BJMB
Brazilian Journal of Motor Behavior

Research Article

Effects of dual task demanding manual dexterity and sit-to-stand in Parkinson disease individuals

TATIANA B. DE FREITAS[1] | JOSÉ E. POMPEU[2] | BRIANA R. B. DE MORAES[3] | SANDRA M. A. A. POMPEU[2] | KEYTE G. DA SILVA[2] | CAMILA TORRIANI-PASIN[1]

[1] Laboratory of motor behavior, School of Physical Education and Sport, University of Sao Paulo, São Paulo, SP, Brazil.
[2] Department of Physical Therapy, Speech and Occupational Therapy, School of Medicine, University of Sao Paulo, São Paulo, SP, Brazil.
[3] Paulista University, São Paulo, SP, Brazil.

Correspondence to: Camila Torriani-Pasin - PhD, Professor of School of Physical Education and Sport, University of São Paulo. Adress: School of Physical Education and Sport - Professor Mello Moraes Avenue, 64. Phone +55 11 3091-8786
email: camilatorriani@gmail.com
https://doi.org/10.20338/bjmb.v15i2.197

HIGHLIGHTS

- Parkinson's disease causes loss of automaticity and impairment in dual task (DT) performance.
- Individuals with PD could have a pattern of prioritization of tasks according to their level of complexity.
- Postural control, upper extremity, and verbal fluency showed worse performance in the dual task condition.

ABBREVIATIONS

DT	Dual task
DTC	Dual task cost
DTI	Dual-task interference
GDS	Geriatric Depression Scale
H&Y	Hoehn and Yard scale
MMSE	Mini Mental Status Examination
PD	Parkinson's disease
PMC	Premotor cortex

PUBLICATION DATA
Received 21 09 2020
Accepted 26 01 2021
Published 01 06 2021

BACKGROUND: Parkinson's disease (PD) causes loss of automaticity and impairment in dual task (DT) performance.
AIM: To investigate the performance and pattern of prioritization of individuals with PD in motor and cognitive DT.
METHOD: An observational, transversal, comparative study assessed 20 individuals with PD between stages 1.5 to 3 of the modified Hoehn and Yahr scale. Performance was assessed during the execution of manual dexterity and sit-to-stand tasks, in a single task or in association with a verbal fluency task.
RESULTS: There was a loss of performance in both dual task conditions. The cost of verbal fluency was higher than the cost of manual dexterity function.
CONCLUSION: Individuals with PD showed worse DT performance and prioritized the manual dexterity task. There was no prioritization between sit-to-stand and verbal fluency. These findings suggest that the nature of tasks can influence the prioritization of dual tasks.

KEYWORDS: Parkinson's disease | Attention | Upper extremity | Postural control

INTRODUCTION

Parkinson´s disease (PD) is caused by the degeneration of dopaminergic neurons of substantia nigra and cholinergic neurons of the pedunculopontine nucleus, among other areas of the brain.[1] The cardinal symptoms of the disease include resting tremor, bradykinesia, rigidity, and postural instability.[2] Due to lesions on the basal ganglia, individuals with PD have less automatic postural control, gait disturbances, and poorer execution of manual tasks.[3] A lack of automaticity results in delayed muscle contraction,[4,5] deficits in dynamic postural control[6–8], for example, turning[6] and obstacle avoidance[7], as well as at upper extremity coordination tasks[9] such as writing[10].

Individuals with PD often require a heightened attentional focus to compensate for reduced automation to successfully perform common balance tasks.[11] Thus, individuals use

cortical mechanisms to control posture and manual tasks that require the use of attentional resources and result in the division of attention between competing task demands.[12]

The division of attention that occurs during simultaneous task performance has been studied using a dual task (DT) paradigm.[13] In the DT paradigm two or more tasks are performed at the same time typically identifying the main task as the "primary task" with an associated "secondary task".[13] Individuals with PD have demonstrated worse performance in DT conditions as compared to a single-task condition. Possible mechanisms contributing to this decrement in task performance are: (1) loss of automaticity; (2) decreased attention resources and (3) the reduced ability to share attention among two or more tasks.[11,12,14]

