1Dual Tasking Interferes with Dynamic Balance in Young and Old Healthy Adults

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3Amal AL-Shaikh Sulaiman[a,1], Marie Kelly[d,2,*], Mairead O'Connor[d,3], Doris Eva-4Bamiou[a,b,c], Marousa Pavlou[d]

6[a] Faculty of Brain Sciences, UCL Ear Institute, University College London, London, 7United Kingdom

8[b] Hearing and Deafness Biomedical Research Centre, National Institute for Health 9Research, London, United Kingdom

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

11[d] Centre for Human and Applied Physiological Sciences, Faculty of Life Sciences and 12Medicine, King's College London, London, United Kingdom.

13[1] Department of Otorhinolaryngology - Head and Neck Surgery, Faculty of Medicine, 14Imam Abdulrahman Bin Faisal University, KFUH, Al-Khobar, Saudi Arabia.

15[2]Department of Physiotherapy, Mercy University Hospital, Grenville Place, Cork, 16Ireland

17[3]Department of Physiotherapy, Croom Hospital, Corrabul, Croom, Co. Limerick, 18Ireland

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20***Corresponding author**: Marie Kelly, Department of Physiotherapy, Mercy University 21Hospital, Grenville Place, Cork, T12 WE28, Ireland.E-mail address: kellym19@tcd.ie, 22Telephone: +353214935340

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24Word count: 2920

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26ABSTRACT

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:

52 Findings suggest that cognitively demanding tasks while walking, have a deleterious

53 effect on dynamic balance and could place older adults at a greater risk of falls.

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76 **1. Introduction**

77   Effective, safe gait is essential for independence and longevity among

78   eldery adults (1). Postural control, fundamental to a person's ability to stand and

79   walk independently, requires sensorimotor processes (2), with the integration of

80   afferent information from many musculoskeletal and neural systems including

81   vestibular, the visual and somatosensory systems (3, 4). Furthermore, this

82   complex motor skill utilises cognitive function, in the form of two intimately linked

83   domains, attention and executive function (5) and hence, is no longer considered

84   an automatic task. In a seminal study, Lundin-Olsson, Nyberg (6) illustrated the

85   attentional demands of gait since those who 'stopped walking when talking' were

86   more likely to fall in the future. Considerable work has demonstrated the value of

87   executive functioning in complex gait situations (7, 8), that are representative of

88   routine environmental challenges. When walking under divided attention

89   conditions, executive function plays an important role in allocating attentional

90   resources, ensuring successful completion of a given task. The importance of

91   executive function becomes more apparent as the difficulty of the secondary task

92   increases (9), which may even expose gait instability among healthy subjects.

93   Various studies have illustrated that both healthy young and older adults

94   walk slower while performing a secondary task (5). Older healthy adults not only

95   reduce gait speed but also become less stable with increased gait variability when

96   dual tasking (8) and this is associated with an increased future falls risk (10). With

97   aging, gait loses automaticity, placing greater demands on declining frontal-

98   dependent executive control resources (11, 12)

99   Functional community mobility requires an ability to perform a secondary task

100   simultaneously while walking, and to adapt to external environmental factors. The

101   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

127 ability on the FGA between healthy older and younger adults, with this information

128 relevant for future dual-task assessment and intervention protocols. A secondary

129 aim was to assess the relationship between dual-tasking performance on the FGA

130 and executive function. It was hypothesised that dual-tasking would interfere with

131 postural stability, presenting a greater challenge to healthy older adults, and that

132 these dual-tasking effects on this complex gait test would be related to executive

133 function.

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135 **2. Materials and methods**

136 *2.1 Participants*

137 A convenience sample of independently mobile, community-dwelling younger (n =

138 41, Male = 19; mean age= 37 years, range = 23 – 58) and older adults (n = 41,

139 Male = 18; mean age = 68.3, range = 60 – 88) were recruited from the university

140 and community via flyers and word of mouth. Participants were included if they

141 were between 18 and 90 years, and able to ambulate without an assistive device.

