Original Article

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Physiotherapy Section

Mild Cognitive Impairment and Hand Dexterity in Individuals with Type 2 Diabetes Mellitus: A Cross-sectional Study

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ABSTRACT

Introduction: Type 2 Diabetes Mellitus (T2DM) presents various complications, but Mild Cognitive Impairment (MCI) has recently gained considerable attention due to its potential progression to dementia. Hand dexterity is highlighted as crucial for cognitive tasks, suggesting that even minor cognitive impairments can impact daily activities. Despite this, there has been no exploration of the relationship between MCI and hand dexterity in individuals with T2DM.

Aim: To determine the relationship between MCI and hand dexterity in people with T2DM.

Materials and Methods: This cross-sectional study included 45 diabetic patients aged 40-60 years from Justice KS Hegde Charitable Hospital in Mangaluru, Karnataka, India. The study was conducted from May 2023 to March 2024. Participants were recruited based on specific inclusion criteria and screened using tools such as the Semmes Weinstein Monofilament and the Montreal Cognitive Assessment (MoCA). Subsequently, selected participants underwent the hand dexterity test using the Box and Block Test (BBT) and their performance values were recorded. The categorical variables were presented as frequency and percentage. The continuous variables were presented as mean±SD. Correlation was performed using Pearson's correlation coefficient. Linear regression was conducted for significant correlations. A p-value <0.05 was considered statistically significant.

Results: Individuals in the study scored lower than expected values on both right and left hand tasks compared to normative scores. Moderate positive correlations were found between BBT scores and MoCA scores for both right (r-value=0.469, p-value=0.001) and left (r-value=0.516, p-value <0.001) hand tasks with p-value <0.05.

Conclusion: The study reveals a significant positive correlation between BBT and MoCA scores. This suggests that hand dexterity is closely linked to cognitive function, emphasising the importance of integrating manual dexterity assessments into cognitive evaluations, particularly in populations where both motor and cognitive abilities are clinically relevant.

Keywords: Cognitive dysfunction, Executive function, Mental status and dementia tests, Motor skills

INTRODUCTION

Diabetes, which is one of the top 10 causes of death, is one of the biggest worldwide health concerns of this century [1]. It is a chronic condition caused by either insufficient insulin production by the pancreas or inefficient utilisation by the body [2]. The prevalence of diabetes is expanding rapidly in low- and middle-income nations. Approximately 77 million Indians over the age of 18 are believed to have Type 2 Diabetes, which is anticipated to reach over 134 million by 2045 [3]. High rates of morbidity and mortality are caused by prolonged periods of uncontrolled serum glucose levels, as they are linked to retinopathy, nephropathy, cardiovascular, cerebrovascular, and peripheral vascular disorders. In addition to these significant morbidities, MCI in T2DM is currently receiving considerable attention because it increases the risk of dementia [4].

Mild Cognitive Impairment (MCI), a clinical condition that exists between normal cognitive ageing and dementia, frequently precedes and progresses into dementia [5]. Defects in insulin signaling, autonomic function, neuroinflammatory pathways, mitochondrial metabolism, the sirtuin-peroxisome proliferator-activated receptor gamma co-activator 1 (SIRT-PGC-1), Tau signaling, hyperglycaemia, vascular disease, hypoglycaemia, insulin resistance and amyloid deposition are all part of the pathophysiology of cognitive decline in diabetes [6,7].

High-level cognitive processes, including executive functions, are greatly influenced by the prefrontal cortices located in the anterior frontal lobe. Studies have shown that damage to the prefrontal cortex in T2DM patients (as indicated by reduced gray matter density) is linked to worsening overall cognition and glucose management [8,9]. The prevalence of MCI was found to be 35.8%, with a greater incidence in the female population [4].

Hand dexterity refers to the skill and performance of the hand, which is essential for cognitive tasks such as writing, cooking, gardening, crafting and playing instruments. The complexity of hand movements necessitates skills in visual search, motor speed, attention management and motor planning [10,11]. Studies have shown a correlation between MCI and hand functions in older adults [12], but no studies have identified this relationship in individuals with T2DM, where cognitive decline may impact hand dexterity. Thus, the purpose of this study was to find a correlation between MCI and hand dexterity in individuals diagnosed with T2DM.

