Received: 13 January 2019 | Accepted: 5 April 2019

DOI: 10.1002/gps.5133

RESEARCH ARTICLE

WILEY International Journal of Geriatric Psychiatry

Fear of falling: A manifestation of executive dysfunction?

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Funding information
Global Brain Health Institute; Irish Life PLC; Atlantic Philanthropies; Irish Government

Objective: Fear of falling (FoF) may be an early marker of decline in global cognitive functioning, but associations with specific domains of cognitive functioning are unclear. The aim was to examine associations between FoF and 4-year decline in memory, processing speed, and executive functioning in adults aged 50 years and older.

Methods: Data were from 5174 participants (mean age = 62.6 ± 8.9 years, range = 50-91, 54.5% female) in The Irish Longitudinal Study on Ageing, a population-based study.

Measurements: FoF was self-reported in 2009 to 2011. Immediate and delayed recall, Colour Trails 1 and 2, choice reaction time, sustained attention to response task, and verbal fluency were measured in 2009 to 2011 and 2014 to 2015. Prospective associations between FoF and domains of cognitive functioning were examined using linear mixed modelling. Adjustment was made for demographic and health factors. Interactions with age were examined.

Results: In 2009 to 2011, 20.6% of participants reported FoF. No statistically significant interaction of FoF with age was found for any of the associations ($P \geq .06$). Participants with FoF had greater decline on delayed recall ($B = -0.19$; 95% CI, −0.32 to −0.06), verbal fluency ($B = -0.52$; 95% CI, −0.88 to −0.18); and the ln-transformed scores for the Colour Trails 1 test ($B = -0.04$; 95% CI, −0.07 to −0.01) and the Colour Trails 2 test ($B = -0.04$; 95% CI, −0.06 to −0.02) than participants without FoF. No statistically significant associations were found for any of the other outcomes.

Conclusions: FoF may be an indicator of decline in domains of cognitive functioning, particularly those related to executive function and processing speed. However, studies with longer follow-up and/or higher average age are required to confirm this.

KEYWORDS

anxiety, cognitive function, executive function, old age

1 | INTRODUCTION

Gait initiation and performance is a complex integrative neurological and psychological process requiring simultaneous interplay between multiple cerebral loci. Gait dyspraxia may evolve for multiple neuropathological reasons such as cortical and subcortical vascular disease,[1] but the origins of psychopathologies related to gait performance are less commonly described. One such psychopathology is fear of falling (FoF).

Approximately half the adults over the age of 65 years report FoF, but prevalence vary between 20% and 85% depending on sample characteristics.[2] FoF has been associated with increased fall risk, altered gait patterns, activity avoidance, and reduced quality of life.[3,4]

In people with a high fall risk, FoF may be a healthy response to increase safety, while absence of FoF may reflect reduced safety awareness and can be detrimental.[5,6] FoF also exists in people without a history of falls or balance problems, and not all people with a past fall

develop FoF.[7] The aetiology of FoF is still poorly understood. Evidence-based programmes are available to reduce FoF,[8,9] but their effectiveness is limited. Better insight into the aetiology of FoF may help to improve the effectiveness of these programmes.

Previous studies show that there is some, albeit weak, evidence that FoF may be an early marker for cognitive decline.[10-13] Our analyses of 4931 Irish adults (aged 50+ years) showed that FoF was associated with an increased risk of decline in global cognitive functioning over 4 years.[10] In contrast, a US study of 219 older adults (aged 60+ years) and two Japanese studies of 101 and 406 older adults (aged 65+ years) found no statistically significant cross-sectional association between FoF and global cognitive functioning.[11-13] It is yet unclear which specific domains of cognitive functioning may be most implicated with FoF.

Executive dysfunction may present as poor selective or divided attention, failed inhibition of interfering stimuli, and difficulty with the planning of actions. Deficits in attention and executive function have been associated with balance problems, limitations in daily activities, and falls.[14-17] Negative appraisal of one's perceived balance and fall risk is believed to result in FoF.[18] Hence, it is plausible that FoF is a manifestation of executive dysfunction. A study among 500 Australian older adults showed that, among those with a low physiological fall risk, having a high perceived fall risk was associated with poorer executive function as measured with the trail making test.[5] That study did not include measures of other domains of cognitive function. A study among 281 Australian older adults showed that concerns about falling was negatively associated with brain volume in regions important for executive functions, emotional control, motor control, and visual processing.[19] In contrast, the two Japanese studies described earlier did not show significant associations between FoF and executive function or processing speed[11] but did find significant associations of FoF with logical memory and subjective memory complaints.[11,13] In summary, there is some but inconsistent evidence that a decline in executive function may be linked with FoF. Greater understanding of the associated cognitive profile may better inform the design of behavioural rehabilitation programmes.

