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ORIGINAL ARTICLE

Gait characteristics in older women with osteoporosis and fear of falling

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Abstract
Ageing affects gait characteristics during walking under single- and dual-task conditions. Osteoporosis in elderly with fear of falling may further implicate gait alterations. The aims were to characterize spatiotemporal gait parameters, by comparing gait performance at comfortable speed to gait at maximal speed and while performing a dual task, respectively, and to investigate the relationship between gait characteristics and ageing in older women with osteoporosis and self-reported fear of falling. Seventy-nine elderly women (mean age 76 years, range 65–87), with osteoporosis and fear of falling, walked at comfortable and maximal speed and during a cognitive dual task, using the GAITRite® walkway system. Subjects were divided into three age groups (65–69, 70–79, 80 + years). Divergences were analysed with analysis of variance. At maximal gait speed participants increased velocity, cadence, step length and swing phase, and reduced both double support and stance phase ($p < 0.001$). Dual-task walking decreased cadence ($p < 0.001$), increased step width ($p = 0.007$) and step length variability ($p < 0.001$). Gait performance, especially during a dual task diverged most in the oldest subjects, indicating that they are at a higher risk of falling. This study only found minute alterations compared with normative gait data in healthy elderly.

Key words: *Aging, geriatrics, rehabilitation*

Introduction

Alterations of spatiotemporal gait characteristics are linked to disability and ageing, and the importance of specific gait parameters on health outcomes and risk of falling has become more acknowledged (1–3). In particular, gait velocity has been found to identify elderly persons with lower functional levels and decreased physiological margins (1), and to predict risks of adverse health outcomes (2). Moreover, stride to stride fluctuations, or gait variability, have been associated with increased risk of falling (3) and frailty (1).

Elderly have been shown to walk at a slower speed and with shorter steps compared with younger counterparts (4), and when adding a cognitive dual task, gait speed and step length is further decreased whereas the gait variability is increased (5). Gait alterations when walking with an added task (i.e. dual task), has been associated with an increased risk of falling (6).

Fear of falling, described as "a loss of self efficacy to perform certain activities without falling" (7), occurs in up to 85% of elderly people, with higher prevalence amongst women and increases with age (8). Fear of falling has been associated with altered spatiotemporal gait characteristics (9), increased risk of falling (10) and severe osteoporosis (11). Considering the increased risk of fractures amongst elderly persons with osteoporosis, fear of falling in combination with osteoporosis may affect spatiotemporal gait characteristics.

Osteoporosis occurs in approximately 300,000 Swedish women aged 50–89 years, and the prevalence increases with age (12). The risk of suffering from a fracture due to osteoporosis has increased two to three times since the 1950s in Scandinavia.

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Impaired gait is considered a key risk factor of falling (13) and functional performance have been found to be reduced in individuals with low bone mineral density (14). However, it remains unclear how gait is affected by osteoporosis due to the ambiguity of the results of the few studies presented in this area (15,16).

The primary aim of this study was to characterize spatiotemporal gait parameters in older individuals with osteoporosis and self-reported fear of falling, by comparing performance of gait at comfortable speed to gait at maximal speed and gait with and without the performance of a dual task. A secondary aim was to investigate the relationship between gait characteristics (velocity and step length) and age, fear of falling, health-related quality of life (HRQL) and physical activity level, in each gait condition.

Methods

Baseline data from 79 community-dwelling older women, with osteoporosis and a reported fear of falling, that participated in an ongoing study regarding balance training (the BETA study, NTC01417598) were used in this study. The subjects were recruited through the endocrinology clinic at Karolinska University Hospital, through advertisements in the Swedish Osteoporosis Society's newsletter and in local newspapers. Inclusion criteria were ≥65 years and diagnosed osteoporosis, verified via dual X-ray absorptiometry, according to WHO (17), in the hip or lumbar spine. Moreover, subjects were required to be independently ambulatory indoors and reported a present fear of falling (obtained through answering yes to the question "are you afraid of falling?"). Exclusion criteria were Mini Mental State Examination score ≤24, and respiratory, cardiovascular, musculoskeletal or neurological disorders that might interfere with participation in a training regime (due to the fact that this study was part of a larger project, where all subjects were randomized into a training regime). Demographics regarding age, body constitution and fear of falling are presented in Table I. The present study was approved by the local ethics committee (2009/819-32) in Stockholm and all subjects gave their written informed consent.

