Dual Tasking Interferes with Dynamic Balance in Young and Old Healthy Adults

Amal AL-Shaikh Sulaiman[a,1], Marie Kelly[d,2,*], Mairead O'Connor[d,3], Doris Eva-Bamiou[a,b,c], Marousa Pavlou[d]

[a] Faculty of Brain Sciences, UCL Ear Institute, University College London, London, United Kingdom

[b] Hearing and Deafness Biomedical Research Centre, National Institute for Health Research, London, United Kingdom

[c] University College London Hospitals, London,United Kingdom

[d] Centre for Human and Applied Physiological Sciences, Faculty of Life Sciences and Medicine, King's College London, London, United Kingdom.

[1] Department of Otorhinolaryngology - Head and Neck Surgery, Faculty of Medicine, Imam Abdulrahman Bin Faisal University, KFUH, Al-Khobar, Saudi Arabia.

[2]Department of Physiotherapy, Mercy University Hospital, Grenville Place, Cork, Ireland

[3]Department of Physiotherapy, Croom Hospital, Corrabul, Croom, Co. Limerick, Ireland

[*]**Corresponding author**: Marie Kelly, Department of Physiotherapy, Mercy University Hospital, Grenville Place, Cork, T12 WE28, Ireland.E-mail address: kellym19@tcd.ie, Telephone: +353214935340

Word count: 2920

ABSTRACT

Background:

Functional mobility requires an ability to adapt to environmental factors together with an ability to execute a secondary task simultaneously while walking. A complex dual-tasking gait test may provide an indication of functional ability and falls risk among community-dwelling older adults.

Purpose:

The aim of this cross-sectional study is to investigate age-related differences in dual-tasking ability and to evaluate whether dual-tasking ability is related to executive function.

Methods:

Forty-one community-dwelling healthy older and forty-one younger adults completed a dual-tasking assessment in which concurrent tasks were incorporated into the Functional Gait Assessment (FGA). The manual dual-task involved carrying a glass of water (FGA-M) while the cognitive dual-tasks involved numeracy (FGA-N) and literacy (FGA-L) related tasks. FGA scores under single (FGA-S) and dual-task conditions together with associated dual-task costs and response accuracy were determined. Executive function was assessed using The Behavioural Assessment of the Dysexecutive Syndrome (BADS).

Results:

FGA-N and FGA-L scores were adversely affected in both groups compared to FGA-S ($p \leq 0.001$). However, score reductions and dual-task costs were significantly greater for older adults compared to younger adults on FGA-N ($p \leq 0.05$) and FGA-L ($p \leq 0.001$), with older adult performance on FGA-N associated with falls risk ($p \leq 0.05$). Executive function did not appear to be related to dual-tasking ability.

Conclusion:

Findings suggest that cognitively demanding tasks while walking, have a deleterious effect on dynamic balance and could place older adults at a greater risk of falls.

Keywords: Dual-task, Dynamic balance, Gait, Aging, Executive function

1. Introduction

Effective, safe gait is essential for independence and longevity among eldery adults (1). Postural control, fundamental to a person's ability to stand and walk independently, requires sensorimotor processes (2), with the integration of afferent information from many musculoskeletal and neural systems including vestibular, the visual and somatosensory systems (3, 4). Furthermore, this complex motor skill utilises cognitive function, in the form of two intimately linked domains, attention and executive function (5) and hence, is no longer considered an automatic task. In a seminal study, Lundin-Olsson, Nyberg (6) illustrated the attentional demands of gait since those who 'stopped walking when talking' were more likely to fall in the future. Considerable work has demonstrated the value of executive functioning in complex gait situations (7, 8), that are representative of routine environmental challenges. When walking under divided attention conditions, executive function plays an important role in allocating attentional resources, ensuring successful completion of a given task. The importance of executive function becomes more apparent as the difficulty of the secondary task increases (9), which may even expose gait instability among healthy subjects.

