inhibitory control, including self-control (behavioural inhibition) and interference control (selective attention and cognitive inhibition)], working memory (WM), and cognitive flexibility (also called set shifting, mental flexibility, or mental set shifting and closely linked to creativity).[6][7]

Executive functions include initiation, inhibition, mental flexibility, novel problem solving, planning, emotion regulation, and self-awareness. These cognitive functions

are necessary for goal-directed behaviour. [8] Even mild form of executive dysfunction might hamper everyday activities depending on the work and situation, which requires various cognitive domains. [9]

Relation between Type 2 diabetes mellitus and executive function: A meta-analysis to determine the alterations in six cognitive domains in individuals with Type 2 Diabetes Mellitus found a reduction in motor function, executive function, processing speed, verbal memory, and visual memory, but a preserved attention/concentration function in diabetic patients compared to nondiabetic individuals. [10]

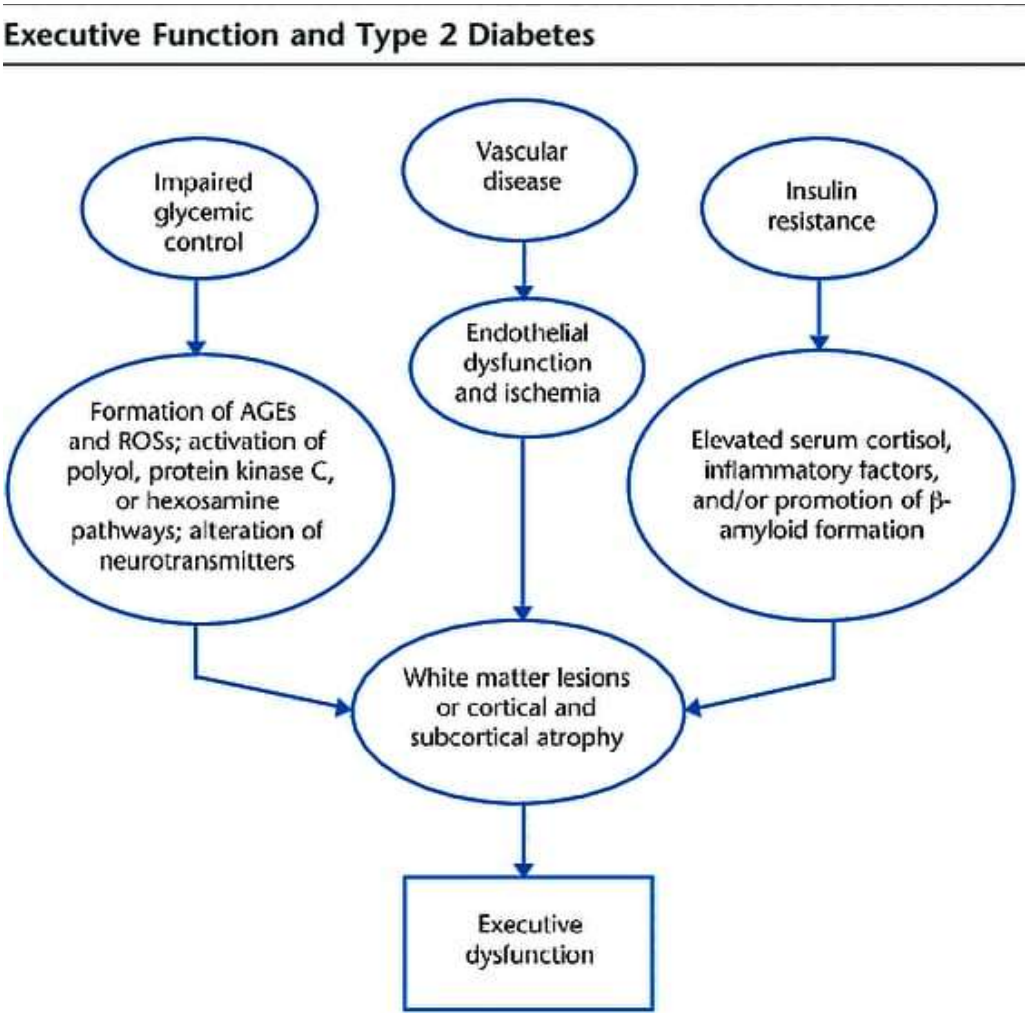

Fig 1: Potential mechanisms contributing to executive dysfunction in diabetes. (AGEs: advanced glycation end products, ROSs: reactive oxygen species.)[10]

Factors affecting Executive function:

