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Association of Cognitive Function, Hand Grip Strength, Dexterity and Functional Abilities in Type 2 Diabetes Mellitus – A Cross Sectional Study

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Abstract:

- ***Background***

"Diabetes mellitus" "(DM)" is the most prevalent "endocrine disorder" globally, marked by metabolic irregularities that present a considerable risk to physical, social, and emotional growth, leading to many health complications. "Type 2 diabetes mellitus" is the predominant form representing 90% of all cases. "Diabetes" is associated with cognitive impairment which includes decline in attention, problem solving, reasoning and other cognitive functions. "Diabetes mellitus" affect the hand functions negatively. It can impair the hand functions like grip strength, dexterity and hand manipulation skills and consequently influence patient's hand functional performance and quality of life.

- ***Purpose***

To determine the relation of cognitive function, hand grip strength, dexterity and functional abilities in "type 2 diabetes mellitus".

- ***Materials and Method***

Fouty three subjects diagnosed with type 2 diabetes mellitus satisfying inclusion criteria were selected. Cognitive function, hand grip strength, hand dexterity and functional abilities of hand were assessed using Montreal Cognitive Assessment, handheld dynamometer, nine hole peg and Duruoz Hand Index respectively

- ***Results and Discussion***

"Regression analysis" was done and found a "significant linear relation" of cognitive function with absolute and relative hand grip strength on dominant hand ($p < .05$) and inconsistent linear relation on non dominant hand ($p > .05$), significant inverse linear relation of cognitive function with dexterity of both hands and functional abilities of hand ($p < .05$). Hyperglycemia mediated endothelial dysfunction leads to microvascular disease and atherosclerosis in "type 2 diabetes mellitus" which contributes to accelerated cortical and subcortical atrophy particularly) the frontal lobe, cerebellum and basal ganglia. Atrophy and changes in functionality of the somatosensory motor cortices may affect the skilled task execution in type 2 diabetes mellitus. Disturbances in insulin level may contribute to the accumulation of amyloid β in neural systems, potentially contributing to changes in cognitive and hand functions.

- ***Conclusion***

There is an association of cognitive function, "hand grip strength", dexterity and "functional abilities of hand" in "type 2 diabetes mellitus".

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Keywords: *"Type 2 Diabetes Mellitus"; "Absolute Hand Grip Strength"; "Relative Hand Grip Strength"; Dexterity; Functional Abilities of Hand.*

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I. INTRODUCTION

"Diabetes mellitus (DM)" encompasses a collection of "metabolic disorders" marked by "chronic hyperglycemia" accompanied by "disturbed carbohydrate, fat and protein metabolism" due to "absolute or relative deficiency in insulin secretion and/or action".[1]

"Type 2 Diabetes Mellitus (T2DM)" is the predominant form, accounting for 90% of all cases and is characterized by pancreatic β-cell dysfunctionandinsulinresistance.[2] According to a study conducted in 2019, currently over 422 million people (8.5%) over the age of 18 globally have "type 2 diabetes mellitus".[3] In 2017,a "study" on Global estimates of diabetes prevalence reports that India currently represents 49% of world's diabetes burden and Kerala is considered to be the diabetes capital, with prevalence nearing 20%.[4,5] In 2019,Vijaykumar G et al reported that the cumulative incidence of T2DM in Kerala is 21.9%.[6] With the increase in prevalence of T2DM, complications associated with the disease also increase and may disturb activities of daily living and quality of life.[1]

Recent evidence suggests that adults with T2DM experience decline in cognitive functions, compared with individuals without T2DM.[3] "Type 2 diabetes"-related cognitive symptoms can be evident even in middle age in several "cognitive functions", including "information processing speed", "executive functions", "attention" and "concentration", "working memory", and "perceptional" and "constructional skills".[7]

Grip strength and dexterity are important measures of hand function.8,9 T2DM can impair the hand functions like grip strength, dexterity and hand manipulation skills and consequently influence patient's hand functional performance and quality of life.10,11 Hand function is crucial to the majority of a person's functional abilities.12 Hand functions addressing functional abilities like dressing, personal hygiene, office tasks decrease moderately in patients with diabetes mellitus13"Diabetes mellitus" is a leading cause of "disability" and often results in many limitations in "daily activities of life".14

People with T2DM suffer from cognitive decline, it includes decline in attention, problem solving, reasoning and other cognitive functions. Diabetes mellitus affect the hand functions negatively. Studies have proven that cognitive impairment as well as hand dysfunction is evident in T2DM. Previous studies reported significant associations between cognitive performance, hand grip strength and hand dexterity in community-dwelling older adults, but not in people with T2DM.

II. MATERIALS AND METHOD

"Analytical cross-sectional study" was conducted with convenience sampling technique for a duration of six months to determine the relation of cognitive function, hand grip strength, dexterity and functional abilities in T2DM**.**

"After receiving approval from the Scientific Committee" and "Institutional Review Board", fourty three individuals diagnosed with T2DM who met the inclusion "criteria were recruited" from the hospital setting, "after obtaining" the "informed consent". Both male and female aged 45 to 60 years diagnosed with T2DM and MoCA score greater than or equal to 10were included in the study. Subjects with co-morbidities that affect gross weight loss such as cancer, hypertension for more than 5 years since onset, chronic kidney disease, medically unstable patients, degenerative and inflammatory conditions of musculoskeletal and nervous system, recent upper extremity surgeries, psychiatric and non- cooperative patients, recent history of upper limb fracture, deformities of upper limb, Body Mass Index(BMI) greater than or equal to 30, not willing to participate in the study were excluded from the study.

