Parkinsonism and Related Disorders 66 (2019) 100–104

Contents lists available at ScienceDirect

Parkinsonism and Related Disorders

journal homepage: www.elsevier.com/locate/parkreldis

Dual-task interference during hand dexterity is a predictor for activities of daily living performance in Parkinson's disease

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ARTICLE INFO

Keywords:
Parkinson's disease
Dual task
Manual dexterity
Activities of daily living
Hand function

ABSTRACT

Introduction: Dual-task interference (DTI) leads to impairment of hand dexterity in Parkinson's disease (PD). The performance of activities of daily living (ADL) is negatively affected by dexterity in PD. However, the contribution of DTI to dexterity-related ADL disability remains unclear. This cross-sectional study aimed to investigate the contribution of DTI to ADL performance as well as other factors affecting dexterity.
Methods: One-hundred and eight patients with PD were assessed using the ADL-related dexterity questionnaire-24 to measure dexterity-related ADL performance. Performance in single and dual task conditions was measured with the 9-hole peg test. Disease severity, cardinal symptoms and grip strength were assessed using Hoehn& Yahr, a modified version of the Unified Parkinson Disease Rating Scale, Part-III, and a hand dynamometer. The age and cognitive status were control variables.
Results: Multiple regression analysis revealed that disease severity explained 8.5% of the variance in dexterity-related ADL ($p = 0.002$). The DTI in the dominant hand was the strongest predictor of ADL performance (R^2 change = 0.44, $p < 0.001$), but DTI in the non-dominant hand did not contribute. When cardinal symptoms were added to the model, bradykinesia contributed to ADL difficulty (R^2 change = 0.072, $p < 0.001$), while tremor and rigidity were not significant in any model. This model accounted for 59.2% of the variance in ADL difficulties in total.
Conclusion: The study demonstrated that disease severity, bradykinesia and DTI in the dominant hand contributed to ADL difficulties in patients with PD, and DTI in the dominant hand is the strongest predictor of ADL performance in PD.

1. Introduction

Dual task (DT) performance involves achieving concurrent tasks, simultaneously. The execution of two tasks at the same time demands a high level of information processing and allocation of attention which is generally impaired in Parkinson's disease (PD) due to basal ganglia dysfunction [1]. The decrease in DT performance is defined as DT interference (DTI). Studies about DT performance in patients with PD showed that their performance decreases and DTI caused difficulties in their daily life, especially in requiring the concurrent cognitive tasks of postural stability and walking [2–4].

Similar to walking or postural stability ability, hand dexterity is essential for independence in activities of daily living (ADL) and is reduced in patients with PD [5]. Moreover, dexterity difficulties are reported as the second contributor to the impairment of PD following ambulation [6]. It is known that writing, tying shoelaces and buttoning activities are difficult for patients with PD [7]. However, these single-task activities do not exactly represent daily life. Therefore, recent studies have focused on the influence of DT performance on hand function [8]. Proud et al. [8] showed that DTI occurred during hand functions when a concurrent cognitive task was added for patients with mild-moderate PD. In addition, Kalirathinam et al. [9] demonstrated DTI involving hand dexterity with both secondary motor and cognitive tasks. Although DTI during hand dexterity was reported in PD, its contribution to disability in ADL remains unclear. Moreover, the preservation of independence in ADL is affected by several clinical properties (disease severity and duration), and cardinal symptoms of PD such as rigidity, bradykinesia and tremor in the upper extremities. Rahman et al. [10] reported that tremor and rigidity affected simple everyday activities and reduced the quality of life. Other investigators showed that bradykinesia represents the best predictor of dexterity-related ADL deficits [11]. However, the common contribution of all

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https://doi.org/10.1016/j.parkreldis.2019.07.017
Received 25 December 2018; Received in revised form 10 July 2019; Accepted 13 July 2019
1353-8020/

these cardinal symptoms to ADL has not yet been studied in patients with PD.