The aim is to examine whether FoF may be a manifestation of executive dysfunction in a large population-based sample of adults aged 50 years and older. For this working hypothesis to be supported by the data, we would expect to find stronger associations between FoF and executive function than between FoF and memory. While the prevalence of FoF is substantial already at the age of 50 to 64 years (17% in Irish adults), this age group is rarely included in studies of FoF. Though as both the prevalence of FoF and the rate of decline in cognitive functioning are higher at older ages,[20,21] the associations may become stronger with age. The modifying role of age was explored.

Key points

- Fear of falling is associated with poorer executive functioning.
- Fear of falling is associated with poorer delayed recall.
- Fear of falling may be a manifestation of executive dysfunction, although a role in memory cannot be ruled out.

2 | MATERIALS AND METHODS

2.1 | Participants

Data were from The Irish Longitudinal Study on Ageing (TILDA), a nationally representative sample of 8175 adults aged 50 years and older.[22] The sample was drawn from the Irish national directory of residential addresses divided into geographical clusters of which 640 were selected based on area level socio-economic status and geographical location. Within each cluster, 40 addresses were randomly selected and visited by an interviewer. All individuals aged 50 years and older living at each address were invited (response rate 62%). Details of the study design and cohort have been reported elsewhere.[22-24] The study design and protocols were approved by the Trinity College Dublin Faculty of Health Sciences Research Ethics Committee. All participants provided written informed consent.

Data collection included a computer-assisted interview, a self-administered questionnaire, and a health assessment carried out by trained research nurses. A total of 8504 adults aged 50 years and older were interviewed at baseline (2009 to 2011). Eighty-five percent of these participants remained at 4-year follow-up (2014-2015). The health assessment was completed by 72% of all participants at baseline and by 81% of participants at 4-year follow-up. Some cognitive tests were completed during the interview and others during the health assessment. Responders to the health assessment were cognitively and physically healthier than the nonresponders.[25] Data were included for 5174 participants who completed the baseline and 4-year follow-up assessments and had complete data on FoF and the covariates at baseline (Figure 1).

2.2 | Cognitive outcomes

Cognitive tests were completed using the same instruments at baseline and 4-year follow up. Verbal memory was measured by immediate and delayed recall of a set of 10 words. The Colour Trails Test (CTT) comprises two subtests.[26] CTT1 measures the time taken to connect numbers from 1 to 8 in consecutive order as quickly as possible. CTT2 measures the time taken to connect numbers from 1 to 23, alternating between colours. CTT1 is largely a test of visual scanning and attention, whereas CTT2 is dependent on additional executive functions such as task switching.[27]

For the two-choice reaction time task (CRT), starting with the finger on a central button, participants were asked to press the buttons "yes" and "no" as quickly as possible in response to the stimuli yes and no, which appeared on the screen (approximately 100 repetitions). Cognitive processing speed was measured as the time taken to release

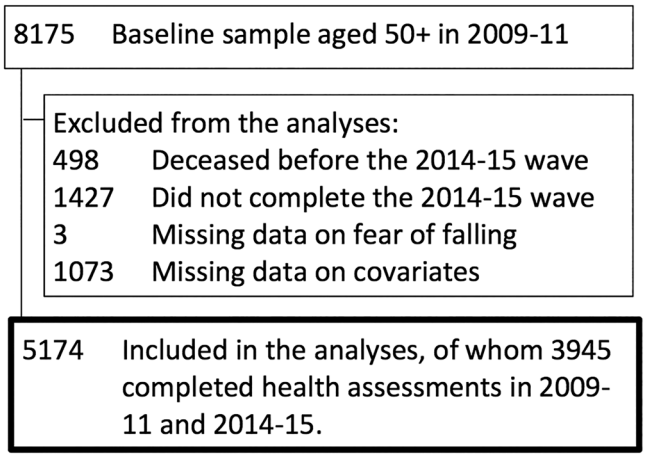

FIGURE 1 Flow chart

the central button on presentation of the stimulus. During the sustained attention to response task (SART),[28] participants were seated in front of a screen that repeatedly displayed the digits 1 to 9 over 4 minutes. Participants were asked to press the space bar as quickly as possible every time a digit appeared, except when the number 3 appeared. Both the mean response time and the standard deviation of response times for correct responses were used. The standard deviation measure refers to the intra-individual variability in response times, which reflects focal inattention. For the verbal fluency test, participants were asked to name as many animals as possible during 1 minute. The scores for CTT1, CTT2, CRT, and SART were reverse coded so that higher scores indicate better performance on all tests.

