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Effect of a Cognitive Task on Voluntary Step Execution in Parkinson's Patients

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Abstract
Background: *During everyday locomotion, one may often be required to quickly initiate a step to avoid potentially threatening situations such as collisions, obstacles, and falls.* ***Objectives:*** *To investigate voluntary step execution of Parkinson's patients during single and dualtask conditions and to compare it with those of older adult subjects.* ***Methods:*** *Fifteen male Parkinson's patients (study group) and fifteen male healthy older adults (control group) participated in this study. The age ranged from 50 to 60 years for both groups. Rapid forward voluntary stepping was performed as a reaction time task while standing on a force platform and (1) awaiting a cutaneous cue (single task) and (2) awaiting a cutaneous cue while performing an attention-demanding Stroop task (dual task).The step initiation phase, preparatory and swing phases were extracted from ground reaction force data.* ***Results:*** *Parkinson's patients were significantly longer than healthy older adults in all step parameters duration during dual task condition, particularly step initiation phase duration.* ***Conclusion:*** *The significant increase in step initiation time during the dual task in Parkinson's patients suggests that they lacked sufficient attentional capacity to divide attention between a voluntary postural task and a cognitive task or their capacity was limited by slowness of information processing speed.*

Key word: *Parkinson's disease, Attention, Stroop task, Force platform, step execution*

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I. Introduction

Parkinson's disease (PD) is a chronic neurodegenerative progressive movement disorder defined by the presence of bradykinesia, tremor, and rigidity [1].

Postural imbalance during dynamic transitional movements such as rising from a chair is the crucial cause of increased possibility of falls. Falls are a characteristic feature of the disease deterioration leading to considerable morbidity and death. Transfers are so problematical in PD; leg weakness, particularly at the hip, explains a part of the limitation experienced by PD patients' while trying to rise from a chair. So, in PD the efficacy of strength training to induce transfers remains to be demonstrated for PD patients. Other strategies to induce transfers are existent, including the chaining technique splitting complex movements up into a series of simple components that are to be achieved sequentially [2].

The capability to take a quick step or to hold for external support in the environment is crucial motor skills that could prohibit a fall from happening. Compensatory strategies, including stepping and grasping, are automatically triggered after different unexpected postural perturbations such as a rapid slip or a trip. A compensatory step provides an enlarged base of support and thus increases the center of mass (COM) displacement that can occur without balance loss [3].

Once a fall is started, a rapid step execution is critical for successful balance recovery. Voluntary stepping may also serve an important stabilizing role after low acceleration falls that may occur due to pushes, impacts from swinging doors/elevators, or when standing in a moving vehicle. Furthermore, voluntary stepping may help preserve balance when self-induced falls occur during walking, rising from a chair, or stumbling on a rug or inappropriately placed furniture or telephone cord, situations that may occur in daily life. The majority of falls in the elderly occur during common daily activities, such as walking or changing position or from tripping or tangling of the feet [4].

The purpose of this study was to investigate, characterize, and quantify voluntary step execution behavior of Parkinson's patients under single and dual task conditions and to compare it with those of age-matched healthy older adults.

II. Material And Methods

This cross sectional case control study was carried out on the outpatient clinic of faculty of physical therapy, Bader University in Cairo (BUC), Egypt. And also in outpatient clinic of faculty of physical therapy, Cairo University, Egypt from December 2018 to June 2019.

Study Design:Cross sectional case control study

Study Location: This study was carried out on the outpatient clinic of faculty of physical therapy, Bader University in Cairo (BUC), Egypt. And also in outpatient clinic of faculty of physical therapy, Cairo university, Egypt.

Study Duration: December 2018 to June 2019.

Sample size:15 patients with Parkinson's disease and 15 healthy aged matched.

Sample size calculation:The sample size, considering confidence level of 95% and power of 80%, also we used similar studies to calculate sample size.

Subjects & selection method: The study population was recruited as being a Parkinson's patients recruited from the outpatient clinic of faculty of physical therapy, Bader University in Cairo (BUC), Egypt. And also in outpatient clinic of faculty of physical therapy, Cairo university, Egypt fromDecember 2018 to June 2019.

Inclusion criteria:

1. Parkinson's patients, stage II & III according to modified Hoehn and Yahr (1997) classification of disabilities.
2. Male sex.
3. Ages ranged from 50 to 60 years.
4. The patients were diagnosed by a neurologist as having Parkinson's disease based on careful clinical assessment and radiological investigations including magnetic resonance imaging (MRI) of the brain.
5. Patients diagnosed and had Parkinson's disease since 5 years.
6. Patients had stable psychological and emotional state.
7. The patients were able to ambulate independently without the use of walking aids, Orthoses, or another person.
8. They scored 24 or higher on Mini-Mental State Test (MMST).
9. Patients scored 45 or more on Berg Balance Scale (BBS).
10. Rapid step test and Maximum step length (RST & MSL) were ≤ 65 seconds.
11. They scored 20 or more on the modified Stroop task (20/25).