Since daily life includes multitasking activities involving hand functions, such as taking notes while speaking on the phone, removing money from a wallet while shopping, preparing a meal while reading the recipe or dressing while chatting, there is a need for studies that investigate whether ADL performance is affected by DTI in PD.

Therefore, this study primarily aimed to determine the impact of DTI during hand dexterity on ADL. We also aimed to identify strong indicators of ADL disability in patients with PD. Based on the fact that hand function is crucial for independence in daily life, we hypothesized that DTI during hand dexterity is a significant indicator, as well as cardinal symptoms, of ADL performance in PD.

2. Methods

2.1. Participants

The participants were diagnosed with idiopathic PD by a neurologist, as determined by the UK Parkinson's Disease Society Brain Bank Criteria [12]. One hundred and eight patients were recruited at the Movement Disorders Clinic of the Education and Research Hospital in Ordu University. All patients gave written informed consent and this study was approved by the Clinical Research Ethics Committee at the University of Ordu. This study was registered at clinicaltrials.gov (NCT 03589872).

The inclusion criteria were: 1) stable drug usage, 2) aged ≤80, 3) scoring at least 24 on Mini Mental State Examination (MMSE) [13], and 4) lower than stage V according to Hoehn & Yahr (H&Y). The participants were excluded if they had a neurologic disorder other than PD, had a deep brain stimulator implanted, had visual disturbances, had a major upper-extremity dysfunction or sensory loss that could impair hand functions or had severe tremor or dyskinesia that could not allow the performing of the Nine Hole Peg Test (9HPT).

2.2. Procedures

A research assistant, blind to the study, asked patients about their history and evaluated the participants in their "on" state, approximately 120 min after drug intake. The Unified Parkinson Disease Rating Scale (UPDRS) and MMSE were performed by a neurologist who has expertise in PD and movement disorders. Hand dominance was determined using the Edinburgh Handedness Inventory [14] by a research assistant. To avoid learning effects during the evaluations, the patients were familiarized through two practice trials with all evaluations and standardized verbal instructions were given by the examiner.

2.3. Outcome measures

Disease severity was determined according to the *H&Y stages.*

Dexterity-related ADL difficulties were measured by the ADL-related dexterity questionnaire 24 (DextQ-24), including 24 questions dealing with bimanual and unimanual activities. Total score ranges from 24 to 96 points. Higher scores indicate more impairment.This is a reliable and valid disease specific questionnaire to evaluate dexterity in patients with PD for nearly all stages of the disease (H&Y I-IV) [15]. Cardinal symptoms, tremor, rigidity and bradykinesia were evaluated using a modified version of UPDRS Part III. Tremor was quantified by items 3.15 to 3.18. Rigidity was quantified by item 3.3. Bradykinesia was quantified by items 3.4 to 3.6 [16].

Isometric grip strength was measured using a Baseline digital hand dynamometer (Fabrication Enterprises, Inc., White Plains, NY). The 9HPT was used to evaluate dexterity and hand function under single-task and DT conditions. The 9HPT is a reliable and valid tool for determining the dexterity and upper extremity function in PD, which involves peg-placement and peg-removal on a pegboard [17]. Trials were performed under the examiner's direction with the same sequence for the dominant hand and then the non-dominant hand, first under single-task and under DT conditions for each hand. The total time of peg-placement and peg-removal for each hand was recorded in seconds for single task conditions. The serial-seven subtraction task (SSST) was chosen as a secondary task which evaluates the attention and concentration demands of cognition [18].

The 9HPT was performed concurrently with SSST using random numbers selected from a box (changed between 290 and 310) for DT conditions [8]. DTI was calculated as follows: ([DT-single-task]/single-task) × 100% [19].

