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ORIGINAL ARTICLE

Development and persistence of fear of falling relate to a different mobility functions in community-dwelling older adults: one-year longitudinal predictive validity study

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Abstract

Background Fear of falling (FoF) is a common psychological problem in community-dwelling older adults. However, which mobility function relate to newly developed FoF and persistent FoF are unknown.

Aims We aimed to clarify which baseline mobility function is an independent predictor of one-year change in FoF.

Methods The study design was a one-year longitudinal predictive validity study. Participants were 581 independently community-dwelling older adults without neurological disorders. We measured FoF, history of falls, inactive lifestyle, and sociodemographic data were obtained via a self-administered questionnaire. Mobility functions were measured by community-based Short Physical Performance Battery (SPPB-com).

Results Newly developed FoF group accounted for 20% among the non-FoF older adults at baseline. Persistent FoF group accounted for 57% among the older adults with FoF at baseline. Risk of newly developed FoF was significantly related to the SPPB-com total score, among the mobility functions, the low gait test score (OR [95% CI] = 2.34 [1.12–5.12]) and the low tandem balance test score (OR [95% CI] = 3.62 [1.46–8.90]) were significantly related. Risk of persistent FoF was also related to SPPB-com total score, among the mobility functions, the five chair stand test score (OR [95% CI] = 1.96 [1.19–3.24]) was significantly related.

Discussion and conclusion The risk of newly developed FoF related to lower ability of standing-balance and gait, the risk of persistent FoF related to lower sit-to-stand ability. Appropriate exercise interventions according to FoF subtype may effectively prevent the risk of developing FoF or experiencing persistent FoF.

Keywords Fear of falling · Development and persistence · Mobility functions · Community-dwelling older

Introduction

Fear of falling (FoF) is a common psychological problem for 21 to 85% of older adults [1]. It is associated with several health-related problems, such as a decline in functional status—that is, the ability to perform activities of daily living (ADL)—mobility disability, activity restriction, musculoskeletal pain, and falls [1–3]. In previous studies, lower mobility functions was associated with new FoF development [4–7]. However, these studies didn't clarify the specific mobility functions in decline associated with new FoF development. If such functions can be identified, and the target physical function for improving FoF is clear, a customised exercise programme could be effective. Thus, we initially aimed to clarify which mobility functions relate to new FoF development.

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Interestingly, some prospective studies suggest that FoF is a reversible feeling; that is, some people have reported FoF development and subsequent improvement [3, 7–9]. These studies point to two subtypes of FoF: transitory and persistent. Transitory FoF has still not yet been defined rigorously. It isn't only 'the state in which people are feeling to repeat improvement and development regarding FoF' but also includes 'the state of not being firmly fixed'. On the other hand, persistent FoF can be defined as the state in which people are feeling FoF continually [3, 7]. A previous study has reported that longer exposure to FoF is associated with an increased risk of functional decline [3]. These results suggest that older people with transitory FoF should be identified early and given proper treatment to prevent their FoF feelings from continuing. However, it was not clear which types of older adults were at high risk for change of transitory FoF to persistent FoF. To our knowledge, there are few studies associated with this clinical question. Based on the study results mentioned above, the specific mobility functions involved may be related to a change in FoF status. Thus, we secondarily aimed to clarify the differences in mobility functions in older adults with transitory FoF and persistent FoF.

In this study, we instigated the change in FoF status as a study interest. We designed a one-year predictive validity study involving community-dwelling older adults. We measured basic physical performance tests at baseline and obtained FoF information with a questionnaire administered at baseline and after one-year. This study aimed to clarify which baseline mobility function is an independent predictor of one-year change in FoF, specifically, (i) which mobility functions relates to newly developed FoF, and (ii) which mobility functions relates to change in transitory FoF to persistent FoF.

