

Original Research Article

Effect of short term strength training on executive function in type 2 diabetes mellitus

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) can lead to executive dysfunction. Many studies proved that Strength training can improve the executive function in healthy individuals. Aim of the study is to evaluate the effect of short term strength training on executive function in T2DM.

Methods: The 53 participants were divided into 2 groups equally by randomization. 5 drop outs from the study. Group A performed strength training and conventional exercises where as group B performed only conventional exercises. There were total 12 sessions for both groups. Sessions were given thrice a week for total 4 weeks. Pre and post measures of digit symbol substitution test (DSST), trail making test (TMT) A and TMT B were taken as outcome measures of executive function.

Results: Statistical result of 48 participants from Independent t-test showed significant difference between both groups which explains improvement in executive function after short term strength training.

Conclusions: Short term strength training can enhance the executive function among patient with T2DM.

Keywords: Executive function, Strength training, Cognition, DSST, T2DM

INTRODUCTION

Diabetes is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both.¹ T2DM is characterized by different combinations of insulin resistance and insulin deficiency. T2DM 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 T2DM 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, T2DM also has been identified as a significant risk factor for falls and disability, as well as for cognitive impairments and dementia.³ T2DM affects cognitive subdomains served by the fronto-temporal lobe, resulting

in a decline in memory, executive function and processing abilities.⁴

Due to the mild symptoms of T2DM in the beginning, its diagnosis is usually delayed for years especially in countries where regular checkup without symptoms is not part of the culture. This delay in diagnosis could increase the incidence of long-term complications in T2DM patients since hyperglycemia is not treated during this undiagnosed period.⁵

Cognition, the states and processes involved in knowing, which in their completeness include perception and judgment. Sensation, perception, motor skill and construction, attention and concentration, memory, executive function, processing speed and language/verbal skill are the subdomains of cognition.⁶

Executive function is one the subdomains of cognition. 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.⁷ Thus, tasks of problem solving, planning, manipulating mazes, and other complex tasks where management of multiple cognitive abilities are required, fall under the domain of executive functioning.^{8,9}

EFs are built such as reasoning, problem solving and planning. EFs include initiation, inhibition, mental flexibility, novel problem solving, planning, emotion regulation, and self-awareness. These cognitive functions are necessary for goal-directed behaviour.¹⁰ Even mild form of executive dysfunction might hamper everyday activities depending on the work and situation, which requires various cognitive domains.¹¹

A meta-analysis to determine the alterations in six cognitive domains in individuals with T2DM 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.¹²

Increasing age is a risk factor for development of cognitive impairment in T2DM. Since diabetes mellitus and old age are both independent risk factors for developing Alzheimer's disease, vascular dementia, and other disorders resulting in culmination of cognitive decline, a combination of both can contribute to higher incidence of cognitive impairment among older diabetics.^{13,14}

Executive dysfunction in older adults with T2DM, potentially because of neuroanatomical changes resulting from impaired glycemic control, vascular disease, and insulin resistance. Although there is empirical support for each of these mechanisms, the etiological pathways underlying diabetes-related cognitive and executive impairments likely result from a multifactorial process including these and other factors.¹⁵

The TMT 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 TMT is a brief paper and pencil neuropsychological test often used for screening for cognitive impairment.¹⁷ The DSST is a paper-and-pencil cognitive test presented on a single sheet of paper.¹⁸ The DSST 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 EFs.¹⁹

Physical activity, including appropriate endurance training and strengthening, is a major therapeutic modality for T2DM. Physical activity can help people with diabetes achieve variety of goals, including increased cardiorespiratory fitness, increased vigour, improved glycemic control, decreased insulin resistance, improved

lipid profile, BP reduction and maintenance of weight loss.²⁰

Strength training has the potential to improve muscle strength and endurance, enhance flexibility and body composition, decrease risk factors for cardiovascular disease, and result in improved glucose tolerance and insulin sensitivity.²¹ Strengthening decreases glycosylated hemoglobin (HbA1c) and total fat mass, reduces abdominal fat mass, and improves insulin resistance.²² Strength training exercises are able to increase the anti-inflammatory balance with an increase in cognition and better physical health.²³

Some literatures are available about effect of strength training on EFs in healthy elders. But there is lack of evidence supporting the short term strength training exercise and its effect on executive function in T2DM purpose of the study is to check the effect of short term strength training on executive function in T2DM.

METHODS

Study design

It was pre post interventional study.

Study population

Patients with T2DM were selected for the study.

Sampling technique

Purposive sampling technique was used.

Study duration

Study conducted for 1 year from May 2023 to May 2024.

