Association of motor index scores with fall incidence among community-dwelling older people

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Abstract

Background: Several kinds of motor dysfunction have been studied for predicting future fall risk in community-dwelling older individuals. However, no study has tested the ability of the fine motor (FINEA) and gross motor (GROSSA) indices to predict the risk of falling, as well as the specific fall type.

Objective: We investigated the associations of FINEA/GROSSA scores with fall risk, accidental falls, and unexplained falls.

Methods: A total of 6267 community-dwelling adults aged ≥50 years were included. First, the associations of FINEA and GROSSA scores with total falls, accidental falls and unexplained falls were assessed in a cross-sectional study and further verified in a prospective cohort after 2 years of follow-up by logistic regression.

Results: We found that high FINEA index and GROSSA index scores were positively associated with the risk of falls (FINEA: total falls: adjusted OR [aOR]=1.50, P=0.001; accidental falls: aOR=1.22, P=0.163; unexplained falls: aOR=2.25, P<0.001; GROSSA: total falls: OR=1.68, P<0.001; accidental falls: aOR=1.42, P=0.002; unexplained falls: aOR=2.50, P<0.001) in a cross-sectional study. After 2 years of follow-up, high FINEA scores were associated with an increased incidence of total falls and accidental falls but not unexplained falls (total falls: aOR=1.68, P=0.003; accidental falls: aOR=1.76, P=0.005; unexplained falls: aOR=1.46, P=0.201). High GROSSA scores were borderline associated with an increased incidence of total falls and unexplained falls but not accidental falls (total falls: aOR=1.31, P=0.066; accidental falls: OR=1.13, P=0.500; unexplained falls: aOR=1.61, P=0.045).

Conclusion: FINEA and GROSSA scores were positively associated with the risk of falls. FINEA or GROSSA may be used as a useful tool to screen for and identify community-dwelling adults at high risk of falling.

Background

Falling is a prevalent geriatric syndrome, affecting approximately one-third of older persons per year[1]. Notably, falling is frequently associated with serious complications to elderly individuals. For example, more than 30% of falls among older adults need medical attention, and approximately 5%-7% of falls result in a fracture, which contributes to high mortality in this elderly population[2–4].

Although the underlying mechanisms of fall risk in elderly individuals have not been completely examined, it has been reported that dysfunction in executive function or motor function, defined as the ability to control, integrate, organize, and maintain information, is widely responsible for falling in elderly individuals[5]. For example, researchers have reported a positive association between gait alterations (speed or stability) and fall risk[6–8]. Furthermore, motor activities (e.g., dance) have been shown to reduce the risk of falling, fall rate, and mobility[9]. Overall, these results indicate that motor or executive function is useful for predicting fall events. On the other hand, epidemiological studies show that cognitive impairment/dementia and falls often coexist in elderly individuals[6, 10, 11]. Falling occurred at 70% per year in older adults with moderate or severe cognitive impairment, which is twice the rate observed among normal adults[12]. Systematic evaluation of the risk of falling might be a necessary step toward the provision of preventive measures in elderly populations, especially in those at ‘high risk of falls’ (e.g., elderly adults).

To date, limited studies have reported the combined assessment of different motor actions as an evaluation index for falls. The FINEA and GROSSA indices are measured by counting the limitations that subjects failed to accomplish and were proposed based on the Irish Longitudinal Study on Ageing (TILDA) cohort, which is a large prospective study investigating social, economic, and health factors in Irish community-dwelling older adults[13]. We previously reported that motor function, assessed by the FINEA and GROSSA indices, was associated with increased incidence of cognitive impairments[14]. Considering a confirmed link between motor function and fall risk in patients with dementia or cognitive impairments, we were curious about the association between FINEA or GROSSA index scores and the risk of falling. Moreover, previous studies have reported the overall fall burden rather than subdividing falls into accidental and unexplained falls. Accidental falls have

been defined as falls due to slipping or tripping, and nonaccidental falls have usually been caused by unrecognized syncope seizures and associated with consciousness loss. It is therefore of vital importance to distinguish between the two types of falls when considering distinct underlying mechanisms. Therefore, based on the TILDA cohort, we aimed to assess the associations between the FINEA and GROSSA indices and the risk of falling in elderly individuals in the present study, as well as conduct a subgroup analysis with accidental and unexplained falls.

Methods

Study sample

We obtained a dataset from TILDA. The study design, inclusion/exclusion criteria, and follow-up of TILDA are published previously[13]. Briefly, TILDA is a national study of Ireland aged 49 years or older aims to assess the impact of health, social and financial circumstances on the aging process in the older Irish individuals. The TILDA includes three data collection waves: wave 1 (from October 2009 to July 2011), wave 2 (from February 2012 to March 2013), and wave 3 (from March 2014 to October 2015). Written informed consent was obtained from cohort participants, and study protocols were approved by the appropriate institutional ethical review boards. TILDA was conducted in accordance with the Declaration of Helsinki.