Methods

Participants

The present study was designed as a one-year predictive validity study. We visited 20 community centers for one-day physical performance check-ups at baseline from April 2016 to March 2017 and conducted follow-up visits a year later. We recruited 1025 adults aged 65 years or older who lived independently in the community at baseline. The inclusion criteria were as follows: (i) didn't receive physical or social care services from the local government and (ii) had no self-reported neurological disorders that could affect mobility or balance. Exclusion criteria were incomplete data for any of the measurements. We followed up with 589 people out of 861 participants (follow-up rate: 68%). Older adults who had neurological disorders during the follow-up period were excluded from the final analysis. The final sample analysed consisted of 581 participants (Fig. 1).

Fear of falling (FoF)

Information regarding FoF was obtained via a single-item question: 'Have you ever felt afraid of falling in your daily life?' Participants responded yes or no. Most past related studies have been conducted using multi-item instruments [1], such as the Fear Efficacy Scale International (FES-I) [10]. However, it is difficult to define FoF subtypes based on the score-differences at baseline and follow-up as there is no reference value. In addition, a single-item question approach has been shown to be clinically applicable as it is less time consuming and easy to carry out. Thus, we adopted a single-item question approach for FoF question. Despite data being

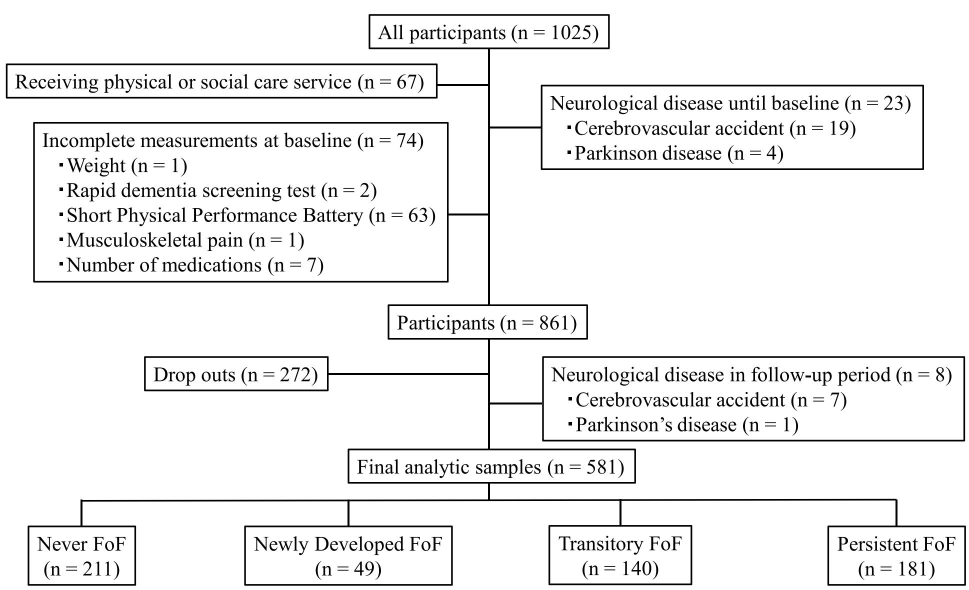

Fig. 1 Flow diagram for the selection of research participants

collected through single-item questions, previous study has reported substantial test–retest reliability (kappa = 0.66) [11] and a rank-biserial correlation coefficient of 0.7 with FES-I [12].

The question was included in the self-administered questionnaire used in the data gathering, which was completed at baseline and follow-up. Participants were classified into four groups according to the combination of FoF at baseline and follow-up [7, 8]. 'Never FoF' was the classification for older adults without FoF at the one-year follow-up, while 'newly developed FoF' was for older adults who had experienced a recent onset of FoF around the time of the follow-up evaluation but had no FoF at baseline. 'Transitory FoF' was defined in our study as 'the state of not firmly fixed FoF'; this classification was for older adults who had FoF at baseline but answered 'without FoF' at follow-up. Persistent FoF was the classification for those with FoF at baseline and at follow-up.