- *Procedure*

Subjects diagnosed with T2DM and MoCA score of 10 or higher were evaluated for their absolute and relative hand grip strength using baseline hydraulic handheld dynamometer, hand dexterity using "Nine Hole Peg Test" and functional abilities of hand using Duruőz Hand Index for both "dominant" and "non dominant hand".

III. RESULTS

"The obtained data was analysed using IBM SPSS Version 20.00. Baseline homogeneity was established using test for linearity". "A p value less than 0.05 was considered as statistically significant". "The statistical analysis of the data showed that all of the variables were normally distributed". "Thus regression was used for the analysis".

The β value for "cognitive function" in relation to "absolute hand grip strength of dominant and non dominant hand" in "type 2 diabetes mellitus" was 0.310 and 0.283 respectively. The positive β value indicated a linear relationship between the variables. As type 2 diabetes mellitus subjects MoCA score (by which "cognitive function" was assessed) increased, the "absolute hand grip strength of dominant and non dominant hand" also increased. The β value between 0.21-0.50 indicated a weak

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relationship between "cognitive function" and "absolute hand grip strength of dominant and non dominant hand" in "type 2 diabetes mellitus".

The β value for "cognitive function" in relation to "relative hand grip strength of dominant and non dominant hand" in "type 2 diabetes mellitus" is 0.307 and 0.281 respectively. The positive β value indicated a linear relationship between the variables. As "type 2 diabetes mellitus" subjects MoCA score increased, the "relative hand grip strength of dominant and non dominant hand" also increased. The β value between 0.21 – 0.50 indicated a weak relationship between "cognitive function" and "relative hand grip strength of dominant and non dominant hand" in "type 2 diabetes mellitus".

The β value for "cognitive function" in relation to "dexterity of dominant and non dominant hand" in "type 2 diabetes mellitus" is -0.599 and -0.488 respectively. The" negative" β value indicated an "inverse linear relationship" between the "variables". As "type 2 diabetes mellitus" subjects MoCA score increased, the time taken to complete "the nine hole peg test of dominant and non dominant hand" decreased. The β value between 0.51 – 0.80 indicated a moderate relationship between "cognitive function" and "dexterity of dominant hand" and the β value between 0.21 – 0.50 indicated a weak relationship between "cognitive function" and "dexterity of non dominant hand" in "type 2 diabetes mellitus".

The β value for "cognitive function" in relation to "functional abilities of hand in type 2 diabetes mellitus" is -0.450. The "negative β value" indicated an "inverse linear relationship" between the variables. As "type 2 diabetes mellitus" subjects MoCA score increased, the "functional abilities of hand" decreased. The β value between 0.21 – 0.50 indicated a weak relationship between "cognitive function" and "functional abilities of hand" in "type 2 diabetes mellitus".

With degrees of freedom 42 and confidence interval 95%,the calculated value of "cognitive function" and "hand grip strength" (absolute and relative)of dominant hand was 2.091and 2.065 respectively. The calculated value of t for "cognitive function" and "hand grip strength" (absolute and relative) of "non dominant hand" was1.890 and 1.875 respectively. The calculated values for "cognitive function" and "dexterity" (dominant and non dominant hand) were 4.785 and 3.576 respectively. The calculated value of t for "cognitive function" and "functional abilities of hand" was 3.222. Since the "calculated values are greater than table value" (Z=1.96 & T=1.682) except for "cognitive function" and "hand grip strength" (absolute and relative)of "non dominant hand", we are "rejecting" the "null hypothesis" and "accepting" the "alternate hypothesis". So there is a significant association between "cognitive function" and "absolute and relative handgrip strength for dominant hand", "dexterity" and "functional abilities" in "type 2 diabetes mellitus". The "association between" "cognitive function" and "absolute and relative handgrip strength" of "non dominant hand" is not significant and consistent.

Table 1 Demographic Representation of Age

Age	Frequency	Percentage
45-50	10	23.2%
51-55	6	14.0%
56-60	27	62.8%
TOTAL	43	100.0%