Previous studies have shown that individuals with PD experience extensive problems during DT (e.g., decrease in walking speed[16] and higher gait variability[13]).[13,15] But most studies that have investigated dual-task interference (DTI) in individuals with PD have focused on gait[13,17,18] and postural control[18–20], while only a small number of studies have investigated the effects of DTI on upper limb tasks. Yet interestingly, studies of the upper limbs have shown impairments of hand dexterity in dual task conditions for individuals with PD.[21,22] DTI accounted for 44% of the variance in dexterity-related activities of daily living performance of the dominant hand.[22] Individuals with PD also demonstrate to reduce performance in a simultaneously performed goal-directed upper-limb motor task when paired with a cognitive task compared to performance in age-matched controlled subjects.[23] Additionally, there are writing deficits in the dual task writing condition compared to age-matched controls, more specifically during small-amplitude movements.[24]

Based on the different attention mechanisms between postural control tasks and upper extremity functional tasks, we speculate that the task which requires the most attentional demand, may be more impacted by dual task performance, and worsen the performance of the primary task. Thus, this study aimed to compare the effect of DT during the performance of postural control task (i.e., 30-s chair stand) and an upper-extremity functional task (i.e., Box and Blocks test) of individuals with PD. We assessed prioritization patterns during the dual tasks involving sit-to-stand and manual dexterity performed in concert with a cognitive task.

METHODS

Subjects

This cross-sectional study was approved by the Ethical Committee of the University (CEP/ICS/UNIP: 641.783). Subjects were invited to participate in the study and were asked to sign the Consent Term in which the objectives and procedures of the study were explained in detail.

Twenty individuals with PD of both sexes were enrolled in this study. The inclusion criteria were: (1) diagnosis of idiopathic PD; (2) individuals between stages 1.0 to 3 of the modified Hoehn and Yard scale (H&Y);[25] (3) on levodopa replacement therapy and (4) no signs of dementia as evaluated by the Mini-Mental Status Examination (MMSE).[26] We adopted cutoff scores of MMSE based on educational level (>20 for illiterates; > 25 for patients with from 1 to 4 years of education; > 26 for patients with 5 to 8; > 28 for patients with 9 to 11 years; > 29 for individuals with more than 11 years of education).[27]

Individuals with other neurological, orthopedic, cardiac, or pulmonary diseases or who were unable to perform the required tasks were excluded from the study.

Procedures

For sample characterization, we performed the Geriatric Depression Scale (GDS) and recorded the age, sex, H&Y, and MMSE of each participant.

Single task assessment

We assessed the performance in single and dual task conditions. Single- and dual-task accomplishments were assessed during the "on" PD medication period, about 40 minutes to two hours after Levodopa was administered. Primary tasks included the postural control task (the 30-s sit-to-stand) and manual dexterity task (Box and Blocks Test), respectively. A secondary, cognitive task (reciting the weekdays backward) was assessed in setting as a baseline condition and associated with each of the primary tasks to form a dual task condition. Each task was performed and recorded for 30 seconds.

Manual dexterity was assessed using the Box and Block test. Individuals seated comfortably on a chair in front of a table where there was a wood box with two compartments of equal dimensions. Inside the box, there were 150 woodblocks. The manual dexterity task consisted of transferring the greater number of blocks from one side of the box to the other side, being one block each time, as fast as possible, and using the dominant hand[28] for 30 seconds. The number of blocks transferred from one to the other side was recorded.[29]

Postural control was assessed using the 30-s sit-to-stand. Each participant began the task seated on a chair without arms and was asked to stand up and sit back down many times as possible and as fast as possible during 30-second intervals. The 30-s sit-to-stand was performed on a chair with a seat height of approximately 44 cm, according to the description in Duncan et al.[30] The subject sat on the center of the chair, with the back straight, the feet parallel and separated by a distance equivalent to the shoulder width, and arms folded across the chest.[30] The number of times the participant stood up from the chair was recorded.[31] The 30-s sit-to-stand test was selected as a measure of postural control because it is a dynamic test which the performance of individuals with PD is related to PD motor impairments. Such as balance disorders and bradykinesia, and postural control to change from one posture to another requires a complex control of the center of mass.[32] It is an easy-to-use and reliable test to assess the risk of falling of this population.[30]

Dual task assessment

We paired each primary task with a simultaneous performance of the cognitive task to form a dual task condition. Verbal instructions were given to the participant to perform the two tasks as best as possible with no prioritization. We recorded the number of blocks transferred from one to the other side, the number of times the individuals stood up from the chair and the number of weekdays recited correctly. We randomized the order of task performance, including single task (30-s chair stand and manual dexterity) as well as single x dual task.