Mobility functions test at baseline

The Short Physical Performance Battery (SPPB) was used to evaluate mobility function objectively. We measured this battery according to previous study methods [13]. The five-chair stand test (5CST) was used to measure the sit-to-stand time from a modular pipe chair with a 45 cm seating height [14]. All tests were performed using a digital stopwatch. For tests of static standing balance, participants maintained standing side-by-side, semi-tandem, and tandem positions for 10 s. For tests of gait, the participants walked either with or without an assistive device on a smooth 5 m long walkway at a self-selected comfortable speed; a 0.5 m space at both ends of the 5 m long walkway was included for acceleration and deceleration. The reasons for setting up such a walkway were as follows. Our study included participants with sensory impairment. Hearing loss delays the response to start instructions, and poor eyesight delays goal timing. To solve these problems, we set a section for acceleration and deceleration. However, some measurement venues could only have a walkway up to 5 m. Thus, according to the minimum scale of the venue, we set to include a section of acceleration and deceleration for 0.5 m. A previous study reported no significant difference in gait speed after adjusting for the type of start (static and moving) [15]. In the present study, original SPPB total score and their sub-score were highly skewed, with 75% of the participants scoring full score. Thus, each score was calculated using the community-based SPPB score (SPPB-com) modified for Japanese community-dwelling older adults [14]. The maximum SPPB-com score was 10 points, and 5CST scores ranged from 0 to 4 points (0 = not able to perform sit-to-stand action, 1 = time taken to perform sit-to-stand action more than 9.7 s, 2 = time taken to perform sit-to-stand action 8.15–9.69 s, 3 = time taken to perform sit-to-stand action 6.85–8.14 s, 4 = time taken to perform sit-to-stand action less than 6.84 s). The range for balance test scores was 0–2 points (0 = not able to maintain tandem stance, 1 = maintain tandem stance for 0–9 s, and 2 = maintain tandem stance for more than 10 s). Scores for the gait test ranged from 0 to 4 points (0 = not able to maintain a balanced gait, 1 = less than 1.10 m/s, 2 = 1.11–1.24 m/s, 3 = 1.25–1.36 m/s, 4 = more than 1.37 m/s). Subjects were categorized into three groups to express their physical functions to according to the SPPB-com total score: lower (0–4), middle (5–7), and higher (8–10) [14]. Additionally, subjects were divided into two groups to express their each mobility function according to each median value of the SPPB-com sub-scores: 5CST: low (0–2) and high (3–4), Tandem balance test: low (0) and high (1), and gait test: low (0–2) and high (3–4).

Self-administered questionnaire and cognitive function tests at baseline

The self-administered questionnaire addressed FoF, history of falls, inactive lifestyle, and sociodemographic data. Data were collected at baseline. The participants' past one-year history of falls was obtained via the question 'Do you have any history of falling in the previous year?' Participants could answer either yes or no. Falling was defined as 'an event that resulted in the participant unintentionally coming to the ground or other lower level' [16]. This definition was noted under the question, participants could answer either yes or no whether they were with or without injury after falling. An inactive lifestyle was determined with the question 'Do you usually stay at home all day long?' (respondents answered yes or no) [17]. Sociodemographic measures included age, sex, height, weight, medical history, number of medication, hospitalizations, and musculoskeletal pain. Cognitive function was assessed using the Rapid Dementia Screening Test (RDST) [18].

Statistical analyses

All participants were divided into two groups based on the FoF status at baseline: (i) older adults without FoF (non-FoF group) and (ii) older adults with FoF (FoF group). First, for the non-FoF group, a binomial logistic regression model was created to investigate the association between the one-year change in FoF and the SPPB-com total score adjusted for other FoF-related factors (i.e. age, sex, past one-year history of falls, musculoskeletal pain, and inactive lifestyle). This model—the 'FoF development risk model'—investigated the association between mobility function and new FoF development in the non-FoF group. Next, for the FoF group, the same binomial logistic regression model was constructed using the same variables. The aim of this model—the 'FoF persistent risk model'—was to investigate the association between mobility functions and persistent FoF among older adults in the FoF group. Finally, for each group (i.e. the non-FoF and FoF groups), another binomial logistic regression model was used to investigate the association between each FoF risk (i.e. development FoF risk or FoF persistent risk) and each sub-score for the SPPB-com (i.e. gait test score, balance test score, and 5CST score), adjusted for age, sex, and past one-year history of falls. The significance level was set at $p<0.05$ for all statistical analyses. All statistical analyses were performed using commercially available software (JMP 12.0; SAS Institute Japan, Tokyo, Japan).