Sample size

Sample size was calculated on the basis of pilot study from TMT B score of group 1 and group 2. Mean±SD of control group and strength training group was -4.2±3.56 and -23±27.34 respectively. Power was 80%, CI at 95% and effect size calculated was 0.96. Sample size was 48.

Study setting

Study carried out at SPB Physiotherapy College OPD (Surat), Dr. Ajay Jain clinic (Majuragate, Surat) and various OPDs attached with it.

Inclusion criteria

Patients of age group 45 to 75 year, with T2DM: <5 years (Diagnosed by clinician), patients on oral anti-diabetic drugs, mini mental state examination score ≥24 were included.

Exclusion criteria

Patients with any neurological disorder, patient with

history of type 1 diabetes mellitus, patients with the physical disability, patients with any visual deficit, patients doing any other forms of exercise, athletes were excluded.

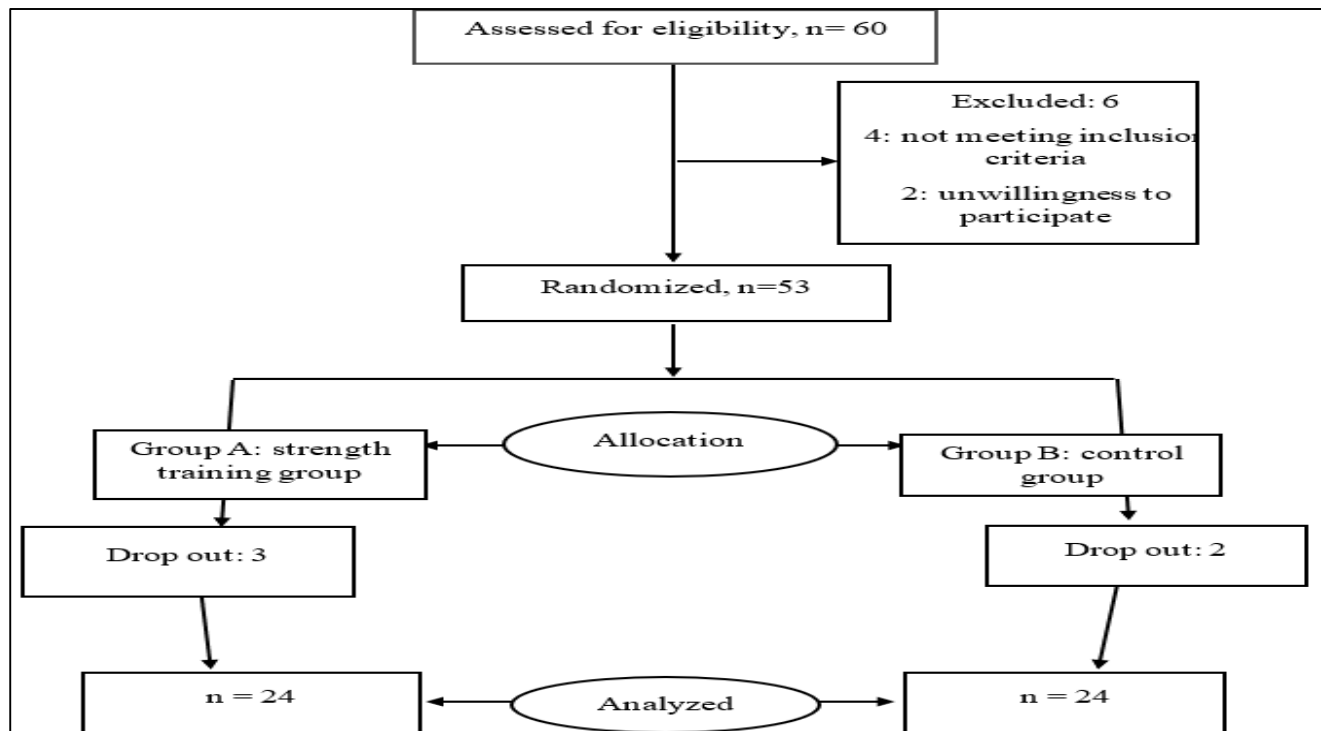


Figure 1: Consort flow diagram.

Outcome measures

DSST, TMT A and B were used.

Procedure

Subjects were preliminary screened based on the inclusion and exclusion criteria and their demographic data were collected. MMSE score was obtained. The purpose of this study was explained and a written informed consent was obtained from all the subjects. They were allocated randomly in to two groups using lottery method in which the first patient was allocated to group A and second to group B. This same sequence was maintained throughout the study. Description of groups are as follow: Group A: Strength training+conventional therapy and Group B: Conventional therapy.