142 Those aged 60 and older were considered older adults. Subjects were excluded if

143 they reported history of falling within the previous 6 months, dementia, as

144 evidenced by a diagnosis of dementia, an unstable medical condition or pathology

145 likely to directly impact on gait (e.g. visual, neurologic, vestibular, orthopaedic).

146 *2.2 Protocol*

147 The study was reviewed and approved by the National Hospital for Neurology and

148 Neurosurgery and Institute of Neurology Joint Ethics Committee and that the

149 procedures followed during the study were in accordance with the Helsinki

150 Declaration of 1975, as revised in 1983.

151 Each participant completed the following assessments:

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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

177 recorded using a recorder and scored following the testing session according

178 to the total number of responses and number of errors made. Since all

179 measures were completed in one session, rests were suggested at various

180 stages in between testing during the session, to help minimize the effect of

181 fatigue. No instruction on task prioritisation was communicated.

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183 *2.3 Statistical analysis*

184 Data analysis was undertaken using the Statistical Package for the Social

185 Sciences Version (SPSS) 22.0 (IBM Corporation, Chicago, IL). A level of

186 significance of $p \leq 0.05$ was set for this study. Normality of the continuous

187 variables was tested with the Shapiro-Wilk test and appropriate descriptive

188 statistics were calculated. Where the normality assumption was violated,

189 equivalent non-parametric tests were used. Independent-samples t-test was

190 performed to assess between-group differences in the TUG score with data

191 reported as mean ± SD. The Mann Whitney U test was utilised to evaluate

192 between-group differences in FGA scores and BADS scores. Median and

193 inter-quartile values (Q1 – Q3) are presented. Given the non-normal

194 distribution these values are better represented by the median rather than the

195 mean, with the median less sensitive to outliers (25). A Chi-Squared test was

196 performed to evaluate the distribution of BADS overall classification.

197 Dual-task costs (DTCs), characterised as the percentage change difference in

198 performance relative to the single-task performance was calculated for all

199 three tasks (FGA-M, FGA-N and FGA-L) using the following equation:

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

202 All DTCs were classified such that a negative value signified a performance

203 decrement and a positive value illustrated a dual-task benefit. Between-group

204 DTC differences were evaluated using the Mann-Whitney test.

205 Response accuracy was assessed under the two dual-task conditions, FGA-N

206 and FGA-L, utilising the following equation:

207 % Response accuracy = 100*(Number of responses – number of errors /

208 Number of responses)

209 Spearman's rank correlations investigated whether BADS scores were

210 correlated with DTCs or FGA scores under the different dual-task conditions.

211 **3. Results**

212 *3.1 FGA score*

213 Both FGA-N (z = -2.76, p ≤ 0.05, *r* = 0.30) and FGA-L (z = -3.23, p ≤ 0.001, *r* =

214 0.36) scores were significantly lower in the older compared to the younger group

215 (Table 2). There were no significant differences between age groups under FGA-

216 S and FGA-M conditions.

217 The only dual-task condition significantly associated with falls risk was FGA-N,

218 $\chi^2(1)$ = 7.57, p ≤ 0.05 (Table 2), with 51.2% of the older group scoring 22 or less.

219 Within the younger group, falls risk was independent of dual-task condition.

220 'Insert Table 2 here'

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222 *3.2 Dual-Task Cost*

223 Dual-task cost (DTC) was significantly different between age groups, with greater

224 cost observed in the older age group for FGA-N (z= -2.37, p ≤ 0.05, r = 0.26) and

225 FGA-L (z= -2.53, p ≤ 0.05, r = 0.28), but not FGA-M (Table 3).

226 'Insert Table 3 here'

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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

252 In this study, we compared dual-task ability on a dual-tasking FGA tool between

253 healthy younger and older adults and we investigated whether a relationship

254 exists between executive function and dual-tasking ability on the FGA. This study

255 adds to emerging evidence on dual-task interference during more attention-

256 demanding gait tasks. Complex dual gait tasks assess the ability to walk in

257 diverse and challenging environments and hence, may provide a more accurate

258 indication of functional ability compared to simple dual gait tasks. Therefore an

259 investigation into age-related differences in dual-tasking ability, on a ecologically

260 valid dual-tasking FGA tool, could provide valuable information for future dual-

261 task assessment and intervention protocols.