In the present study, we aim to assess the association of FINEA or GROSSA with falls (total falls, accidental falls, unexplained falls). This study comprised two-stage to interpret the findings. Firstly, a cross-sectional study was conducted using data of wave 2, resulting in data yielded association between FINEA and GROSSA and fall risk. Since dementia is a syndrome of cognitive impairment that could affect memory and the record of falls in TILDA was got through questionnaire, those with comorbidity of dementia (recorded by self-reported doctor-diagnosed questionnaire) in wave 2 were excluded[15]. Then, we excluded subjects with a history of falls in wave 2 and assessed the association after subsequent falls at 2-year follow-up (aka. Wave 3).

FINEA and GROSSA assessments

The definition of FINEA and GROSSA assessments has been described in our previous report[14]. Briefly, the FINEA and GROSSA were measured by counting the limitations that subjects failed to accomplish. The items of FINEA evaluation included: picking up a small coin from a table, eating (such as cutting up food), and dressing. The subscales of GROSSA measures included: walking 100 meters, walking across a room, climbing one flight of stairs without resting for long periods, getting in or out of bed, bathing, or showering. These subscales were summed, and the high index represented decreased motor function.

Co-variables

Demographic, clinical, and comorbidity data were recorded. Cognitive functioning was assessed using the Mini-Mental State Examination score (0–30), and less than 24 is considered indicative of cognitive impairment. The depressive symptom was assessed by the Centre for Epidemiological Studies Depression Scale, and a score of 16 or more is considered depression. The educational levels were defined as primary, secondary, and high. Self-reported smoking status was classified as never smoker, a past smoker, or a current smoker. Physical activity levels were divided into three groups using the short form eight-item version of the International Physical Activity Questionnaire as follows: low, moderate, or high. The baseline self-reported doctor-diagnosed diseases were cardiovascular disease, diabetes or high blood sugar, stroke, mini-stroke or transient ischemic attack (TIA), and eye disease (glaucoma, cataracts, age-related macular degeneration).

Outcomes of falls

In both wave2 and wave3, the participants were asked, “Have you had any falls since the last interview?”, “Were any of these falls non-accidental, i.e., with no apparent or obvious reason?”. Unexplained and accidental fallers were defined according to their answer. Individuals with a history of both unexplained and accidental falls were placed into a group of unexplained fallers.

Statistical analyses

The data were analyzed using SPSS Statistics Version 25.0 (IBM SPSS Statistics, IBM Corporation, Chicago, IL, USA) for Windows. The normality of the data was analyzed using the Kolmogorov-Smirnov (KS). The normally distributed continuous variables are expressed as the means with standard deviations (SD), and nonnormally distributed variables are expressed as medians with interquartile ranges (IQRs). The differences between the groups in the continuous variables were compared using unpaired Student's t-tests (normal distribution) or Wilcoxon-Mann-Whitney tests (nonnormal distributions). The categorical variables, which are reported as counts and percentages, were compared using $\chi 2$ tests.

Both FINEA and GROSSA were categorized into binary variables (FINEA score = 0 and FINEA score = 1–3, GROSSA score = 0 and GROSSA score = 1–5) as we previously reported. We then combined FINEA and GROSSA index which was divided into three categories (group1: FINEA score = 0 and GROSSA score = 0; group2: FINEA score = 0 or GROSSA score = 0, group3: FINEA score = 1–3 and GROSSA score = 1–5).

Univariate and multivariate logistic regression analysis expressed as odds ratios (ORs) and 95% confidence intervals (CIs) was used to assess the relationship between the FINEA/GROSSA and falls. The adjusted variables were age, sex, educational level, exercise, smoking, DM or high blood sugar, stroke, mini-stroke or TIA, eye disease, history of fainting, afraid of falling, cognitive impairment, and cardiovascular disease, which was conformed to previous report. $P < 0.05$ was considered statistically significant in all analyses.

Results

In total, 7,207 subjects were recruited for wave 2 of TILDA. After excluding subjects with comorbid dementia and missing data (N = 929 for dementia; N = 5 for missing FINEA or GROSSA scores; N = 6 for missing a history of falls), 6,267 subjects were included. A flowchart of the selection of eligible individuals from TILDA is shown in Fig. 1. The basic characteristics of the included subjects are presented in Table 1. The median age was 64.0 (57.0–72.0) years, 45% were males, and 12.5% had comorbid eye disease. More than half of the individuals had moderate or high physical activity levels (68.3%), and cardiovascular disease and depression were the most common comorbidities. The mean FINEA and GROSSA scores were 0.08 (± 0.33) and 0.21 (± 0.67), respectively. Notably, 21.9% of patients had a history of falls since the last TILDA interview.

Table 1
Baseline characteristics of subjects included in the cross-sectional study

Variables	**N% or median (IQR)** **(N = 6267)**
Age (years)	64.0 (57.0,72.0)
Sex (male%)	2821 (45.0)
BMI (kg/m^2) *	28.1 (25.3, 31.3)
Education level, n (%)	
Lower	1733 (27.7)
Secondary	3640 (58.1)
High	894 (14.3)
Levels of physical activity, n (%)	
Low	1989 (31.7)
Moderate	2213 (35.3)
High	2065 (33.0)
Smoking, n (%)	
Never	4591 (73.3)
Past	1383 (22.1)
Current	293 (4.7)
History of fainting, n (%)	1173 (18.7)
Fall since last interview, n (%)	1375 (21.9)
Unexplained falls, n (%)	298 (4.8)
Afraid of falling, n (%)	1544 (24.6)
Comorbidities, n (%)	
Cognitive impairment	379 (6.0)
Depression	1574 (25.1)
CVD	2531 (40.4)
DM or high blood sugar	457 (7.3)
Stroke	97 (1.5)
Mini stroke or TIA	134 (2.1)
Eye disease	782 (12.5)

CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack, FINA: fine motor index; GROSSA: gross motor index. Physical activity levels were divided into three groups using the short form eight-item version of the International Physical Activity Questionnaire as follows: low, moderate, or high. Cognitive functioning was assessed using the MMSE score (0–30) and less than 24 is considered indicative of cognitive impairment. The depressive symptom was assessed by the Centre for Epidemiological Studies Depression Scale and score of 16 or more is considered depression.