Intervention

Group A: Experimental group (Strength training+conventional therapy)

Pre measures of DSST and TMT A and B were taken before starting first session. Average of 3 trials for both tests were considered as final score.

Warm up for 5 min was done prior to session which consist of arm rotation, neck rotation and march on one place.

Participants performed the strength training exercise 3 days per week for the 4 weeks (12 workouts total).

Workout consists of 12 strength training exercise that are chest press, squat, lateral pull, leg extension, abdominal crunch, lateral lift, elbow flexion, horizontal leg press, pectoral deck, oblique, hip abductor, gluteus (Hip extension).²⁴

Chest press, lateral pull, leg extension pectoral deck was done on multi station gym. Horizontal leg press was done on leg press machine. Lateral lift and elbow extension was done by considering 1 RM of patients by dumbbell. Hip extension and hip abduction were done by weight cuff after taking 1 RM. 40 to 60% of 1 RM was taken as weight for dumbbells and weight cuff. Squats, abdominal crunches and abdominal oblique was done on mat.

Participants completed 10 repetitions of all 12 exercises. 30s of rest period was allowed in between the exercises. Extra 1 min of break was allowed after 4 exercises if patient requires. Participants have to complete 2 sets which took maximum 28 min.

Cool down was done by participant which consisted of deep breathing exercises and relaxation for 7 minutes.

Post measures of DSST and TMT A and B was taken. Average of 3 trials for both tests were considered as final.

Group B: Control group

Pre and post measures of DSST and TMT A and B was taken before first session and after last session. Average of 3 trials for both tests were considered as final score.

As a conventional protocol participant did as following for 15 min.²⁵

Stretching exercises: 2-4 repetitions with 10 second hold for each muscles: biceps, triceps, hamstring, quadriceps and calf muscle.

Balance exercises: Standing on one foot for any duration, walk on heels and toes, walk backwards and sideways, and sit to stand for 10 times each.

RESULTS

Statistical analysis was done using SPSS version 20.

This study included age, DSST, TMT A and TMTB as quantitative variables, for that Shapiro-Wilk test was applied to check the normality of the data. The data follows normal distribution ($p > 0.05$).

This study included gender as qualitative variable. Baseline characteristics were compared between intervention group using an independent t-test for quantitative variables and homogeneity of dependent variables i.e. DSST TMT A and TMT B score before the exercise.

Paired t test was used to analyze the differences pre and post exercise within each group and independent t-test for between groups comparison. The level of significance for all statistical data was set at $\alpha = 0.05$.

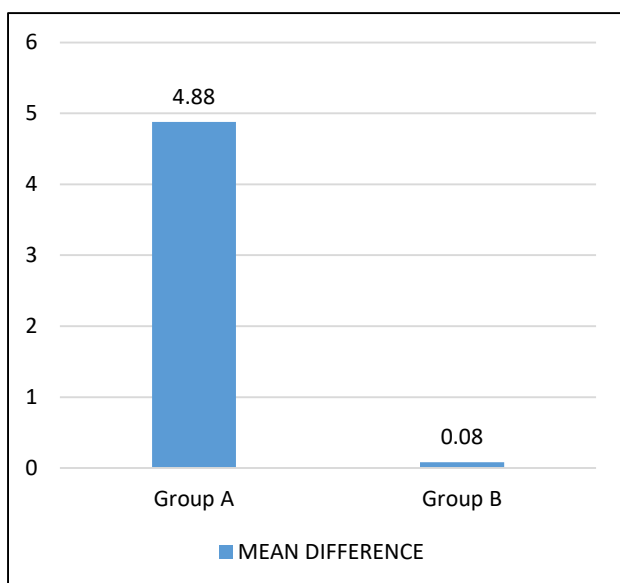


Figure 2: Intergroup comparison of DSST for both groups.

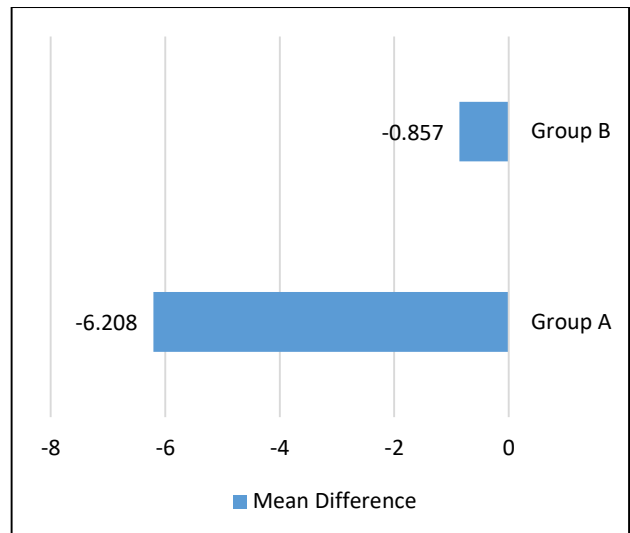


Figure 3: Intergroup comparison of TMT A for both groups.