Results

Table 1 shows the sociodemographic data for all participants and dropouts from the study. Older adults with FoF at baseline represented 55% of all participants. Participants were divided into four groups: never FoF ($n=211$), newly developed FOF ($n=49$), Transitory FoF ($n=140$), and persistent FoF ($n=181$). Table 2 shows the demographic data for FoF-related factors applicable to the four groups. Table 3 shows the results of the binomial logistic regression analysis for each model. In the FoF development risk model, we found a significant relation between the risk of newly developed FoF and the SPPB-com total score: the lower group (odds ratio [OR]: [95% confidence interval (95% CI)] = 4.85 [1.82–13.2]). Furthermore, in the FoF persistent risk model, there was a significant difference between the risk of persistent FoF and the SPPB-com total score: the middle group (OR [95% CI] = 1.90 [1.12–3.24]) and lower group (OR [95% CI] = 3.14 [1.68–6.00]). Table 4 shows the results of the binomial logistic regression for the relation between each FoF risk and sub-scores of SPPB-com in each model. In the FoF development risk model, a significant relation was observed between the FoF development and the low SPPB-com score for gait test (OR [95% CI] = 2.34 [1.12–5.12]) and the low score for tandem balance test (OR [95% CI] = 3.62 [1.46–8.90]). In the FoF persistent risk model, the Persistent FoF was significantly related to the low 5CST (OR [95% CI] = 1.96 [1.19–3.24]).

Discussion

We designed this prospective cohort study for community-dwelling older adults. We clarified (i) which mobility functions relates to newly developed FoF and (ii) which mobility function relate to persistent FoF. Results indicated that newly developed FoF and persistent FoF is related to certain mobility functions.

Table 1 Baseline sociodemographic data for all participants and dropouts from the study

Baseline characteristic	Participants ($n=861$)		
	Final analytic sample ($n=581$)	Dropouts ($n=272$)	p-value
Age, year, mean ± SD	76.0 ± 5.3	75.6 ± 5.9	0.32
Female, *n*, %	376, 65	151, 56	0.01
Height, cm	154.5 ± 8.7	155.7 ± 8.8	0.07
Weight, kg	55.0 ± 9.9	55.4 ± 10.4	0.65
Hypertension, *n*, %	281, 48	127, 47	0.74
Diabetes mellitus, *n*, %	75, 13	30, 11	0.52
Cardiovascular disease, *n*, %	68, 12	45, 17	0.04
Respiratory disease, *n*, %	23, 4	6, 2	0.16
Musculoskeletal pain, *n*, %	318, 55	146, 54	0.84
Inactive lifestyle, *n*, %	54, 9	35, 13	0.12
Hospitalizations, *n*, %	61, 11	29, 11	0.81
Past 1year history of falls, *n*, %	114, 20	52, 19	084
Fear of falling, *n*, %	320, 55	133, 49	0.89
Rapid dementia screening test	10.1 ± 2.5	9.9 ± 2.5	0.30
SPPB-com total score			
High (8–10), *n*, %	108, 51	91, 33	0.16
Middle (5–7), *n*, %	85, 40	122, 45	
Low (0–4), *n*, %	18, 9	59, 21	

Mean ± SD mean ± standard deviation; comparison of all participants and dropouts by *t*-test, χ^2-test; *SPPB-com* community-based short physical performance battery

Table 2 Baseline factors related to the one-year change in fear of falling (FoF)