2.3 | Fear of falling

FoF was measured using the question "Are you afraid of falling?" The response options were yes and no. Validation of this single item against the well-validated 16-item falls efficacy scale[29] (both measured in wave two, 2012) in this cohort showed modest agreement[10] (76.3%).

2.4 | Characteristics and covariates

Socio-demographic factors included age, sex, and education. The number of doctor-diagnosed chronic conditions included heart attack, heart failure, or angina; cataracts; stroke; diabetes; lung disease; asthma; arthritis; osteoporosis; cancer; peptic ulcer; hip fracture; hypertension; and high cholesterol. Depressive symptoms were assessed using the 20-item Centre for Epidemiological Studies Depression scale (range 0-60).[30] Anxiety was measured with the anxiety subscale of the Hospital Anxiety and Depression scale (range 0-21).[31] Medication use was based on self-report and confirmed by cross-checking with medication labels. Participants were classified as having polypharmacy if they use five medications or more. Self-rated vision and hearing were dichotomised as "poor-fair" and "good-excellent." The number of limitations in six daily activities (ADL, including dressing, walking, bathing, showering, eating, getting in or out of bed, and using the toilet)[32] and six instrumental daily activities (IADL, including preparing a hot meal, doing household chores, shopping for groceries, making telephone calls, taking medications, and managing money)[33] were based on self-reported difficulty with each of these activities. The number of falls in the previous year was recorded and dichotomised as "fallers" and "non-fallers." Smoking history and alcohol intake (categorised as presence or absence of problem drinking based on the CAGE questionnaire) were categorised as indicated in Table 1.[34] Physical activity was measured with the 8-item International Physical Activity Questionnaire (IPAQ), which asks about walking and moderately and vigorously intense activities[35] in the past 7 days. In accordance with the IPAQ scoring protocol, participants were classified as "active" if they met the recommended level of a minimum of 150 minutes of activity per week. Social activity was based on the number of eight activities that participants engaged in

TABLE 1 Baseline characteristics of participants with and without fear of falling

	No Fear of Falling (n = 4106)	Fear of Falling (n = 1068)	*P* Value
Age, mean (SD)	61.9 (8.6)	65.2 (9.4)	<.001
Sex, % women	49.3	74.6	<.001
Education, %			.001
Primary/none	22.4	29.5	
Secondary	42.3	40.9	
Tertiary or higher	35.3	26.6	
1+ ADL limitations, %	5.3	14.2	<.001
1+ IADL limitations, %	3.0	12.2	<.001
Vision, % blind-poor-fair	6.7	11.2	<.001
Hearing, % poor-fair	11.9	16.2	<.001
Polypharmacy (5+ medications), %	16.4	29.0	<.001
Depressive symptoms, % highest quartile	18.3	35.2	<.001
Anxiety, % highest quartile	20.7	37.1	<.001
No chronic conditions, median [IQR]	1 [1-2]	2 [1-3]	<.001
Current smoker, %	14.5	17.0	.12
Problem drinker, %	12.9	11.3	.16
Physical activity, % active	37.8	24.8	<.001
Social activities, mean (SD)	2.9 (1.4)	2.7 (1.4)	<.001
Faller in past 12 months, %	16.6	31.1	<.001
MoCA, median [IQR]	25 [22-27]	26 [24-28]	<.001

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; IQR, interquartile range; MoCA, Montreal Cognitive Assessment; SD, standard deviation.

at least once per month (range 0-8). The Montreal Cognitive Assessment (MoCA) was used to describe global cognitive function.[36]

2.5 | Statistical analyses

Analyses were done using Stata version 14.1 (Stata, College Station, TX). Descriptive statistics were used to describe and compare participants with and without FoF at baseline.