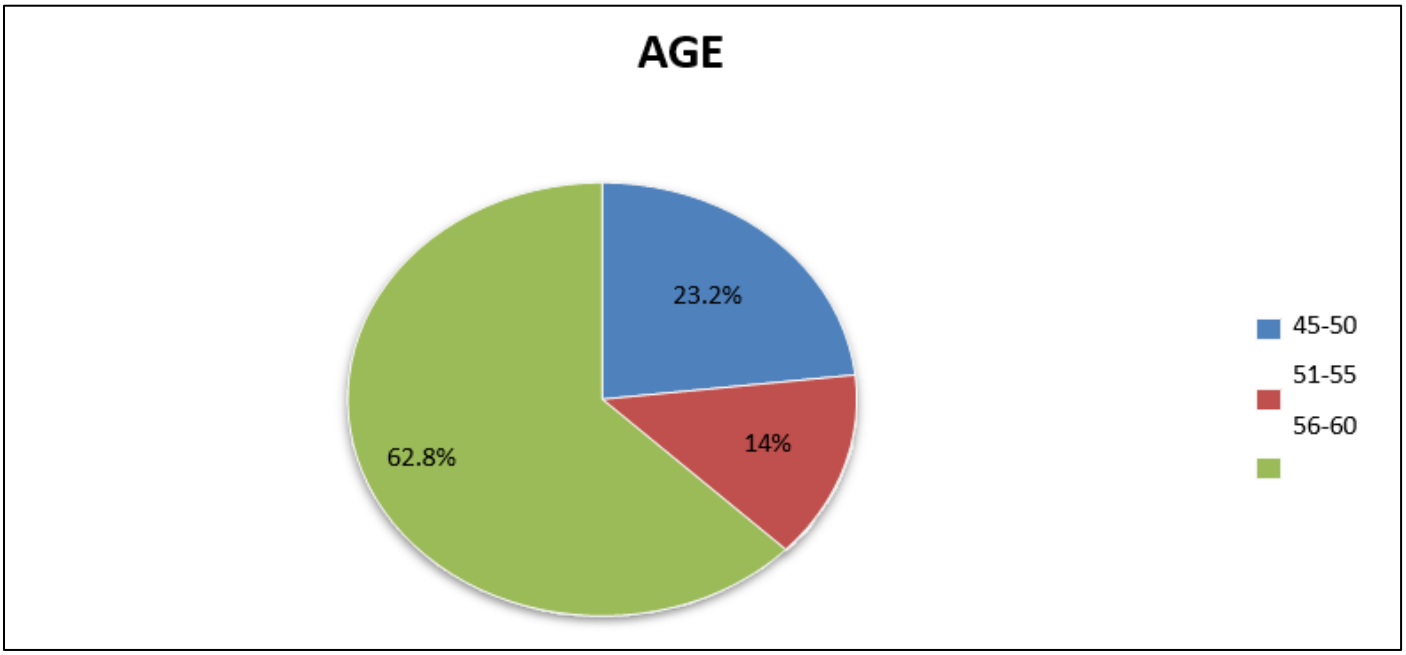

Fig 1 Demographic Representation of Age

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Table 2 Demographic Representation of Gender

Gender	Frequency	Percentage
“Male”	“17”	“39.5%”
“Female”	“26”	“60.5%”
“Total”	“43”	“100.0%”

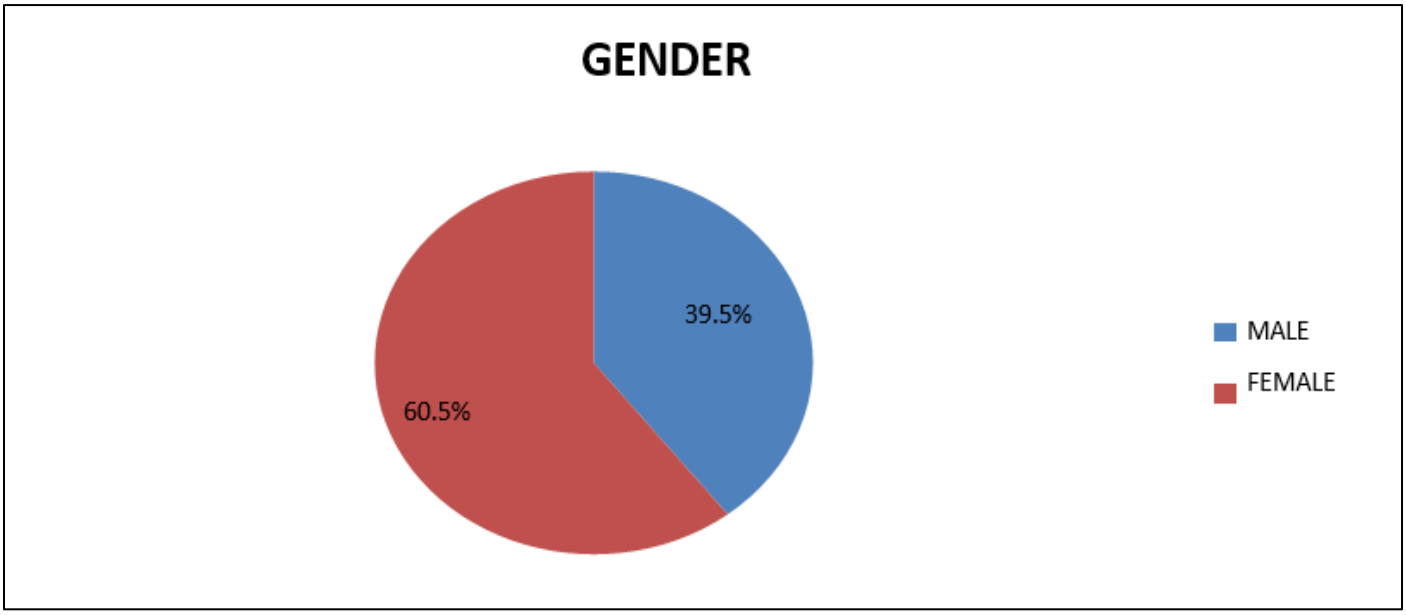


Fig 2 Demographic Representation of Gender

Table 3 Demographic Representation of Duration of “Type 2 Diabetes Mellitus”

Duration of “Type2diabetes Mellitus” (In Years)	Frequency	Percentage
0-5	23	53.5%
6-10	9	20.9%
11-15	5	11.6%
16-20	2	4.7%
21-25	2	4.7%
26-30	2	4.7%