1. Aging: Aging is associated with a decrease in physiological capacities, especially functional and cognitive abilities.
2. Gender: Women will have more executive and cognitive abilities than male.
3. Level of education: Higher education will have lesser effect of executive decline with aging.
4. Functional Performance and Lifestyle: Factors such as lifestyle and physical and functional performance, especially at the end of adult life and the beginning of old age, are directly related to executive functions.
5. Muscle Mass: Significant gains in muscle strength are associated with cognitive improvements in the elderly [11]
6. Sleep: sleep parameters differ in the way they benefit or impair EF. Parameters

such as greater wake after sleep onset and lower sleep efficiency, in addition to circadian fragmentation of sleep, showed more consistent results and are potentially correlated with worsening in EF measures[12]

7. Self efficacy, self awareness and social skill: self-efficacy, self-awareness, and social skills significantly affect executive function.[13]
8. Other Factors: Alcohol, Cerebral blood flow [14], Metabolic disorder [10] and neurological disorder [15].

There are no specific sign and symptoms for executive dysfunction. Difficulty or inability to do initiation, inhibition, mental flexibility, novel problem solving, planning, emotion regulation, and self-awareness can be consider as executive dysfunction. But for Confirmation we need to know about the tools to assess the executive function.

Assessment of Executive function:

A. Trail Making Test : The Trail Making Test is one of the most commonly used tests in the assessment of inhibition function (i.e., the ability to suppress irrelevant or interfering stimuli or impulses). [16] The Trail Making Test (TMT) is a brief paper and pencil neuropsychological test often used for screening for cognitive impairment.[17] It has two parts. Part A appears to be dependent primarily on the efficiency of visual scanning and psychomotor speed. In contrast, Part B specifically as an executive task consists of alternation between serial sequences of letters and numbers is thought to require executive control, specifically, flexibility of thinking and greater demand for working memory. Part A consists of one sample test and one task. The numbers are randomly printed on the sample worksheet. The subject is required to join consecutive numbers in order by drawing connecting lines. The worksheet consists of numbers 1 to 25. The time taken to join consecutive numbers is taken as the subject's score. Part B consists of a sample test as well as the main task. The numbers 1 to 4 and the letters A to D are presented on a sample worksheet. The numbers 1 to 13 and letters A to L are presented on the task worksheet. The participant is required to alternate between numbers and letters as s/he proceeds in an ascending sequence. Subjects are asked to connect numbers-alphabets as fast as they can. The examiner points out errors as they occur so that the subject can complete the test without errors. The score is only based on the time taken.If the time taken to complete Part A is less than the time taken to complete Part B, the subject is considered to have difficulties in complex conceptual tracking. In general, performance is considered to be impaired if scores exceed 40 seconds for part A and 91 seconds for part B.[18]

B. The DSST (Digit Symbol Substitution Test) is a paper-and-pencil cognitive test presented on a single sheet of paper. [19] The Digit Symbol Substitution Test requires the integration of complex neuropsychological processes and measures a number of areas of cognitive function, in particular cognitive and psychomotor speed, attention, visual scanning, and executive functions. [20] It reflects the speed of information processing as an executive function, and in comparison with other cognitive tests, its performance is strongly correlated with the volume of the prefrontal cortex. [21]. Digit symbol substitution test (DSST) evaluates the working memory, organization of perceived stimuli, visomotor coordination, and selective attention, which are executive cognitive functions. DSST was validated in Europe and the United States, mainly in the older adult population. Due to its iconographic nature, no linguistic translation is required. Explain all participants about how to respond and use as an example the first 10 boxes with their respective symbols to ensure that patient understood

how to perform the test. Participants have to match numbers with their respective symbol in order and without skipping any box, as fast as possible and without any kind of external help. Test has a total duration of 90 s (in triplicate). The number of binomials number-symbol paired correctly constituted score of the participant in the DSST. Blank space between two completed items does not invalidate the test; however, two or more consecutive blank spaces point to the end of the test. Paired symbols after two or more blank spaces are not considered in total score. DSST has no cutting points, score constitutes a continuous variable and has no individual value; it takes utility at population level when different groups are compared and is also useful when applied in the same individual overtime.[22]