MATERIALS AND METHODS

This cross-sectional study was conducted from May 2023 to March 2024. The participants were patients admitted to the Medicine, Orthopaedics, and Surgery Units or who visited the Physiotherapy OPD of Justice KS Hegde Charitable Hospital, Mangaluru, Karnataka, India. The ethical clearance for the proposed study was acquired from the Institutional Ethics Committee of Nitte Institute of Physiotherapy, Mangaluru, Karnataka, India, under Ref: NIPT/IEC/Min//26/2022-2023, dated 9-02-2023.

Inclusion criteria: Patients with T2DM aged 40 to 60 years who were right-hand dominant, had been on insulin or oral hypoglycaemic medication for more than a year, had MoCA scores between 18 and 25 and were able to read and write in Kannada or English were included in the study.

Exclusion criteria: Patients with neurological diseases such as stroke or Parkinson's disease, those with psychiatric illnesses, hearing or visual impairments, impaired hand sensations as determined by the Semmes-Weinstein monofilament test with a log number of 2.83 [13], a diagnosis of diabetic peripheral neuropathy, or musculoskeletal conditions affecting hand function were excluded from the study.

Sample size: A study by Chakraborty A et al., showed a prevalence of 27% of MCI in T2DM [4]. Taking this value as a reference, the minimum required sample size with a 5% level of significance and a 13% absolute precision was determined to be 45.

The sample size was estimated using the formula:

$$n=\{(Z_{1-\alpha/2})^2\times P\times(1-P)\}/d^2$$

where, $Z_{1-\alpha/2}$=1.96 and d=absolute precision

Study Procedure

Participants were screened based on the inclusion and exclusion criteria using the data screening tool. The purpose and procedure of the study were explained and informed written consent was obtained from the participants who met the inclusion criteria. Participants were screened to see if they had intact hand sensations using the Semmes-Weinstein monofilament. A monofilament with a log number of 2.83 that produces a force of 0.07g was used. If they were able to perceive the monofilament, they underwent cognitive evaluation using MoCA, which is a 30-point test that can be administered in 10 minutes and assesses various cognitive domains such as short-term memory, visuospatial abilities, executive functions, attention, concentration, working memory, language, abstract reasoning and orientation to time and place [5]. The level of cognitive education was divided into four categories: 1-4 years, 5-8 years, 9-12 years, and more than 12 years. For participants with 12 years of education, an education benefit of 1 point was added to their MoCA score (if <30). Participants with MoCA scores between 18 and 25 were included in the study.

Hand dexterity was evaluated using the Box and Block Test (BBT), which consisted of 150 blocks and a wooden box with two sections divided by a partition [14,15]. The participants were instructed to transfer as many blocks as possible, one at a time, from one compartment of the box to another in a span of 60 seconds. They began the test using their dominant hand and were allowed a minimum of 15 seconds to practice before it started. The test included two trials for each hand, and the average was documented. Patients' BBT scores were compared with age- and gender-specific normative values [15].

STATISTICAL ANALYSIS

Statistical analysis of the data was performed using Statistical Package for the Social Sciences (SPSS) version 23.0. Categorical variables were presented as frequency and percentage. Continuous variables were presented as mean±SD. Correlation was performed using Pearson's correlation coefficient. Linear regression was conducted for significant correlations. A p-value <0.05 was considered statistically significant.