*Values available in 4665 participants;

Variables	N% or median (IQR) (N = 6267)
FINEA	0.08 (0,0)
GROSSA	0.21 (0.0)
CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack, FINA: fine motor index; GROSSA: gross motor index. Physical activity levels were divided into three groups using the short form eight-item version of the International Physical Activity Questionnaire as follows: low, moderate, or high. Cognitive functioning was assessed using the MMSE score (0–30) and less than 24 is considered indicative of cognitive impairment. The depressive symptom was assessed by the Centre for Epidemiological Studies Depression Scale and score of 16 or more is considered depression.	
*Values available in 4665 participants;	

Cross-sectional study

Associations between FINEA scores and falls

We first explored the association between FINEA scores and falls (total falls, accidental falls, and unexplained falls) in a cross-sectional cohort from Wave 2. As shown in Table 2, we found that FINEA scores were positively associated with the risk of falling categorized as total falls, accidental falls and unexplained falls (total falls: aOR = 1.50, 95% CI: 1.19–1.91, P = 0.001; accidental falls: aOR = 1.22, 95% CI: 0.92–1.61, P = 0.163; unexplained falls: aOR = 2.25, 95% CI: 1.58–3.22, P < 0.001).

Table 2
Logistic regression analysis of fine motor index or gross motor index with risk of falls in cross-sectional study.

Outcome	Events/N	Unadjusted	P	Model 1	P	Model 2 +CI	P	Model 3 +CVD	P
FINEA*									
Total falls	1232/5885	1 (ref.)	< 0.001	1 (ref.)	0.001	1 (ref.)	0.001	1 (ref.)	0.001
	143/382	2.26 (1.82,2.81)		1.52 (1.20,1.92)		1.50 (1.19,1.91)		1.50 (1.19,1.91)	
Accidental falls	987/5640	1 (ref.)	< 0.001	1 (ref.)	0.136	1 (ref.)	0.160	1 (ref.)	0.163
	85/324	1.68 (1.30, 2.17)		1.24 (0.94,1.63)		1.22 (0.92,1.62)		1.22 (0.92,1.61)	
Unexplained falls	242/4895	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001
	56/295	4.51 (3.28, 6.19)		2.22 (1.55,3.18)		2.22 (1.55,3.19)		2.25 (1.58,3.22)	
GROSSA*									
Total falls	1086/5506	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001
	289/761	2.49 (2.12, 2.93)		1.70 (1.40,2.07)		1.68 (1.38,2.04)		1.68 (1.38,2.04)	
Accidental falls	894/5314	1 (ref.)	< 0.001	1 (ref.)	0.002	1 (ref.)	0.002	1 (ref.)	0.002
	178/650	1.87 (1.55, 2.25)		1.43 (1.15,1.79)		1.41 (1.13,1.77)		1.42 (1.13,1.77)	
Unexplained falls	190/4610	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001
	108/580	5.32 (4.13, 6.87)		2.57 (1.86,3.53)		2.52 (1.83,3.47)		2.50 (1.81,3.45)	
FINEA + GROSSA*									
Total falls	1033/5327	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001
	252/737	2.16 (1.83, 2.55)	< 0.001	1.57 (1.29,1.91)	< 0.001	1.55 (1.27,1.89)	< 0.001	1.55 (1.27,1.89)	< 0.001
	90/203	3.31 (2.49, 4.40)		2.14 (1.56,2.93)		2.10 (1.53,2.88)		2.10 (1.53,2.88)	
Accidental falls	859/5153	1 (ref.)	< 0.001	1 (ref.)	0.012	1 (ref.)	0.015	1 (ref.)	0.014
	163/648	1.68 (1.39,2.04)	< 0.001	1.33 (1.07,1.67)	0.016	1.32 (1.06,1.66)	0.021	1.32 (1.06,1.66)	0.022
	50/163	2.21 (1.57,3.11)		1.58 (1.09,2.30)		1.55 (1.07,2.26)		1.55 (1.07,2.26)	

*: index scores = 0 is reference. In subgroup analysis of accidental falls, the individuals with history of unexplained falls were excluded from total individuals. In subgroup analysis of unexplained falls, the individuals with history of accidental falls were excluded from total individuals.5 individuals were excluded from subgroup analysis because of unknown falling type. Model 1: adjusted for age, sex, educational level, exercise, smoking, DM or high blood sugar, stroke, mini-stroke or TIA, eye disease, history of fainting, afraid of falling. Model2: Model1 + cognitive impairment. Model3: Model2 + CVD. FINEA: fine motor index, GROSSA: gross motor index, CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack. CI: cognitive impairment.