C. Stroop test: Among the neuropsychological tools used to access executive functions, the Stroop test is usually used. This test evaluates the ability to inhibit cognitive interference, that is, it generates a stimulus incongruity effect.[23] There is no standardized version of the Stroop, but all the variations on Stroop's original procedure have this in common: there are three cards-the "color card" (card A) on which there are 100 patches of from three to five different colors, the "word card" (card B) on which are printed (in black and white) the names of the colors, and the "color-word card" (card C) on which are printed the names of the colors, but printed in an ink of a conflicting color (e.g. the word RED might be printed in green, yellow, or blue, but never in red). Each card has 100 items to be named. The subject's (S's) task on card A is simply to utter the names of the colored patches as rapidly as possible, scanning the rows from left to right. On card B the S reads. aloud the color names as rapidly as possible. On card C the S is required to name the colors of the inks while ignoring the conflicting printed color names. The S's basic score on each card is the total time (in seconds) he takes to utter the 100 names. Stroop (2) used five colors, but there has been no consistency in the number of colors used by other investigators; the number ranges from three to five, and the same colors are not always used. The size and dimensions of the cards, the print, the spacing of items, etc. also are not standardized. Furthermore, in some versions the color patches and color-words are printed on a white background and the words are printed black on white, while other versions use a black background on all three cards, with card B having the words in white on a black background.[24]

D. Clock drawing test: Neuropsychological test scores generally reflect the integrity of both the cognitive domain in question and its executive control. In the case of clock drawing, a subject's performance requires the separate analysis of visuoconstructional praxis and the executive control demanded by the testing paradigm. The executive clock drawing task (CLOX) The CLOX has been divided into two parts to help discriminate the executive control of clock drawing from clock drawing itself. The patient is first instructed to draw a clock on the back of the CLOX form (see fig 3). He or she is instructed only to "Draw me a clock that says 1:45. Set the hands and numbers on the face so that a child could read them." The instructions can be repeated until they are clearly understood, but once the subject begins to draw no further assistance is allowed. The subject's performance is rated according to the CLOX directions, and scored as "CLOX1". CLOX1 reflects performance in a novel and ambiguous situation. The patient is presented only with a blank surface and no further guidance regarding the task. He or she is responsible for choosing the clock's overall form (a digital or analog face, alarm clock, wrist watch, or wall clock, etc), its size, position on the paper,

elements (hands, numbers, date indicators), the forms of these elements (hands as arrows, relative lengths, roman v arabic numerals, etc). Furthermore, the patient must also initiate and persist in clock drawing through a sequence of constructional actions (usually drawing the outer circle, followed by placing the numbers if any, followed by setting the time). Finally, he or she must monitor progress as the task unfolds, both anticipating (placing the 12, 6, 3, and 9 first) and/ or correcting errors as they occur.[25]

E. Verbal Fluency Test: The Verbal Fluency battery includes tests for Letter and Category fluency. In Verbal fluency test the subject is evaluated for maximum number of word production, within a set time frame, and within a specific constraint, In the Letter Fluency test, the subject is given three separate one-minute trials for the letters F, A, and S. The Category Fluency test is a one-minute trial for a single category like birds which can fly, four legged animals etc.[26]
F. Wisconsin card sorting test: It consists of sixty four tests cards and 4 stimulus cards. Each card is a square of dimensions 8cms by 8cms. The stimuli vary in 3 attributes: color(red, green, yellow, blue), form(triangle, star, cross, circle) and number(1,2,3,4). [26]

Management of executive function in Type 2 Diabetes Mellitus:

Exercise is one of the three major components in managing type 2 DM along with diet and medications. It has been evidenced that reduction in blood sugar levels and body fat composition improves the risk toward cardiovascular and cardiorespiratory problems, physical functioning, cognitive dysfunctions, and well-being in patients with Type 2 DM. Exercise interventions such as aerobics, yoga, and other physical activities have improved the neurocognitive function in individuals with type 2 diabetes mellitus.[27]

Physiotherapy Management Protocols:

A. Structured exercise program of strengthening and aerobic exercise: Aerobic exercises carried out for 30 min for 5 days/week. The regime was structured such that a gap of no more than 2 consecutive days without physical activity was advised. Resistance exercise was performed thrice a week targeting all major muscle groups, 8–10 repetitions into three sets with two kg dumbbells. The resistance exercises included dumbbell flies, seated single leg extension, dumbbell shoulder press, dumbbell bent over row, standing leg curls, dumbbell biceps curls, dumbbell up-right row, dumbbell triceps kickbacks, and abdominal curls.[27]
B. Resistance program: Circuit training exercise regime (40 minutes) with progressive high intensity protocol in a sequential order of (1) Biceps curls (2) Triceps extensions (3) Hamstring curls (4) Quadriceps extension (5) Calf raises by using free weights (weight cuffs and dumbbells). Perform the resistance exercises at an intensity of 60%-70% of one repetition maximum for 3 sets of 10 repetitions. A 30 second break is given in between the sets and after each exercise one minute rest is given. As each subject's strength of muscle increased, the given weight is then can be increased up to their maximum of 75%-80% of 1-RM[28]