Dual task cost

The dual task cost (DTC) is a measure of the impact of performing a secondary task on the performance of a reference task.[13] The DTC allows a more direct comparison of dual-task deficits across studies and provides a way to assess the relative effects of individual, tasks, and environmental factors.[13]

The DTC was calculated by the difference between performance on the dual task condition and performance on each single task condition, as described by McDowd[33]: *DTC (%) = [(dual task – single task) / single task] x 100%*.

Statistical analysis

SPSS was used to perform statistical analysis.

The homogeneity of variance was performed using the Kolmogorov-Smirnov and Levene test, respectively, and these tests showed that our data presented normality conditions. We applied a Student paired t-test to compare the performance in single and dual task conditions (i.e., manual dexterity in single task versus manual dexterity in the dual task; sit-to-stand in single task versus sit-to-stand in the dual task).

The performance of the secondary tasks in the three conditions (single task versus manual dexterity in the dual task versus sit-to-stand in the dual task) was assessed using a one-way ANOVA. To detect differences among the conditions, we conducted a Tukey post hoc test.

We also ran a one-way ANOVA followed by a Tukey post hoc test to compare the DTC between the different conditions. An alpha level of 0.05 was selected as statistical significance.

RESULTS

The sample consisted of twenty individuals with idiopathic PD, characteristics of the sample are highlighted in Table 1. All participants were being treated with levodopa and/or its synergists.

Table 1 – Characteristics of participants.

	Sex	HY	Age (Years)	Disease (Years)	MMSE (Score)	GDS-15 (Score)
Mean (SD)	13 men 7 women	25%: 1.0 25%: 1.5 25%: 2.0 20%: 2.5 5%: 3.0	60.1 (10.4)	7.9 (4.0)	27.0 (2.8)	3.5 (3.1)

Legend: SD, Standard Deviation; HY: Hoehn and Yard modified scale; MMSE, Mini Mental Status Examination; GDS-15, Geriatric Depression Scale – 15.

All participants completed the tests. The number of times that the participants were able to sit and stand and the number of blocks that were transferred from one box to another on the single task was higher than in the dual task ($p=0.002$ and $p<0.001$, respectively). (Table 2).

Table 2 – Sit-to-Stand task, manual dexterity, single- and dual-task

	Mean (SD) (numbers of times)	*p value*	*Cohen D*
Sit-to-Stand task - single task	9.9 (3.80)	0.002*	2.42
Sit-to-Stand task - dual task	8.0 (3.08)		
Manual dexterity - single task	18.8 (7.40)	0.000*	1.27
Manual dexterity - dual task	14.7 (5.79)		

Legend: SD: standard deviation; *: difference between single and dual task.

Performance of verbal fluency in the single task was higher than in the dual task conditions (ANOVA, Tukey post hoc test, p<0.001) (Table 3).

Table 3 – Performance of verbal fluency, single- and dual- task

	Mean (SD) (words)	*p value*
Verbal fluency - single task	30.2 (12.80)	
Verbal fluency - Sit-to-Stand task	18.5 (9.54)	<0.001*
Verbal fluency - Manual dexterity	15.9 (7.18)	

Legend: SD: standard deviation; *: difference between single and dual task.

The cost of verbal fluency was higher than the cost of manual dexterity (ANOVA, Tukey post hoc test: * p=0.019) (Table 4). There was no difference between the costs of manual dexterity and postural control tasks.