Outcome	Events/N	Unadjusted	P	Model 1	P	Model 2 +CI	P	Model 3 +CVD	P
Unexplained falls	172/4466	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001	1 (ref.)	< 0.001
	88/573	4.53 (3.45,5.96)	< 0.001	2.45 (1.75,3.43)	< 0.001	2.40 (1.71,3.37)	< 0.001	2.38 (1.70,3.34)	< 0.001
	38/151	8.40 (5.64,12.50)		3.96 (2.50,6.27)		3.92 (2.48,6.22)		3.93 (2.48,6.23)	

*: index scores = 0 is reference. In subgroup analysis of accidental falls, the individuals with history of unexplained falls were excluded from total individuals. In subgroup analysis of unexplained falls, the individuals with history of accidental falls were excluded from total individuals.5 individuals were excluded from subgroup analysis because of unknown falling type. Model 1: adjusted for age, sex, educational level, exercise, smoking, DM or high blood sugar, stroke, mini-stroke or TIA, eye disease, history of fainting, afraid of falling. Model2: Model1 + cognitive impairment. Model3: Model2 + CVD. FINEA: fine motor index, GROSSA: gross motor index, CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack. CI: cognitive impairment.

Associations between GROSSA scores and falls

As shown in Table 2, GROSSA scores were positively associated with the risk of falling categorized as total falls, accidental fall and unexplained falls (total falls: aOR = 1.68, 95% CI: 1.38–2.04, P < 0.001; accidental falls: aOR = 1.42, 95% CI: 1.13–1.77, P = 0.002; unexplained falls: aOR = 2.50, 95% CI: 1.81–3.45, P < 0.001).

Associations between combined motor index scores and falls

As shown in Table 2, the FINEA/GROSSA/combined motor index scores were positively associated with the risk of falling categorized as total falls, accidental falls, and unexplained falls (total falls: aOR for Group 2 = 1.55, 95% CI: 1.27–1.89, P < 0.001, Group 3 = 2.10, 95% CI: 1.53–2.88, P < 0.001; accidental falls: aOR for Group 2 = 1.32, 95% CI: 1.06–1.66, P = 0.014, Group 3 = 1.55, 95% CI: 1.07–2.26, P = 0.022; unexplained falls: aOR for Group 2 = 2.38, 95% CI: 1.70–3.34, P < 0.001, Group 3 = 3.93, 95% CI: 2.48–6.23, P < 0.001).

Prospective cohort study

Positive associations between FINEA/GROSSA/combined motor index scores and fall risk were found in the cross-sectional study. To further determine their associations with falling, we analyzed their relationship after 2 years of follow-up. We excluded individuals with a history of falling in wave 2 (N = 1173) and those who were lost to follow-up (N = 882), eventually resulting in 4,212 subjects in the prospective study. The details of the subject selection are shown in Fig. 1. The basic characteristics of the included individuals are presented in Table 3.

Table 3
Baseline characteristics of subjects included in prospective cohort study

	FINEA = 0 (N = 4032)	FINEA = 1–3 (N = 180)	P-value	GROSSA = 0 (N = 3882)	GROSSA = 1–5 (N = 330)	P-value
Age (years)	62.00 (56.0,70.0)	68.0 (60.2,77.7)	< 0.001	62.0 (56.0,70.0)	67.0 (59.0,77.0)	< 0.001
Sex (male%)	1885 (46.8)	86 (47.8)	0.787	1847 (47.6)	124 (37.6)	< 0.001
BMI (kg/m^2)*	28.00 (25.31,31.11) (N = 3129)	28.83 (25.80,32.66) (N = 135)	0.056	27.91 (25.26,30.95) (N = 3027)	29.86 (26.57,38.61) (N = 237)	< 0.001
Education level, n (%)			0.006			< 0.001
Lower	1007 (25.0)	58 (32.2)	0.029	938 (24.2)	127 (38.5)	< 0.001
Secondary	2427 (60.2)	106 (58.9)	0.727	2353 (60.6)	180 (54.5)	0.031
High	598 (14.8)	16 (8.9)	0.027	591 (15.2)	23 (7.0)	< 0.001
Levels of physical activity, n (%)			< 0.001			< 0.001
Low	1143 (28.3)	100 (55.6)	< 0.001	1044 (26.9)	199 (60.3)	< 0.001
Moderate	1447 (35.9)	52 (28.9)	0.055	1409 (36.3)	90 (27.3)	< 0.001
High	1442 (35.8)	28 (15.6)	< 0.001	1429 (36.8)	41 (12.4)	< 0.001
Smoking, n (%)			< 0.001			< 0.001
Never	3115 (77.3)	68 (37.8)	< 0.001	3066 (79.0)	117 (35.5)	< 0.001
Past	799 (19.8)	74 (41.1)	< 0.001	731 (18.8)	142 (43.0)	< 0.001
Current	118 (2.9)	38 (21.1)	< 0.001	85 (2.2)	71 (21.5)	< 0.001
History of fainting, n (%)	682 (16.9)	36 (20.0)	0.281	649 (16.7)	69 (20.9)	0.052
Fall since last interview, n (%)	700 (17.4)	57 (31.7)	< 0.001	666 (17.2)	91 (27.6)	< 0.001
Unexplained falls, n (%)	166 (4.1)	17 (9.4)	0.001	148 (3.8)	35 (10.6)	< 0.001

BMI: body mass index, CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack, FINEA: fine motor index, GROSSA: gross motor index. Physical activity levels were divided into three groups using the short form eight-item version of the International Physical Activity Questionnaire as follows: low, moderate, or high. Cognitive functioning was assessed using the MMSE score (0–30) and less than 24 is considered indicative of cognitive impairment. The depressive symptom was assessed by the Centre for Epidemiological Studies Depression Scale and score of 16 or more is considered depression.