2.4. Statistical analysis

All analyses were performed using IBM SPSS version 20.0. Demographic and clinical variables are presented as mean and standard deviation. The dependent variable, DextQ-24, was distributed normally and the independent variables (DTI, clinical and cardinal symptom measures) were checked for multicollinearity problems. The Pearson test was used for correlation analysis. Hierarchical multiple regression analyses were performed to explore the contribution of clinical measures, DTI, isometric grip strength, and cardinal symptoms to the dexterity-related ADL performance with the forward method. In the first block, clinical scores such as MMSE, disease severity (H&Y stage) and age were entered into the regression model. In the second block, DTIs were entered into the model. Lastly, cardinal symptoms including bradykinesia, rigidity, and tremor scores of the upper extremity and isometric grip strength were integrated into the regression model. The level of significance for all tests was set at $p < 0.05$.

3. Results

One hundred and forty-two subjects with PD were assessed for eligibility. Fifteen subjects declined to participate and nineteen subjects did not meet the inclusion criteria (e.g. irregular drug use, presence of psychiatric problems, having severe tremor, MMSE score < 24). A total of one hundred and eight patients with PD were recruited to our study as participants, whose PD duration was mean 4.83 ± 3.24 years. Their mean age ± SD was 69.67 ± 6.62 years and the majority of the participants were male (66.7%), right handed (85.2%) and had mild or moderate stage idiopathic PD (83.3%). The demographic and basal clinical characteristics of the participants are given in Table 1.

Table 2 presents the univariate analysis. The results of hierarchical multiple regression analysis to identify the predictive variables for the dexterity-related ADL difficulty are shown in Table 3. In the first model, H&Y stage accounted for 8.5% of the variation in dexterity-related ADL difficulty ($F = 9.891$, $p = 0.002$). In the second model, H&Y stage and DTI scores of the dominant hand accounted for 52.5% of the variation in dexterity-related ADL difficulty ($F = 58.090$, $p = 0.000$). Finally, in the third model, H&Y stage, DTI score of dominant hand and bradykinesia scores accounted for 59.2% of the variation in dexterity-related ADL difficulty ($F = 51.470$, $p = 0.000$). DTI score of the dominant hand alone was responsible for 44% of the variation of dexterity-related difficulty in ADL. H&Y stages alone predicted dexterity-related difficulty in ADL ($\beta = 0.292$, $t(106) = 3.145$, $p = 0.002$) and continued to predict it after including the DTI score in the models (H&Y: $\beta = 0.313$, $t(105) = 4.659$, $p = 0.000$; DTI: $\beta = 0.664$, $t(105) = 9.864$, $p = 0.000$), but it did not continue to predict the dexterity-related ADL difficulty after including bradykinesia in the models (H&Y: $\beta = 0.098$, $t(104) = 1.235$, $p = 0.219$). Therefore, we removed the H&Y from the third model and we found that DTI in the dominant hand and bradykinesia score were significant predictors of variance in dexterity-related ADL difficulty (DTI:$\beta = 0.639$, $t(104) = 10.242$, $p = 0.000$; bradykinesia:$\beta = 0.406$, $t(104) = 6.542$, $p = 0.000$). Other independent variables (age, MMSE, tremor, rigidity, grip strength, DTI in the non-dominant hand) were not significant predictors to determine the

Table 1
The demographics and basal clinical features of the participants (n = 108).