Table 4 – Costs in dual task conditions

	Mean (SD) (%)	*p value*
Sit-to-Stand task	15.5 (24.08)	
Manual dexterity	20.8 (13.20)	0.019[a]
Verbal fluency	44.9 (22.21)	

Legend: SD: standard deviation; [a] difference between cost of verbal fluency and manual dexterity

DISCUSSION

The main results of the present study were: (1) sit-to-stand, manual dexterity, and verbal fluency reduced performance in DT, and (2) the cost of verbal fluency associated with manual dexterity was higher than the costs of the other tasks. Together, these results showed that individuals with PD prioritized tasks according to the level of complexity. Hierarchically, postural control (represented by the 30-sit-to-stand task) is less dependent on superior cortical function. This is followed by manual dexterity, and then language, respectively.[34] The higher the level of attention required by the task, the higher the DT cost is per condition.[35–38]

In the present study, individuals with PD demonstrated worse performance of upper extremity and postural control when each of these tasks was performed togeher with a verbal fluency task. The poorer performance associated with DT condition performance in DT may

be related to the division of attention between the tasks or with the reduced attentional resources.[3]

Individuals with neurological disorders may be susceptible to DTI, as higher attentional demand is required to perform the primary task. Due to the raised attentional demand, there are fewer attentional resources available for the simultaneous performance of tasks.[39] Specifically in individuals with PD, the damage to the lesion on the basal ganglia can cause loss of automaticity. Studies show that movements that were automatic before the disease become more dependent upon cortical areas, and tasks that were once automatic now require attentional resources for successful performance. Lesions of the basal ganglia can result in hyper-connectivity between the inferior parietal lobule and premotor cortex (PMC) and between the cerebellum and the PMC and primary motor.[8] This hyper-connectivity can overload the system, causing an increase in DTC.[8,19,40,41]

Wu & Hallet[42] also demonstrated that individuals with PD had greater activity in the cerebellum, premotor area, parietal cortex, precuneus, and prefrontal cortex compared to non-PD subjects while performing automatic movements in DT condition. However, the increased activation of cortical areas during steps tasks in the DT condition was not found by Pelicioni et al.[43] The authors found that the PD group demonstrated reduced cortical activity in the dorsolateral prefrontal cortex, supplementary motor area, and PMC during more complex stepping tasks that required inhibitory control.[43]

Investigation of secondary task performance is extremely important in the DT paradigm because the performance of the primary task can be maintained or at least, less affected to the detriment of the secondary task.[44] In the present study, our results showed that there was worsening performance in both the primary and secondary task suggesting that the secondary task was also affected.

In order to compare the effect of dual tasks on the primary and secondary tasks we analyzed the cost of the dual task over the primary and secondary tasks. The cost of the dual task analysis allowed an investigation of task prioritizations. In other words, we intend to understand how individuals with PD share attention between the different tasks. Verbal fluency in association with upper extremity function demonstrated the greatest DTC. In this condition, verbal fluency had a cost of approximately 50%. The decreased attentional reserves may be insufficient to be shared between the two tasks (i.e., language and upper extremity function). Thus, both tasks can compete for cortical resources.[3,9,12,45] Previous studies showed that lesions on dopaminergic neurons can cause deficiencies in the capacity to share attention among tasks.[9,11,46]

Consistent with the results of this study, other studies showed a loss of upper extremity performance in dual task conditions with prioritization of the motor task.[9,12] Nocera et al[47] showed that individuals with PD had a worse performance of the cognitive task, thus suggesting prioritization of the motor task. Pradhan et al[48] assessed the performance of individuals with PD in a dual task condition that incorporated a finger opposition as the primary task of this study paired with a secondary subtraction task. In the dual task condition, individuals showed worsening of performance during both tasks, but with a greater decrease of performance of the secondary task. Proud and Morris[21] replicated these results using a manual accuracy task and an associated subtraction task. Results also showed that performance was worse in the dual task condition, but with prioritization of the manual task.

According to our findings, these results show that individuals with PD prioritized upper extremity function over verbal fluency task in a DT condition. Task prioritization suggests that when there is competition for attentional resources, the person must decide how to prioritize the two tasks. This self-selected strategy of task prioritization is determined by the need to reduce the danger and maximize the pleasure.[39,49]

On the other hand, there was no difference between the cost of postural control and the cost of verbal fluency in the dual task condition when combining these two tasks. Dual task affects the costs of postural control and verbal fluency similarly in terms of prioritization pattern between these tasks. Kelly et al[46] suggested that the severity of the disease should be a factor to consider. In the more severe stages of PD, there is a clear task prioritization pattern. In fact, this clear issue could explain our findings since most of our sample is composed of individuals with PD who showed mild motor impairments. Also, Freitas et al[50] did not find prioritization between the task of sitting and standing (postural control task) and the secondary task in a dual task condition.