*Values available in 3264 participants

	FINEA = 0 (N = 4032)	FINEA = 1–3 (N = 180)	P-value	GROSSA = 0 (N = 3882)	GROSSA = 1–5 (N = 330)	P-value
Afraid of falling, n (%)	726 (18.0)	73 (40.6)	< 0.001	644 (16.6)	155 (47.0)	< 0.001
Comorbidities, n (%)						< 0.001
Cognitive impairment	150 (3.7)	11 (6.1)	0.102	131 (3.4)	30 (9.1)	< 0.001
CESD	837 (20.8)	83 (46.1)	< 0.001	775 (20.0)	145 (43.9)	< 0.001
CVD	1465 (36.3)	110 (61.1)	< 0.001	1378 (35.5)	197 (59.7)	< 0.001
DM or high blood sugar	253 (6.3)	24 (13.3)	< 0.001	228 (5.9)	49 (14.8)	< 0.001
Stroke	37 (0.9)	6 (3.3)	0.009	34 (0.9)	9 (2.7)	0.005
Mini stroke or TIA	66 (1.6)	10 (5.6)	0.001	65 (1.7)	11 (3.3)	0.030
Eye disease	412 (10.2)	36 (20.0)	< 0.001	372 (9.6)	76 (23.0)	< 0.001
FNEA	0 (0,0)	1 (1,1)	< 0.001	0 (0,0)	0 (0,0)	< 0.001
GROSSA	0 (0,0)	0 (0,1)	< 0.001	0 (0,0)	1 (1,2)	< 0.001

BMI: body mass index, CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack, FINEA: fine motor index, GROSSA: gross motor index. Physical activity levels were divided into three groups using the short form eight-item version of the International Physical Activity Questionnaire as follows: low, moderate, or high. Cognitive functioning was assessed using the MMSE score (0–30) and less than 24 is considered indicative of cognitive impairment. The depressive symptom was assessed by the Centre for Epidemiological Studies Depression Scale and score of 16 or more is considered depression.

*Values available in 3264 participants

Associations between the baseline FINEA/GROSSA/combined motor index scores and falls after two years of follow-up

We found that FINEA scores were positively associated with total falls and accidental falls (total falls: aOR = 1.68, 95% CI: 1.19, 2.38, P = 0.003; accidental falls: aOR = 1.76, 95% CI: 1.18–2.61, P = 0.005) but not unexplained falls (aOR = 1.46, 95% CI: 0.82–2.62, P = 0.201) (Table 4).

Table 4
Logistic regression analysis of fine motor index or gross motor index with risk of falls in prospective cohort study.

Outcomes	Events/N	Unadjusted	P	Model1	P	Model2 +CI	P	Model3 +CVD	P
FINEA*									
Total falls	700/4032	1 (ref.)	< 0.001	1 (ref.)	0.003	1 (ref.)	0.003	1 (ref.)	0.003
	57/180	2.21 (1.60, 3.05)		1.68 (1.19,2.38)		1.68 (1.19,2.38)		1.68 (1.19,2.38)	
Accidental falls	526/3858	1 (ref.)	< 0.001	1 (ref.)	0.005	1 (ref.)	0.006	1 (ref.)	0.005
	39/162	2.01 (1.39, 2.91)		1.75 (1.18,2.61)		1.75 (1.18,2.61)		1.76 (1.18,2.61)	
Unexplained falls	166/3498	1 (ref.)	< 0.001	1 (ref.)	0.201	1 (ref.)	0.205	1 (ref.)	0.201
	17/140	2.77 (1.63, 4.72)		1.46 (0.82,2.61)		1.46 (0.81,2.60)		1.46 (0.82,2.62)	
GROSSA*									
Total falls	666/3882	1 (ref.)	< 0.001	1 (ref.)	0.068	1 (ref.)	0.067	1 (ref.)	0.066
	91/330	1.84 (1.42, 2.37)		1.31 (0.98,1.75)		1.31 (0.98,1.75)		1.31 (0.98,1.76)	
Accidental falls	512/3728	1 (ref.)	0.037	1 (ref.)	0.496	1 (ref.)	0.502	1 (ref.)	0.500
	53/292	1.39 (1.02, 1.90)		1.13 (0.80,1.59)		1.13 (0.80,1.59)		1.13 (0.80,1.59)	
Unexplained falls	148/3364	1 (ref.)	< 0.001	1 (ref.)	0.050	1 (ref.)	0.046	1 (ref.)	0.045
	35/274	3.18 (2.15, 4.71)		1.59 (1.00,2.53)		1.60 (1.01,2.55)		1.61 (1.01,2.56)	
FINEA + GROSSA*, #									
Total falls	642/3780	1 (ref.)	0.004	1 (ref.)	0.570	1 (ref.)	0.567	1 (ref.)	0.560
	82/354	1.47 (1.14,1.91)	< 0.001	1.09 (0.81,1.46)	< 0.001	1.09 (0.81,1.47)	< 0.001	1.09 (0.81,1.47)	< 0.001
	33/78	3.58 (2.27,5.66)		2.53 (1.55,4.11)		2.53 (1.56,4.12)		2.54 (1.56,4.13)	
Accidental falls	492/3630	1 (ref.)	0.132	1 (ref.)	0.660	1 (ref.)	0.661	1 (ref.)	0.659
	54/326	1.27 (0.93,1.72)	< 0.001	1.08 (0.77,1.52)	0.008	1.08 (0.77,1.52)	0.008	1.08 (0.77,1.52)	0.008
	19/64	2.69 (1.56,4.64)		2.17 (1.23,3.86)		2.17 (1.22,3.85)		2.18 (1.23,3.86)	