Various studies have illustrated that both healthy young and older adults walk slower while performing a secondary task (5). Older healthy adults not only reduce gait speed but also become less stable with increased gait variability when dual tasking (8) and this is associated with an increased future falls risk (10). With aging, gait loses automaticity, placing greater demands on declining frontal-dependent executive control resources (11, 12)

Functional community mobility requires an ability to perform a secondary task simultaneously while walking, and to adapt to external environmental factors. The aim of the dual-task gait assessment is to compare task performance while walking and concurrently completing an attention-demanding task, to baseline performance of either one of the individual tasks (13). Deficits in performance while dual-tasking, referred to as dual-task costs (DTCs) (14), are thought to represent interference as both tasks compete for brain cortical resources. Therefore, if information processing is limited, it may be important to prioritise one task over the other. The posture first strategy, originally proposed by Shumway-Cook et al. (15), suggests that when dual-tasking, postural control will be favoured over the execution of a secondary task, to prevent a loss of balance.

Much of the dual-task interference related research utilises spatiotemporal gait parameters as outcome measures, which often require sophisticated equipment and a laboratory and therefore may lack clinical utility (8, 16). A possible exception to this is gait speed, however such a one dimensional measure cannot adequately capture the multidimensional nature of gait (17). This may partly explain its insufficient sensitivity (18) with Menant et al. (19) concluding that dual-tasking tests of gait speed did not demonstrate a superior predictive ability for falls over single task tests.

The Functional Gait Assessment (FGA) is an easy to administer, reliable and valid gait assessment tool requiring minimal space or equipment (20). Currently, dual-task protocols do not sufficiently assess the skills necessary for everyday functional mobility. Complex gait tests such as a dual-tasking FGA, which evaluate a range of clinical gait activities, may be a better tool to investigate age-related differences in dual-tasking ability. Such an assessment tool could also serve to partly address the standardisation concerns, which have prevented the development of evidence-based recommendations for clinical practice. Therefore, the main objective of this cross-sectional study was to compare dual-tasking ability on the FGA between healthy older and younger adults, with this information relevant for future dual-task assessment and intervention protocols. A secondary aim was to assess the relationship between dual-tasking performance on the FGA and executive function. It was hypothesised that dual-tasking would interfere with postural stability, presenting a greater challenge to healthy older adults, and that these dual-tasking effects on this complex gait test would be related to executive function.

2. Materials and methods

2.1 Participants

A convenience sample of independently mobile, community-dwelling younger (n = 41, Male = 19; mean age= 37 years, range = 23 – 58) and older adults (n = 41, Male = 18; mean age = 68.3, range = 60 – 88) were recruited from the university and community via flyers and word of mouth. Participants were included if they were between 18 and 90 years, and able to ambulate without an assistive device. Those aged 60 and older were considered older adults. Subjects were excluded if they reported history of falling within the previous 6 months, dementia, as evidenced by a diagnosis of dementia, an unstable medical condition or pathology likely to directly impact on gait (e.g. visual, neurologic, vestibular, orthopaedic).

2.2 Protocol

The study was reviewed and approved by the National Hospital for Neurology and Neurosurgery and Institute of Neurology Joint Ethics Committee and that the procedures followed during the study were in accordance with the Helsinki Declaration of 1975, as revised in 1983.

Each participant completed the following assessments:

A. Behavioural Assessment of the Dysexecutive Syndrome (BADS) test: an ecologically valid and reliable battery comprising of six sub-tests, which evaluate a range of executive function constructs (21). The six sub-tests include:(1) Rule shift cards; to evaluate cognitive flexibility (2) Action program; to assess ability to identify and implement a solution to a practical problem. (3) Key search; test assesses ability to plan a strategy to solve a problem (4) Temporal judgment; involves judgment and abstract thinking (5) Zoo map; to assess spontaneous planning abilities, and (6) Modified six elements; to assess the ability to plan, organise and monitor behaviour.
B. Timed Up and Go test (TUG): a reliable and valid dynamic test which involves standing up from chair (approximate seat height 46cm), walking three metres at normal pace, turning around and walking back to the chair, sitting back down again (22). A cut-off score of 13.5 suggests an increased falls risk in community dwelling older adults, with a higher specificity than sensitivity reported in the literature (23).
C. FGA: a reliable and valid (20) standardised measure of functional gait, which is scored on a 4-level (0-3) ordinal scale with a maximum score of 30 achievable; a cutoff score of 22/30 predicts falls in community dwelling older adults (24). FGA was performed under single and dual-task conditions (Table1).

‘Insert Table 1 here’

To reduce potential practice or learning effects from trial to trial, a different letter or number was used across successive trials. The responses were recorded using a recorder and scored following the testing session according to the total number of responses and number of errors made. Since all measures were completed in one session, rests were suggested at various stages in between testing during the session, to help minimize the effect of fatigue. No instruction on task prioritisation was communicated.