262 The main findings from this study indicate that additional cognitive tasks had a

263 destabilising effect on dynamic balance for both younger and older adults,

264 however, older adults were significantly more affected. No other study to date has

265 investigated age-related differences in dual-tasking ability while utilising a dual-

266 task FGA test, although the findings of this study are consistent with a body of

267 work pertaining to spatiotemporal gait parameters. Reduced gait speed together

268 with increased stride-to-stride variability in stride length, stride velocity and/or

269 stride time has been reported in older adults compared with younger adults, under

270 cognitive dual task conditions (27-29) with increased stride-to-stride variability a

271 marker of gait instability which predicts falls (30). A strength of the present study,

272 in contrast to previous studies evaluating age-related differences (27-29), is that it

273 utilised the recommended DTC formula (31) to account for dual-task interference

274 on dynamic balance. This will facilitate between-study comparisons in the future

275 (31) with the DTC also important as it accounts for baseline differences in single

276 task performance, providing a true dual-task change (32).

277 In order to investigate whether FGA performance with a secondary dual-task is

278 suitable for determining falls risk, the FGA scores under the three dual-task

279 conditions were compared to a previously determined cut off value for FGA-S,

280 which predicts a fall within six months, in community-dwelling older adults (24).

281 Only performance on FGA-N was significantly associated with falls risk for older

282 adults, with 51% scoring less than 22. This finding adds to growing literature

283 linking dual-task interference to falls risk (10). The concept of prioritization may

284 serve as a possible explanation for the observed decline in dynamic balance while

285 performing a secondary cognitive task. In this study, participants were not given

286 explicit instructions regarding task prioritisation. However, the performance of

287 secondary cognitive tasks had a deleterious effect on dynamic balance in the

288 older group, with FGA-N significantly associated with an increased falls risk. This,

289 together with the comparable cognitive performance between both age groups

290 suggests that healthy older adults do not prioritise gait, under cognitive dual-task

291 conditions, consistent with previous findings (33, 34). This is in contrast with the

292 "posture first strategy", in which all attention is directed toward maintaining

293 balance and preventing falls. However, recent research suggests this is

294 dependent on environmental factors, individual characteristics and the complexity

295 of motor and cognitive task demands (35, 36). The effect of dual tasking on the

296 posture first strategy has recently been attributed to the neural insufficiency

297 model; increased brain activation in the context of diminished gait performance

298 (11, 37, 38).

299 The cognitive tasks used in our study, classified as mental tracking tasks (2) were

300 utilised since emerging evidence suggests that they are most disruptive on gait

301 performance, compared to other types of secondary tasks (2, 39) and may have

302 superior falls predictive ability (39). However, the effects of the cognitive mental

303 tracking tasks did not appear to be equal. Results indicate that the numeracy task

304 was the most difficult with the greatest median score reduction and DTC observed

305 in both groups. This is consistent with literature indicating that the effect of the

306 secondary task is dependent on its complexity (40). Since significant dual-task

307 decrements were observed under both cognitive dual-task conditions, this might

308 demonstrate that the type of secondary task is relevant with a cognitive task more

309 challenging than a dual-manual task.