Patient's characteristics	X ± SD (min-max) or N (%)
Age (years)	69.67 ± 6.62 (54–79)
Gender (male)	72 (66.7)
Disease duration (years)	4.83 ± 3.24 (1–14)
Dominant hand (right)	92 (85.2)
Disease severity (H&Y stage)	
Stage 1	36 (33.3)
Stage 2	54 (50)
Stage 3	12 (11.1)
Stage 4	6 (5.6)
MMSE	26.02 ± 1.99 (24–30)
Levadopa equivalent dosage	680.93 ± 257.71 (0–1200)
DexQ-24	45.09 ± 13.58 (25–75)
Tremor score	6.93 ± 4.65 (0–18)
Bradykinesia score	9.33 ± 4.73 (2–19)
Rigidity score	2.35 ± 1.65 (0–6)
Grip strength (kg)	26.89 ± 9.50 (9–42)
9HPT (seconds)	
single task-dominant hand	47.13 ± 16.14 (21.65–96.99)
single task-nondominant hand	50.46 ± 19.29 (25.15–99.47)
dual task-dominant hand	76.56 ± 27.69 (31.75–136.82)
dual task-nondominant hand	77.24 ± 28.53 (32.20–155.86)
DTI (%)	
dominant hand	65.62 ± 39.62 (0.98–185.33)
nondominant hand	58.54 ± 45.34 (−6.12-254.23)

DexQ-24: ADL-related dexterity questionnaire 24; DTI: dual task interference; H&Y: Hoehn and Yahr; MMSE: mini mental state examination; 9HPT: nine hole peg test.

variance in the dependent variable ($p > 0.05$) (Table 3).

4. Discussion

This study demonstrated that disease severity, DTI in the dominant hand and bradykinesia contributed significantly to dexterity-related ADL disability in patients with PD. Other cardinal symptoms (rigidity and tremor), grip strength, DTI in the non-dominant hand, cognitive state and age did not contribute significantly to dexterity-related ADL disability. Moreover, our results showed that DTI in the dominant hand is a stronger indicator of dexterity-related ADL performance than bradykinesia and disease severity.

The dexterity-related ADL disability has clinical relevance in PD, as performance of ADL is linked to quality of life [20]. It is also known that executive functions [21] and dexterity are important predictors of ADL performance in patients with PD [5]. Unfortunately, the effect of these predictors on ADL has not yet been considered together. Previous studies demonstrated that hand function in PD deteriorates during the DTs [7–9]. The researchers addressed different aspects of DT on hand function [7,9,22]. Kalirathinam et al. [9] showed that the cognitive tasks had more interference effect on hand dexterity than motor tasks. Consistent with Kalirathinam et al.'s study, Bank et al. [23] reported that DTI during upper extremity movement is correlated more with cognitive function than motor function. However, it is also known that the interference changes depending on the level of attention required by the cognitive task. Zirek et al. [22], in a study investigating which cognitive task causes more interference, found that the SSST was most likely to cause interference during the timed up and go test. The SSST, which requires complex attention to finish the test, significantly impaired the motor function of patients with PD due to limited attention resources [24]. In this study we showed that concurrently SSST also has interference effects on the functioning of dominant and non-dominant hands and even the mean DTI in the present study (65.62% and 58.54%) was higher than previously reported average values for healthy controls (below 25%) [23]. Moreover, our findings demonstrated that while the DTI in the dominant hand was responsible for 44% variance in dexterity-related ADL difficulties, the DTI in the non-dominant hand had no predictive role for ADL performance. We think

Table 3
The contribution of the independent variables to dexterity-related ADL performance.

Independent Variables	β	t	p	R^2	ΔR^2	F of ΔR^2
Model 1				0.085	0.085	9.891**
Age	0.152	1.534	0.128			
H&Y stages	0.292	3.145	**0.002**			
MMSE	−0.111	−1.174	0.243			
Model 2				0.525	0.440	58.090**
Age	−0.023	−0.309	0.758			
H&Y stages	0.313	4.659	**0.000**			
MMSE	0.039	0.560	0.577			
DTI in dominant hand	0.664	9.864	**0.000**			
DTI in non-dominant hand	−0.151	−1.621	0.108			
Model 3				0.592	0.067	76.061**
Age	−0.079	−1.135	0.259			
H&Y stages	0.098	1.235	0.219			
MMSE	0.112	1.693	0.094			
Tremor	0.144	1.816	0.072			
Rigidity	−0.154	−1.376	0.172			
Bradykinesia	0.406	6.542	**0.000**			
Grip strength	−0.174	−2.622	0.071			
DTI in dominant hand	0.639	10.242	**0.000**			
DTI in non-dominant hand	−0.093	−1.055	0.294			

DTI: dual task interference; H&Y: Hoehn and Yahr; MMSE: mini mental state examination; **:$p < 0.01$.