2.3 Statistical analysis

Data analysis was undertaken using the Statistical Package for the Social Sciences Version (SPSS) 22.0 (IBM Corporation, Chicago, IL). A level of significance of $p \leq 0.05$ was set for this study. Normality of the continuous variables was tested with the Shapiro-Wilk test and appropriate descriptive statistics were calculated. Where the normality assumption was violated, equivalent non-parametric tests were used. Independent-samples t-test was performed to assess between-group differences in the TUG score with data reported as mean ± SD. The Mann Whitney U test was utilised to evaluate between-group differences in FGA scores and BADS scores. Median and inter-quartile values (Q1 – Q3) are presented. Given the non-normal distribution these values are better represented by the median rather than the mean, with the median less sensitive to outliers (25). A Chi-Squared test was performed to evaluate the distribution of BADS overall classification.

Dual-task costs (DTCs), characterised as the percentage change difference in performance relative to the single-task performance was calculated for all three tasks (FGA-M, FGA-N and FGA-L) using the following equation:

Dual-task cost (%) = 100*(Multi task – Single task / Single task)

All DTCs were classified such that a negative value signified a performance decrement and a positive value illustrated a dual-task benefit. Between-group DTC differences were evaluated using the Mann-Whitney test.

Response accuracy was assessed under the two dual-task conditions, FGA-N and FGA-L, utilising the following equation:

% Response accuracy = 100*(Number of responses – number of errors / Number of responses)

Spearman's rank correlations investigated whether BADS scores were correlated with DTCs or FGA scores under the different dual-task conditions.

3. Results

3.1 FGA score

Both FGA-N (z = -2.76, $p \leq 0.05$, $r = 0.30$) and FGA-L (z = -3.23, $p \leq 0.001$, $r = 0.36$) scores were significantly lower in the older compared to the younger group (Table 2). There were no significant differences between age groups under FGA-S and FGA-M conditions.

The only dual-task condition significantly associated with falls risk was FGA-N, $\chi^2(1) = 7.57$, $p \leq 0.05$ (Table 2), with 51.2% of the older group scoring 22 or less. Within the younger group, falls risk was independent of dual-task condition.

'Insert Table 2 here'

3.2 Dual-Task Cost

Dual-task cost (DTC) was significantly different between age groups, with greater cost observed in the older age group for FGA-N (z= -2.37, $p \leq 0.05$, r = 0.26) and FGA-L (z= -2.53, $p \leq 0.05$, r = 0.28), but not FGA-M (Table 3).

'Insert Table 3 here'

3.3 Response Accuracy to cognitive tasks

There were no statistically significant differences between groups for response accuracy under both FGA-N and FGA-L conditions (Table 4).

'Insert Table 4 here'

3.4 BADs Scores

BADs age corrected score did not show significant differences between-groups. When comparing performance between the younger and older age groups for each sub-test, significant differences were observed for Test 3 (z = -2.79, $p \leq 0.05$, r = 0.35) and Test 5 (z = -3.01, $p \leq 0.05$, r = 0.35) (Fig. 1), which evaluate planning and behavioural regulation respectively (26).

'Insert Figure 1 here'

3.5 Correlation Analysis

In both the younger and older groups, no statistically significant correlations were noted between the BADS age corrected score or tests sub-scores and the FGA-S, FGA-M, FGA-N, FGA-L and the associated DTCs ($p > 0.05$).

3.6 TUG score

The TUG scores were statistically different between the two age groups (t (80) = -

3.402, $p \leq 0.001$, $d = 0.75$) with a longer duration noted for older (8.68s ± 1.81s) compared to younger (7.47s ± 1.38s) subjects.

3 Discussion

In this study, we compared dual-task ability on a dual-tasking FGA tool between healthy younger and older adults and we investigated whether a relationship exists between executive function and dual-tasking ability on the FGA. This study adds to emerging evidence on dual-task interference during more attention-demanding gait tasks. Complex dual gait tasks assess the ability to walk in diverse and challenging environments and hence, may provide a more accurate indication of functional ability compared to simple dual gait tasks. Therefore an investigation into age-related differences in dual-tasking ability, on a ecologically valid dual-tasking FGA tool, could provide valuable information for future dual-task assessment and intervention protocols.

