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Effects of fear of falling and step length on the future risk of falls in non-demented older adults

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박지선

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Abstract

Effects of fear of falling and step length on the future risk of falls in non-demented older adults

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This study aimed to investigate the effects of fear of falling (FOF) and not long normalized step length (NL-NSL) on the future risk of falls in older adults. We enrolled 306 community-dwelling non-demented older adults aged 60 years or older. We evaluated the FOF using a 4-point Likert scale. We obtained step length using a triaxial accelerometer and normalized it using height. We defined the lowest and middle tertiles of the normalized step length as NL-NSL. FOF tripled (OR [odds ratio] = 3.1, 95% confidence interval [CI] = 1.3–7.3) and NL−NSL more than doubled (OR = 2.3, 95% CI = 1.1–5.6) the risk of falls during the 2−year follow−up period. When the participants without a previous history of falls were analyzed separately, only NL−NSL increased the risk of falls (OR = 3.3, 95% CI = 1.1–12.1). Older adults at risk of falls can be identified using a simple question on FOF and step length obtained from a wearable triaxial accelerometer, even if there is no accurate information on past fall experience.

Keywords : Fear of falling, Normalized step length, Fall prediction, older adults

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I . Introduction

A fall is an unexpected event in which someone comes to rest on the ground, floor, or lower level, which involves accidentally slipping or tripping .[1-3] Falls can lead to injuries, fractures, bruises or other physiological consequences that are associated with mortality and morbidity.[1,4] In addition, many falls are repeated.[5] Thus, the first line of defense to defend against the harmful effects of falls and to keep them socially and physically active is to detect the risk of falls at an early stage.

Fear of falling (FOF) is a persistent concern about falls.[6] In many previous studies,[5,7-11] but not all,[12,13] FOF was associated with the risk of falls in older adults. Although it is not fully understood how FOF increases the future risk of falls, FOF was associated with other risk factors for falls such as muscle weakness, abnormal balance, and limited postural control.[14-18] In addition, FOF is common in older adults with a previous history of falls as a psychological consequence of past fall experience.[19] Since a previous fall is a strong risk factor of future falls, FOF may be indirectly associated with the future risk of falls in older adults who have experienced a fall previously.[5,19,20] In fact, older adults with FOF and a previous history of falls showed different gait features from those with FOF but no previous history of falls,[21] and an association of FOF with the future risk of falls disappeared when the history of falls was adjusted in non-demented older adults.[11] Therefore, FOF alone might not be sufficient to detect the risk of falls in those without a fall history.

Among gait features, gait speed and step length were associated with the risk of falls regardless of a previous history of falls. The slower the gait and the shorter the step length, the higher the risk of falls.[21-25] Since gait speed is the product of step length and cadence,[26] the association of slow gait speed with the risk of falls may be attributable to the association of short step length with the risk of falls. Furthermore, FOF was associated with slow gait speed,[21,27-29] suggesting that the association of FOF with the risk of falls may be also attributable, at least in part, to the association of short step length with the risk of falls. As a result, it can be deduced that considering short step length along with FOF will be a powerful indicator in identifying a fall−prone group among people without a history of falls.

However, the effects of FOF and step length on the future risk of falls have never been investigated simultaneously. Furthermore, most previous studies on the effect of step length on the risk of falls did not normalize step length[20,24,30] despite step length is considerably influenced by body shape such as height or leg length. In this study, we investigated the effects of FOF and normalized step length on the future risk of falls in healthy older adults. In addition, we compared their effects on the future risk of falls in the participants with a previous history of falls and those without a previous history falls separately.

Ⅱ. Methods

Participants

We enrolled 306 community-dwelling non-demented older adults aged ≥ 60 years from the Korean Longitudinal Study on Cognitive Aging and Dementia (KLOSCAD) **(Figure 1)**.[31] The KLOSCAD is a nationwide, multi-center, population-based prospective cohort study on older adults in South Korea. In the KLOSCAD, 6,818 Koreans aged 60 years or older were randomly sampled from 30 villages and towns of 13 districts across South Korea using residential rosters in the end of 2009. Among them, the participants who were enrolled from Yongin, the largest satellite city of Seoul were invited to this KLOSCAD Gait Study (KLOSCAD-GS). The baselines assessment of the KLOSCAD was conducted from November 2010 to October 2012. Four 2-year follow-up assessments were conducted from November 2012 to December 2020. All participants had normal or corrected-to-normal vision, and were free from major psychiatric, neurologic, or musculoskeletal disorders that may influence gait and/or fall risk.

All participants provided written informed consent themselves or via their legal guardians. All procedures were performed in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the Seoul National University Bundang Hospital (IRB: B-1603/338-301).