	Final analytic sample ($n=581$)			
Baseline	Without FoF		With FoF	
Follow-up	Without FoF	With FoF	Without FoF	With FoF
	Never FoF ($n=211$)	Newly Developed FoF ($n=49$)	Transitory FoF ($n=140$)	Persistent FoF ($n=181$)
Baseline characteristic				
Age, year	75.0 ± 5.2	75.9 ± 5.1	76.2 ± 5.6	76.9 ± 5.2
Female, *n*, %	97, 46	35, 71	103, 74	141, 78
Musculoskeletal pain, *n*, %	104, 50	26, 53	72, 52	114, 63
Inactive lifestyle, *n*, %	14, 7	9, 18	10, 7	22, 12
Hospitalizations, *n*, %	31, 15	5, 10	12, 9	13, 7
Past one-year history of falls, *n*, %	29, 14	8, 16	31, 22	47, 26
Rapid Dementia Screening Test	10.2 ± 2.5	9.7 ± 2.6	10.3 ± 2.3	9.9 ± 2.7
SPPB-com total score				
High (8–10), *n*, %	108, 51	16, 33	62, 44	45, 25
Middle (5–7), *n*, %	85, 40	18, 37	52, 37	72, 40
Low (0–4), *n*, %	18, 9	15, 31	26, 19	64, 35
Low five chair stand test (0–2), *n*, %	68, 32	21, 43	60, 43	114, 63
Low tandem balance test (0–1), *n*, %	15, 7	12, 25	18, 13	34, 19
Low gait test (0–2), *n*, %	114, 54	35, 71	79, 56	130, 71

Mean ± SD mean ± standard deviation, *SPPB-com* community-based short physical performance battery

Table 3 Association of (Relation between) one-year change in fear of falling (FoF) with (and) baseline mobility functions according to a multiple logistic regression analysis

	FoF development Risk model		FoF persistent Risk model	
	Never FoF vs. newly developed FoF		Transitory FoF vs. persistent FoF	
	Odds ratio (95% CI)	*p*-value	Odds ratio (95% CI)	*p*-value
Baseline FoF risk factors				
SPPB-com total score				
High (8–10)	1.00 (Reference)	< 0.01	1.00 (Reference)	< 0.01
Middle (5–7)	1.44 (0.66–3.17)		1.90 (1.12–3.24)	
Low (0–4)	4.85 (1.82–13.2)		3.14 (1.68–6.00)	
Age	1.00 (0.94–1.07)	0.94	1.00 (0.96–1.05)	0.83
Sex (Female)	2.94 (1.48–6.15)	< 0.01	1.36 (0.80–2.33)	0.26
Past one-year history of falls	1.31 (0.50–3.13)	0.57	1.14 (0.66–1.97)	0.64
Musculoskeletal pain	1.14 (0.58–2.26)	0.70	1.41 (0.88–2.26)	0.15
Inactive lifestyle	2.41 (0.87–6.42)	0.09	1.59 (0.74–3.86)	0.23
Generalised R^2	0.17		0.09	

95% CI 95% confidence interval, *SPPB-com* community-based short physical performance battery

Relation between new FoF development risk and baseline mobility function(s)

As a result of the binomial logistic regression analysis in the FoF development risk model, newly developed FoF after one-year was found to be related to the SPPB-com total score. Furthermore, among mobility function tests, the tandem balance test and gait test were significantly related to newly developed FoF. These results indicated that older adults in the non-FoF group who had lower abilities in terms of balance and walking tended to develop FoF by the one-year follow-up. A systematic review reported that static balance and walking ability were related to FoF development [1]. A Cochrane Review reported that exercises with

Table 4 Relation between one-year change in fear of falling (FoF) and each baseline mobility function by multiple logistic regression analysis