The main findings from this study indicate that additional cognitive tasks had a destabilising effect on dynamic balance for both younger and older adults, however, older adults were significantly more affected. No other study to date has investigated age-related differences in dual-tasking ability while utilising a dual-task FGA test, although the findings of this study are consistent with a body of work pertaining to spatiotemporal gait parameters. Reduced gait speed together with increased stride-to-stride variability in stride length, stride velocity and/or stride time has been reported in older adults compared with younger adults, under cognitive dual task conditions (27-29) with increased stride-to-stride variability a marker of gait instability which predicts falls (30). A strength of the present study, in contrast to previous studies evaluating age-related differences (27-29), is that it utilised the recommended DTC formula (31) to account for dual-task interference on dynamic balance. This will facilitate between-study comparisons in the future (31) with the DTC also important as it accounts for baseline differences in single task performance, providing a true dual-task change (32).

In order to investigate whether FGA performance with a secondary dual-task is suitable for determining falls risk, the FGA scores under the three dual-task conditions were compared to a previously determined cut off value for FGA-S, which predicts a fall within six months, in community-dwelling older adults (24). Only performance on FGA-N was significantly associated with falls risk for older adults, with 51% scoring less than 22. This finding adds to growing literature linking dual-task interference to falls risk (10). The concept of prioritization may serve as a possible explanation for the observed decline in dynamic balance while performing a secondary cognitive task. In this study, participants were not given explicit instructions regarding task prioritisation. However, the performance of secondary cognitive tasks had a deleterious effect on dynamic balance in the older group, with FGA-N significantly associated with an increased falls risk. This, together with the comparable cognitive performance between both age groups suggests that healthy older adults do not prioritise gait, under cognitive dual-task conditions, consistent with previous findings (33, 34). This is in contrast with the "posture first strategy", in which all attention is directed toward maintaining balance and preventing falls. However, recent research suggests this is dependent on environmental factors, individual characteristics and the complexity of motor and cognitive task demands (35, 36). The effect of dual tasking on the posture first strategy has recently been attributed to the neural insufficiency model; increased brain activation in the context of diminished gait performance (11, 37, 38).

The cognitive tasks used in our study, classified as mental tracking tasks (2) were utilised since emerging evidence suggests that they are most disruptive on gait performance, compared to other types of secondary tasks (2, 39) and may have superior falls predictive ability (39). However, the effects of the cognitive mental tracking tasks did not appear to be equal. Results indicate that the numeracy task was the most difficult with the greatest median score reduction and DTC observed in both groups. This is consistent with literature indicating that the effect of the secondary task is dependent on its complexity (40). Since significant dual-task decrements were observed under both cognitive dual-task conditions, this might demonstrate that the type of secondary task is relevant with a cognitive task more challenging than a dual-manual task.

Subclinical age-related differences were observed with respect to the BADS total profile and standardised scores, which were not significant when age was removed as a confounding factor. This result was not surprising given the existing literature on the high vulnerability of the frontal lobe to age-related changes and the associated subclinical decline of executive functions with advancing age (41). When performance was analysed for each sub-test, the results indicated that the planning and behavioural regulation abilities of the older group were significantly reduced compared to the younger group as reflected in the BADs subscore in two tests (key search & zoo map test). While age-related deficits in performance on The Zoo Map Test have been reported elsewhere (42), no studies to our knowledge have observed these findings with respect to The Key Search Test.

The results from this study indicate that executive function is not related to dual-tasking ability on a complex dual-tasking FGA. This finding is in sharp contrast to existing literature (7, 8, 37, 43, 44) and is particularly unexpected given that executive function is considered most relevant in complex gait situations (9, 45-47), akin to the various FGA items. The contrasting results may be partially explained by differences in methodological design. This study utilised the FGA clinical gait tool to assess dynamic balance under dual-task conditions, whereas the majority of the existing research evaluated selected gait parameters such as speed and stride-time variability (7, 8, 37, 43, 44). These spatiotemporal parameters are not considered representative of dynamic postural control, with step width and step width variability thought to more accurately reflect this key feature of gait (17). Furthermore, to our knowledge, only one study examines the interplay between executive function and gait has utilized the BADS (48) in a cohort post-stroke. Another possible explanation is the relatively young age (mean age 68.3) of the older adult group, compared to other studies (7, 37) although studies exist with similar older adult groups indicating an association between executive function and dual task ability (8, 43).