The lack of prioritization between postural control and verbal fluency also can be explained by the nature of the two tasks. Postural control depends mainly on the brain steam, the spinal cord, and the cerebellum, integrating information of vestibular, visual, and somatosensory systems.[51] Verbal fluency is a cognitive task that is controlled by cortical areas associated with language and executive functions, the association of the cortex of the left frontal, the parietal and the temporal regions.[34] Therefore, postural control and verbal fluency do not compete for the same resources of attention and cortical circuits. A review by Stuart et al[52] demonstrated that the cortical activity appears to increase from baseline in postural control task in PD, and it may represent cortical compensation for subcortical dysfunction with the pathology of the PD. However, despite the absence of prioritization, both tasks showed a decreased performance in a dual task condition. Marchese et al[53] stated that postural control in PD can be affected because individuals have to use more attention to compensate for the deficiencies of balance due to lesions on the basal ganglia. Therefore, we speculate that the worsening of the postural control in a dual task condition can occur due to the reduction of attention caused by the associated cognitive task.

One limitation of our study is the lack of a control group with neurologically healthy older participants and the small sample size. Thus, we were unable to determine whether or not these results are exclusively caused by the disease, or whether age could have an impact on the prioritization pattern during dual task conditions.

Individuals with PD have difficulty with DTs, which limits participation in the community. In this study, we explored the impact of carrying out DT in tasks with different demands. The relevant results here can be used to guide clinicians to develop strategies to navigate task prioritization and improve function in this population.

CONCLUSION

The assessment of individuals with PD in conditions associating postural control and upper-extremity function with a cognitive task of verbal fluency showed that all tasks were negatively impacted by the dual task performance. The tasks of postural control, manual dexterity, and verbal fluency performed worse in the dual task condition as compared

to each task in a single task condition. However, the cost of verbal fluency was higher than the cost of the associated DT verbal fluency with the upper extremity function condition. There was no evidence of prioritization in the dual task condition in the postural control task.

REFERENCES

1. Rodriguez-Oroz MC, Jahanshahi M, Krack P, et al. Initial clinical manifestations of Parkinson's disease: features and pathophysiological mechanisms. *Lancet Neurol*. 2009;8(12):1128-1139. doi:10.1016/S1474-4422(09)70293-5
2. Fox SH, Katzenschlager R, Lim S-Y, et al. The Movement Disorder Society Evidence-Based Medicine Review Update: Treatments for the motor symptoms of Parkinson's disease. *Mov Disord*. 2011;26 Suppl 3:S2-41. doi:10.1002/mds.23829
3. Wu T, Hallett M, Chan P. Motor automaticity in Parkinson's disease. *Neurobiol Dis*. 2015;82:226-234. doi:10.1016/j.nbd.2015.06.014
4. Bleuse S, Cassim F, Blatt J, et al. Anticipatory postural adjustments associated with arm movement in Parkinson's disease: a biomechanical analysis. *J Neurol Neurosurg Psychiatry*. 2008;79:881-888. doi:10.1136/jnnp.2006.107318
5. Falaki A, Huang X, Lewis MM, Latash ML. Impaired synergic control of posture in Parkinson's patients without postural instability. *Gait Posture*. 2016;44:209-215. doi:10.1016/j.gaitpost.2015.12.035.Impaired
6. Mellone S, Mancini M, King LA, Horak FB, Chiari L. The quality of turning in Parkinson's disease: a compensatory strategy to prevent postural instability? *J Neuroeng Rehabil*. Published online 2016:13-39. doi:10.1186/s12984-016-0147-4
7. Simieli L, Gobbi BTB, Orcioli-silva D, et al. The variability of the steps preceding obstacle avoidance (approach phase) is dependent on the height of the obstacle in people with Parkinson's disease. *PLoS One*. Published online 2017:1-15.
8. Vervoort G, Heremans E, Bengevoord A, et al. Dual-task related neural connectivity changes in patients with Parkinson' Disease. *Neuroscience*. Published online January 2016:1-11. doi:10.1016/j.neuroscience.2015.12.056
9. Wu T, Wang L, Hallett M, Li K, Chan P. Neural correlates of bimanual anti-phase and in-phase movements in Parkinson's disease. *Brain*. 2010;133(Pt 8):2394-2409. doi:10.1093/brain/awq151
10. Heremans E, Nackaerts E, Vervoort G, Broeder S, Swinnen SP, Nieuwboer A. Impaired Retention of Motor Learning of Writing Skills in Patients with Parkinson ' s Disease with Freezing of Gait. *PLoS One*. 2016;(February):1-13. doi:10.1371/journal.pone.0148933
11. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. *Gait Posture*. 2002;16(1):1-14. doi:10.1016/S0966-6362(01)00156-4
12. Wu T, Hallett M. A functional MRI study of automatic movements in patients with Parkinson's disease. *Brain*. 2005;128(10):2250-2259. doi:10.1093/brain/awh569