310   Subclinical age-related differences were observed with respect to the

311 BADS total profile and standardised scores, which were not significant when age

312 was removed as a confounding factor. This result was not surprising given the

313 existing literature on the high vulnerability of the frontal lobe to age-related

314 changes and the associated subclinical decline of executive functions with

315 advancing age (41). When performance was analysed for each sub-test, the

316 results indicated that the planning and behavioural regulation abilities of the older

317 group were significantly reduced compared to the younger group as reflected in

318 the BADs subscore in two tests (key search & zoo map test). While age-related

319 deficits in performance on The Zoo Map Test have been reported elsewhere (42),

320 no studies to our knowledge have observed these findings with respect to The

321 Key Search Test.

322 The results from this study indicate that executive function is not related to

323 dual-tasking ability on a complex dual-tasking FGA. This finding is in sharp

324 contrast to existing literature (7, 8, 37, 43, 44) and is particularly unexpected

325 given that executive function is considered most relevant in complex gait

326 situations (9, 45-47), akin to the various FGA items. The contrasting results may

327   be partially explained by differences in methodological design. This study utilised

328   the FGA clinical gait tool to assess dynamic balance under dual-task conditions,

329   whereas the majority of the existing research evaluated selected gait parameters

330   such as speed and stride-time variability (7, 8, 37, 43, 44). These spatiotemporal

331   parameters are not considered representative of dynamic postural control, with

332   step width and step width variability thought to more accurately reflect this key

333   feature of gait (17). Furthermore, to our knowledge, only one study examines the

334   interplay between executive function and gait has utilized the BADS (48) in a

335   cohort post-stroke. Another possible explanation is the relatively young age

336   (mean age 68.3) of the older adult group, compared to other studies (7, 37)

337   although studies exist with similar older adult groups indicating an association

338   between executive function and dual task ability (8, 43).

339 Present findings bring forth several issues with possible clinical importance.

340 Foremost, older adults did not appear to prioritise the dynamic balance tasks in

341 accordance with the posture first strategy under cognitive dual-task load, with

342 performance on the FGA-N significantly associated with falls risk. This may have

343 future application for multi-task training and falls risk assessment.

344 A number of limitations are acknowledged with a lack of test order randomization

345 foremost. However, the observation that dual-task interference was greatest on

346 the second last task (FGA-N) rather than the last (FGA-L), suggest these

347 systematic bias had limited impact. Another limitation is that the secondary

348 cognitive tasks were not assessed in the single-task condition, i.e. when sitting,

349 and as such, their relative DTC cannot be determined.

350   **4 Conclusion**

351 In conclusion, this study utilised a dual-tasking FGA tool with findings providing

352 additional evidence that attentional processes are involved in walking and that

353 attention-demanding cognitive tasks have a destabilising effect on dynamic

354 balance. The resultant postural instability is however, more pronounced in the

355 older participants with performance under numeracy dual-task conditions

356 significantly associated with falls risk. Executive function did not appear to be

357 significantly related to dual-task ability. However, this study was conducted on a

358 relatively homogenous population and hence, these results should be interpreted

359 with caution. Further research involving a large heterogeneous population is

360 warranted to validate these findings.

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

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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

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550   Abbreviations: FGA-M, Functional Gait Assessment manual task; FGA-N,

551   Functional Gait Assessment numeracy task; FGA-L, Functional Gait

552   Assessment literacy task

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

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	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%

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559 Abbreviations: Q1, Quartile 1; Q3, Quartile 3; FGA-S, Functional Gait Assessment

560 single task; FGA-M, Functional Gait Assessment manual task; FGA-N, Functional

561 Gait Assessment numeracy task; FGA-L, Functional Gait Assessment literacy task

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

563 *p ≤ 0.05, **p ≤ 0.001

564 *†A significant relationship between dual-task condition and fall risk, p ≤ 0.05

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

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| | 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)]*

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577 Abbreviations: DTC, Dual-Task Cost; Q1, Quartile 1; Q3, Quartile 3; Functional Gait

578 Assessment single task; FGA-M, Functional Gait Assessment manual task; FGA-N,

579 Functional Gait Assessment numeracy task; FGA-L, Functional Gait Assessment

580 literacy task, *p ≤ 0.05.