SPPB-com sub-scores	FoF development risk model		FoF persistent risk model	
	Never FoF vs. newly developed FoF		Transitory FoF vs. persistent FoF	
	Odds ratio (95% CI)	*p*-value	Odds ratio (95% CI)	*p*-value
Five chair stand test score				
High (3–4)	1.00 (Reference)	–	1.00 (Reference)	–
Low (0–2)	1.10 (0.44–1.91)	0.81	1.96 (1.19–3.24)	< 0.01
Tandem balance test score				
High (2)	1.00 (Reference)	–	1.00 (Reference)	–
Low (0–1)	3.62 (1.46–8.90)	< 0.01	1.13 (0.57–2.25)	0.81
Gait test score				
High (3–4)	1.00 (Reference)	–	1.00 (Reference)	–
Low (0–2)	2.34 (1.12–5.12)	0.02	1.57 (0.95–2.60)	0.08
Generalised R^2	0.15		0.07	

95% CI 95% confidence interval, *SPPB-com* community-based short physical performance battery; both models were adjusted for age, sex, and past one-year history of falls at baseline

balance and walking elements could be effective in preventing FoF development [19]. Our results support these systematic reviews. Thus, exercises aimed at improving balance and walking ability are recommended to prevent FoF from developing.

Additionally, our results can be partly explained by new FoF concept introduced in previous important study suggesting that FoF originates from an individual's (i.e. older adults) appraisal of his/her balance function in combination with other contributors [20]. Considering our results and this concept, not only improving one's objective ability to balance but also gaining confidence regarding such ability was possibly important for preventing newly developed FoF. However, we didn't assess one's own appraisal of balance function in our study. Therefore, there is a need to clarify the relationship between newly developed FoF and the objective/subjective balance function.

Relationships between FoF persistent risk and baseline mobility function(s)

Based on the FoF persistent risk model, the one-year change in FoF was found to be significantly related to the SPPB-com total score. Furthermore, mobility function tests revealed that a lower 5CST score was significantly related to the change in FoF. Our results indicated that older adults with low sit-to-stand ability tended to experience persistent FoF. Previous studies have shown that older adults with persistent FoF had decreased mobility functions compared to older adults in the Never FoF category [7, 8]. Additionally, previous study reported that a longer duration of FoF was associated with an increased risk for a decline in ADL performance, and its effect was much stronger than that of other risk factors [3]. Our results were in line with these previous studies.

Additionally, a previous study reported an association between sit-to-stand ability and anxiety [21]. Generally, we need to stand from a seated position (from a chair or the floor) in order to move. Thus, older adults with either a sit-to-stand inability or standing-up anxiety may experience FoF every time they move. This perspective is partially consistent with previous study showing an association between FoF and a sedentary lifestyle [6]. However, we didn't assess standing-up anxiety and a sedentary lifestyle in our study. Therefore, further study is needed to clarify the relationship between persistent FoF and standing-up anxiety and a sedentary lifestyle.

Conceptualizing process pertaining to FoF and mobility functions

Taking all our results and results of other studies together, we conceptualised a relationship between the process of experiencing new FoF development or persistent FoF and mobility functions (Fig. 2). Our findings indicate that the process that involved FoF related to lower specific mobility functions among community-dwelling older adults. A previous study reported a positive dose–response relationship between the process of experiencing FoF and a decline in functional status for performing ADL [3]. Hence, our findings are consistent with those of the previous study. As a hypothesis, in older adults without FoF, when their balance and gait ability are lowered, they experience staggering or stumbles during standing or walking in their daily lives, and it leads to the development of FoF. Older adults with FoF decrease physical activity in daily life and may gradually shift to a sedentary lifestyle [6] while repeating, developing, and improving their FoF. When standing ability (lower limb muscle strength) decrease, older adults easily feel concern about standing-up before moving, which is a path of

