Original Article

Correlation of Visuo-Spatial Skills, Executive Function and Psychomotor Speed on Fall Risk and Overall Functional Mobility in Patients with Parkinson's Disease

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Abstract

Background and Objectives: Spectrum of cognitive impairments, is frequently observed in early stages of Parkinson's disease. Diminished functional mobility, often manifesting as falls, is commonly seen in conjunction with these impairments. This study aims to explore the correlation between visuospatial skills, executive function, and psychomotor speed with fall risk and overall functional mobility in patients with early Parkinson's disease.

Study design: Cross sectional study with correlational analysis.

Methods: 52 Parkinson's patients in Hoehn and Yahr stage 1 and 2 were included and evaluated for Visuospatial skills and Psychomotor speed by using Digit Symbol Substitution Test (DSST), Executive functions by using Trail Making Test-A (TMT-A), Fall-risk and overall functional mobility by Timed Up and Go Test (TUG) with its subscales.

Results: The data normality was established by Kolmogorov Smirnov test and Karl Pearson's correlation coefficient test was used to draw correlational analysis. Significant negative correlation was observed between Visuospatial skills, Psychomotor speed (DSST) with fall risk and overall functional mobility-TUG Normal ($r = 0.3284$), Cognitive Dual task ($r = -0.4270$ and Motor Dual Task $r = -0.4334$) and a significant positive correlation between Executive function (TMT-A) with fall risk and functional mobility-TUG Normal ($r = 0.5846$), Cognitive Dual task ($r = 0.4364$) and Motor Dual Task ($r = 0.4039$).

Conclusions: Results indicate that Visuo spatial skills, Executive function and psychomotor speed have a substantial relationship with fall risk and overall functional mobility as demonstrated by significant correlation between all 3 variants of Timed up and go test.

Keywords: Visuo-spatial skills; Executive function; Psychomotor- speed; Fall risk; Functional mobility.

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Introduction

Parkinson disease first described in 1817 as a 'shaking palsy' is a progressive neurodegenerative disorder of central nervous system with both motor and non-motor symptoms.[1,2].

A population-based survey in Gujarat, India revealed that age related prevalence rate was 308.9 per 100000 populations above the age of 60.[3] Gender specific prevalence rate was reported higher in men than women in India as well as across the world.[4]

While the disease has a progressive deteriorating effect on mobility and muscle control [3]it may also present with an array of cognitive deficits ranging from subjective-cognitive-decline (PD-SCD) to mild-cognitive-impairment (PD-MCI) and late-stage-dementia (PD-D)[5]. About 31% of diagnosed patients are known to present with measurable cognitive decline**even in the early stages of the disease besides an associated bradyphrenia.[6,7]**

Patients with PD demonstrate limited ability to cope with tasks that require complex cognitive demandsassociated with walking like perceiving and avoiding obstacles, capacity to prioritize and interpret the task demandsand divided attention for dual tasks.[8] The executive function deficit was seen to be associated with gait impairment and freezing of gait (FOG).[9,10] Overall, cognitive abilities are considered vital determinants of one's functional-mobility which is a known predictor of mortality and hospitalization.[11]

A phenomenon of fall is usually an expression of diminished functional mobility and is often seen in patients with Parkinson's disease.[12] It is estimated that 70% to 87% of individuals with Parkinson's disease fall at some point during the course of their disease.[13]It is well emphasized that preserving functional-mobility and preventing falls is one of the most important facets of PD management. Early employment of potential strategies to prevent falls is critical howeverit is an un-met need in PD[14].

In view of the above scenario, precisely understanding the interplay between the specific cognitive components and overall functional-mobility and fall riskcould be deemedsignificant. Further, there are fewer studies, which address the early cognitive decline in Parkinsons and its influence on functional mobility and fall risk. This study was hence conducted, with an objective to evaluate specific cognitive attributes namely executive functions, visuo-spatial skills and psychomotor speed in early stages of PD and further correlate it with fall risk and functional mobility.

Materials and Methods

This cross- sectional study included patients in early stages of Parkinson's disease.The participants were recruited from the urban and sub-urban communities of Hubli-Dharwad.