Clinical assessments

Geriatric psychiatrists or neurologists with expertise in dementia research performed face-to-face standardized diagnostic interviews, physical and neurological examinations, and laboratory tests using the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease Assessment Packet (CERAD-K)[32] and the Mini International Neuropsychiatric Interview .[33]

Research neuropsychologists or trained research nurses administered the CERAD−K neuropsychological assessment battery.[32,34] Trained research nurses administered the Tinetti Performance−Oriented Mobility Assessment[35] and Cumulative Illness Rating Scale.[36] All participants self−administered the Korean version of Geriatric Depression Scale.[37] Then, a panel of geriatric psychiatrists diagnosed dementia according to the Diagnostic and Statistical Manual of Mental Disorders, 4th edition criteria.[38]

Fall assessment

We defined a fall as an unexpected event in which the participants come to rest on the ground, floor, or lower level.[2] We evaluated a history of falls within 12 months before the gait assessment by a face−to−face interview, and the incident falls for about 24 months (24.01 ± 0.1; ranges from 24 months to 25 months) after the gait assessment by telephone interviews every six months. We also evaluated the FOF using a single−item 4−point Likert scale.[39,40] We asked the participants to rate their FOF by choosing one of "not at all", "a little", "a lot" and "a lot more" in response to a question "Are you afraid of falling?". We defined the presence of FOF as choosing "a lot" or "a lot more".[21,41]

Gait assessment

We analyzed the gait of each participant using a wearable inertia measurement unit (IMU), FITMETER® (FitLife Inc., Suwon, Korea), or ActiGraph® (SMD solution, Seoul, Korea). The IMUs were hexahedrons (size = 35 × 35 × 13 mm, weight = 14 g for FITMETER®; size = 30 × 40 × 10 mm, weight = 17 g for ActiGraph®) with smooth edges, and have a digital tri−axial accelerometer (BMA255, BOSCH, Germany) and gyroscope (BMX055, BOSCH, Germany).

They measured tri−axial acceleration up to ± 8 g (with resolution of 0.004 g/0.00024 g) and tri−axial angular velocity up to ± 1,000° /s (with resolution of 0.03° /s) at a sample rate of 250 Hz. We fixed an IMU to each participant with an elastic band at the 3rd – 4th lumbar vertebrae, which is the approximate center of the body mass. We asked each participant to walk back and forth three times on a 14−m flat straight walkway at a comfortable self−selected pace and to start turning after passing the 14−m line.

To measure steady−state walking by minimizing acceleration effects, we analyzed the data of the central 10−m mark of the 14−m flat straight walkways after eliminating the 2−m long walks prior to the start and each turn. We preprocessed the IMU signals, identified each step, and estimated six gait features, including cadence (steps/min), step time (s), gait speed (cm/s), step length (cm), step time variability (%), and step time asymmetry (%) using the methods described in our previous works.[42,43] We defined gait speed as the distance of body movement on level ground in centimeters per second and estimated the gait speed using the method described in detail in our previous works.[42,43] We estimated gait variability using step time variability. We defined step time as the duration of each step (s) from the initial contact of one foot to the initial contact of the opposite foot and estimated the step time by multiplying 60 with the inversed cadence. We defined the step time variability as the percentage mean of the step time regularity (the variance over the mean of the left and right step times, %) and estimated the step time variability.

We obtained the normalized step length (NSL) using the following equation to adjust for inter−individual physical differences[44], and defined the lowest and middle tertiles of NSL (≤39.1) a ‘not long NSL (NL−NSL)’.

$$\text{Normalized step length} = \text{step length (cm)} / \text{height (cm)} \times 100$$

Statistical

We compared the continuous and categorical variables using Student's t−test and chi−squared tests respectively between groups. We analyzed the correlation of FOF score and NSL with gait features using Pearson' s correlation test.

We examined the effects of NSL, FOF, and their interaction on the risks of incident falls using stepwise binary logistic regression analysis adjusted for age, sex, body mass index (BMI), and arm length for all participants and those without a history of falls within the previous year, respectively. McFadden's adjusted R^2 and likelihood ratio test were implemented to compare the models. Then we conducted Kaplan−Meier survival analysis with log−rank test to examine differences in survival rate for the first fall during the 24−month follow−up period according to the presence of FOF or NL−NSL. In addition, we performed these analyses in the participants without a history of fall within the past 12 months separately.

We performed all statistical analyses were performed using R version 4.1.2 (Foundation for Statistical Computing, Vienna, Austria).

Ⅲ. Results

Among the 306 participants, 32 and 204 had FOF and NL−NSL, respectively (**Table 1**). The participants with FOF were more likely to be women and to have shorter leg length than those without FOF. Although gait variables were comparable between the participants with FOF and those without FOF, falls were more common in the participants with FOF not only during the 12 months before the assessment but also during the 24−month follow−up period than those without FOF. The participants with NL−NSL were older and heavier and had higher BMI than those without NL−NSL. They showed slower gait speed, higher step time variability, lower cadence and lower vertical height displacement of center of mass (CoM) than the participants without NL−NSL. They had more falls during the 24−month follow−up period than the participants without NL−NSL.