*: index = 0 used as reference. #: was the sum of both binary variables (FINEA, GROSSA), and divided into 3 groups according to results (0,1,2). In subgroup analysis of accidental falls, the individuals with history of unexplained falls were excluded from total individuals. In subgroup analysis of unexplained falls, the individuals with history of accidental falls were excluded from total individuals. Model 1: adjusted for age, sex, educational level, exercise, smoking, DM or high blood sugar, stroke, mini-stroke or TIA, eye disease, history of fainting, afraid of falling. Model2: Model1 + cognitive impairment. Model3: Model2 + CVD. CI: cognitive impairment, FINEA: fine motor index, GROSSA: gross motor index, CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack.

Outcomes	Events/N	Unadjusted	P	Model1	P	Model2 +CI	P	Model3 +CVD	P
Unexplained falls	144/3282	1 (ref.)	0.001	1 (ref.)	0.984	1 (ref.)	0.973	1 (ref.)	0.960
	26/298	2.08 (1.35,3.22)	< 0.001	1.01 (0.61,1.67)	0.002	1.01 (0.61,1.68)	0.002	1.01 (0.61,1.68)	0.002
		6.30 (3.32,11.93)		3.07 (1.50,6.28)		3.09 (1.51,6.32)		3.10 (1.51,6.36)	
	13/58								

*: index = 0 used as reference. #: was the sum of both binary variables (FINEA, GROSSA), and divided into 3 groups according to results (0,1,2). In subgroup analysis of accidental falls, the individuals with history of unexplained falls were excluded from total individuals. In subgroup analysis of unexplained falls, the individuals with history of accidental falls were excluded from total individuals. Model 1: adjusted for age, sex, educational level, exercise, smoking, DM or high blood sugar, stroke, mini-stroke or TIA, eye disease, history of fainting, afraid of falling. Model2: Model1 + cognitive impairment. Model3: Model2 + CVD. CI: cognitive impairment, FINEA: fine motor index, GROSSA: gross motor index, CVD: cardiovascular disease, DM: diabetes, TIA: Transient Ischemic Attack.

GROSSA scores had borderline significance associated with total falls and unexplained falls (total falls: aOR = 1.31, 95% CI: 0.98–1.76, P = 0.066; unexplained falls: aOR = 1.61, 95% CI: 1.01–2.56, P = 0.045) but not with accidental falls (aOR = 1.13, 95% CI: 0.80–1.60, P = 0.500) (Table 4).

The combined motor index scores were positively associated with falling categorized as total falls, accidental falls, and unexplained falls (total falls: aOR for Group 2 = 1.09, 95% CI: 0.81–1.47, P = 0.560, Group 3 = 2.54, 95% CI: 1.56–4.13, P < 0.001; accidental falls: aOR for Group 2 = 1.08, 95% CI: 0.77–1.52, P = 0.659, Group 3 = 2.18, 95% CI: 1.23–3.86, P = 0.008; unexplained falls: aOR for Group 2 = 1.01, 95% CI: 0.61–1.68, P = 0.960, Group 3 = 3.10, 95% CI: 1.51–6.36, P = 0.002) (Table 4).

Discussion

Our study showed that among community-dwelling older people, motor function assessed by the FINEA index at baseline was significantly associated with an increased risk of total falls after 2 years of follow-up. Baseline GROSSA scores were borderline significantly associated with total fall risk. When the FINEA and GROSSA indices were combined, the association with falls was more robust.

Predictive factors for the risk of falls have been investigated for decades, and factors including visual deficits, muscle strength, motor function, and postural control have been found to be associated with the risk of falls[16, 17]. Among these factors, motor function, gait and balance have been the most studied and have been shown to be firmly linked to the risk of falls in the elderly. The underlying mechanism lies in gait dysfunction or motor dysfunction that is a failure of sophisticated mechanisms of brain mobility control and becomes apparent in falling, known as “brain failure”[6, 18]. These results have been reinforced by well-established relationships among gait or motor function, cognitive impairment and falling[8, 19–21]. Our previous study showed significant associations between motor function assessed by the FINEA or GROSSA indices and cognitive impairments. Therefore, we are not surprised that both motor indices were likely to be associated with falling in the present study, which further confirmed the firm associations between motor function, cognitive impairments, and falls.