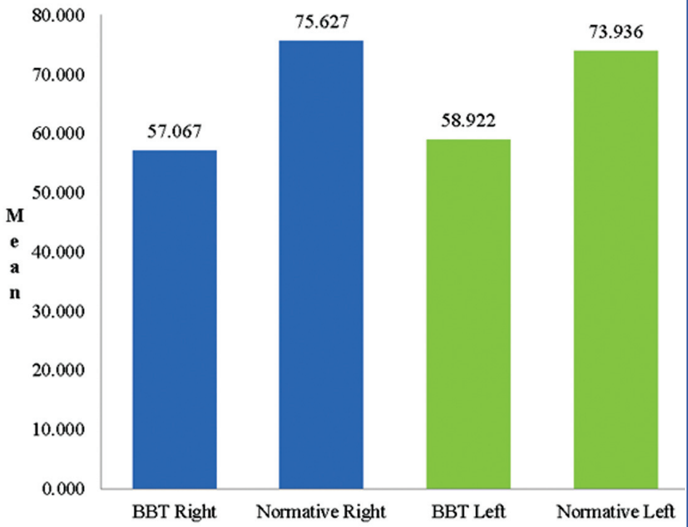
RESULTS

The study included 45 patients with T2DM, with ages ranging from a minimum of 40 years to a maximum of 60 years, and a mean age of approximately 54.5±7 years in males and 54.9±5.6 years in females, respectively. Among them, 17 were females (37.8%), and 28 were males (62.2%). Eight patients (17.8%) had more than 12 years of education, while two patients (4.4%) had one to four years of education. The most common educational category was between five to eight years, comprising 20 patients (44.4%), while 15 patients (33.3%) had between nine to 12 years of education. The majority of the patients, 25 (55.6%), had been diagnosed with diabetes for a duration ranging from one to five years. Following this, 13 patients (28.9%) had diabetes for six to 10 years, five patients (11.1%) had a longer duration of 11 to 15 years, while only two patients (4.4%) had been diabetic for 16 to 20 years [Table/Fig-1].

Parameters		Mean±SD
Age (years)	Male	54.5±7.0
	Female	54.9±5.6
		n (%)
Gender	Male	28 (62.2)
	Female	17 (37.8)
Education (in years)	>12	8 (17.8)
	1-4	2 (4.4)
	5-8	20 (44.4)
	9-12	15 (33.3)
Duration of diabetes (In years)	1-5	25 (55.6)
	6-10	13 (28.9)
	11-15	5 (11.1)
	16-20	2 (4.4)

[Table/Fig-1]: Showing demographic in patients.

The mean score for BBT scores of right hand among individuals was 57.067±10.282. In contrast, the normative mean score for the right hand was substantially higher at 75.627±3.673. Similarly, for BBT scores of left hand the mean score is 58.922±11.775 also the normative mean score for the left hand was notably higher at 73.936±2.879, indicating that individuals in the study score lower than the expected normative levels [Table/Fig-2].



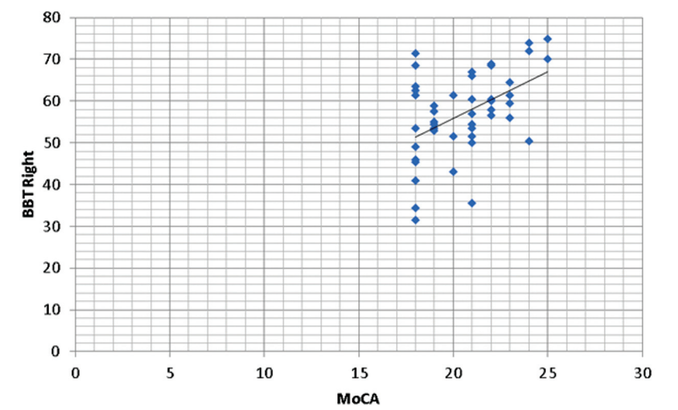
[Table/Fig-2]: Representing mean of BBT score and its normative value.

The correlation analysis reveals a significant positive association between both BBT Right and BBT Left scores with MoCA. BBT Right shows a moderate positive correlation with MoCA scores (r-value=0.469, p-value=0.001), and BBT Left exhibits a moderate positive correlation (r-value=0.516, p-value <0.001) with p-value <0.05 [Table/Fig-3-5]. The linear regression model indicates that for every one-unit increase in MoCA score, there's an associated increase of approximately 2.800 units in the BBT Left task score (β=0.516, p-value <0.001), with a statistically significant effect observed (t=3.949, p-value <0.001) and an increase of approximately 2.220 units in the BBT Right task score (β=0.469, p-value=0.001), indicating a statistically significant effect (t=3.477, p-value=0.001). This suggests that higher MoCA scores are linked to improved performance on both BBT left and right tasks [Table/Fig-6].

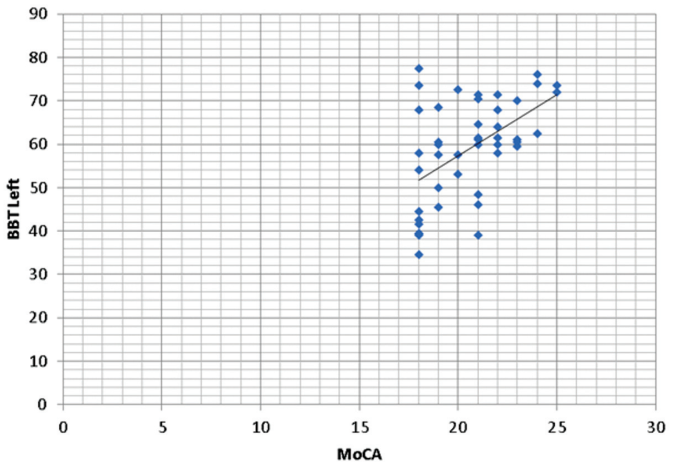
Correlation		BBT Right	BBT Left
MoCA	r-value	0.469**	0.516**
	p-value	0.001	0.000