Among the 248 participants without a previous history of falls, 17 and 164 had FOF and NL−NSL, respectively (**Table 2**). In these participants without a previous history of falls, those with FOF were also more likely to be women than those without FOF. All gait variables except medio−lateral displacement of CoM and the number of falls during the 24−month follow−up period were comparable between the participants with FOF and those without FOF. The participants with NL−NSL were older and heavier and had higher BMI than those without NL−NSL. They showed slower gait speed, higher step time variability, lower cadence and lower vertical height displacement of CoM than those without NL−NSL. Although the participants with NL−NSL showed more falls than those without NL−NSL during the 24−month follow−up period, the difference between the two groups was not statistically significant ($p = 0.077$).

As shown in **Table 3**, NSL was strongly correlated with all other gait parameters except medio−lateral displacement of CoM but FOF score was correlated with medio−lateral displacement of CoM only.

In all the participants, the participants with FOF (survival rate = 66.0%, 95% CI = 51.0–84.0%) and those with NL–NSL (survival rate = 82.0%, 95% CI = 77.0–87.0%) showed lower 24–month survival rates than those without FOF (survival rate = 87.0%, 95% CI = 83.0–91.0%) and those without NL–NSL (survival rate = 91.0%, 95% CI = 86.0–97.0%) respectively, and the differences were statistically significant (X^2 = 10.20, p = 0.001 by log rank test, **Figure 2a** for FOF; X^2 = 4.50, p = 0.033 by log rank test, **Figure 2b** for NL–NSL). Although the participants with FOF and those with NL–NSL had a shorter mean survival time than those without FOF and those without NL–NSL respectively, the differences were not statistically significant (20.8 ± 5.9 months versus 22.3 ± 5.2 months, p = 0.070 for FOF; 21.7 ± 5.8 months versus 22.9 ± 3.9 months, p = 0.164 for NL–NSL).

When we analyzed the participants without a previous history of falls within past 12 months separately, the participants with FOF (survival rate = 76.0%, 95% CI = 59.0–100.0%) and those with NL–NSL (survival rate = 87.0%, 95% CI = 82.0–92.0%) showed lower 24–month survival rate than those without FOF (survival rate = 91.0%, 95% CI = 87.0–95.0%) and those without NL–NSL (survival rate = 95.0%, 95% CI = 91.0–100.0%), respectively. The difference in the survival rate between those with FOF and those without FOF was not statistically significant (X^2 = 3.40, p = 0.064 by log rank test, **Figure 2c**) but that between those with NL–NSL and those without NL–NSL was significant (X^2 = 3.90, p = 0.049 by log rank test, **Figure 2d**). Although the participants with FOF and those with NL–NSL showed a shorter mean survival time than those without FOF and those without NL–NSL respectively, the differences were not significant (21.9 ± 5.4 months versus 22.6 ± 4.8 months, p = 0.442 for FOF; 22.2 ± 5.3 months versus 23.3 ± 3.5 months, p = 0.648 for NL–NSL).

In the stepwise logistic regression analysis on all participants **(Table 4)**, higher FOF score increased while longer NSL decreased the future risk of falls

(OR = 1.7, 95% CI = 1.1–2.4 for FOF score; OR = 0.9, 95% CI = 0.8–1.0 for NSL). Presence of FOF tripled and NL-NSL doubled the risk of incident falls during the 24-month follow-up period (OR = 3.1, 95% CI = 1.3–7.3 for FOF; OR = 2.3, 95% CI = 1.1–5.6 for NL-NSL). The interaction between FOF and NL-NSL was not statistically significant. However, when we analyzed the participants without a history of falls within past 12 months separately (Table 5), NSL decreased the future risk of falls (OR = 0.9, 95% CI = 0.8–1.0) and the NL-NSL group were at about three times higher future risk of falls (OR = 3.3, 95% CI = 1.1–12.1). However, FOF score and the presence of FOF did not significantly increase the future risk of falls (OR = 1.5, 95% CI = 0.9-2.4 for FOF score; OR = 2.6, 95% CI = 0.6–9.0 for the presence of FOF).

Ⅳ. Discussion

This study demonstrated that FOF and NL−NSL independently increased the future risk of falls in healthy older adults. However, only NL−NSL increased the future risk of falls in those without a previous history of falls.

In most previous studies, but not all,[12,13] FOF increased future risk of falls in older adults.[5,7−10] In healthy older adults, FOF increased the risk of falls within 12 ~ 20 months by 2 ~ 4 times.[5,7−11] FOF may reflect physical changes associated with falls. FOF was associated with the abnormal balance, altered postural control, and changed gait patterns.[14] With the increase of FOF, gait showed more cautious adjustments[15] such as higher stride time variability,[45,46] lower gait speed, shorter stride length, and longer double support time.[21] These patterns of gait are quite similar to those of higher−level gait disorder which is a well−known high risk condition of falls.[14] In the current study, the participants with FOF might have also walked more cautiously than those without FOF because they showed the smaller medio−lateral displacement of CoM than the participants without FOF. However, all gait variables except medio−lateral displacement of CoM were comparable between the participants with FOF and those without FOF. This discrepant result may be, at least in part, attributable to the difference in the severity of FOF between study samples.