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594 Table 4: Response accuracy for cognitive tasks for both groups

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Response Accuracy	Young Median (Q1 – Q3)	Old 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)

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597 Abbreviations: Q1, Quartile 1; Q3, Quartile 3; FGA-N, Functional Gait Assessment

598 numeracy task; FGA-L, Functional Gait Assessment literacy task

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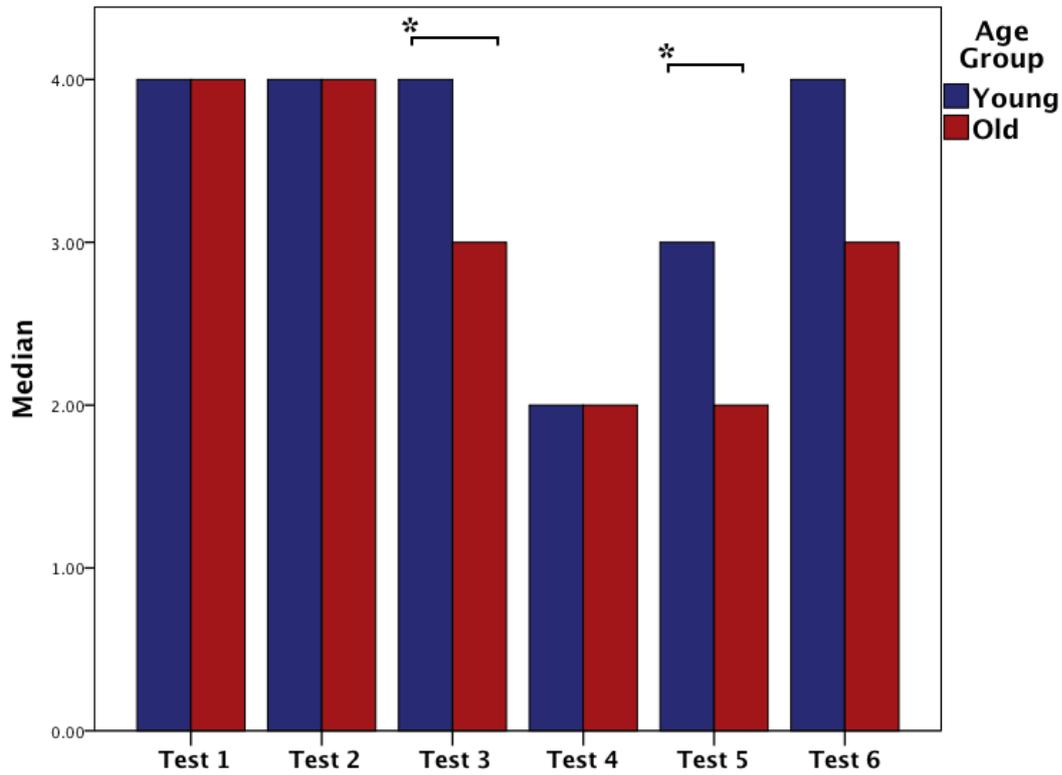602

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615 Figure 1: Median Behavioural Assessment of the Dysexecutive Syndrome (BADS)

616 sub-test scores for both groups

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620 Abbreviations: Test 1= Rule Shift Cards; Test 2= The Action Programme; Test 3=

621 The Key Search Task; Test 4= The Temporal Judgement Test; Test 5= The Zoo Map

622 Test; Test 6= The Modified Six Elements Test. *p ≤ 0.05

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REVIEWER 3

I found this article well written, novel and interesting. The data analysis
section was detailed and the discussion section was very thorough.

More detail on study population would be useful for context. It would be useful to have a table with the sample demographics. Further detail on participant background from a socioeconomic perspective may be relevant considering the results where participants struggled with the numeracy task.