Mixed-effects linear models were used to examine the associations between FoF (2009-2011) and change in memory and executive function (2009-2011 and 2014-2015). The models included random intercepts. All models were analysed after minimal adjustment for age, age^2 (to account for the nonlinear association between age and cognition), and sex, and separately, after additional adjustment for education, depressive symptoms, anxiety, ADL, and IADL limitations, and fall history. These covariates were measured in 2009 to 2011 and selected based on associations with both FoF and cognitive function found in previous studies[10] and confirmed in the current sample. No adjustment was made for comorbidity as this may be a mediator rather than a confounder. Random effects treating wave as nested within participant were included to account for the repeated measurements of cognition over time. Standard errors were adjusted for non-independence arising from intragroup correlation at the household level. To examine interaction with age, models with and without the product term of age with FoF were compared using the likelihood ratio test. If the interaction was statistically significant, the models were refitted stratified by age.

Immediate and delayed recall and verbal fluency were measured as part of the computer-assisted interview and completed by approximately 5174 participants. These outcomes were normally distributed and included in the models as raw data. The CTT1, CTT2, CRT, and SART were measured during the health assessment and completed by approximately 3945 participants. The scores for these tests were not normally distributed. After excluding outliers (CTT: ≥99th percentile; SART ≥95th percentile; CRT: <0.75th and ≥99th percentiles) and conducting ln-transformation (CTT, CRT), the distributions were approximately normal. After appropriate transformation and exclusion of outliers, assumptions for linear regression were met for all outcomes.

To examine the influence of attrition and missing data on the findings, descriptive statistics were used to examine differences in baseline characteristics between those included in the analysis and those excluded because of missing data.

3 | RESULTS

Data were included from 5174 participants of whom 3945 completed the health assessments at baseline and follow-up (63.3% and 48.3% of the original sample, respectively) (Figure 1). Compared with participants whose data were excluded from the analyses (n = 2998), those whose data were included were younger, more likely to have higher levels of education, less likely to have limitations in daily functioning, less likely have depressive symptoms, and had better health and more favourable lifestyles than those excluded from the analyses ($P < .001$, Data S1). They were also less likely to report FoF and had better scores on all cognitive tests ($P < .001$).

Of the 5174 participants, 1068 (20.6%) reported FoF. In 2009 to 2011, participants with FoF were older, more likely to be female, and more likely to have ADL or IADL limitations, poor vision, polypharmacy, depressive symptoms, anxiety, and a history of falls than participants without FoF ($P \leq .001$, Table 1). They were also less likely to be sufficiently physically active and had more chronic conditions ($P < .001$). Table 2 presents the mean values for each of the cognitive outcomes and for each group measured in 2009 to 2011 and in 2014 to 2015.

No statistically significant interaction with age was found for any of the models ($P > .06$, Table 3). After adjustment for age and sex, FoF at baseline was associated with all cognitive outcomes at 4-year follow up ($P \leq .009$) except CRT. These associations attenuated after additional adjustment for education, depressive symptoms, anxiety, ADL and IADL limitations, and fall history but remained statistically significant for delayed recall ($B = -0.19$; 95% CI, −0.32 to −0.06), CTT1 ($B =$

TABLE 2 Mean (standard deviation) scores for domains of cognitive function

	No Fear of Falling		Fear of Falling	
	2009-2011	2014-2015	2009-2011	2014-2015
Immediate recall	6.0 (1.6)	6.0 (1.7)	5.7 (1.7)	5.7 (1.8)
Delayed recall	6.3 (2.2)	6.2 (2.5)	5.8 (2.3)	5.6 (2.7)
Colour Trail Test 1[a]	1.0 (0.4)	1.0 (0.4)	0.9 (0.4)	0.9 (0.4)
Colour Trail Test 2[a]	1.3 (0.3)	1.3 (0.3)	1.2 (0.3)	1.2 (0.3)
Sustained attention (M)[a]	0.6 (0.2)	0.7 (0.2)	0.6 (0.2)	0.6 (0.2)
Sustained attention (SD)[a]	1.7 (0.5)	1.8 (0.6)	1.6 (0.5)	1.6 (0.5)
Choice reaction time	260.8 (77.2)	264.2 (79.8)	256.5 (78.5)	259.2 (82.1)
Verbal fluency	21.8 (6.9)	19.3 (5.8)	20.0 (6.8)	18.0 (5.7)

Abbreviations: M, mean; SD, standard deviation.

[a]Results presented after ln-transformation of the scores.