Self Remainder and assistive tools for Care Givers:[29]

A. Recording and alarming devices:

1. Multi-memo voice recorder: records reminder messages
2. Talking recordable products (e.g., photo album programmed to create audio and visual reminders of photos, important information, or medications
3. Reminder clocks: records messages and allows set times for playback

4. Automated pill dispensers: beep (alarm) and open or vibrate to remind caregivers and those with dementia to take their medication
5. Vibrating or audio watch: provides reminder alarms
6. Diabetes Sentry wrist alarm: worn to monitor perspiration or a decrease in skin temperature in the event of a hypoglycemic reaction

B. Insulin and injectable devices:

1. Insulin pens that provide memory of time and dose of previous insulin injections such as the NovoPen Echo or the Timesulin pen cap memory device
2. Insulin pump: may be appropriate if caregiver is available and well educated in its use
3. Choice of injectable device that is easiest to use for the individual patient

C. GPS tracking and emergency alert/ alarm devices:

1. GPS tracking devices: worn or attached to the patient to alert caregivers if the patient has left a certain area
2. Alert necklace or bracelet: alerts emergency personnel of patient's diagnoses or impairments in case of emergency

D. Picture phones:

Help patients who struggle to remember names or phone numbers by incorporating programmable, large buttons with clear covers in which to insert pictures (i.e., elder phones)

E. Electrical use monitors: Devices that can be plugged into a wall outlet or power strip and will monitor a person's use of electrical appliances and alert caregivers if commonly used appliances have not been turned on or off (e.g., Evermind)

F. Talking glucose meters: Voice-activated blood glucose meters that allow patients to audibly track their blood glucose level and history of readings (e.g., Prodigy Voice no code talking glucose meter, Gmate VOICE Speaking Meter, or SOLUS V2)

G. CGM devices

1. CGM devices for personal wear (e.g., Dexcom G5, Medtronic Enlite, or Medtronic Guardian): alert patients or caregivers to fluctuating blood glucose levels and blood glucose levels that are above or below preset parameters. The share feature of the Dexcom G5 might be particularly useful in patients with cognitive impairment.
2. mySentry Remote Glucose Monitor: a device that displays a patient's blood glucose levels but can be set up in a caretaker's room. Customizable alarms can be set to alert the caregiver to dangerous glucose levels.
3. CGM devices for professional use (e.g., Dexcom G4 Platinum professional or Medtronic iPro2 Professional CGM: used to track a patient's glucose levels for a designated number of days; data downloading allows the medical provider to see glucose trends, glycemic excursions, and problematic glucose patterns and direct changes in therapy to address them.

Declaration by Authors

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REFERENCES

1. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes care. 2010 Jan 1;33(Supplement_1):S62-9.
2. Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, Colagiuri S, Guariguata L, Motala AA, Ogurtsova K, Shaw JE. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation

Diabetes Atlas. Diabetes research and clinical practice. 2019 Nov 1;157:107843.
3. Rucker JL, McDowd JM, Kluding PM. Executive function and type 2 diabetes: putting the pieces together. Physical therapy. 2012 Mar 1;92(3):454-62.
4. Zheng F, Yan L, Yang Z, Zhong B, Xie W. HbA1c, diabetes and cognitive decline: the English Longitudinal Study of Ageing. Diabetologia. 2018 Apr;61(4):839-48.
5. Barkley RA. The executive functions and self-regulation: An evolutionary neuropsychological perspective. Neuropsychology review. 2001 Mar;11(1):1-29.
6. Lehto JE, Juujärvi P, Kooistra L, Pulkkinen L. Dimensions of executive functioning: Evidence from children. British journal of developmental psychology. 2003 Mar;21(1):59-80.
7. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. Cognitive psychology. 2000 Aug 1;41(1):49-100.
8. Graber JJ, Dhib-Jalbut S. Interferons, Editor (s): Michael J. Aminoff, Robert B. Daroff. Encyclopedia of the Neurological Sciences.
9. Kodl CT, Seaquist ER. Cognitive dysfunction and diabetes mellitus. Endocrine reviews. 2008 Jun 1;29(4):494-511.
10. Palta P, Schneider AL, Biessels GJ, Touradji P, Hill-Briggs F. Magnitude of cognitive dysfunction in adults with type 2 diabetes: a meta-analysis of six cognitive domains and the most frequently reported neuropsychological tests within domains. Journal of the International Neuropsychological Society. 2014 Mar;20(3):278-91.
11. Braga PL, Henrique JS, Almeida SS, Arida RM, Gomes da Silva S. Factors affecting executive function performance of Brazilian elderly in the Stroop test. Brazilian Journal of Medical and Biological Research. 2022 Apr 27;55.
12. Sewell KR, Erickson KI, Rainey-Smith SR, Peiffer JJ, Sohrabi HR, Brown BM. Relationships between physical activity, sleep and cognitive function: A narrative review. Neuroscience & Biobehavioral Reviews. 2021 Nov 1;130:369-78.
13. Navayuth T, Yurayat P. Factors Affecting the Executive Function in Undergraduate Students. Journal of Education and Learning. 2022;11(4):131-7.
14. Noël X, Sferrazza R, Van der Linden M, Paternot J, Verhas M, Hanak C, Pelc I, Verbanck P. Contribution of frontal cerebral blood flow measured by 99mTc-Bicisate SPECT and executive function deficits to predicting treatment outcome in alcohol-dependent patients. Alcohol and alcoholism. 2002 Jul 1;37(4):347-54.
15. Araujo GC, Antonini TN, Anderson V, Vannatta KA, Salley CG, Bigler ED, Taylor HG, Gerhardt C, Rubin K, Dennis M, Lo W. Profiles of executive function across children with distinct brain disorders: traumatic brain injury, stroke, and brain tumor. Journal of the International Neuropsychological Society. 2017 Aug;23(7):529-38.
16. Chang YK, Etnier JL. Effects of an acute bout of localized resistance exercise on cognitive performance in middle-aged adults: A randomized controlled trial study. Psychology of Sport and Exercise. 2009 Jan 1;10(1):19-24.
17. Alves CR, Gualano B, Takao PP, Avakian P, Fernandes RM, Morine D, Takito MY. Effects of acute physical exercise on executive functions: a comparison between aerobic and strength exercise. Journal of Sport and Exercise Psychology. 2012 Aug 1;34(4):539-49.
18. Bhatia T, Shriharsh V, Adlakha S, Bisht V, Garg K, Deshpande SN. The trail making test in India. Indian journal of psychiatry. 2007 Apr;49(2):113.
19. Jaeger J. Digit symbol substitution test: the case for sensitivity over specificity in neuropsychological testing. Journal of clinical psychopharmacology. 2018 Oct;38(5):513.
20. Joy S, Fein D, Kaplan E. Decoding digit symbol: speed, memory, and visual scanning. Assessment. 2003 Mar;10(1):56-65.
21. Rosano C, Studenski SA, Aizenstein HJ, Boudreau RM, Longstreth Jr WT, Newman AB. Slower gait, slower information processing and smaller prefrontal area in older adults. Age and ageing. 2012 Jan 1;41(1):58-64.
22. Palma-Díaz EJ, Estrella-Castillo DF, Zapata-Vázquez RE, García-Santamaría E, Rubio Zapata HA. Executive dysfunction in

middle-aged hypertensive adults. Revista mexicana de neurociencia. 2020 Jun;21(3):90-6.
23. Braga PL, Henrique JS, Almeida SS, Arida RM, Gomes da Silva S. Factors affecting executive function performance of Brazilian elderly in the Stroop test. Brazilian Journal of Medical and Biological Research. 2022 Apr 27;55.
24. Jensen AR. Scoring the Stroop test. Acta psychologica. 1965 Oct;24(5):398-408.
25. Royall DR, Cordes JA, Polk M. CLOX: an executive clock drawing task. Journal of Neurology, Neurosurgery & Psychiatry. 1998 May 1;64(5):588-94.
26. Mythili V. *Assessment of Executive Function in Type 2 Diabetes Mellitus: A Case Control study* (Doctoral dissertation, Madras Medical College, Chennai).
27. Kour H, Kothiwale VA, Goudar SS. Role of structured exercise therapy on cognitive markers and stress parameters in young patients with Type 2 diabetes mellitus. Indian Journal of Health Sciences and Biomedical Research (KLEU). 2022 Jan 1;15(1):70.
28. Beesmol Babu, Manju Unnikrishnan, Remya N et.al. Effect of resistance training on improving cognitive function in subjects having type 2 diabetes with mild cognitive impairment. Int J Health Sci Res. 2022; 12(10):174-184.
29. Hopkins R, Shaver K, Weinstock RS. Management of adults with diabetes and cognitive problems. Diabetes Spectrum. 2016 Nov 1;29(4):224-37.

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