Exclusion criteria:

1. Female sex.
2. Parkinson's patients, stage IV & V according to modified Hoehn and Yahr (1997) classification of disabilities.
3. Patients diagnosed and had Parkinson's disease less than 5 years.
4. Patients aged less than 50 years.
5. Patients with other neurological disorders except for Parkinson's disease.
6. Patients who are deaf or blind.
7. Patients who aren't alert enough to complete the assessment.

Procedure Methodology:following each subject or their relatives reads and signs an informed consent, then, the patients were assessed by an experienced PT; demographic data were obtained including age, sex. Fifteen male Parkinson's patients form the study group. Evaluation environment was constant through the study. The analysis procedures were done to each patient by the same physiotherapist, a brief explanation about the protocol of evaluation was given to each patient.

Instrumentation:the data were collected through the use of: 1) Opto-electronic motion analysis system with a force plate unit; Qualisys Motion Capture System was used in this study to measure movements or excursions of the ankle, knee and hip joints; of the lower limbs in conjunction with a force plate unit; An Advanced Mechanical Technology Inc., USA (AMTI) to measure the ground reaction force (GRF) magnitude at hip, knee and ankle joints during forward step execution phases.

Procedures:subjects were instructed to stand upright and barefoot on a Force platform in a standardized stance, their feet abducted 10°, their heels separated mediolaterally by 6cm [5], and their hands crossed over their chest.

Six voluntary step execution trials in forward direction were conducted for each subject, under two different task conditions preceding the step execution:

(1) Single task (standing and viewing a target placed on a wall 3 meters away) and

(2) Dual task (standing and performing a modified Stroop task that was projected onto a wall 3 meters in front of the subject (100 cm wide by 50 cm high).

The Stroop task is one of the most widely used measures of cognitive functioning. Several modified versions have been created since the task's development in 1935. Variants include single-stimulus and card versions, color-word and picture-word tasks, sorting and matching versions, and visual and auditory analogs. The standard color-word Stroop task requires participants to name the color of ink in which a color name is printed while ignoring the written word. It is well-established that naming the color in which incongruent color-word stimuli are printed (e.g., the word red printed in blue ink) takes longer than naming the color of congruent color-word stimuli (e.g., the word red printed in red ink), naming color swatches, or reading color names printed in black ink. Increased reaction times during incongruent color-word trials have been attributed to the interfering effects of the printed color name on the different colored ink. The standard color-word task has been presented in a variety of ways that differ based on the number of trials, items, and colors although all include a trial with incongruent color-word stimuli. These test versions are commonly used in clinical practice [6].

The modified Stroop task used in the present study consisted of reading off colors from a printout showing 25 colored words (five lines of five words), representing color names that are different from the printed colors. For example, the word yellow is printed in red ink. The subjects were instructed to name the colors of the inks, as quickly as possible, until the end of the procedure. The modified Stroop test was used because it requires a considerable amount of focused attention and few instructions to perform. In addition, it requires only direct verbal responses and does not address memory [4].

Subjects were allowed a brief learning period in a sitting position before the start of the experiment. Subjects were instructed to stand evenly on both feet and to step as quickly as possible after a tap cue on the heel of the affected stepping foot provided manually by the experimenter. This cue may resemble the cutaneous stimulus experienced when the foot hits an object before a stumble or a trip. The base (support) leg had to remain in contact with the floor and to not lift off during the step [7].

III. Result

The two groups were comparable regarding age, weight, height, and body mass

The two groups were comparable regarding age, weight, height, and body mass index (BMI) as appeared in table no 1. On the other hand table no 2 indicates mean values of Mean values of MMST, RST&MSL and BBS for both groups: There was a highly statistically significant difference of MMST, RST&MSL and BBS (P=0.0001). Table 3 shows a highly statistically significant differences between patient and control group as regards of step initiation phase, step preparation phase, step swing phase, and step time under both single and dual task conditions groups with p-value (0.0001).

Table no 1: Demographic and clinical characteristics of the two studied groups.

	study group n=15	control group n=15	p-value
Age (years)	54.20±3.12	55.47±2.61	0.238
Height (cm)	168.2±4.33	167±4.66	0.47
Weight (kg)	69.20±4.07	68.80±5.80	0.828
Body mass index (Kg/m^2)	24.52±4.16	24.67±6.81	0.261

Table no 2: Mean values of MMST, RST&MSL and BBS of the two studied groups.

	study group n=15	control group n=15	p-value
MMST	26.87±1.64	29.53±0.64	0.0001**
RST&MSL	55.13±6.57	42±4.42	0.0001**
BBS	47.87±2.33	55.47±0.74	0.0001**

Table no 3: Mean values of step initiation phase, step preparation phase, step swing phase, and step time between control and study groups under both single and dual task conditions groups.

		study group n=15	control group n=15	p-value
Step Initiation Phase (millisecond.)	Single Task	230.27+13.33	175.53+9.91	00001**
	Dual Task	452.47+14.12	287.67+13.77	00001**
Step Preparation Phase (millisecond.)	Single Task	440.93+15.96	395.07+10.12	00001**
	Dual Task	516.07+12.56	445.33+13.30	00001**
Step Swing Phase (millisecond)	Single Task	389.27+13.03	351.60+12.56	00001**
	Dual Task	432+13.34	371.93+14.54	00001**
Step Time (millisecond)	Single Task	1060.47+31.88	922.20+20.88	00001**
	Dual Task	1400.40+35.07	1104.93+29.91	00001**

IV. Discussion

The current study examined whether an attention-demanding cognitive task would delay the execution of a voluntary step more than with the single-task condition of only performing the step.