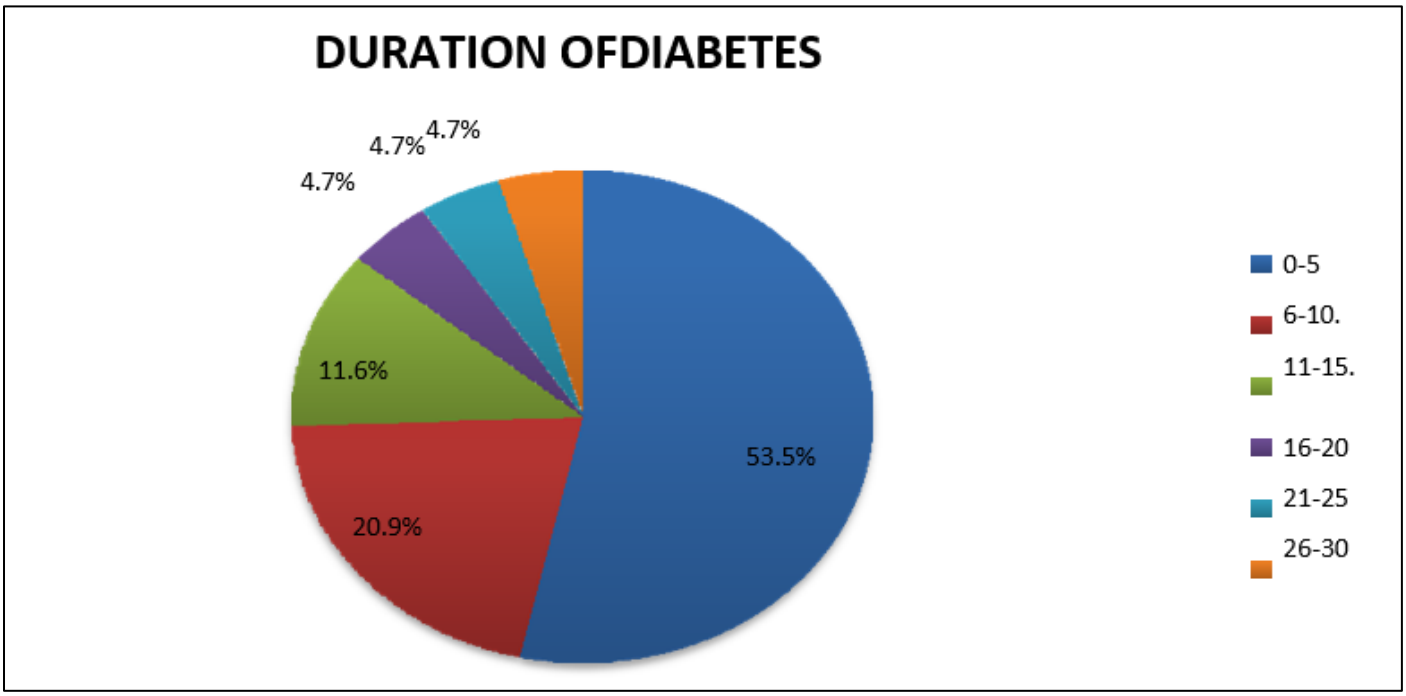


Fig 3 Demographic Representation of Duration of “Type 2 Diabetes Mellitus”

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1968

Table 4 Demographic Representation of MoCA Score of Subjects in the Study

MoCA Score	Frequency	Percentage
26-30	5	11.6%
18-25	26	60.5%
12-17	12	27.9%
Total	43	100%