FOF does not only reflect physical changes associated with balance and gait. According to a previous path analysis on older adults with hip/pelvic factures, FOF was directly associated with fall−related post−traumatic stress symptoms and indirectly with psychological inflexibility.[39] Although fall−related post−traumatic stress symptoms may increase future risk of falls in the long run by increasing frailty due to low social activities.[8,47,48] the association of FOF with future risk of falls disappeared when the fall experiences within the past 12 months were adjusted in non−demented older adults.[11] In line with this study, FOF did not influence the future risk of falls and mean survival to falls in the participants without a previous history of falls in the current study. In the current study, about a half of the participants with FOF did not have a history of falls within the past year. FOF in the individuals without a previous history of falls may be more likely to be attributable to recognition of postural instability and/or gait difficulty (PIGD) than that in the individuals

According to Allali et al., FOF increased the risk of fall by 71% in older adults with PIGD but not in those without PIGD.[11]

Postural instability and slow gait were commonly associated with short step length. [49-52] Step length can be shortened when dorsiflexion of feet is reduced at the heel strike and swing phases[53] and/or reduced push-off power at the late stance phase[53,54] due to weakening of lower limb muscles. Higher maximum and mean step length were associated with lower risk of falls In community-dwelling older adults[22,23] short step length of 47.2 cm or below quadrupled the future risk of falls in the patients with chronic kidney disease.[24] However, step length should be normalized by height or leg length for inter-individual comparisons because inter-individual differences in height or leg length can lead to inter-individual differences in spatiotemporal gait features.[44,55,56] For example, taller people are more likely to have longer step length.[44,56] In the current study, NL-NSL (26.3 ~ 39.0) more than doubled the risk of future falls in all participants and more than tripled the risk of future falls in the participants without a history of falls in the past year. In the current study, the height and step length of the participants with NL-NSL ranged widely from 144.0 ~ 180.0 cm and 43.2 ~ 69.4 cm, respectively.

There are several limitations to be noted. First, the interaction between FOF and NL-NSL was not statistically significant in the current study. However, whether the relationship between FOF and NL-NSL is additive or multiplicative needs to be further investigation with well-powered samples. Second, the current study ascertained the presence of FOF using a single-item question. However, the effect of FOF on the risk of falls may be different by how FOF was evaluated. Third, the current study enrolled healthy older adults only. The effects of FOF and NL−NSL may be different quantitatively and/or qualitatively in those with medical conditions that may influence gait or balance. Fourth, the current study extensively controlled the effects of potential confounders including age, gender, BMI, and arm length. However, other factors that were not controlled in the current study might have confounded the results.

Despite these limitations, this study demonstrated conclusively that older adults at risk of falls could be identified using a simple question on FOF and step length obtained from a wearable triaxial accelerometer, even if precise information on prior fall experience is unavailable.

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Table 1. Characteristics of all participants

	Fear of falling				Normalized step length			
	Absent (n = 274)	Present* (n = 32)	F or X^2	p	Long (n = 102)	Not long† (n = 204)	F or X^2	p
Age (years)	72.2 (5.0)	71.8 (4.5)	0.509	0.612	71.0 (3.7)	72.8 (5.4)	− 3.075	0.002
Sex (men)	156 (56.9)	9 (28.1)	8.447	0.004	54 (52.9)	111 (54.4)	0.015	0.903
Education (years)	13.3 (4.1)	12.8 (3.3)	0.662	0.508	13.5 (3.8)	13.2 (4.1)	0.653	0.514
MMSE (points)	27.9 (2.1)	28.0 (1.7)	− 0.221	0.825	28.2 (1.6)	27.8 (2.2)	1.588	0.113
Height (cm)	161.7 (8.4)	159.1 (7.8)	1.689	0.092	160.5 (8.6)	161.9 (8.2)	− 1.405	0.161
Weight (kg)	63.2 (8.8)	60.4 (9.2)	1.646	0.101	60.8 (8.7)	63.9 (8.7)	− 2.958	0.003
Body mass index (kg/㎡)	24.1 (2.5)	23.8 (2.7)	0.572	0.568	23.6 (2.5)	24.3 (2.5)	− 2.651	0.008
Arm length (cm)	55.8 (3.8)	54.6 (3.2)	1.797	0.073	55.2 (3.9)	55.9 (3.7)	− 1.485	0.139
Leg length (cm)	86.1 (5.6)	83.8 (5.6)	2.171	0.031	85.5 (5.5)	86.0 (5.7)	− 0.763	0.446
Gait speed (cm/sec)	115.4 (16.7)	114.6 (18.3)	0.263	0.792	129.4 (11.5)	108.3 (14.5)	12.823	<0.001
Gait cadence (steps/min)	114.2 (9.8)	116.6 (10.3)	− 1.343	0.180	118 (8.8)	112.6 (9.8)	4.635	<0.001
Step time variability (%)	3.2 (0.9)	3.1 (0.9)	0.593	0.553	3.0 (0.8)	3.3 (0.9)	− 3.354	<0.001
Step time asymmetry index (%)	3.4 (2.9)	4.1 (3.2)	− 1.326	0.186	3.1 (2.6)	3.6 (3.1)	− 1.599	0.111
Vertical height displacement (cm)	3.4 (0.7)	3.2 (0.6)	1.680	0.094	4.1 (0.6)	3.0 (0.5)	15.547	<0.001
Medio−lateral displacement (cm)	2.3 (0.7)	2.1 (0.6)	1.789	0.075	2.3 (0.7)	2.3 (0.7)	0.721	0.472