13. Kelly VE, Eusterbrock AJ, Shumway-Cook A. A review of dual-task walking deficits in people with Parkinson's disease: motor and cognitive contributions, mechanisms, and clinical implications. *Parkinsons Dis*. 2012;2012:1-14. doi:10.1155/2012/918719
14. Dirnberger G, Jahanshahi M. Executive dysfunction in Parkinson's disease: a review. *J Neuropsychol*. 2013;7(2):193-224. doi:10.1111/jnp.12028
15. Broeder S, Nackaerts E, Nieuwboer A, Smits-Engelsman B, Swinnen S, Heremans E. The effects of dual tasking on handwriting in patients with Parkinson's disease. *Neuroscience*. 2014;28(263):193-202.
16. Brauer SG, Morris ME. Can people with Parkinson's disease improve dual tasking when walking? *Gait Posture*. 2010;31(2):229-233. doi:10.1016/j.gaitpost.2009.10.011
17. Jacobs JV, Nutt JG, Carlson-Kuhta P, Allen R, Horak FB. Dual tasking during postural stepping responses increases falls but not freezing in people with Parkinson's disease. *Park Relat Disord*. 2014;20(7):779-781. doi:10.1016/j.parkreldis.2014.04.001
18. De Freitas TB, Leite PHW, Doná F, Pompeu JE, Swarowsky A, Torriani-Pasin C. The effects of dual task gait and balance training in Parkinson's disease: a systematic review. *Physiother Theory Pract*. Published online December 3, 2018:1-9. doi:10.1080/09593985.2018.1551455
19. Fernandes Â, Coelho T, Vitória A, et al. Standing balance in individuals with Parkinson ' s disease during single and dual-task conditions. *Gait Posture*. 2015;42:323-328. doi:10.1016/j.gaitpost.2015.06.188
20. Fernandes Â, Rocha N, Santos R, Tavares JMRS, Rocha N, Santos R. Effects of dual-task training on balance and executive functions in Parkinson ' s disease : A pilot study. *Somatosens Mot Res*. 2015;32(2):122-127. doi:10.3109/08990220.2014.1002605
21. Proud EL, Morris ME. Skilled Hand Dexterity in Parkinson's Disease: Effects of Adding a Concurrent Task. *Arch Phys Med Rehabil*. 2010;91(5):794-799. doi:10.1016/j.apmr.2010.01.008
22. Acaröz Candan S, Özcan TŞ. Dual-task interference during hand dexterity is a predictor for activities of daily living performance in Parkinson's disease. *Park Relat Disord*. 2019;66(December 2018):100-104. doi:10.1016/j.parkreldis.2019.07.017
23. Bank PJM, Marinus J, van Tol RM, et al. Cognitive-motor interference during goal-directed upper-limb movements. *Eur J Neurosci*. 2018;48(10):3146-3158. doi:10.1111/ejn.14168
24. Broeder S, Nackaerts E, Nieuwboer A, Swinnen SP, Heremans E. The effects of dual tasking on handwriting in patients with Parkinson´s disease. *Neuroscience*. 2014;263:193-202. doi:10.1016/j.neuroscience.2014.01.019
25. Goetz CG, Poewe W, Rascol O, et al. Movement Disorder Society Task Force report on the Hoehn and Yahr staging scale: status and recommendations. *Mov Disord*. 2004;19(9):1020-1028. doi:10.1002/mds.20213
26. Rovner BW, Folstein MF. Mini-mental state exam in clinical practice. *Hosp Pract (Off Ed)*. 1987;22(1A):99, 103, 106, 110.