To reduce the risk of falls, relevant training has been widely explored. A meta-analysis that assessed the preventive role of exercise on fall risk among community-dwelling individuals showed that functional and balance exercises could reduce the rate of falls by 24%[22]. Fall prevention trials (both multifactorial and single-factor interventions) among cognitively normal elderly individuals showed significant effectiveness while failing in those with cognitive impairment[23, 24]. Detecting the risk of falls for prevention trials in individuals with normal cognitive function would be more significant. However, risk assessment tools that have been developed for predicting future falls, including the Berg balance scale, timed up and go test, performance oriented mobility assessment, functional reach test, gait speed test, and history of falls, have shown low predictive ability (area under the curve < 0.7)[25]. Therefore, more sensitive and specific prediction tools should be further investigated. Our study showed that both FINEA and GROSSA indices could predict the risk of falls, and more robust results were observed with the combined motor index. Both the FINEA and GROSSA are simple, feasible, self-report questionnaires, and they might be an effective tool to screen for and identify community-dwelling older people who are at a high risk of falling.

Based on our prospective cohort study, FINEA and GROSSA scores were significantly associated with accidental falls and unaccidental falls, respectively. Where are there these differences? Beside the difference reflection of muscle dysfunction across the two motor index, deficiencies in FINEA performance (bimanual motor performance) may be associated with changes in the size or structure of the corpus callosum[26, 27]. While impairments in GROSSA performance (primate bipedal locomotion) may be caused by changes in the brainstem, cerebellum, and forebrain[28]. As the brain remains an incompletely understood and mysterious organ, the potential for diverse associations between areas associated with differences in motor and cognitive performance, which could result in distinct predictions regarding falling type, should be further studied.

General speaking, unaccidental fall are associated with more intracranial injury and are more likely due to syncope or underlying cardiovascular disease[29]. One-third of patients admitted to an orthopaedic ward had unaccidental fall[30]. Our results showed GROSSA was associated with risk of unaccidental fall, moreover, the relationship is more robust when combination of FINEA and GROSSA index scores. Participants with dysfunction of motor index seemed to be more appropriate for unaccidental falls prevention interventions.

Our findings may be explained by several possible mechanisms. The effective coordination of the basal ganglia and brainstem systems, regulated muscle tone, and functional processing of sensory information could lead to a normal gait[31]. Therefore, both impairments in muscle tone and neural regulation could cause an increased fall risk. Regarding muscle, decreased strength or power of muscle due to multiple factors (increasing age, alterations in nervous systems, etc.) caused atrophy that could decrease dynamic balance abilities and increase the risk of falling[32]. Paratonia was also found to be associated with a decline in both fine and gross motor performance[33]. Regarding neural impairments, postural and gait stability and adjustments during walking, the harmonious modulation of trunk/ankle flexibility under physiological perturbations, and support in the center of body mass are needed to prevent falls that require attention and executive resources[34]. White matter brain regions are areas connecting cortical and subcortical regions. Pathological changes in these regions could decrease connectivity between different brain areas and cause an increase in fall risk[35]. In patients at risk of falling, magnetic resonance imaging showed abnormal white matter in the genu and splenium of the corpus callosum, medial frontal and parietal subcortical pathways, posterior cingulum, prefrontal, and orbitofrontal pathways, and longitudinal pathways that connect the frontal, parietal, and temporal lobes[36]. Damage in different locations within the central nervous system could cause an increased risk of falling. Therefore, combining assessments of several motor functions that change earlier or more typically with deficiencies in different brain areas or muscle atrophy with different underlying causes could help better detect individuals at a higher risk of falling.

Strengths and limitations

Our study has several strengths. We first introduced fine motor or gross motor index scores as being associated with the risk of falls in community-dwelling adults. This association persisted when adjusted the cognitive impairment, which suggests a role of FINEA/GROSSA on fall in these cognitively normal participants. Second, this research was based on a well-designed

study with a large sample size, which makes the results more credible. Third, both the FINEA and GROSSA are simple, feasible, self-report questionnaires that could be used as tools to screen for and identify older patients at high risk of falling.

Our study also has limitations. First, although our sample size was large, the number of individuals with motor dysfunction (FINEA > 0 or GROSS > 0) was limited. This imbalanced dataset might have influenced our results. Second, wave 2 of TILDA did not collect information on gait alterations (such as speed or stability), which have been well established in the association with falls[6, 16, 33, 37]. Third, previous also have shown depression and antidepressant use was independently associated with fall[38], however, the dataset of our study does not include information of depression diagnosis and antidepressant use. Fourth, our sample was Irish, so further analyses based in other populations, including Americans and Asians, should be further investigated.

Conclusion

FINEA or GROSSA scores were positively associated with the risk of falling. The FINEA or GROSSA may be used as a useful tool to screen for and identify community-dwelling adults at high risk of falling. Patients with dysfunction of FINEA or GROSSA may be an appropriate target for falls prevention interventions.