Purposive sampling was employed **to ensure inclusion, of participants who specifically met the criteria for early PD as determined by screening outcomes and who hadbasic formal education**. **This method was chosen to target individuals with characteristics relevant for this study.**The sample size was calculated considering the age- related prevalence of Parkinson's disease in India[3] over the age of 60, using the formula

$$n = Z^2 \times P \times (1-P)/d^2.$$

where n is the required sample size, prevalence P = 0.00309, Z-score for the desired confidence level for 95%; Z = 1.96, d is the desired precision of 2% the required minimum sample size was calculated as 29.58~ 30 participants. The study was conducted over a duration of 1 year and included 52 participants.

Inclusion criteria: Patients of any gender diagnosed with and in early stages of Parkinson's disease, i.e. Hoehn and Yahr[15]stage 1 and 2, with an ability to read and write (at-least 5 years of formal education) and willing to participate were included.

Exclusion criteria: Patients diagnosed with Alzheimer's disease or Parkinson-plus syndromes, and patients with communication impairments (verbal, nonverbal, or both). Additionally, patients with a history of or co-existing chronic neurological conditions, visual deficits, diabetic neuropathy, or musculoskeletal conditions that limited their independent mobility in the last three months were excluded.

Data Collection: The contact details of patients diagnosed with idiopathic Parkinson's disease by a qualified medical practitioner/ Neurologist were taken from the Medical Record Department and were contacted via a phone call and explained about the research. The patients who were willing to participate were invited to the Neuro-physiotherapy OPD for screening of inclusion and further study procedures. Willing patients who could not visit the outpatient facility were screened for inclusion and evaluated in their home settings by the researcher personally visiting such patients. The patients were explained the study procedure and an information sheet was shared with all requisite details explained. Patients were evaluated in their ON phase of medication. The demographic details of every participant were noted and they were evaluated for visuospatial skills and psychomotor speed by using **Digit symbol substitution test (DSST)[16], executive functions by using Trail making test- Part A (TMT-A)[17], and Functional mobility using Timed up and go test (TUG)[18]** with cognitive and motor dual tasks. The data obtained was analyzed statistically using SPSS version 20.0.

The study was presented to the Institutional Ethics Committee (IEC) of SDM Medical College and Hospital and the approval was obtained. The study was also registered under the Clinical Trials Registry India (CTRI) with No CTRI/2021/01/030811before the patient recruitments were initiated.

Results

The socio-demographic characteristics of the participants i.e. age, gender and educational levels were noted. The present study recruited 52 patients with Parkinson's disease which included 35 (67.31%) male and 17 (32.69%) female participants. Mean age of the participants was 66.52±6.4 years. The level of education of the participants was segregated in 3 categories. The maximum numbers of respondents were in secondary schooling group i.e. 26 (50.0%), 17 (32.69%) were in a category of primary schooling and the least number of participants were in degree + group i.e. 9 (17.51%) participants. While the mean DSST scores were comparable between genders, female gender fared better with mean TMT scores. Both cognitive parameter scores were better among participants with greater educational levels. (Table 1)

Table 1. Mean scores of DSST and TMT as per Gender and Education levels among study population.

Criteria	No. of respondents	% of respondents	DSST score		TMT score	
Gender			Mean	SD	Mean	SD
Male	35	67.31	24.6	8.01	121	47
Female	17	32.69	22.8	9.83	104	45.8
Total	52	100				
Educational level/ Qualification						
Primary	17	32.69	16.9	5.08	145	23
Secondary	26	50	26.2	7.04	101	46.4
Degree+	9	17.31	32.9	7.92	93	58.8
Total	52	100				

Kolmogorov Smirnov test was used to analyze the data normality of Digit Symbol Substitution Test, Trail Making Test Part A, TUG (Normal), TUG (Cognitive) and TUG (Motor) values of study population, and the scores of all these were found to follow a normal distribution. (Table 2) Therefore, the parametric correlational tests were applied for further analysis.

Table 2. Normality of DSST scores, TMT A (secs) scores, TUG Normal (secs), TUG Cog (secs) and TUG Motor (secs) by Kolmogorov Smirnov test.

Variables	Z-value	p-value
DSST scores	1.139	0.149
TMT A (secs)	1.13	0.1546
TUG normal (secs)	1.181	0.123
TUG cog (secs)	1.043	0.227
TUG motor (secs)	1.107	0.1038

Correlation between Executive functions (TMT part A), Visuo spatial skills, psychomotor speed (DSST) and Fall risk and functional mobility (TUG normal, cognitive and motor dual tasks) was done using Karl Pearson's correlation coefficient method. p value ≤ 0.05 (95% CI) was considered as statistically significant.