TABLE 3 Prospective associations between fear of falling (2009-2011) and change in domains of cognitive functioning (2009-2011 to 2014-2015) in adults aged 50 years and older

Domain of Cognitive Functioning	Interaction with Age		Adjusted for Age and Sex		Fully Adjusted Model[a]	
	P	N	*B* (95% CI)	*P*	*B* (95% CI)	*P*
Immediate recall	.06	5164	−0.21 (−0.30 to −0.12)	<.001	−0.09 (−0.18 to 0)	.05
Delayed recall	.99	5113	−0.36 (−0.50 to −0.22)	<.001	−0.19 (−0.32 to −0.06)	.005
Colour Trail Test 1[b]	.49	3875	−0.06 (−0.09 to −0.04)	<.001	−0.04 (−0.07 to −0.01)	.002
Colour Trail Test 2[b]	.92	3790	−0.06 (−0.08 to −0.03)	<.001	−0.04 (−0.06 to −0.02)	<.001
Sustained attention (M)[b]	.28	3156	−0.02 (−0.04 to −0.01)	.009	−0.02 (−0.04 to 0)	.06
Sustained attention (SD)[b]	.32	3156	−0.06 (−0.10 to −0.02)	.004	−0.04 (−0.08 to 0)	.05
Choice reaction time	.44	2840	−4.98 (−11.9 to 1.90)	.16	−3.10 (−10.06 to 3.86)	.38
Verbal fluency	.17	5150	−0.94 (−1.30 to −0.58)	<.001	−0.52 (−0.88 to −0.18)	.003

Abbreviations: *B*, regression coefficient; CI, confidence interval; M, mean; SD, standard deviation.

[a]Adjusted for age, age^2, sex, education, depressive symptoms, anxiety, limitations in daily activities, limitations in instrumental daily activities, and fall history.

[b]Results presented after ln-transformation of the scores.

−0.04; 95% CI, −0.07 to −0.01), CTT2 (*B* = −0.04; 95% CI, −0.06 to −0.02), and verbal fluency (*B* = −0.52; 95% CI, −0.88 to −0.18).

4 | DISCUSSION

Previous analyses in the same sample showed that FoF was associated with decline in global cognitive function.[10] The current results add that this association may be explained predominantly by declines in executive function. Associations were found between FoF and delayed recall, verbal fluency, and both Colour Trail Tests. No statistically significant associations were found with other outcomes (although associations with immediate recall and sustained attention approached statistical significance). The sample is relatively young and healthy, and few participants declined during 4 years of follow-up. Replication in a sample with longer follow-up or a larger proportion of older participants is required to verify these findings.

Previous studies found that FoF was associated with logical memory and subjective memory complaints.[11,13] In the current study, FoF was associated with delayed recall and the association with immediate recall approached statistical significance (*B* = −0.09; 95% CI, −0.18 to 0; *P* = .05). Delayed recall is cognitively more demanding than immediate recall and therefore more sensitive to change in this relatively young and healthy sample. Decline in delayed recall is also an early neuropsychological feature of Alzheimer's disease.[37,38] If the association between FoF and delayed recall is confirmed in future studies, this would strengthen the hypothesis that FoF is a marker for early cognitive decline.

FoF was associated with a greater decline in verbal fluency, CTT1, and CTT2 and approached statistical significance for sustained attention (mean: *B* = −0.02; 95% CI, −0.04 to 0; .06; SD: *B* = −0.04; 95% CI, −0.08 to 0; *P* = .05). Again, the lack of statistically significant associations with sustained attention may be explained by limited statistical power. The only other study that examined these relationships found no associations between FoF and any measure of executive function or processing speed.[11] However, the study was cross-sectional in design and included only 101 participants. Associations of FoF with executive function are plausible and intuitive given the strong associations of falls with FoF[2] and of falls with executive function and processing speed.[39-41] Some evidence for a link between FoF and executive function comes from experimental studies and neuroimaging studies. A study in 50 older adults performing a gait adaptability test found that better processing speed was associated with more accurate foot placement[42] and that the association between gait speed and fall risk was partly explained by executive function and FoF.[43] A study among 57 older adults showed that FoF was associated with prolonged anticipatory postural adjustments when initiating walking, particularly under dual-task conditions.[44] Considering the neuroimaging literature, a cross-sectional study among 281 older adults (70-90 years) found associations between poor falls efficacy and lower brain volumes in areas important for executive functions.[19] Also, in a prospective study of 117 older adults (60 years or older), those who developed FoF over 2 years had a greater decrease in cerebral glucose metabolism in the left supplementary motor area, which plays an important role in preparation of motor behaviour.[45] These collective findings contribute to the notion that FoF is associated with executive function, but further research is required to confirm this. Alternatively, it may be that FoF is associated with specific cognitive processes that are assessed more prominently with CTT and verbal fluency than with other tests of executive function and processing speed. People with mild cognitive impairment and Alzheimer's disease have more difficulty with tasks that require multisensory integration[46] and processing of more complex visual stimuli that place greater demands on cross-cortical interaction.[47,48] The CTT assess complex visual processing to a greater extent than the other tests. The greater decline in trail making performance in those with FoF could reflect a deficit in higher order visuocognitive processing in this group. Self-reported poor vision is a stronger predictor of FoF than measured

visual acuity and contrast sensitivity.[49] However, additional adjustment for self-reported vision in the models for the CTT did not change the findings, suggesting that these associations are not explained by the individual's perception of vision.