27. Brucki SMD, Nitrin R, Caramelli P, Bertolucci PHF, Okamoto IH. Suggestions for utilization of the mini-mental state examination in Brazil. *Arq Neuropsiquiatr*. 2003;61(3 B):777-781. doi:10.1590/S0004-282X2003000500014
28. Lahr J, Pereira MP, Henrique P, et al. The onset side of the disease influences the manual dexterity in patients with Parkinson's disease. *Rev Ter Ocup niv São Paulo*. 2018;29(3):223-229.
29. Dahdal P, Meyer A, Chaturvedi M, et al. Fine motor function skills in patients with Parkinson's Disease with and without mild cognitive impairment. *Dement Geriatr Cogn Disord*. 2016;42(3):127-134.
30. Duncan RP, Leddy AL, Earhart GM. Five times sit-to-stand test performance in Parkinson's disease. *Arch Phys Med Rehabil*. 2011;92(9):1431-1436. doi:10.1016/j.apmr.2011.04.008
31. Landers M, Lopker M, Newman M, Gourlie R, Sorensen S, Vong R. A Cross-sectional Analysis of the Characteristics of Individuals With Parkinson's Disease Who Avoid Activities and Participation Due to Fear of Falling. *J Neurol Phys Ther*. 2017;41(1):31-42.
32. Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age Ageing*. 2006;35(SUPPL.2):7-11. doi:10.1093/ageing/afl077
33. McDowd J. The effects of age and extended practice on divided attention performance. *J Gerontol*. 1986;41(6):764-769.
34. Kandel E, Jessel T, Schwartz JH. *Essentials of Neural Science and Behavior*.; 1995.
35. Corp DT, Lum JAG, Tooley GA, Pearce AJ. Corticospinal activity during dual tasking: a systematic review and meta-analysis of TMS literature from 1995 to 2013. *Neurosci Biobehav Rev*. 2014;43:74-87. doi:10.1016/j.neubiorev.2014.03.017
36. Schaefer S. The ecological approach to cognitive-motor dual-tasking: findings on the effects of expertise and age. *Front Psychol*. 2014;5:1167. doi:10.3389/fpsyg.2014.01167
37. Yang L, Liao LR, Lam FMH, He CQ, Pang MYC. Psychometric properties of dual-task balance assessments for older adults: A systematic review. *Maturitas*. 2015;80(4):359-369. doi:10.1016/j.maturitas.2015.01.001
38. Menant JC, Schoene D, Sarofim M, Lord SR. Single and dual task tests of gait speed are equivalent in the prediction of falls in older people: a systematic review and meta-analysis. *Ageing Res Rev*. 2014;16:83-104. doi:10.1016/j.arr.2014.06.001
39. Plummer P, Eskes G. Measuring treatment effects on dual-task performance: a framework for research and clinical practice. *Front Hum Neurosci*. 2015;9:1-7. doi:10.3389/fnhum.2015.00225
40. Peterson DS, Fling BW, Mancini M, Cohen RG, Nutt JG, Horak FB. Dual-task interference and brain structural connectivity in people with Parkinson's disease who freeze. *J Neurol Neurosurg Psychiatry*. 2015;86(7):786-792. doi:10.1136/jnnp-2014-308840