Abbreviations

aOR Adjusted OR

CIs Confidence intervals

DM Diabetes mellitus

FINEA Fine motor

GROSSA Gross motor

IQRs Interquartile ranges

KS Kolmogorov-Smirnov

ORs Odds ratios

SD Standard deviations

TIA Transient Ischemic Attack

TILDA The Irish Longitudinal Study on Ageing

Declarations

Ethics approval and consent to participate

Ethical approval for the TILDA project was gained from the Faculty of Health Sciences Research Ethics Committee, Trinity College Dublin based on the Declaration of Helsinki. Written informed consent to participate in TILDA was obtained from all participants as part of the initial screening that preceded the study interview.

Consent for publication

Not applicable.

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Competing interests

The authors declare no competing financial interests.

Authors' contributions

All authors have read and approved of the submission of this manuscript. J.F-W and Y.L-Z were responsible for the entire project and revised the draft. X.L, A.A., and J-Y performed the data extraction, statistical analysis, and interpreting the data. A.A. and X.L. drafted the first version of the manuscript. All authors participated in the interpretation of the results and prepared the final version of the manuscript.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

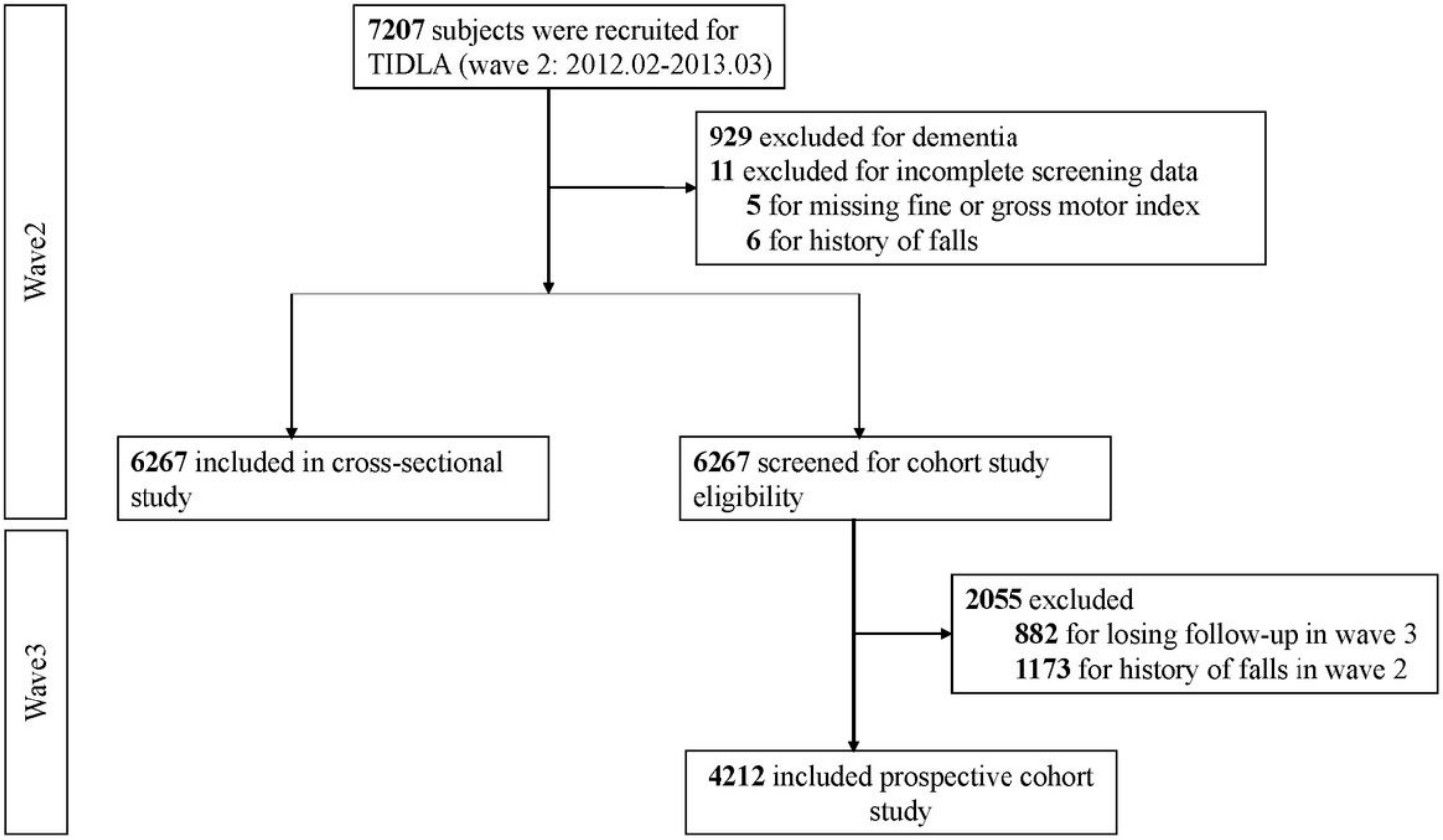

Figure 1

Participant Flow in a cross-sectional study and prospective cohort study of the relationship between fine/gross motor index and risk of falls in participants included in TILDA.

Note: TILDA: Irish Longitudinal Study on Ageing