[Table/Fig-3]: Showing correlation between MoCA and hand dexterity.
"r"=Pearson correlation coefficient; *Significant

The correlation analysis shows that individuals with higher performance on the BBT right task tend to exhibit better visuospatial/executive function (r-value=0.468, p-value=0.001), and individuals with higher



[Table/Fig-4]: Representation of correlation between BBT right and MoCA.



[Table/Fig-5]: Representation of correlation between BBT left and MoCA.

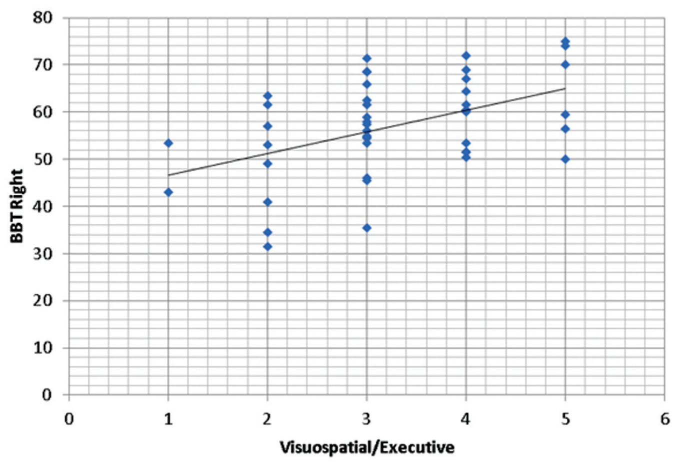
Model		Unstandardised coefficients		Standardised coefficients	t	Sig.
		B	Std. Error	Beta		
Left	(Constant)	1.363	14.653		0.093	0.926
	MoCA	2.800	0.709	0.516	3.949	0.001
Right	(Constant)	11.429	13.195		0.866	0.391
	MoCA	2.220	0.638	0.469	3.477	0.001

[Table/Fig-6]: Linear regression analysis: relationship between MoCA and BBT of left and right hand.
a. Dependent Variable: BBT

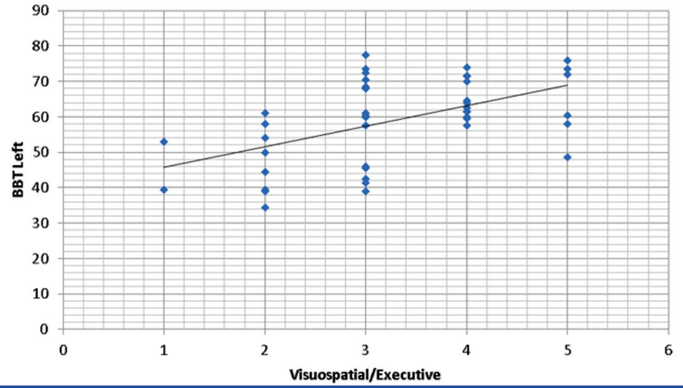
performance on the BBT left demonstrate better visuospatial/executive function (r-value=0.518, p-value <0.001) as well as memory recall abilities (r-value=0.370, p-value=0.012) [Table/Fig-7-10].

Correlation		BBT right	BBT left
Visuospatial/Executive	r-value	0.468**	0.518**
	p-value	0.001	<0.001
Naming	r-value	0.094	0.169
	p-value	0.541	0.266
Attention	r-value	0.108	0.061
	p-value	0.478	0.693
Language	r-value	-0.194	-0.243
	p-value	0.201	0.108
Abstraction	r-value	-0.138	-0.131
	p-value	0.367	0.392
Memory-delayed recall	r-value	0.293	0.370*
	p-value	0.051	0.012
Orientation	r-value	0.264	0.238
	p-value	0.080	0.116