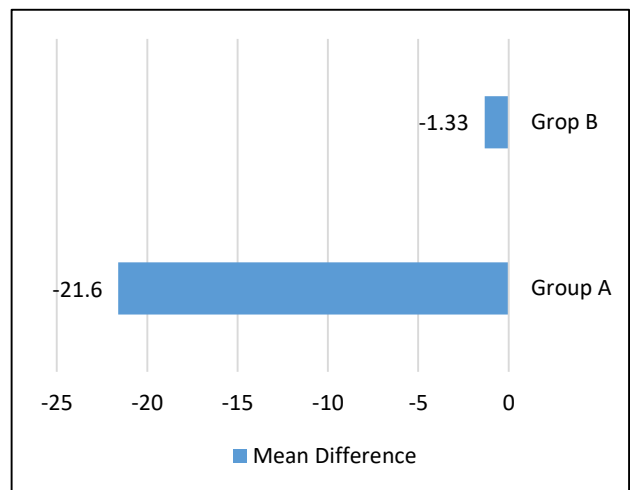


Figure 4: Intergroup comparison of TMT B for both groups.

Table 1: Baseline characteristics of subjects (quantitative variables).

Characteristics	Mean±SD, group 1	Mean±SD, group 2	P value
Age (in years)	55.1±6.95	53.9±6.05	0.075*
DSST	22.0±5.85	23.6±8.52	0.069*
TMT A	46.5±10.94	46.7±17.07	0.181*
TMT B	99.8±20.73	102.8±21.56	0.111*

*Independent t-test for quantitative data.

Table 2: Baseline characteristics of subjects (qualitative variable).

Gender	Group A	Group B	P value
Male	10	13	0.386
Female	14	11	

*Chi-square test for categorical qualitative data

Table 3: Intragroup comparison of DSST, TMT A and TMT B for both groups.

Test	Group	Pre	Post	Mean difference $\pm$ SD	P value
DSST	Group A	22.0 $\pm$ 5.85	26.7 $\pm$ 7.50	4.88 $\pm$ 2.82	<0.001
	Group B	23.6 $\pm$ 8.52	23.8 $\pm$ 8.48	0.08 $\pm$ 1.21	0.504
TMT A	Group A	46.45 $\pm$ 10.94	40.45 $\pm$ 11.56	-6.208 $\pm$ 4.20	<0.001
	Group B	46.70 $\pm$ 17.07	46.0 $\pm$ 16.65	-0.875 $\pm$ 2.05	0.121
TMT B	Group A	99.8 $\pm$ 20.73	79.6 $\pm$ 22.8	-21.6 $\pm$ 16.70	<0.001
	Group B	102.8 $\pm$ 21.56	101.8 $\pm$ 20.8	-1.33 $\pm$ 3.27	0.166

Table 4: Intergroup comparison of DSST, TMT A and TMT B for both groups.

Test	DSST		TMT A		TMT B	
	Group A	Group B	Group A	Group B	Group A	Group B
Pre	22.0 $\pm$ 5.85	23.6 $\pm$ 8.52	46.5 $\pm$ 10.9	46.7 $\pm$ 17.1	99.8 $\pm$ 20.73	102.8 $\pm$ 21.56
Post	26.7 $\pm$ 7.50	23.8 $\pm$ 8.48	40.5 $\pm$ 11.6	46.0 $\pm$ 16.6	79.6 $\pm$ 22.8	101.8 $\pm$ 20.8
Mean difference	4.88 $\pm$ 2.82	0.08 $\pm$ 1.21	-6.208 $\pm$ 4.20	-0.875 $\pm$ 2.05	-21.6 $\pm$ 16.70	-1.33 $\pm$ 3.27
P value	<0.001		<0.001		<0.001	

DISCUSSION

The purpose of the study was to examine the effect of short-term strength training on executive function in T2DM. Results of the analysis showed that the strength training exercise has beneficial effects on executive function among T2DM.

Participants of group A, who were performing strength training exercises showed improvement in DSST score with mean difference value of 4.88 and standard deviation of $\pm$ 2.82. In TMT A time taken to fulfilling test was reduced by -6.208 mean difference and $\pm$ 4.20 standard deviation. TMT B also showed reduction in the time with mean difference of -21.6 and $\pm$ 16.70 of standard deviation. Hence, all of three outcome measures showed significant improvement in executive function with $p < 0.001$, suggestive of improvement in executive function after strength training exercises among T2DM population.