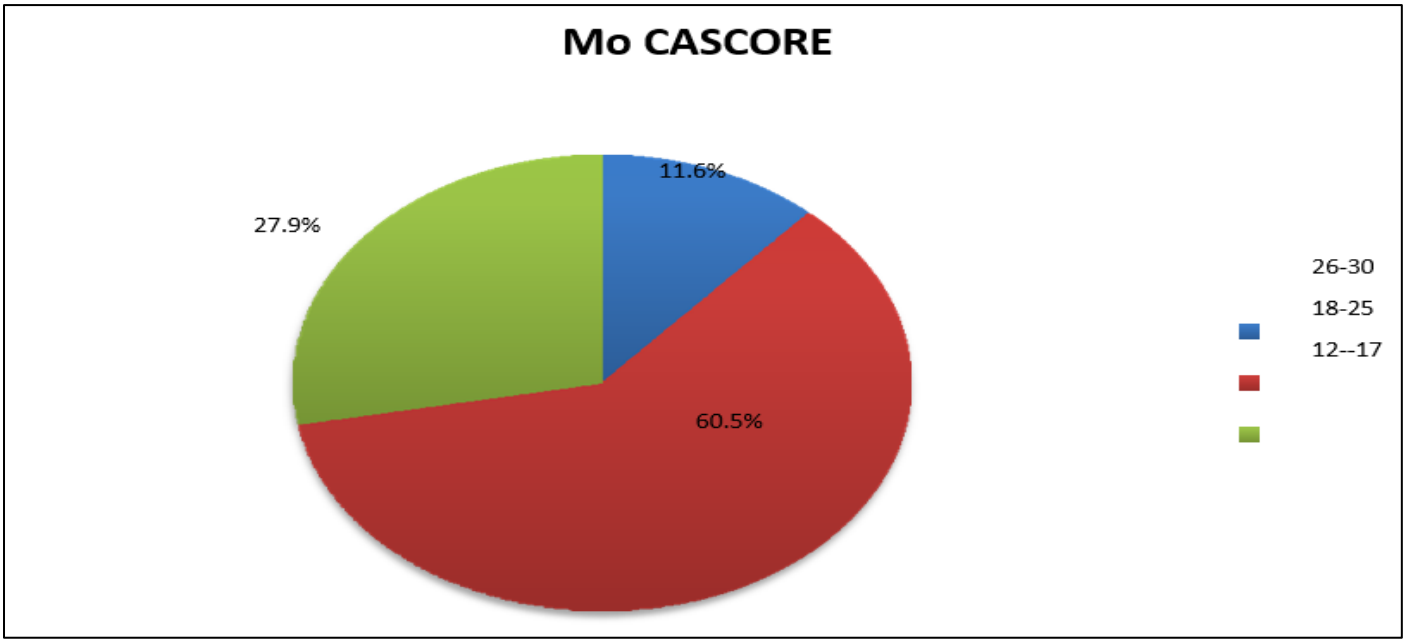


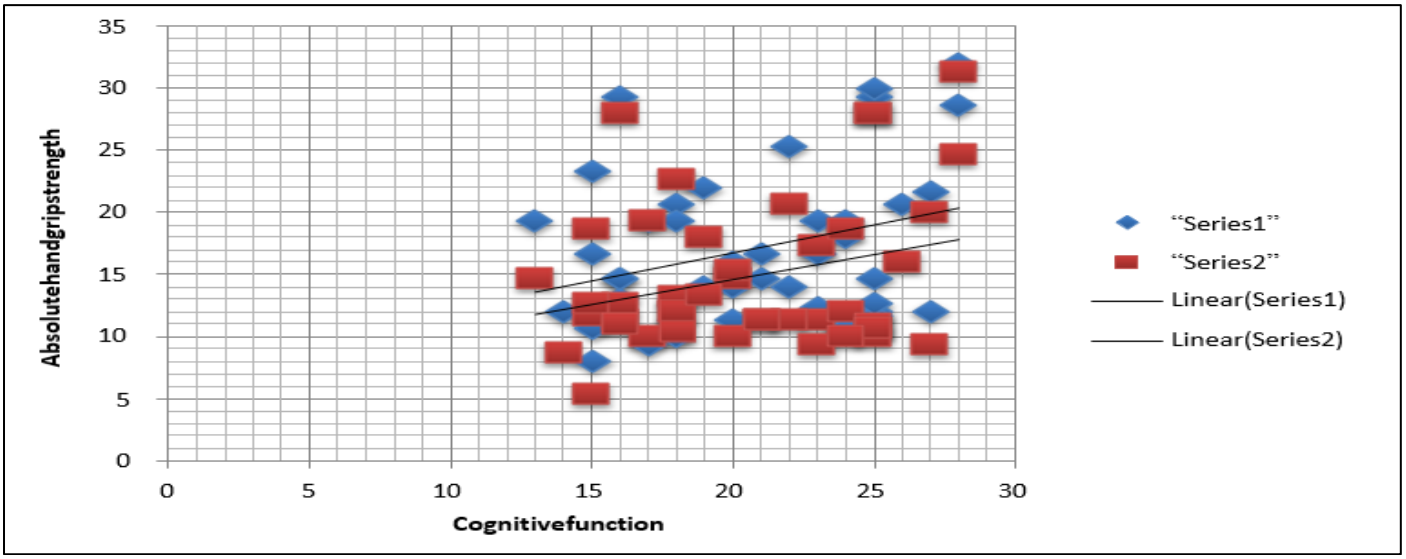
Fig 4 Demographic Representation of MoCA Score of Subjects in the Study

Table 5(a): Regression of "Absolute Hand Grip Strength of Dominant Hand" on "Cognitive Function"

Linear Regression Model	Standardized Coefficients Beta(β)	t	Sig.
Absolute Hand Grip Strength of Dominant Hand	.310	2.091	.043
Cognitive Function			

Table 5 (b): Regression of "Absolute Hand Grip Strength of Non Dominant Hand" on "Cognitive Function"

Linear Regression Model	Standardized Coefficients Beta(β)	T	Sig.
"Absolute Hand Grip Strength of Non Dominant Hand"	.283	1.890	.066
"Cognitive Function"			



Graph 1: Regression of Absolute "Hand Grip Strength of Dominant and Non Dominant Hand" on "Cognitive Function"