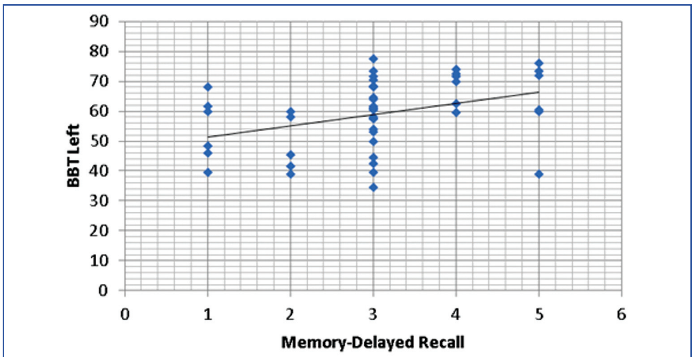
[Table/Fig-7]: Showing correlation between domains of MoCA and hand dexterity.
"r"=Pearson correlation coefficient; * Significant



[Table/Fig-8]: Representation of correlation between visuospatial/executive function and BBT right.



[Table/Fig-9]: Representation of correlation between visuospatial/executive function and BBT left.



[Table/Fig-10]: Representation of correlation between memory-delayed recall and BBT left.

DISCUSSION

The study aimed to investigate the relationship between MCI and hand dexterity in middle-aged adults with T2DM. The investigations revealed a significant correlation between hand dexterity and MCI. The scores from the BBT for the right and left hand demonstrated a moderate positive correlation with MoCA scores.

In line with the current study, Kobayashi-Cuya KE et al., discovered that among community-dwelling older adults, Purdue pegboard test performance was significantly correlated with executive function variables such as Trail Making Test A (r-value=-0.39, p-value <0.01), Trail Making Test B (r-value=-0.25, p-value <0.01), and digit symbol scores (r-value=0.47, p-value <0.01) [11]. Researchers Hesseberg K et al., found that in elderly patients with dementia and MCI, the finger tapping test was strongly associated with the clock drawing test and Trail Making Test B, while the grooved pegboard test was significantly associated with Trail Making Tests A and B [16]. In both cross-sectional and longitudinal analyses, Abe T et al., found that the peg-moving task had a significant connection with cognitive function in healthy older adults [17].

The rationale for the results mentioned above is that higher-level cognitive functioning is associated with both frontostriatal and frontoparietal connectivity. The frontoparietal connection is susceptible to impairment in early Alzheimer's disease, MCI and normal ageing. A disruption in dopaminergic striatal innervation can lead to dysfunction of the frontostriatal network and impairment in gross hand motor function, particularly motor speed [18].

The current study examined the correlation between domains of MoCA and BBT scores. The results indicated a positive relationship between visuospatial/executive functions and BBT scores of the right hand, while a positive relationship was found between visuospatial/executive functions, memory delayed recall and BBT scores of the left hand.

In accordance with the findings of the present study, Miyano I et al., discovered a positive correlation between hand dexterity and cognitive areas such as memory, executive function, attention and processing speed [19]. This suggests that sensorimotor coordination and cognitive processes—especially executive functions—play an intricate role in hand dexterity. Hand dexterity can be affected by executive function impairments, which can make it difficult to perform tasks requiring manual coordination and precision.

In the current study, all participants exhibited right-hand dominance; however, the analysis revealed that hand dexterity in both the right and left hands positively correlated with cognition. This suggests that cognitive impairment affects hand dexterity regardless of hand dominance.

The findings of the study conducted by Liu J and Shi H suggest that finger exercises have a positive impact on cognitive function, as measured by various assessment tools like the MoCA, Mini-Mental State Examination (MMSE) and Activities of Daily Living (ADL), highlighting the significance of early intervention with finger exercises for older adults who may be experiencing cognitive decline [20]. Furthermore, it opens up avenues for future research to explore the potential benefits of finger exercises or other forms of rehabilitation in treating diabetic patients with MCI. This could ultimately contribute to the development of more effective strategies for managing cognitive impairment and enhancing the quality of life for diabetic patients.

Limitation(s)

The majority of the patients in the present study were males. This disparity in the ratio can introduce a potential confounding factor that may affect the generalisability of the findings. Longitudinal studies could be conducted to monitor changes in hand dexterity and cognitive function over time, offering important insights into how these abilities develop in people with T2DM.

CONCLUSION(S)

The study reveals a positive correlation between BBT scores and MoCA scores, indicating a close link between hand dexterity and cognitive function. This suggests the importance of integrating manual dexterity assessments into cognitive evaluations, especially in patients with T2DM. Hand dexterity tests can indeed serve as useful indicators of cognitive decline in patients with T2DM; however, longitudinal investigations are needed to determine the predictive capacity of these tests.

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