Control group had mean difference of 0.08 and standard deviation of $\pm$ 1.21 in DSST. There was mean difference of -0.875 and $\pm$ 2.05 of standard deviation on TMT A and mean difference of -1.33 and $\pm$ 3.27 of standard deviation in TMT B. The result showed no improvement in control group with $p = 0.504$, 0.121 and 0.166 respectively for DSST, TMT A and TMT B.

Our study is in line with study conducted by Chang et al who checked Effects of acute high-intensity resistance exercise on cognitive function and oxygenation in prefrontal cortex and the effects of high-intensity resistance exercise on cognitive function were evaluated with the Stroop test and measures of tissue oxygen index in the left and right pre frontal cortex (PFC) before and after a single bout of different types of exercise. PFC oxygenation in high-intensity exercise compared with moderate-intensity exercise and controls. These results

suggest that high-intensity exercise may not improve cognition as effectively as moderate-intensity exercise.²⁶

Another study held by Chang et al reported significant cognitive benefits immediately after very light, to moderate intensity exercise, but not after hard to maximal intensity exercise, and further found exercise at all intensities except very light, resulted in improved cognition following a post-exercise.²⁷ Johnson et al examined if an acute bout of exercise improves the cognitive performance of older adults. They concluded that in particular for older adults who may be physically deconditioned and have a limited exercise capacity, regular, acute bouts of resistance training or aerobic exercise may be an appropriate prescription not only for improved health and fitness, but also cognition. Moderate intensity exercise is said to stimulate levels of arousal and activation that result in the optimal release of catecholamines, such as dopamine and norepinephrine, and enhance cognition (the catecholamines hypothesis [McMorris et al]).²⁸

Hillman and colleagues examined the effects of moderately intense acute exercise on cognitive performance. Acute cardiovascular exercise and executive control function. Their results showed that the benefits of acute exercise were greater for the executive function condition than for the basic information processing condition.²⁹

Paul et al conducted the study to evaluate the acute effects of high-intensity resistance exercise on cognitive function. Study ended with conclusion that tasks associated with information processing and response inhibition exhibited improvements by high intensity exercise while tasks associated with memory and recall exhibited decrements following the high-intensity resistance exercise stress.³⁰

The Strength training programme was focused on whole body muscles. The training session was designed with moderate intensity of 40 to 60% of 1 RM which was proven efficient enough to target physiological changes in the muscle of the body. Appropriate sessions and sets with enough repetitions were performed by the participants for whole strength training programme.

Strength training focuses on the blood pumping effect in respect with the intensity and frequency. It enhances the blood flow to the major parts of the body. The blood flow raises in the cerebrum thereby increase in Hb concentration. As the Hb concentration in the cerebrum increase it also lead to increase in oxygenation in the cerebral area. Oxygen is responsible for activation of the tissue, here it may activate the cerebral tissue or more precisely can increase the activation of prefrontal cortex (PFC) tissues which is directly related to executive functioning improvement.³¹

T2DM is negatively associated with IGF-1. It suggests a role of IGF1 levels in determining the risk of development of T2DM.³²

As the oxygen reaches to the PFC, it also release higher concentration of neurotransmitter to the PFC. Neurotransmitters are responsible for neurogenesis, neuronal excitement, activation and survival, neural plasticity and growth. All these mechanisms are the basis of the general physiological arousal. The strength training can be a base to modulate the levels of insuline growth factor 1 (IGF-1), neurotrophins such as brain derived neuro factors (BDNF) at the level of straitum, hippocampus and cortical areas which can be a reason for improving executive function in T2DM population.³²

The control group performed balance and stretching exercises for 15 minutes. Many studies have been established which proves that light exercises make very less to no changes in the EFs. As goal of the study was to check the effect of strength training exercise only, the protocol was designed by keeping that in mind for gaining minimal to no effect on manipulating the outcomes.

Limitations

The study have some limitations which should be overcome to have an additional results. The limitation to choose a base of any physiological evidence which can confirm the probable physiological process of results after the strength training (fMRI, BDNF and IGF1). The lack of follow up to determine long term effect of training for participants.

Future recommendation

Outcome measures like oxygen index of pre forntal cortex can be taken as physiological evidence after strength training. The study can be performed among chronic T2DM with mild cognitive impairment (MCI). Effect of short term strength training on executive function can be

checked on other neurological conditons which affects executive function

CONCLUSION

The present study concluded that short term strength training was enhancing the executive function among patient with T2DM.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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