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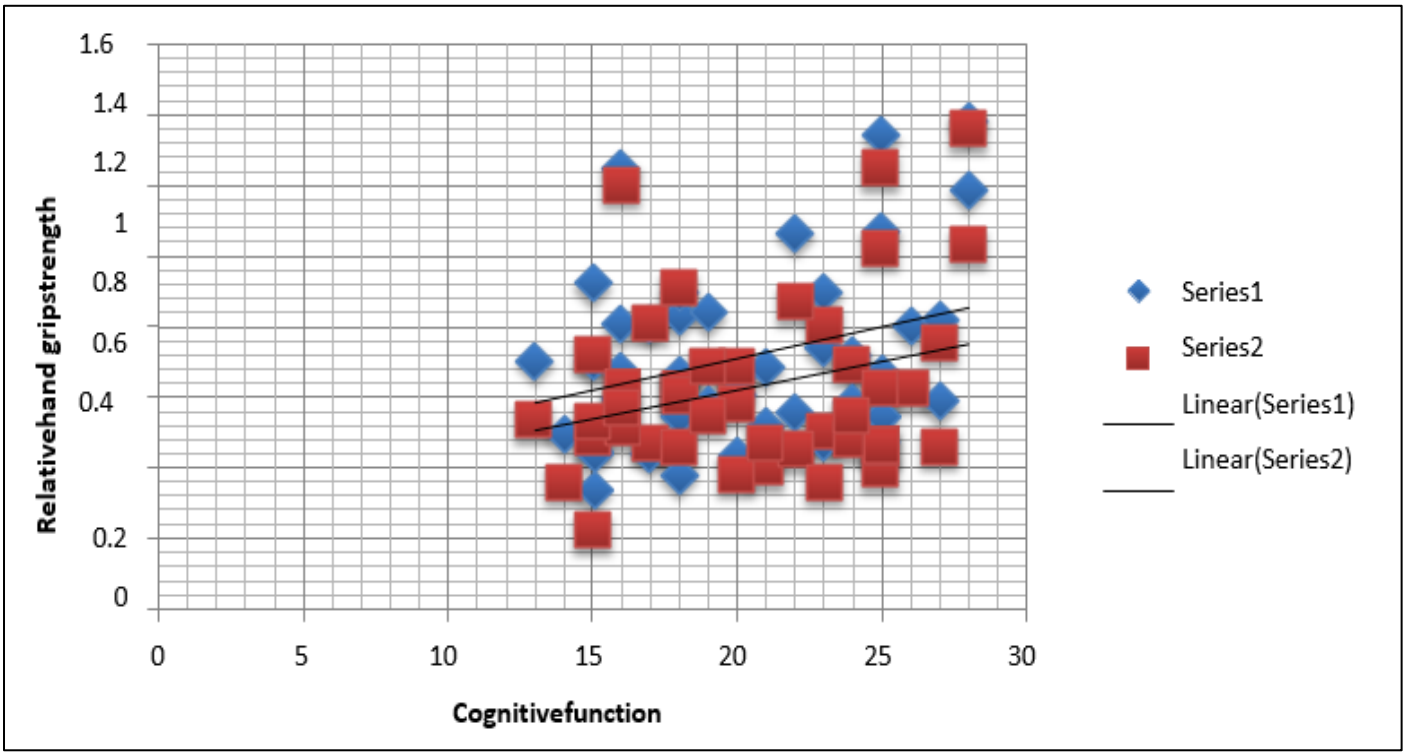
Table 6 (a): Regression of "Relative Hand Grip Strength of Dominant Hand" on "Cognitive Function"

Linear Regression Model	Standardized Coefficients Beta(β)	t	Sig.
Relative Hand Grip Strength of Dominant Hand	.307	2.065	.045
Cognitive Function			

Table 6 (b): "Regression of Relative Hand Grip Strength of Non Dominant Hand" on "Cognitive Function"

LinearRegressionModel	Standardized Coefficients Beta(β)	t	Sig.
Relative Hand Grip Strength of Non Dominant Hand	.281	1.875	.068
Cognitive Function			



Graph 2: Regression of "Relative Hand Grip Strength of Dominant and Non Dominant Hand" on "Cognitive Function"

Table 7 (a): Regression of "Dexterity of Dominant Hand" on "Cognitive Function"

Linear Regression Model	Standardized Coefficients Beta(β)	t	Sig.
Dexterity of Dominant Hand	-.599		
Cognitive Function		-4.785	.000

Table 7 (b): Regression of "Dexterity of Non Dominant Hand" on "Cognitive Function"

Linear Regression Model	Standardized Coefficients Beta(β)	t	Sig.
Dexterity of Non Dominant Hand	-.488	-3.576	.001
Cognitive Function			