A quick step execution, whether it is compensatory in nature and triggered by a perturbation or voluntary, is an important skill that can serve to alter the base of support, preserve stability, and prevent a fall. A delayed initiation and completion of a voluntary step may well be a marker of increased risk of falling. Using an inverted pendulum model, one study predicted that a faster response time would be the most important factor for successful balance recovery. Furthermore, using an optimal control model of compensatory stepping, another study claimed that, to prevent the COM from falling beyond the stability margins, a step must be completed within approximately 1,100 msec.[8].

There are a range of pathophysiological factors that may be involved in these stroke-related changes:

The 31% and 57% increases in step initiation phase duration during the single and dual tasks, respectively, are most likely, but not exclusively, due to slowness of information processing speed in Parkinson's patients and this mental slowness affects all the reaction time tasks [9].

The 12% and 16% increases in step preparation phase duration during the single and dual tasks, respectively, are most likely that Parkinson's patients may need more time to plan an anticipatory control strategy, a finding supported by Winstein and his colleagues who found that in persons with Parkinson's disease, the primary deficit associated with sensorimotor asymmetry is the failure of weight transfer during standing and walking [10].

Furthermore Brunt and others indicated that TA activity, which mainly contributed to the forward progression of body, was absent in the affected swing limb during gait initiation. Instead, increased gastrocnemius activity, which serves to control the forward acceleration of COM, is observed in the unaffected stance limb during execution of the first step from asymmetrical limb loading while standing [11].

In addition, the prolonged stance phase (preparation phase) has been attributed to difficulty in advancing the leg during swing phase due to diminished strength and decreased power generated at push-off at the ankle [12].

The 11% and 16% increases in step swing phase duration during the single and dual tasks, respectively, is most likely a consequence of muscle weakness in the lower extremity which can be attributed to disuse atrophy and/or the disruption in descending neural pathways leading to inadequate recruitment of motor neuronpools [13].

This comes in agreement with model of Sohlberg and Mateer. This is a hierarchic model which is based on the recovering of attention processes of brain damage patients. This model has been shown to be very useful in evaluating attention in very different pathologies, correlates strongly with daily difficulties and is especially helpful in designing stimulation program such as APT (attention process training), a rehabilitation program for neurological patients [14].

Increases in step time, particularly significant in Parkinson's patients were due primarily to a prolongation of the step initiation phase and secondarily to a prolongation of the step preparation and swing phases. This comes in agreement with Melzer and Oddssonwho found that a major source of delay during voluntary step execution was the step initiation phase [4].

Also, increases in step time may increase risk of falls in Parkinson's patients. This comes in agreement with Mayo & his colleagueswho stated that slow response time could increase fall risk in those patients especially when they were distracted during routine activities that required more concentration [15].

Furthermore, during the single-task condition, the Parkinson's patients executed a step in about 1 second. Under the dual-task condition, the execution was delayed by about 400 msec. bringing the duration above the 1,100 msec.thresholds that has been cited as critical to prevent a fall from occurring after a balance perturbation [16].

Cognitive deficits were evident in the present study even though the participant sample had near normal MMST scores and were considered highly recovered. These findings come in agreement with McDowd and his colleagues who supported the notion that specific and sensitive measures are required to fully characterize cognitive function in Parkinson's patients [17].

The findings of the current study revealed that Parkinson's patients had lower scores than healthy controls in RST&MSL which are consistent with Schulzand other researcherswho found that balance-impaired older adults had lower volitional stepping performance than healthy controls [18].

Finally, the results of the present study add to a growing body of evidence Peterson& his colleagues showing that central processing factors and attentional capacity are important limitations for postural reactions [19].

V. Conclusion

A concurrent attention-demanding task can significantly delay voluntary balance responses in Parkinson's patients, which may lead to an increased risk of falls and ensuing injuries. These results indicate that rapid voluntary stepping during a dual-task condition is more taxing for the available cognitive resources in patients with Parkinson's disease than in healthy older adult subjects.

The findings from this study may serve as a basis for the development and the implementation of new balance retraining programs to improve stability with the use of multiple tasks. This study offers support for a balance training program that involves a protocol beginning with single tasks and moving to multi-tasks that progress in difficulty. This multitask training program may be an appropriate intervention choice for the improvements of postural control in specific subpopulations of patients and older adults with balance impairments.

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