Table 3. Correlational analysis of DSST and TMT- A scores with TUG (Normal, Cognitive and Motor) scores

Correlation between DSST scores with TUG (normal), TUG (cog) and TUG (motor)	
Variables	**r- value**
TUG Normal (secs)	–0.3284 (p = 0.0175*)
TUG Cog (secs)	–0.4270 (p = 0.0016*)
TUG Motor (secs)	–0.4334 (p = 0.0013*)
Correlation between TMT A (secs) scores with TUG (normal), TUG (cog) and TUG (motor)	
TUG Normal (secs)	0.5846 (p = 0.0001*)
TUG Cog (secs)	0.4364 (p = 0.0012*)
TUG Motor (secs)	0.4039 (p = 0.0001*)

There is a significant negative correlation observed between Visuo- spatial skills, Psychomotor speed (Digit Symbol Substitution Test) with fall risk and overall functional mobility -Timed Up and Go (TUG) Normal, Cognitive and Motor Dual Task. (Table 3 and Figure 1)

A significant positive correlation was observed. between Executive Function (Trail Making Test- Part A) with Fall Risk and Overall Functional Mobility -Timed Up and Go (TUG) Normal, Cognitive, Motor Dual Task. (Table 3 and Figure 2)

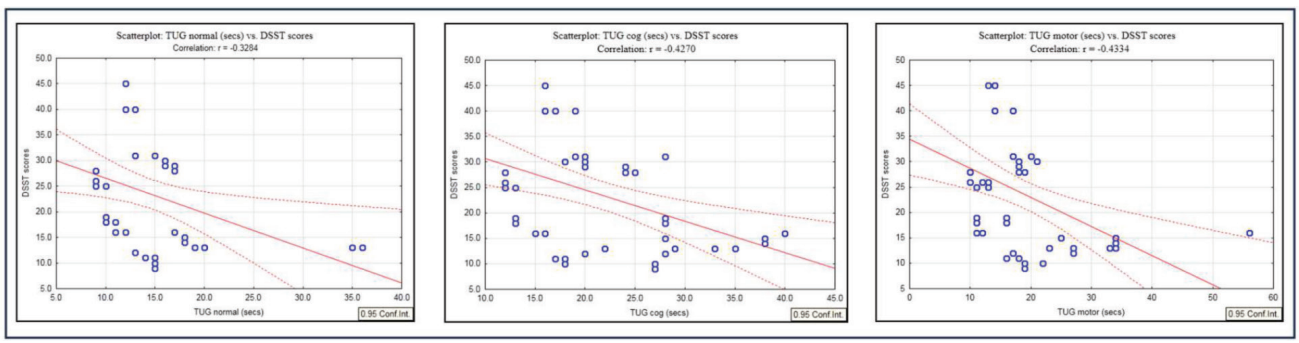

Figure 1: Correlation between DSST scores with TUG Normal (secs), TUG Cog (secs) and TUG Motor (secs).

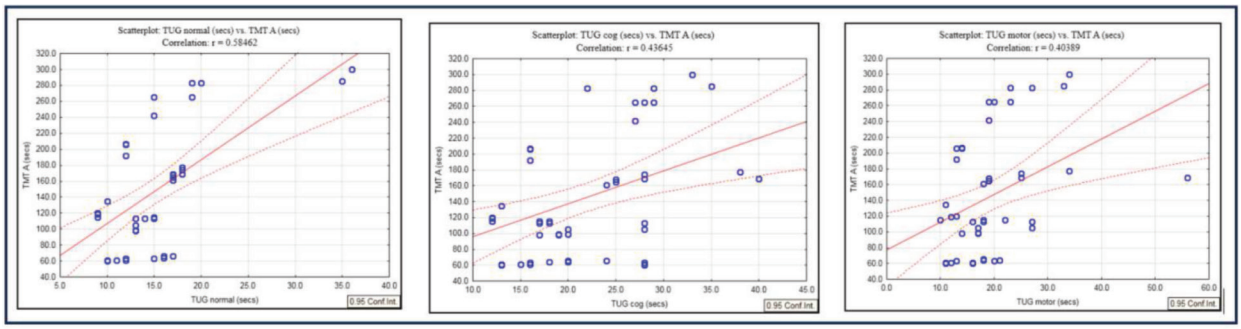

Figure 2: Correlation between TMT A (secs) scores with TUG normal (secs), TUG cog (secs) and TUG motor (secs)