Present findings bring forth several issues with possible clinical importance. Foremost, older adults did not appear to prioritise the dynamic balance tasks in accordance with the posture first strategy under cognitive dual-task load, with performance on the FGA-N significantly associated with falls risk. This may have future application for multi-task training and falls risk assessment.

A number of limitations are acknowledged with a lack of test order randomization foremost. However, the observation that dual-task interference was greatest on the second last task (FGA-N) rather than the last (FGA-L), suggest these systematic bias had limited impact. Another limitation is that the secondary cognitive tasks were not assessed in the single-task condition, i.e. when sitting, and as such, their relative DTC cannot be determined.

4 Conclusion

In conclusion, this study utilised a dual-tasking FGA tool with findings providing additional evidence that attentional processes are involved in walking and that attention-demanding cognitive tasks have a destabilising effect on dynamic balance. The resultant postural instability is however, more pronounced in the older participants with performance under numeracy dual-task conditions significantly associated with falls risk. Executive function did not appear to be significantly related to dual-task ability. However, this study was conducted on a relatively homogenous population and hence, these results should be interpreted with caution. Further research involving a large heterogeneous population is warranted to validate these findings.

- **Conflict of interest:** The authors have no conflict of interest to report

- **Funding:** This research received partial funding from the Ménière's Society, UK

- **Acknowledgment:** The authors would like to thank all those who participated in the study and acknowledge the support of their departmental colleagues

References

1. Studenski S, Perera S, Patel K, Rosano C, Faulkner K, Inzitari M, et al. Gait speed and survival in older adults. Jama. 2011;305(1):50-8.
2. Al-Yahya E, Dawes H, Smith L, Dennis A, Howells K, Cockburn J. Cognitive motor interference while walking: A systematic review and meta-analysis. Neuroscience & Biobehavioral Reviews. 2011;35(3):715-28.
3. 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:ii7-ii11.
4. Vouriot A, Gauchard GC, Chau N, Benamghar L, Lepori ML, Mur JM, et al. Sensorial organisation favouring higher visual contribution is a risk factor of falls in an occupational setting. Neurosci Res. 2004;48(3):239-47.
5. Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. Movement disorders : official journal of the Movement Disorder Society. 2008;23(3):329-42; quiz 472.
6. Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops walking when talking" as a predictor of falls in elderly people. Lancet (London, England). 1997;349(9052):617.
7. Caetano MJD, Lord SR, Brodie MA, Schoene D, Pelicioni PHS, Sturnieks DL, et al. Executive functioning, concern about falling and quadriceps strength mediate the relationship between impaired gait adaptability and fall risk in older people. Gait & posture. 2018;59:188-92.
8. Forte R, Pesce C, Di Baldassarre A, Shea J, Voelcker-Rehage C, Capranica L, et al. How Older Adults Cope with Cognitive Complexity and Environmental Constraints during Dual-Task Walking: The Role of Executive Function Involvement. International journal of environmental research and public health. 2019;16(10).
9. Ble A, Volpato S, Zuliani G, Guralnik JM, Bandinelli S, Lauretani F, et al. Executive function correlates with walking speed in older persons: the InCHIANTI study. Journal of the American Geriatrics Society. 2005;53(3):410-5.
10. Muir-Hunter SW, Wittwer JE. Dual-task testing to predict falls in community-dwelling older adults: a systematic review. Physiotherapy. 2016;102(1):29-40.
11. Mirelman A, Maidan I, Bernad-Elazari H, Shustack S, Giladi N, Hausdorff JM. Effects of aging on prefrontal brain activation during challenging walking conditions. Brain and cognition. 2017;115:41-6.
12. Holtzer R, Mahoney JR, Izzetoglu M, Izzetoglu K, Onaral B, Verghese J. fNIRS study of walking and walking while talking in young and old individuals. The journals of gerontology Series A, Biological sciences and medical sciences. 2011;66(8):879-87.
13. Pashler H. Dual-task interference in simple tasks: data and theory. Psychol Bull. 1994;116(2):220-44.
14. Plummer P, Eskes G. Measuring treatment effects on dual-task performance: a framework for research and clinical practice. Frontiers in human neuroscience. 2015;9:225.
15. Shumway-Cook A, Woollacott M, Kerns KA, Baldwin M. The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. The journals of gerontology Series A, Biological sciences and medical sciences. 1997;52(4):M232-40.
16. McGough EL, Kelly VE, Weaver KE, Logsdon RG, McCurry SM, Pike KC, et al. Limbic and Basal Ganglia Neuroanatomical Correlates of Gait and Executive Function: Older Adults