Response:
Thanks – agree this may be relevent but unfortunately this data was not captured during assessment

More information on sample would be useful to ensure reliability. How were they recruited? Where were they recruited from?

Response:
Thanks – this has been updated to:
'were recruited from the university and community via flyers and word of mouth.' – Line 139/140

Small details- the wording of some of the references seemed to be incorrect- e.g. line 37 and 59/60- "proposed by Shumway-Cook, Woollacott [10] suggests that..", I don't think this reads very well.

Response:
Thanks – have updated to:
The posture first strategy, originally proposed by Shumway-Cook et al. (10), suggests that when dual-tasking

Note that there is no explanation for the FGA-S in the abstract.

Response:
Thanks this has been modified accordingly – line 41 – FGA scores under single (FGA-S) and dual-task

I wondered if there was a reference or evidence to support the statement in lines 71-73, including a reference if available would be good.

Response:
If I'm not mistaken this line is now 100-103 – apologies if I am. A reference has been added in:
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 (9)

Suggest to review the wording of the following:
Line 111- "To assess the ability to time-management" does not read well.

Response:
Thanks – this has been updated to: to assess the ability to plan, organise and monitor behaviour. Now appears to be line 159-160.

Line 112-114 for the description of the timed up and go- should probably include that the person has to sit back down in the chair.

Response:
Thanks this has been updated - walking three metres at normal pace, turning around and walking back to the chair, sitting back down again. Now appears to be line 161-164.

Line 204 -"Complex dual gait tasks may simulate real life situation and.."

Response:
Thanks – now updated to: 'Complex dual gait tasks assess the ability to walk in diverse and challenging environments and hence, may provide a more accurate'. Now appears to be line 256-258.

Line 224 - "Furthermore, we investigate.." check the tense.

Response:
Thanks – this has now been updated to: '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'. This now appears to be line 277/280.

Overall I found the article very interesting and useful to extend the knowledge in the area of gait, balance and falls assessment in the older population. Well done!

Thanks very much again for feedback – very helpful.

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REVIEWER 4
Overall, this is a well written manuscript. The aim is clear and explored well, the methodology is fairly sound and the writing clarity is high. I have one major comment and a few minor comments.

Major Comment: The secondary aim 'to assess the relationship between dual-tasking performance on the FGA and executive function', is not very specific and unclear. Can the authors please reconsider how this is explained throughout as the majority of the manuscript is well written, whereas this section lets it down.

Thanks for feedback – we have modified mainly the introduction and discussion sections that refer to executive function and/or BADS in order to improve explanation etc – we hope this has helped.

Minor Comments:
Page 1, Line 23-24: FGA-S abbreviation needs to be clearly stated.

Thanks – we have now modified accordingly – line 41 – FGA scores under single (FGA-S) and dual-task

Page 2 Line 26, how was falls risk measured exactly? Was it with the FGA

Thanks. This has now been updated to: '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' I hope that this is clearer.

Page 4, Line 88, for 'M', please write Male

Thanks – this has been updated accordingly

Page 4, Line 90, why were the ages 20-90 chosen? Why was 18 years not the younger end of the cut-off?. Furthermore, what were the cut-offs for young

and older adults?

Thanks for highlighting this error – this has been updated to 18-90. The line: Those aged 60 and older were considered older adults – has also been inserted – line 142

Page 5, the TUG, the paper chosen suggests a very high sensitivity and specificity for a tool that although commonly used, is not very accurate. Can you include other papers?

Thanks this has been updated accordingly indicated the higher specificity than sensitivity, referring to a high quality systematic review published in 2014.

Page 7, Line 162, please remove '(i.e worse)

Thanks – this has been removed

Overall discussion is fine but sections focusing on the secondary objective could be clearer.

Thanks very much – we hope you find that the adjustments through the text focusing on the secondary objective have improved the clarity etc

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