Normalized step length	37.4 (3.6)	37.1 (3.9)	0.527	0.599	41.3 (2.0)	35.4 (2.6)	19.970	<0.001
Fallers								
Within 12 months before assessment	43 (15.7)	15 (46.9)	16.163	<0.001	18 (17.6)	40 (19.6)	0.066	0.797
Within 24 months after assessment	35 (12.8)	11 (34.4)	8.845	0.003	9 (8.8)	37 (18.1)	3.918	0.048

SD, standard deviation; MMSE, Mini-Mental State Examination

Continuous variables are presented as mean (standard deviation) and categorical variables as number (%). Continuous and categorical variables were compared using Student's t tests and chi square tests, respectively.

*Scored 3 or 4 on a single-item 4-point Likert scale on fear of falling

† The lowest and middle tertiles of normalized step length (≤39.1)

Table 2. Characteristics of the participants without a previous history of falls within the past 12 months

	Fear of falling				Normalized step length			
	Absent (n = 231)	Present* (n = 17)	F or X^2	p	Long (n = 84)	Not long† (n = 164)	F or X^2	p
Age (years)	72.0 (4.9)	72.5 (4.9)	−0.456	0.649	710 (3.7)	72.5 (5.3)	−2.409	0.017
Sex (men)	136 (58.9)	4 (23.5)	6.673	0.010	48 (57.1)	92 (56.1)	<0.001	0.983
Education (years)	13.3 (4.2)	13.2 (3.1)	0.165	0.869	13.5 (3.9)	13.3 (4.2)	0.423	0.673
MMSE (points)	27.9 (2.1)	28.2 (1.5)	−0.550	0.583	28.1 (1.7)	27.8 (2.3)	1.079	0.282
Height (cm)	161.9 (8.4)	158.2 (7.5)	1.776	0.077	161.0 (8.9)	162.0 (8.2)	−0.879	0.380
Weight (kg)	63.4 (8.9)	59.4 (9.9)	1.790	0.075	61.2 (8.8)	64.1 (9.0)	−2.420	0.016
Body mass index (kg/㎡)	24.1 (2.5)	23.7 (3.2)	0.671	0.503	23.6 (2.5)	24.4 (2.5)	−2.372	0.018
Arm length (cm)	56.1 (3.9)	54.4 (3.5)	1.815	0.071	55.4 (4.1)	56.3 (3.7)	−1.748	0.082
Leg length (cm)	86.3 (5.7)	84.6 (5.5)	1.177	0.240	85.9 (5.6)	86.3 (5.8)	−0.593	0.554
Gait speed (cm/sec)	115.7 (16.9)	110.7 (18.3)	1.153	0.250	129.0 (11.7)	108.3 (14.9)	11.140	<0.001
Gait cadence (steps/min)	114.0 (9.7)	113.0 (10.0)	0.380	0.704	117.2 (8.5)	112.2 (9.9)	3.945	<0.001
Step time variability (%)	3.2 (0.9)	3.4 (0.9)	−0.805	0.422	3.0 (0.8)	3.3 (0.9)	−2.940	0.004
Step time asymmetry index (%)	3.3 (2.9)	4.5 (2.8)	−1.687	0.093	3.0 (2.6)	3.6 (3.0)	−1.596	0.112
Vertical height displacement (cm)	3.4 (0.7)	3.2 (0.6)	1.416	0.158	4.1 (0.6)	3.0 (0.5)	13.937	<0.001

Medio-lateral displacement (cm)	2.4 (0.7)	2.0 (0.6)	2.228	**0.027**	2.4 (0.8)	2.3 (0.7)	0.415	0.679
Normalized step length	37.5 (3.6)	37.2 (3.8)	0.282	0.778	41.3 (2.0)	35.5 (2.6)	17.913	**<0.001**
Fallers within 24 months after assessment	21 (9.1)	4 (23.5)	2.223	0.136	4 (4.8)	21 (12.8)	3.127	0.077

SD, standard deviation; MMSE, Mini-Mental State Examination

Continuous variables are presented as mean (standard deviation) and categorical variables as number (%). Continuous and categorical variables were compared using Student's t tests and chi square tests, respectively.