With Mild Cognitive Impairment and Intact Cognition. American journal of physical medicine & rehabilitation. 2018;97(4):229-35.
17. Lord S, Galna B, Verghese J, Coleman S, Burn D, Rochester L. Independent domains of gait in older adults and associated motor and nonmotor attributes: validation of a factor analysis approach. The journals of gerontology Series A, Biological sciences and medical sciences. 2013;68(7):820-7.
18. Beauchet O, Allali G, Annweiler C, Berrut G, Maarouf N, Herrmann FR, et al. Does change in gait while counting backward predict the occurrence of a first fall in older adults? Gerontology. 2008;54(4):217-23.
19. 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 research reviews. 2014;16:83-104.
20. Wrisley DM, Marchetti GF, Kuharsky DK, Whitney SL. Reliability, internal consistency, and validity of data obtained with the functional gait assessment. Physical therapy. 2004;84(10):906-18.
21. Wilson BA, Alderman N, Burgess PW, Emslie H, Evans JJ. BADS: Behavioural assessment of the dysexecutive syndrome1996.
22. Podsiadlo D, Richardson S. The timed" Up & Go": a test of basic functional mobility for frail elderly persons. Journal of the American geriatrics Society. 1991;39(2):142-8.
23. Barry E, Galvin R, Keogh C, Horgan F, Fahey T. Is the Timed Up and Go test a useful predictor of risk of falls in community dwelling older adults: a systematic review and meta-analysis. BMC Geriatr. 2014;14:14.
24. Wrisley DM, Kumar NA. Functional gait assessment: concurrent, discriminative, and predictive validity in community-dwelling older adults. Physical therapy. 2010;90(5):761-73.
25. D'Addio G, Cesarelli M, Corbi G, Romano M, Furgi G, Ferrara N, et al., editors. Reproducibility of heart rate turbulence indexes in heart failure patients. 2010 Annual International Conference of the IEEE Engineering in Medicine and Biology; 2010: IEEE.
26. Norris G, Tate RL. The Behavioural Assessment of the Dysexecutive Syndrome (BADS): Ecological, concurrent and construct validity. Neuropsychological rehabilitation. 2000;10(1):33-45.
27. Beauchet O, Kressig RW, Najafi B, Aminian K, Dubost V, Mourey F. Age-related decline of gait control under a dual-task condition. J Am Geriatr Soc. 2003;51(8):1187-8.
28. Priest AW, Salamon KB, Hollman JH. Age-related differences in dual task walking: a cross sectional study. Journal of neuroengineering and rehabilitation. 2008;5:29.
29. Granacher U, Bridenbaugh SA, Muehlbauer T, Wehrle A, Kressig RW. Age-related effects on postural control under multi-task conditions. Gerontology. 2011;57(3):247-55.
30. Callisaya ML, Blizzard L, Schmidt MD, Martin KL, McGinley JL, Sanders LM, et al. Gait, gait variability and the risk of multiple incident falls in older people: a population-based study. Age and ageing. 2011;40(4):481-7.
31. 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. Parkinson's disease. 2012;2012:918719.
32. Riby L, Perfect T, Stollery B. The effects of age and task domain on dual task performance: A meta-analysis. European Journal of Cognitive Psychology. 2004;16(6):863-91.