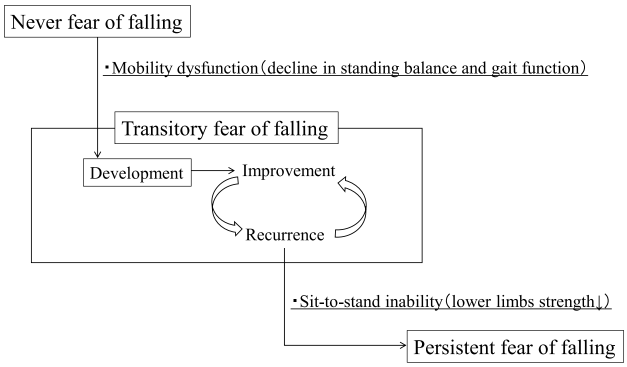

Fig. 2 Conceptualisation process pertaining of fear of falling and mobility functions

persistent FoF. However, this is a topic for a future study aimed at clarifying the relation between longitudinal change in mobility functions and FoF subtypes quantitatively, a well-designed cohort study is needed.

Furthermore, if we interpret our results on the basis of the previous study model for perceiving and physiological fall risk [22], we can get a new insight for the FoF intervention. The previous study showed that older adults with low fall efficacy tend to have more rate of falling, less of the muscle strength and balance function, independent of physiological fall risk. These results suggest that the psychological perception of falls may be important to predict future falling and lower mobility functions [22]. Taken our results and results of other studies together, an individual intervention program according to each FoF sub-types for the older adults with FoF might be effective for falls and lower mobility functions. However, in order to clarify this new hypothesis, we also need a well-designed cohort and intervention study.

Limitations

This study has some limitations. First, there was sampling bias. Physical measurement check-ups were performed for participants who applied to participate themselves twice at baseline and at one-year follow-up. Thus, it was assumed that the study participants were older adults who were highly conscious of their own health. Additionally, the follow-up rate was 68%. Regarding study participants, there were more females and cardiovascular disease patients than dropout participants. Previous studies have reported that women are one of the FoF risk factors. [7, 8]. Therefore, our study sample was possibly weighted towards older adults with a high risk for FoF. Second, there was a limitation regarding participant-reported single-item questions such as FoF and inactive lifestyle. Measurement bias such as over-report and recall may have occurred in these questions. Additionally, the answers to these questions may have been affected by population characteristics such as age and cultural background [23]. Thus, generalizing our findings to other countries should be careful. Furthermore, the FoF assessments in our study included only two trials—at baseline and follow-up. Hence, we were incapable of knowing how FoF changed during follow-up. To address these problems, there is needed for further longitudinal studies using quantitative assessments, such as the FES-I [11] and International Physical Activity Questionnaire [24]. Third, the power (1–β) in the development FoF risk model was possibly low because we couldn't gather enough older adults with newly developed FoF. Finally, the lower value in Nagelkerke's Generalised R^2 [25] was shown in the FoF persistent risk model (0.07). Therefore, other potential factors should be considered.

Conclusion

Few studies have clarified the mobility functions related to each FoF subtype; newly developed FoF or persistent FoF. Our results suggested that certain mobility functions are independent predictor of newly developed FoF and persistent FoF, specificity, (i) gait and static balance performance are related to newly developed FoF, and (ii) sit-to-stand ability is related to persistent FoF. These point highlights the novelty of our study. We believe that our findings provide the clinical suggestion for the need for effective exercise interventions for FoF according to FoF subtype. Consequently, a well-designed cohort and intervention study is needed to clarify effective interventions for FoF.

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Author contributions KO made substantial contributions to data acquisition, data analysis, and interpretation of the data analysis, and has been involved in drafting the manuscript. TA and YF made substantial contributions to the interpretation of the data analysis, and have been involved in revising the manuscript. YY and AN made substantial contributions to data acquisition. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest No commercial party having a direct financial interest in the results of the study supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

Ethical approval The study was carried out in accordance with the principles of the Helsinki Declaration. The study was approved by the Study Ethics Committee of Kobegakuin University (Approval No. HEB130712-1) and informed consent was obtained from all participants prior to their participation.

Statement of human and animal rights This article does not contain any studies with animals performed by any of the authors.

Informed consent All participants gave their informed consent before inclusion in the study.

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