[*]Scored 3 or 4 on a single-item 4-point Likert scale on fear of falling

[†]The lowest and middle tertiles of normalized step length (≤39.1)

Table 3. Correlations of fear of falling score and normalized step length with gait parameters*

	Fear of falling score		Normalized step length	
	r	p	r	p
Gait speed (cm/sec)	−0.038	0.504	0.823	<0.001
Gait cadence (steps/min)	0.087	0.129	0.435	<0.001
Step time variability (%)	0.007	0.897	−0.276	<0.001
Step time asymmetry index (%)	0.010	0.864	−0.150	0.009
Vertical height displacement (cm)	−0.100	0.081	0.791	<0.001
Medio−lateral displacement (cm)	−0.138	0.016	0.075	0.192

*Pearson' s correlation analysis

Table 4. Effects of fear of falling and normalized step length on the risk of falls in the 24−month follow−up period in all participants

	Model 1*		Model 2*		Model 3*	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Continuous variables						
FOF score**	**1.7 (1.1−2.4)**	**0.007**	**1.7 (1.1−2.4)**	**0.010**	0.6 (0−19.1)	0.731
NSL	−		**0.9 (0.8−1.0)**	**0.022**	0.8 (0.7−1)	0.093
FOF*NSL	−		−		1 (0.9−1.1)	0.522
McFadden's R^2_{Adj}	0.070 (0.023)		0.090 (0.036)		0.092 (0.030)	
Log likelihood	−120.50		−117.81†		−117.61‡	
Categorical variables						
FOF (+)††	**3.3 (1.4−7.7)**	**0.006**	**3.1 (1.3−7.3)**	**0.010**	1.3 (0.1−9.2)	0.818
NL−NSL	−	−	**2.3 (1.1−5.6)**	**0.042**	2.0 (0.9−5.1)	0.118
FOF (+)*NL−NSL	−	−	−	−	2.9 (0.3−65.4)	0.393
McFadden's R^2_{Adj}	0.069 (0.023)		0.087 (0.033)		0.09 (0.028)	
Log likelihood	−120.56		−118.27§		−117.85¶	

FOF, fear of falling; NSL, normalized step length; NL−NSL, not long NSL; NA, not applicable

*Stepwise binary logistic regression analysis adjusted for age, sex, body mass index and arm length as covariates

†p = 0.020 compared to the Model 1

‡ $p = 0.055$ compared to the Model 1 and $p = 0.527$ compared to the Model 2

§ $p = 0.006$ compared to the Model 1

¶ $p = 0.067$ compared to the Model 1 and $p = 0.363$ compared to the Model 2

** A single−item 4−point Likert scale score on fear of falling

†† Scored 3 or 4 on a single−item 4−point Likert scale on fear of falling

Table 5. Effects of fear of falling and normalized step length on the risk of falls in the 24−month follow−up period in the participants without a previous history of falls within the past 12 months

	Model 1*		Model 2*		Model 3*	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Continuous variables						
FOF score**	1.5 (0.9−2.4)	0.117	1.5 (0.9−2.4)	0.132	0.1 (0−9.6)	0.365
NSL	−		**0.9 (0.8−1.0)**	**0.03**	**0.8 (0.6−1)**	**0.04**
FOF*NSL	−		−		1.1 (1−1.2)	0.273
McFadden's R^2_{Adj}	0.041 (−0.033)		0.072 (−0.015)		0.079 (−0.019)	
Log likelihood	−77.71		−75.25§		−74.63¶	
Categorical variables						
FOF (+)††	2.5(0.6−8.5)	0.150	2.6(0.6−9.0)	0.158	NA	0.988
NL−NSL			**3.3(1.1−12.1)**	**0.043**	2.6(0.9−9.7)	0.105
FOF (+)*NL−NSL					NA	0.987
McFadden's R^2_{Adj}	0.039(−0.035)		0.069 (−0.017)		0.080 (−0.019)	
Log likelihood	−77.92941		−75.46322§		−74.58174¶	

FOF, fear of falling; NSL, normalized step length; NL−NSL, not long NSL; NA, not applicable

*Stepwise binary logistic regression analysis adjusted for age, sex, body mass index and arm length as covariates