33. Agmon M, Kodesh E, Kizony R. The effect of different types of walking on dual-task performance and task prioritization among community-dwelling older adults. TheScientificWorldJournal. 2014;2014:259547.
34. Yogev-Seligmann G, Rotem-Galili Y, Mirelman A, Dickstein R, Giladi N, Hausdorff JM. How does explicit prioritization alter walking during dual-task performance? Effects of age and sex on gait speed and variability. Physical therapy. 2010;90(2):177-86.
35. Schaefer S, Schellenbach M, Lindenberger U, Woollacott M. Walking in high-risk settings: do older adults still prioritize gait when distracted by a cognitive task? Experimental brain research. 2015;233(1):79-88.
36. Sun R, Shea JB. Probing attention prioritization during dual-task step initiation: a novel method. Experimental brain research. 2016;234(4):1047-56.
37. Halliday DW, Hundza SR, Garcia-Barrera MA, Klimstra M, Commandeur D, Lukyn TV, et al. Comparing executive function, evoked hemodynamic response, and gait as predictors of variations in mobility for older adults. Journal of clinical and experimental neuropsychology. 2018;40(2):151-60.
38. Hawkins KA, Fox EJ, Daly JJ, Rose DK, Christou EA, McGuirk TE, et al. Prefrontal over-activation during walking in people with mobility deficits: Interpretation and functional implications. Human Movement Science. 2018;59:46-55.
39. Chu YH, Tang PF, Peng YC, Chen HY. Meta-analysis of type and complexity of a secondary task during walking on the prediction of elderly falls. Geriatrics & gerontology international. 2013;13(2):289-97.
40. 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.
41. Zanto TP, Gazzaley A. Aging of the frontal lobe. Handb Clin Neurol. 2019;163:369-89.
42. Allain P, Nicoleau S, Pinon K, Etcharry-Bouyx F, Barre J, Berrut G, et al. Executive functioning in normal aging: a study of action planning using the Zoo Map Test. Brain and cognition. 2005;57(1):4-7.
43. Ijmker T, Lamoth CJ. Gait and cognition: the relationship between gait stability and variability with executive function in persons with and without dementia. Gait & posture. 2012;35(1):126-30.
44. Kearney FC, Harwood RH, Gladman JR, Lincoln N, Masud T. The relationship between executive function and falls and gait abnormalities in older adults: a systematic review. Dementia and geriatric cognitive disorders. 2013;36(1-2):20-35.
45. Iersel MBv, Kessels RP, Bloem BR, Verbeek AL, Olde Rikkert MG. Executive functions are associated with gait and balance in community-living elderly people. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2008;63(12):1344-9.
46. Liu-Ambrose T, Katarynych LA, Ashe MC, Nagamatsu LS, Hsu CL. Dual-task gait performance among community-dwelling senior women: the role of balance confidence and executive functions. Journals of Gerontology Series A: Biomedical sciences and medical sciences. 2009;64(9):975-82.
47. Watson N, Rosano C, Boudreau R, Simonsick EM, Ferrucci L, Sutton-Tyrrell K, et al. Executive function, memory, and gait speed decline in well-functioning older adults. Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences. 2010;65(10):1093-100.
48. Hayes S, Donnellan C, Stokes E. Executive dysfunction and balance function post-stroke: A cross-sectional study. Physiotherapy. 2016;102(1):64-70.

Table 1: Functional Gait Assessment (FGA) Dual Task Conditions.

Dual Task Condition	**Dual Task**
FGA-Manual (FGA-M)	Manual task of carrying a tumbler half-filled with water in their dominant hand
FGA-Numeracy (FGA-N)	Cognitive numeracy tasks include: * serial subtractions of seven starting at 100 * Multiplication tables of eight * Division tables of 7
FGA-Literacy (FGA-L)	Cognitive literacy tasks include: * Alternate Letters of the alphabet * Alternate days of the week *Alternate months of the year

Abbreviations: FGA-M, Functional Gait Assessment manual task; FGA-N, Functional Gait Assessment numeracy task; FGA-L, Functional Gait Assessment literacy task

Table 2: Functional Gait Assessment (FGA) scores and risk of fall for both groups

	Young (n = 41)		**Old (n = 41)**	
	Median (Q1 – Q3)	**Risk of Fall (%)[a]**	**Median (Q1 – Q3)**	**Risk of Fall (%)[a]**
FGA-S	29 (28 – 30)	0%	28 (26.5 – 29)	0%
FGA-M	28 (26.5 – 30)	2.4%	28 (26 – 29)	0%
FGA-N	26 (23 – 27.5)	22.0%	22 (20 – 26)*	51.2%*†
FGA-L	27 (22 – 28.5)	26.8%	23 (20.5 – 25)**	43.9%

Abbreviations: Q1, Quartile 1; Q3, Quartile 3; FGA-S, Functional Gait Assessment single task; FGA-M, Functional Gait Assessment manual task; FGA-N, Functional Gait Assessment numeracy task; FGA-L, Functional Gait Assessment literacy task

a = The risk of fall was calculated based on a total score of 22 or less (24)

*$p \leq 0.05$, **$p \leq 0.001$

*†A significant relationship between dual-task condition and fall risk, $p \leq 0.05$