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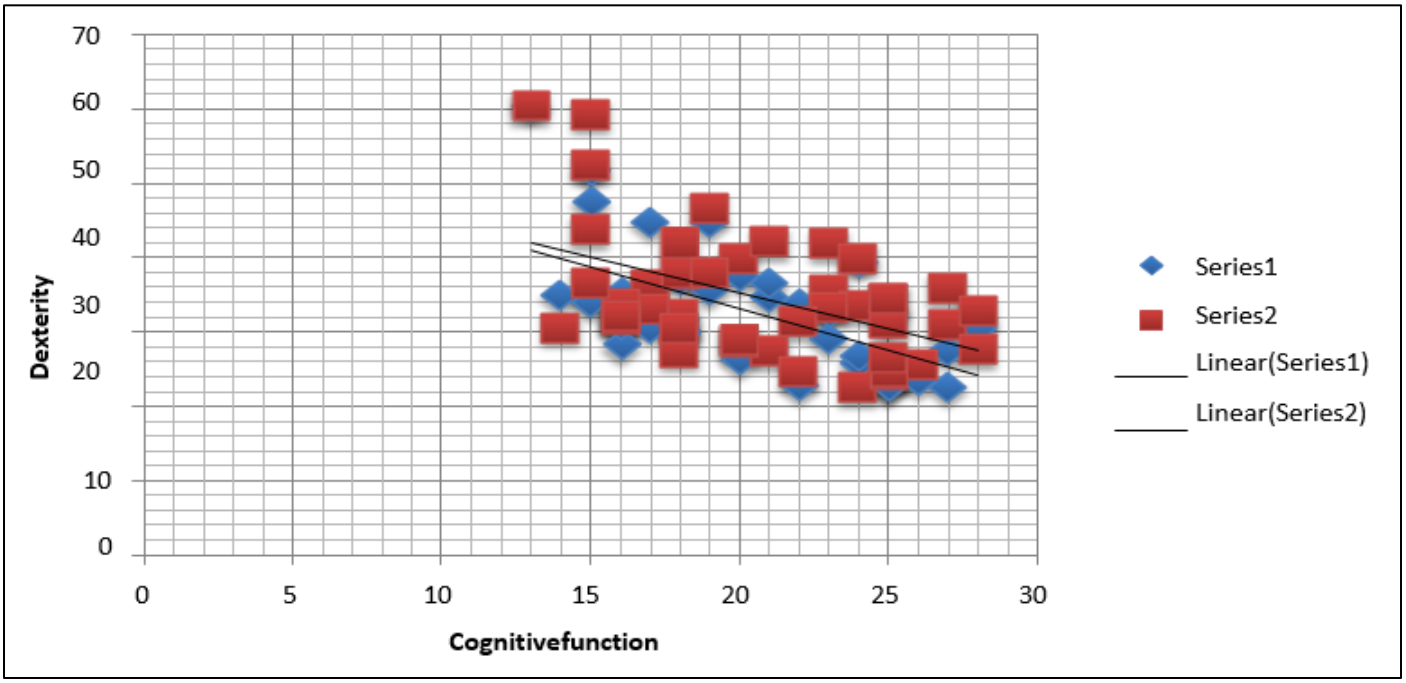
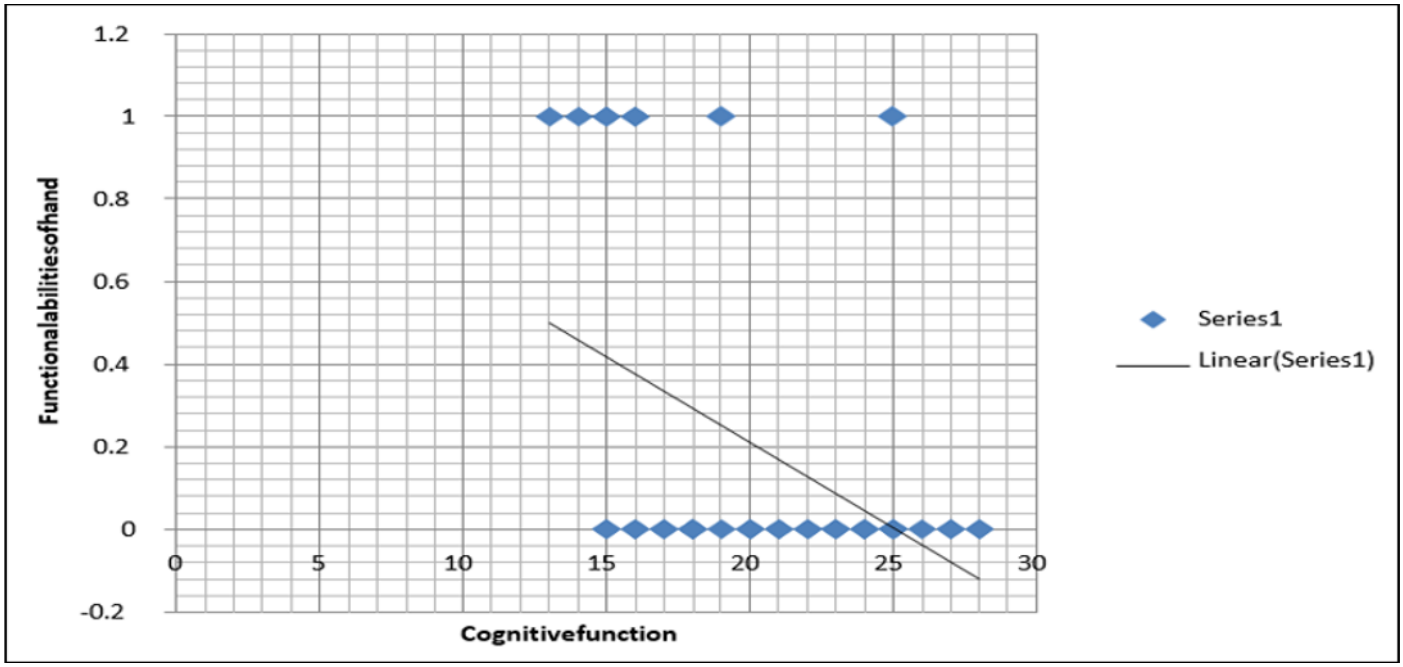


Graph 3: Regression of "Dexterity of Dominant" and "Non Dominant Hand" on "Cognitive Function"

Table 8 Regression of "Functional Abilities of Hand" on "Cognitive Function"

Linear Regression Model	Standardized Coefficients Beta(β)	t	Sig.
Functional Abilities of Hand	-.450	-3.222	.002
Cognitive Function			



Graph 4: Regression of "Functional Abilities of Hand" on "Cognitive Function"

IV. DISCUSSION

The "results" of this study revealed that "cognitive function" has a "significant direct linear relationship" with "absolute" and "relative hand grip strength of dominant hand". But the "non dominant hand" showed insignificant and inconsistent direct linear relationship of "cognitive function" with "absolute and relative hand grip strength". A significant inverse linear "relationship of cognitive function with dexterity of dominant and non dominant hand" was obtained. The study also found a significant inverse linear "relationship of cognitive function with functional abilities of hand".

The vascular and neurodegenerative effects of diabetes are linked to the development of cognitive impairment.[15]

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People with diabetes show several motor dysfunctions.[16] "Chronic hyperglycemia", "insulin resistance", "inflammation" and "oxidative stress" owing to "diabetes" can cause mixed cerebrovascular and neurodegenerative lesions.[17] Individuals with diabetes also showed accelerated cortical and subcortical atrophy, symptomatic or asymptomatic infarcts and white matter lesions in periventricular and subcortical areas.[18,19] The sensori motor cortices, basal ganglia, cerebellum ,brain stem are important in generating motor commands.[16] This might be the reasons for decrease in motor function which in turn have reduced hand grip strength and dexterity thereby functional abilities of hand.