41. Pelykh O, Klein A-M, Bötzel K, Kosutzka Z, Ilmberger J. Dynamics of postural control in Parkinson patients with and without symptoms of freezing of gait. *Gait Posture*. 2015;42(3):246-250. doi:10.1016/j.gaitpost.2014.09.021
42. Wu T, Hallett M. A functional MRI study of automatic movements in patients with Parkinson's disease. *Brain*. 2005;128:2250-2259. doi:10.1093/brain/awh569
43. Pelicioni PHS, Lord SR, Okubo Y, Sturnieks DL, Menant JC. People With Parkinson ' s Disease Exhibit Reduced Cognitive and Motor Cortical Activity When Undertaking Complex Stepping Tasks Requiring Inhibitory Control. *Neurorehabil Neural Repair*. 2020;34(2):1088-1098. doi:10.1177/1545968320969943
44. Leone C, Patti F, Feys P. Measuring the cost of cognitive-motor dual tasking during walking in multiple sclerosis. *Mult Scler*. 2015;21(2):123-131. doi:10.1177/1352458514547408
45. Lu C-F, Liu Y-C, Yang Y-R, Wu Y-T, Wang R-Y. Maintaining Gait Performance by Cortical Activation during Dual-Task Interference: A Functional Near-Infrared Spectroscopy Study. *PLoS One*. 2015;10(6):e0129390. doi:10.1371/journal.pone.0129390
46. Kelly VE, Eusterbrock AJ, Shumway-cook A. A Review of Dual-Task Walking Deficits in People with Parkinson ' s Disease : Motor and Cognitive Contributions , Mechanisms , and Clinical Implications. *Parkinsons Dis*. 2012;2012:1-14. doi:10.1155/2012/918719
47. Nocera J, Roemmich R, Elrod J, Altmann L, Hass C. Effects of cognitive task on gait initiation in Parkinson disease: Evidence of motor prioritization? *J Rehabil Res Dev*. 2013;50(5):699-708.
48. Pradhan SD, Brewer BR, Carvell GE, Sparto PJ, Delitto A, Matsuoka Y. Assessment of fine motor control in individuals with Parkinson's disease using force tracking with a secondary cognitive task. *J Neurol Phys Ther*. 2010;34(1):32-40. doi:10.1097/NPT.0b013e3181d055a6
49. Yogev-Seligmann G, Giladi N, Brozgol M, Hausdorff JM. A training program to improve gait while dual tasking in patients with Parkinson's disease: A pilot study. *Arch Phys Med Rehabil*. 2012;93(1):176-181. doi:10.1016/j.apmr.2011.06.005
50. de Freitas TB, da Silva KG, Nuvolini RA, et al. Dual-task demands in various motor skills through Parkinson's disease progression. *Motriz Rev Educ Fis*. 2019;25(1):1-7. doi:10.1590/s1980-6574201900010011
51. Takakusaki K. Functional Neuroanatomy for Posture and Gait Control. *J Mov Disord*. 2017;10(1):1-17. doi:10.14802/jmd.16062
52. Stuart S, Vitorio R, Morris R, Martini DN, Fino PC, Mancini M. Cortical activity during walking and balance tasks in older adults and in people with Parkinson ' s disease : A structured review. *Maturitas*. 2018;113(April):53-72. doi:10.1016/j.maturitas.2018.04.011
53. Marchese R, Bove M, Abbruzzese G. Effect of cognitive and motor tasks on postural stability in Parkinson's disease: a posturographic study. *Mov Disord*. 2003;18(6):652-658.

ACKNOWLEDGMENTS

The authors would like to thank the Universidade Paulista for the collaboration in this study, and Dr. Lauri Bishop for her comments and feedback on the paper.

Citation: Freitas TB, Pompeu JE, Moraes BRB, Pompeu SMAA, Silva KG, Torriani-Pasin C. Effects of dual task demanding manual dexterity and sit-to-stand in individuals with Parkinson's disease. *BJMB.* 2021. 15(2): 137-148.
Editors: Dr Fabio Augusto Barbieri - São Paulo State University (UNESP), Bauru, SP, Brazil; Dr José Angelo Barela - São Paulo State University (UNESP), Rio Claro, SP, Brazil; Dr Natalia Madalena Rinaldi - Federal University of Espírito Santo (UFES), Vitória, ES, Brazil.

Funding: There was no funding for this study.
Competing interests: The authors have declared that no competing interests exist.
DOI: https://doi.org/