†p = 0.027 compared to the Model 1

[‡]p = 0.046 compared to the Model 1 and p = 0.266 compared to the Model 2

[§]p = 0.006 compared to the Model 1

[¶]p = 0.067 compared to the Model 1 and p = 0.363 compared to the Model 2

[**]A single−item 4−point Likert scale score on fear of falling

[††]Scored 3 or 4 on a single−item 4−point Likert scale on fear of falling

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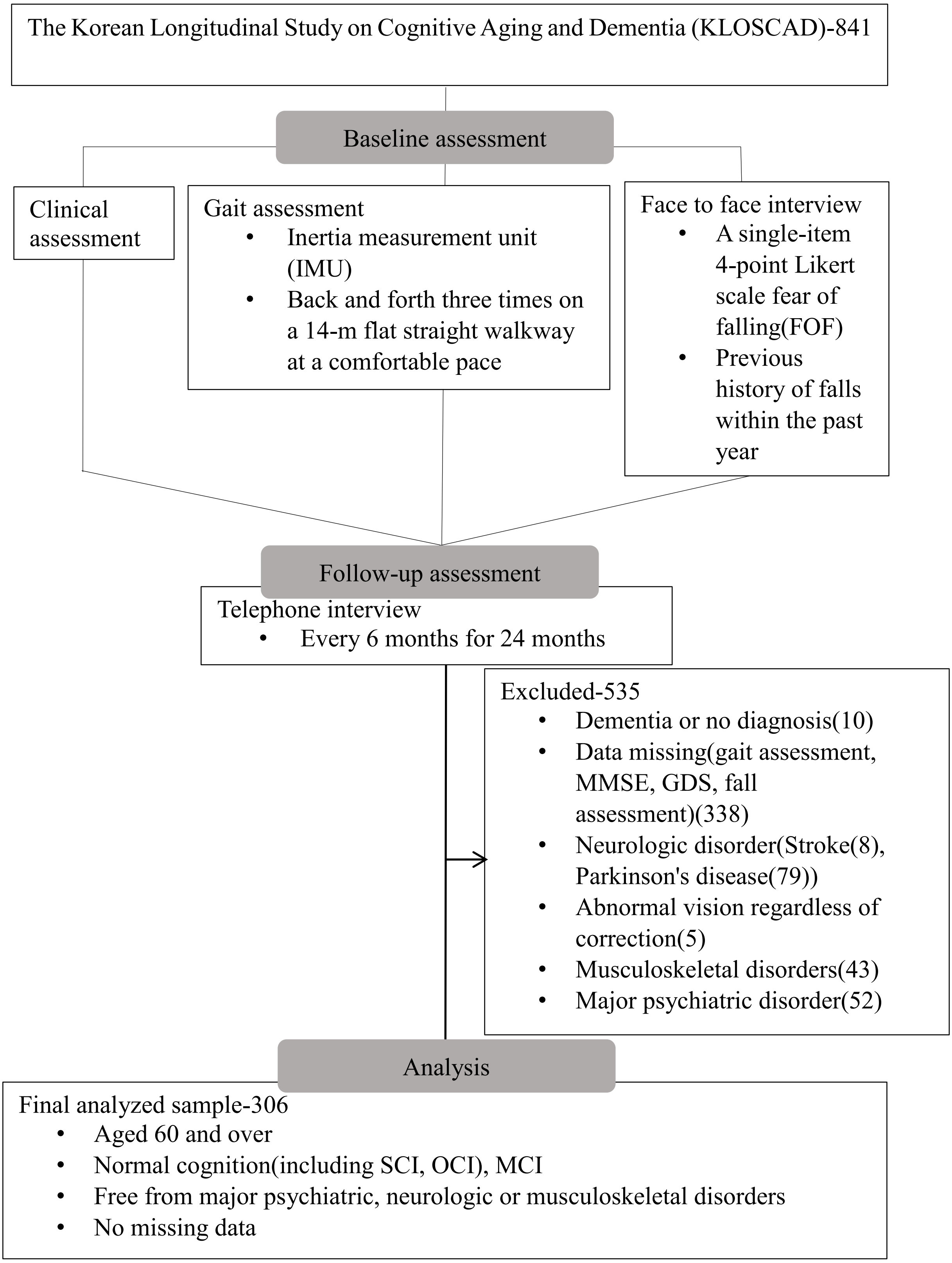