Hyperglycemia mediated endothelial dysfunction leads to microvascular disease and atherosclerosis in T2DM which affects the structure and function of brain.[20]T2DM disease process mainly affects the frontal lobe, cerebellum and basal ganglia.[19]Cognitive function is correlated with neural activity in the cerebellar loops and basal ganglia, associated with the prefrontal cortex.[21] The involvement of prefrontal cortex, basal ganglia and cerebellum in T2DM may contribute to decrease in cognitive functions.T2DM related changes in frontal lobe, cerebellum, basal ganglia contributes to the impairment in motor and cognitive function may be the reason for association between cognitive function, hand grip strength, hand dexterity and functional abilities of hand.

T2DM is linked to alterations cerebral energy homeostasis, potentially leading to "inflammation" and can significantly "alter vascular physiology", such as decreased "endothelial dependent vasodilation" and inadequacy in "cerebral vascular reactivity".[22] Chronic hyperglycemia elevates the synthesis of "advanced glycation end products" (AGEs) resulting in the production of "reactive oxygen species". This "reactive oxygen species" promotes "oxidative stress" that leads to inflammation.[23] "Mitochondrial oxidative stress" modifies the "endoplasmic reticulum signaling", leading to activation of significant "cell damaging pathways" and subsequent "neuronal damage", ultimately culminating in a decrease in gray matter volume.[18]Disturbances in physiological insulin levels may also results in "apoptosis", "oxidative stress", "β amyloid toxicity" and "ischemia".[24] The above mentioned pathological changes leading to reduction in "gray matter" volume can also be a contributing factor for the changes in "motor functions" and "cognitive functions" in T2DM.

Studies examining the "gray matter" changes using high resolution T1-weighted images showed a decreased activity and reduction in primary motor cortex volumes in T2DM.[19]Studies prove that primary motor cortex volumes is strongly associated with grip strength as well as manual dexterity and the activity in this area is decreased in individuals with diabetes which leads to reduction in upper extremity control.[25,26,27] One of the main reason for the reduction in grip strength and dexterity along with cognitive function is due to the reduction in primary motor cortex volume which may further contribute to the reduction functional abilities of the hand.

Decline in insulin and insulin resistance may impair "regional glucose metabolism" and contribute to "gray matter volume changes".[18]Deposition of amyloid β plaques in cognitive systems occurring due to disturbances in insulin levels affect the motor function, play an important role in planning and execution.[28,24]Daily "hand dexterity" tasks usually demand "executive functioning" and "attention".[29] These changes related to T2DM in the brain might lead to the alterations in "cognitive function" ,"hand functions" especially dexterity.

"Diabetes" is linked with "atrophy" and "altered function" of the "somatosensory" and "motor cortices" as well as their corresponding "white matter" projections which may affect the execution of skilled tasks. Complications of diabetes in the "central nervous system" may precede peripheral "nervous system" complications, which result in sensorimotor impairments even in individuals who do not have diagnostic signs of "peripheral neuropathy".[19] The impairment in "skilled task execution" along with the peripheral nervous system complication may be another contributing factor in declining motor functions especially "dexterity" which thereby contribute to reduction in "functional abilities of the hand".

This study clearly states an association of "cognitive function", "hand grip strength", "dexterity" and "functional abilities" and the possible reasons for this association indicates that a decline in "cognitive function" will lead to decline in the "hand grip strength", "dexterity" and thereby "functional abilities of hand" .A reduction in "hand functions" at early stages of T2DM in relation to cognitive impairment must be a concern.

V. LIMITATIONS

- Subjects with diabetes within a duration of 5years exhibiting different levels of MoCA scores was not obtained.
- Even though the inclusion criteria covered a wide age range of 45 to 60 years most of the participants were between 56 and 60 years old
- Equal gender distribution was not obtained
- The majority of the subjects had a duration of diabetes mellitus ranging from 0-5years.

VI. SUGGESTION FOR FUTURE STUDIES

- Same study can be conducted in type1diabetes mellitus.
- Same study can be conducted by including the age matched non diabetic population.
- The involvement of hand grip strength, dexterity and functional abilities of hand in each levels of cognitive decline can be studied separately.
- Can be focused on developing and implementing the interventions to improve cognitive function, hand grip strength, dexterity and functional abilities of hand on different levels of cognitive function.

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VII. CONCLUSION

"This study aimed" to determine the relation of cognitive function, "hand grip strength", dexterity & functional abilities in type 2 diabetes mellitus. The study concluded that there is an association of cognitive function, hand grip strength, dexterity and functional abilities of hand in T2DM

LIST OF ABBREVIATIONS

- aHG–Absolute Hand grip Strength
- DHI - Duruöx Hand Index
- DM–Diabetes Mellitus
- MoCA–Montreal CognitiveAssessment NHPT- Nine Hole Peg Test
- rHG-Relative Handgrip Strength T2DM –Type2Diabetes Mellitus

➢ *Author Contributions:*

The author's confirm contribution to the paper as follows:

- Study conception and Design: Remya N and Giny Paul;
- Data Collection: Giny Paul;
- Review and Editing: Remya N and Praveen Baby
- Analysis and Interpretation: Reethu Elsa Baby and Manju Unnikrishnan
- Draft Manuscript: GinyPaul
- All the authors reviewed the results and approved the final version of manuscript.
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- "Ethical Approval: Approved"

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