Discussion

Cognitive impairments are known to occur in the early stages of Parkinson's Disease (PD), notably in domains such as executive function, visuospatial skills, attention, and psychomotor speed.[6, 7, 19] These cognitive deficits are critical as they directly impact functional mobility components such as gait, static and dynamic balance, and turning during gait. Literature suggests that executive function and attention are strongly related to gait,[20, 21] while visuospatial skills and attention are linked to measures of static balance and gait initiation.[22]Additionally, impaired psychomotor or processing speed is reported to be associated with difficulties in turning during gait even in early disease stages.[23]

In the early stages of PD, patients generally remain mobile, however the combination of cognitive deficits may impair functional mobility and manifest as an increased risk of falls. Earlier, it was considered that falls are an occurrence in the later stages of the disease[24] primarily due to motor symptoms, and as patients become wheelchair-bound or bedridden, the risk of falling diminishes as they are no longer ambulant. On the contrary, our study findings show early-stage cognitive impairments in PD like executive function, visuospatial skills, and psychomotor speed[19,25, 26,] impacting functional mobility in early stages,as demonstrated by a significant correlation with all three variants of the Timed Up and Go (TUG) test. This outcome aligns with findings of some other previous research reports.[27, 28.] We noted a decline in executive functions in male more than female participants as confirmed by TMT mean scores while psychomotor speed score of DSST were similar between genders. Additionally, all the parameters were progressively better in participants who had greater educational levels and was clearly observable by the mean scores of DSST and TMTwhich corroborates with the earlier reports that higher education is protective and may be predictive of cognitive decline[11]

Postural control requires the integration of multiple systems, including visual, somatosensory, and vestibular systems, with motor processes to maintain spatial position of the body and orientation as per changing environmental conditions.[29] The basal ganglia, modulated by dopaminergic projections, play a crucial role in mediating cognitive and motor functions to produce appropriate actions. PD patients exhibit a significant reduction in dopaminergic projections to the striatum, impacting both cognitive and motor functions.[20] Bradyphrenia largely interferes with movement planning and increasing reaction time. The existence of bradyphrenia in PD has been debated due to overlap with dementia, aging, and depression, all of which also slow cognitive processing.[7,31]

Our study had the following strengths: 1. Usage of specific and salient cognitive measures inclusive of visuo-spatial skills, attention, executive function and psychomotor speed with respect to postural control and gait; 2. Patients with homogeneity in terms of disease staging; 3. Assessment performed in the ON stage of medication; 4. Functional mobility assessment through a standardized, quantitative tool with cognitive and motor dual tasks.

However, our study had some limitations. 1. The recruited patients were in the initial stages of PD, so the results may not generalize to later stages. 2. Future studies could include larger sample sizes and consider evaluating patients during both ON and OFF phases to account for the influence of medication on motor and non-motor symptoms. 3. While the current study presents a significant correlation among cognitive parameters and fall-risk, it does not establish a cause-and-effect relationship.This may be a further research interest. 4. **Additionally,the correlation between cognitive parameters and fall risk was not analyzed with respect to certain attributes like age, gender or educational qualifications of patients and could be considered in future research.**

Physical therapy interventions typically focus on strength, flexibility, and balance training for PD patients. However, given the significant relation of cognitive impairments on fall risk and functional mobility, tailored interventions addressing these factors utilising evidenced strategies and newer technology tools may be incorporated into rehabilitation programs.[32, 33] for a prolonged preservation of mobility domains. Further longitudinal research is necessary to validate these findings and provide a comprehensive understanding of the underlying mechanisms of fall risk in individuals with parkinsonian disorders.

Conclusion

Our study confirms that executive function, visuospatial skills, and psychomotor speed are on a decline in early disease stages and we conclude that these significantly influence fall risk and overall functional mobility in Parkinson's Disease, as evidenced by their correlation with the Timed Up and Go test variants. These findings underscore the importance of incorporating cognitive training into rehabilitation programs for PD patients to enhance functional mobility and reduce fall risk.

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