Table 2
The correlations among the clinical properties of the participants.

Correlations	DexQ-24	H&Y	Bradykinesia	Rigidity	Tremor	9HPT- dominant hand	9HPT-nondominant hand	DTI- dominant hand	DPI-nondominant hand	MMSE
DexQ-24	–									
H&Y	0.292**	–								
Bradykinesia	0.429**	0.623**	–							
Rigidity	0.274**	0.497**	0.830**	–						
Tremor	0.226*	0.283**	0.597**	0.626**	–					
9HPT- dominant hand	0.441**	0.516**	0.765**	0.716**	0.503**	–				
9HPT- nondominant hand	0.311**	0.548**	0.734**	0.633**	0.532**	0.771**	–			
DTI-dominant hand	0.654**	0.032	0.068	−0.021	−0.147	−0.237*	−0.070	–		
DTI-nondominant hand	0.378**	0.026	0.035	−0.054	−0.201*	−0.117	−0.321**	0.698**	–	
MMSE	−0.162*	−0.189*	−0.307**	−0.350**	−0.340**	−0.295**	-.0304**	−0.210*	−0.128	–

The numbers in the cells present the coefficient of correlation. DexQ-24: activities of daily living-related dexterity questionnaire-24; DTI: dual-task interference; H&Y: Hoehn and Yahr; MMSE: mini-mental state examination; 9HPT: nine-hole peg test (single task); *:$p < 0.05$; **:$p < 0.01$.

that the difference between the contribution of the dominant and non-dominant hand is likely a result of the dominant hand function related with ADL performance [8]. This result has clinical importance because a recent study emphasized that the role of interference on the ADL performance should be investigated [23]. The present research may provide useful insight into overcoming this shortcoming in the literature by showing whether DTI is an indicator of difficulties with ADL and that cognitive-related motor interference during dexterity contributes to the ADL difficulties.

The timed pegboard tests are widely used to accurately determine ADL performance relating to upper extremities in the clinical setting [25]. Earth et al. [17] showed that the average value for 9HPT in patients with Parkinson's disease was 31.4 s with the dominant hand and 32.2 s with the non-dominant hand, while Grice et al. [26] reported that the mean normative data for 9HPT in the healthy population with age above 55 changed between 17.86 and 25.95 s. The 9HPT's averages in the present study might be higher than the previous study due to scores of cardinal symptoms in our sample were almost twice as much as in those Earth et al.'s study [17]. The association between the 9HPT performance and cardinal symptoms in this study supports our thought. Although it is known that the cardinal symptoms affect motor performance, the studies about which cardinal symptom is more decisive for hand function or motor performance in ADL are still in progress. Earth et al. [17] showed, during an investigation of the factors affecting 9HPT results, that bradykinesia had an effect on the 9HPT results, but tremor and rigidity had no effect. Another study reported that bradykinesia contributed to 12% of the variance in motor function, while rigidity or tremor did not contribute [27]. These studies are in keeping with our findings, which showed that while bradykinesia contributed to 7.2% of the disability in dexterity-related ADL, no significant contribution of tremor and rigidity could be demonstrated. Whereas bradykinesia was the most significant predictor in cardinal symptoms, its contribution to ADL disability was limited compared to the contribution of DTI in the dominant hand. Therefore, we think that DTI should be targeted to develop ADL performance in addition to bradykinesia.