Figure 1. Flow chart of study

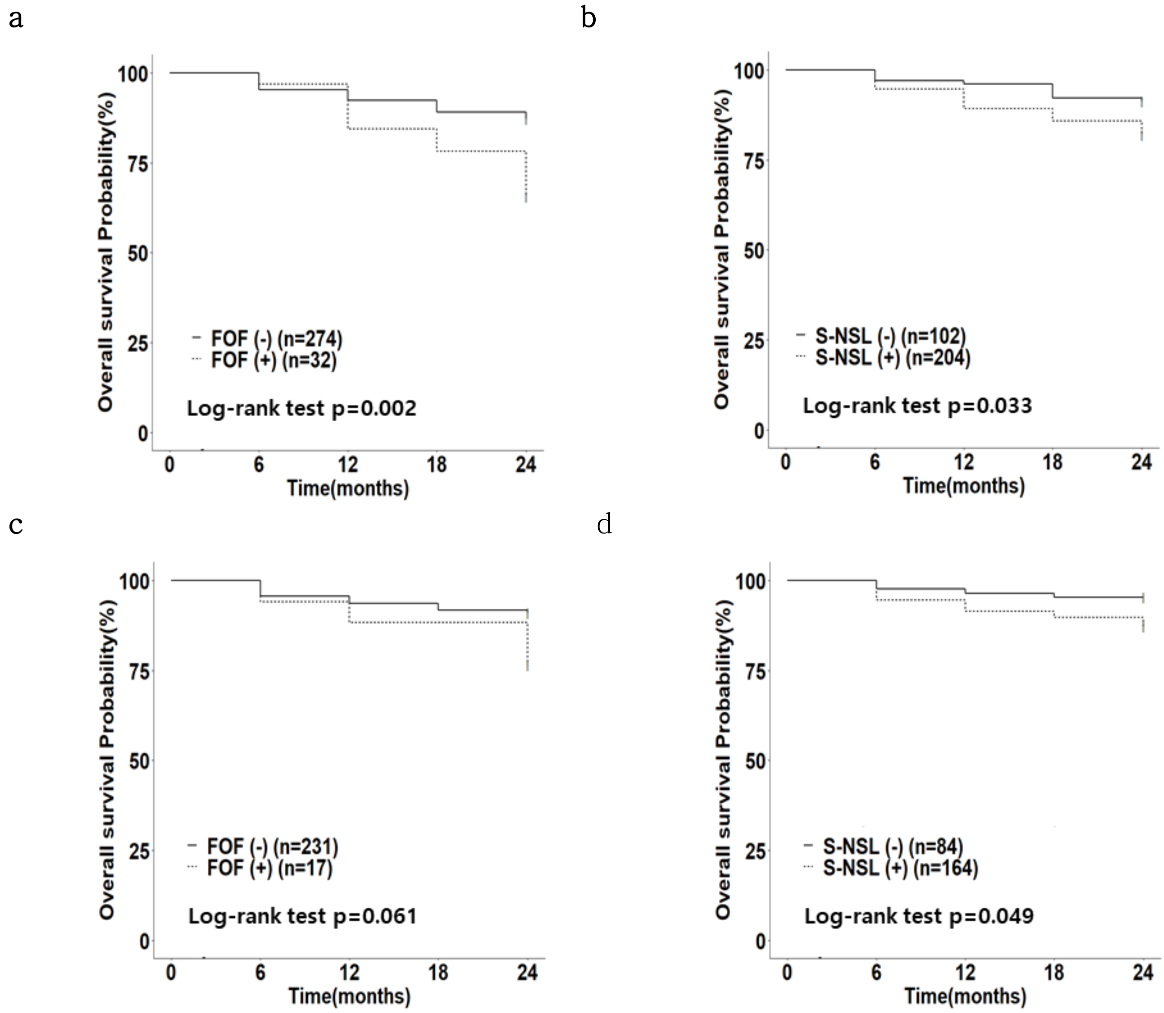

Figure 2. Kaplan–Meier estimates of survival functions describing time to an incident fall during the 24–month follow–up period

a. For the group with FOF and the group without FOF in all participants; b. For the group with NL–NSL and the group without NL–NSL in all participants; c. For the group with FOF and the group without FOF in the participants without a history of falls within past 12 months; d. For the group with NL–NSL and the group without NL–NSL in in the participants without a history of falls within past 12 months

FOF, presence of fear of falling; NL–NSL, not long normalized step length

국문 초록

이 연구는 낙상 두려움과 짧은 정규화 보폭이 노인들의 미래 낙상 위험에 미치는 영향을 확인할 목적으로 수행되었다. 연구에는 지역사회에 거주하는 60세 이상의 비치매 노인 306명이 참여했다. FOF는 4점 리커트 척도를 사용하여 평가했다. 정규화 보폭은 보폭을 3축 가속도계를 이용해 추정하고, 이를 다시 키로 나누어 얻었다. 1삼분위와 2삼분위 정규화 보폭을 짧은 정규화 보폭으로 정의했다. 2년간의 추적 관찰 기간 동안 낙상두려움은 3배(OR = 3.1, 95% CI = 1.3 – 7.3), 짧은 정규화 보폭은 2배 이상(OR = 2.3, 95% CI = 1.1 – 5.6) 미래 낙상 위험을 증가시키는 것으로 나타났다. 과거 1년 내 낙상 경험이 없는 참가자들만을 대상으로 분석했을 땐, 짧은 정규화 보폭만이 미래 낙상의 위험을 증가시켰다(OR = 3.3, 95% CI = 1.1 – 12.1). 과거 낙상 경험에 대한 정확한 정보가 없더라도, 3축 가속도계에서 얻은 정규화 보폭과 FOF에 대한 간단한 질문을 사용하여 미래 낙상 위험이 있는 노인들을 식별할 수 있다.

주요어: 낙상 두려움, 정규화 보폭, 낙상 예측, 노인

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