A priori, we expected to find stronger associations in those over the age of 75 than in those aged 50 to 75 years. The results did not confirm this. Participants over the age of 75 years were underrepresented (n = 210, 6%). This likely resulted in limited statistical power to detect interactions with age. Replication in samples with larger numbers of adults over the age of 75 years are required to verify this. Studies that start at a younger age but with longer follow-up are required to specify the age from which FoF can differentiate between those with and without cognitive decline.

We hypothesised that FoF is a manifestation of executive dysfunction and tested this by examining associations of FoF with memory and executive function. We found associations with both domains of cognitive function. As there was no clear differentiation in tasks associated with FoF, we cannot say that the working hypothesis is supported by the current findings. However, executive function has been proposed to include retrieval processes and organisation of material for encoding/rehearsal of learned material. Hence, the association found between FoF and the recall tests could be partly explained by the role of executive functions in memorising and recall.

We were interested in whether FoF predicts cognitive decline; however, it is possible that FoF, rather than being causally related, is part of the prodrome of mild cognitive impairment. FoF results in restriction of activity and loss of functional independence and is seen as a major constraint to rehabilitation.[50] Better understanding of the cognitive profiles implicated in FoF will result in more bespoke and targeted rehabilitation programmes, which can impact on FoF, quality of life, and falls risk.[51]

Strengths of this study include the large sample size with repeated measurements. The original sample was representative of the Irish population[22] over the age of 50 years, but because of attrition and missing data, the analysis sample included only 40% of the original sample (Figure 1). Nonresponse analyses showed that the analysis sample was younger, healthier, and had more favourable health behaviours than those excluded from the analyses. They also were less likely to report FoF and had better cognitive function (Data S1). Hence, the generalizability of the findings is limited to a relatively younger and healthier population over the age of 50 years. The current findings may underestimate the true associations between FoF and cognitive functions. FoF was measured with a single question. This single question mimics questions used in the clinical settings. This question agrees modestly with the validated falls efficacy scale, but it should be noted that FoF and falls efficacy are like but distinct constructs.[52] A review of studies validating FoF instruments found that there is limited evidence about the measurement properties of any FoF measures, including single-item measures.[53] Single-item measures have been criticised for potential underestimation of the prevalence of FoF.[52] We used linear mixed models to examine group differences in change in cognitive functioning measured at two time points. The models account for measurement error, regression to the mean, and within-person correlation of the repeated measures. However, estimates may reflect reduced practice effect rather than decline in cognitive function.[54,55]

5 | CONCLUSION

In conclusion, the current findings add to the evidence that FoF may be an indicator of decline in cognitive functioning in adults over the age of 50. FoF may be a manifestation of executive dysfunctioning, but role of decline in memory cannot be ruled out. Studies with longer follow-up and including a greater number of participants older than 75 years are required to confirm the associations between FoF and declines in executive function and memory.

ACKNOWLEDGEMENTS

We are grateful to all of the TILDA respondents for participating in the study. The Irish Longitudinal Study on Ageing is supported by the Irish Government; the Atlantic Philanthropies; and Irish Life PLC. This work was supported by a Global Brain Health Institute fellowship to G.P. The funding sources had no involvement in the study design; the collection, analysis and interpretation of data; the writing of the manuscript; and in the decision to submit the manuscript for publication.

CONFLICT OF INTEREST

None declared.

DATA AVAILABILITY STATEMENT

Researchers interested in using TILDA data may access the data for free from the following sites: Irish Social Science Data Archive at University College Dublin, http://www.ucd.ie/issda/data/tilda/; Interuniversity Consortium for Political and Social Research (ICPSR) at the University of Michigan, http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/34315.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Peeters G, Feeney J, Carey D, Kennelly S, Kenny RA. Fear of falling: A manifestation of executive dysfunction? *Int J Geriatr Psychiatry*. 2019;34:1275–1282. https://doi.org/10.1002/gps.5133