Table 3: Dual-task cost (DTC) for both groups

	Young (n = 41)	**Old (n= 41)**
	Median [Q1 – Q3]	**Median [Q1 – Q3]**
FGA-M	0.00 [-5.12 – 0]	0.00 [-3.70 – 3.45]
FGA-N	-10.34 [-24.5 – (-5.12)]	-17.85 [-24.5 – (-10.34)]*
FGA-L	-7.14 [-20.35 – (-1.67)]	-17.24 [-21.13 – (-10.71)]*

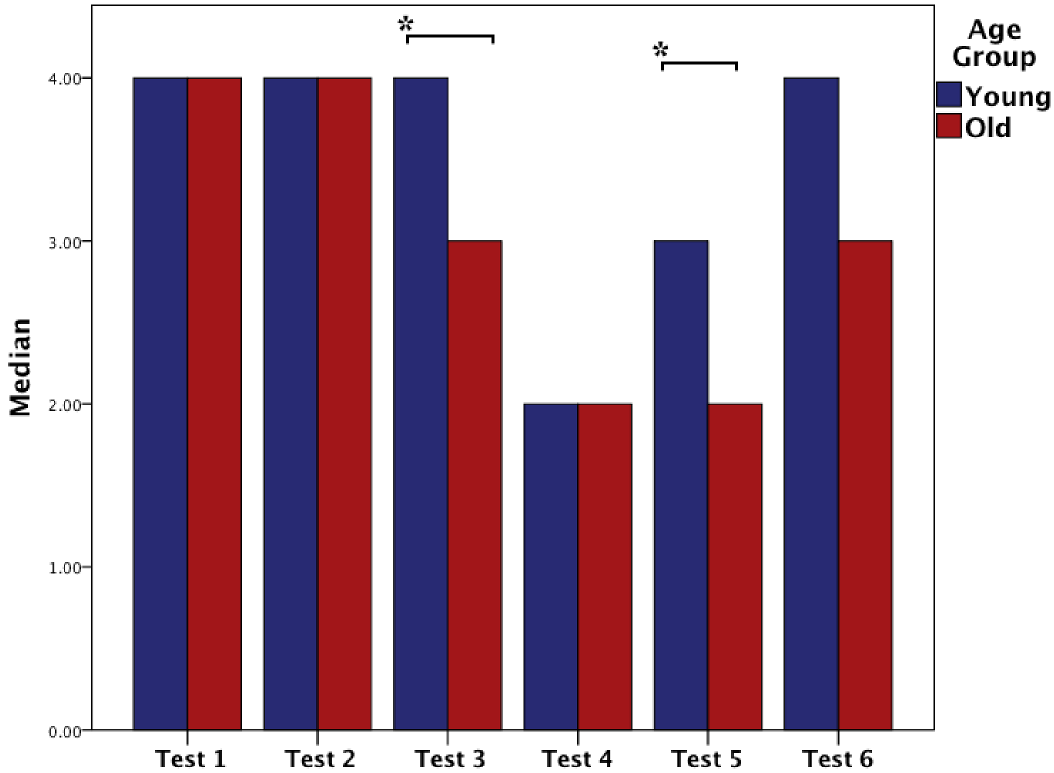
Abbreviations: DTC, Dual-Task Cost; Q1, Quartile 1; Q3, Quartile 3; Functional Gait Assessment single task; FGA-M, Functional Gait Assessment manual task; FGA-N, Functional Gait Assessment numeracy task; FGA-L, Functional Gait Assessment literacy task, *p ≤ 0.05.

Table 4: Response accuracy for cognitive tasks for both groups

Response Accuracy	**Young**	**Old**
	Median (Q1 – Q3)	**Median (Q1 – Q3)**
FGA-N	91.43 (86.36 – 95.65)	89.69 (82.88 – 92.66)
FGA-L	94 (84.72 – 97.62)	91.36 (82.27 – 95.52)

Abbreviations: Q1, Quartile 1; Q3, Quartile 3; FGA-N, Functional Gait Assessment numeracy task; FGA-L, Functional Gait Assessment literacy task

Figure 1: Median Behavioural Assessment of the Dysexecutive Syndrome (BADS) sub-test scores for both groups



Abbreviations: Test 1= Rule Shift Cards; Test 2= The Action Programme; Test 3= The Key Search Task; Test 4= The Temporal Judgement Test; Test 5= The Zoo Map Test; Test 6= The Modified Six Elements Test. *p ≤ 0.05