Disease severity is related to functional status in PD. Lopez et al. [28] also reported that motor severity is strongly correlated with the phone useability, which is an indicator of instrumental ADL performance. On the other hand, the increase in the severity of the disease may cause dysfunctions in daily life by affecting the cognitive function as well as motor function. In agreement with previous studies, our first model also indicates that the disease severity alone is responsible for 8.5% of the disability in ADL. Interestingly, this model demonstrates that although the cognition is an essential component for DT skills, MMSE performance did not contribute to ADL performance. Besides, not having any contribution of MMSE to ADL was against our findings, which showed that cognitive-related motor interference during dexterity contributes to the ADL difficulties. Reasons for this discrepancy are likely related to characteristics of MMSE. The first reason may be that MMSE has more significant ceiling effect and lower sensitivity for screening accuracy in PD [29]. The second reason might be regarding that MMSE contains several subdomains (orientation, language, record, recall, visual construction) different from the cognitive qualification (especially executive function and attention) required for continuity of daily life related to dexterity. Another reason may be attributed to the weak association of the MMSE performance with cardinal symptoms, ADL performance, DTI, and hand function in our study. Based on these comments, another cognitive measure tool (e.g., MOCA, Stroop test) could be used to expose the contribution of cognition to dexterity related ADL dysfunction. Further studies should address this proposition.

Our predictive model is responsible for nearly 60% of the variance in ADL disability in PD. When considering the significant contributors in all blocks, the strongest predictor of ADL disability is DTI in the dominant hand with 44% contribution rate. These findings further demonstrate the importance of cognition for success in dexterity-related ADL. Therefore, the integration of exercises for dexterity with concurrent cognitive tasks such as counting backward, question response task, word list generation, singing, and arithmetic tasks in rehabilitation programs may help to improve the functionality of patients with PD and to convert their strategies to more flexible ones during DT conditions [30].

There are several limitations. First, the majority of our participants were in the mild and moderate stage of PD and a few patients were in the severe stage. Therefore, the results cannot be generalized to all stages of PD. Nevertheless, we believe that DTI will also have an effect on ADL performance for patients in the severe stage, as cognitive and hand function deteriorates with the progression of the disease. Future studies should be planned with homogeneous groups in all stages of PD. Second, DextQ-24 was used to measure dexterity-related ADL difficulties. However, it is scored according to the patient's experience, which may involve recall error, overrating or underrating of actual performance in ADL. The potential errors were diminished by the exclusion criteria (not included the scores below 24 on MMSE). Third, the accuracy of the SSST calculation was not checked but most of the participants successfully completed this task. We think that the mind being busy with a cognitive task is more important than whether the calculation is done incorrectly or not completed in a serial way. The accuracy of the SSST results could be monitored objectively in future studies. Fourth, the lack of controls is considered another limitation. However, we tried to overcome this limitation by the discussion of the normative value of 9HPT and DTI in healthy subjects. Future studies should use groups matched in terms of sex, age and cognitive status for controls. In addition, we did not evaluate other factors that may have affected dexterity, such as sensory, limb-kinetic apraxia [11]. These factors should be considered in further studies.

In conclusion, the disease severity, DTI in the dominant hand and bradykinesia accounted for 8.5%, 44%, and 7.2% of the variance in dexterity-related ADL performance, respectively. DTI should be taken into consideration, because it is the strongest predictor of ADL performance in PD, in addition to the disease specific features. Focusing on the DT performance to increase ADL performance in patients with PD may be a useful strategy for planning interventions or rehabilitation. In other words, practicing hand functions with a concurrent cognitive task may be used to increase the functionality in daily life and thus, optimize ADL performance for individuals with PD.

Funding

None.

Declaration of interests

None.

Author contributors

Sevim Acaröz Candan: Research Project: conceptualization, organization and execution; Statistical Analysis: design, execution, review and critique; Manuscript Preparation: writing, review and critique.

Tuba Şaziye Özcan: Research Project: organization; Statistical Analysis: review and critique; Manuscript Preparation: review and critique.

Acknowledgements

The authors would like to thank all the patients involved in the study.

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