To investigate how specific gait parameters were affected within and between different age groups, the subjects were divided into three age groups: 65–69 years, 70–79 years and 80 + years (similarly to Hollman et al. (18) and Chui & Lusardi (19)). Gait parameters were obtained using an electronic walkway with embedded pressure sensors (GAITRite®, CIR Systems Inc., Clifton, NJ). This walkway is connected to a computer with a software programme for analysis of the gait parameters. Several studies have shown the GAITRite® system to be a valid and reliable tool for measurements of spatiotemporal gait parameters (20).

The participants walked upon the walkway system six times per gait condition and a mean was calculated for each condition. Prior to the test session, all participants performed test trials until they were adequately acquainted with the gait conditions.

Performance of the gait conditions were investigated in the following order:

1. Single-task walking at comfortable speed, subjects were instructed walk at their comfortable speed
2. Single-task walking at maximal speed, subjects was instructed to walk as fast as possible.
3. Dual-task walking at comfortable speed, subjects was instructed to walk at comfortable speed while reciting every second letter of the Swedish alphabet. Following a standardized protocol, and prior to each walk, the subjects received a randomized letter to start with and were instructed to pay equal attention to both tasks.

Nine parameters of gait were obtained and included in this analysis: (1) velocity (m/s), (2) cadence (steps/min), (3) step length (cm), (4) step width (i.e. heel to heel distance in cm), (5) swing phase (in percentage of the gait cycle, % GC), (6) stance phase (% GC), (7) double support time (% GC), (8) step length variability (mean standard deviations of the step length), and (9) step width variability (mean standard deviations of step width).

Table I. Subject characteristics: age (years), height (cm), body mass index (BMI; kg/m^2) and Falls Efficacy Scale – International (FES-I) score.

	Age		Height		BMI		FES-I	
Subjects	Mean	Range	Mean	Range	Mean	Range	Mean	Range
All ($n = 79$)	76	65–87	162	141–173	25	16–35	28	19–46
65–69 ($n = 13$)	68	65–69	160	141–173	27	17–35	29	20–44
70–79 ($n = 43$)	74	70–79	163	150–171	25	17–31	27	19–46
80+ ($n = 23$)	83	80–87	160	151–173	25	16–35	28	22–42

Each walk started 2 m in front of the 7.30-m-long walkway (active sensor area of 6.71 m), and ended 3 m behind it, to limit the risk of gait parameters being affected by acceleration or deceleration in gait speed. In addition to assessing gait, subjects also underwent testing of fear of falling, HRQL and physical activity level.

The Falls Efficacy Scale – International (FES-I) was used to assess subjects' concern about fear of falling. FES-I is a rating scale that consists of 16 items, regarding a variety of activities of daily living, e.g. getting dressed, taking a shower, climbing stairs or going to the shop. Subjects rate their concern of falling during these activities on a 4-point scale, ranging from 1 (not at all concerned) to 4 (very concerned), with a total score ranging from 16 to 64 (21). The FES-I has been found to be reliable in elderly with and without osteoporosis (22).

For assessment of HRQL, the Short Form 36 Health Survey (SF-36) was used. The SF-36 is a generic health survey consisting of 36 questions (ordinal scale), ranging from 0 to100. The physical component score reflects health in areas such as physical functioning, role limitations due to physical problems, bodily pain and general health. The physical functioning scale is an index that reflects self-care, mobility, and other physical and body movements of physical functioning. The SF-36 has been found to be valid and reliable for a general Swedish population (23).

Level of physical activity was estimated according to the Frändin–Grimby scale, a graded scale ranging from 1 (sedentary) to 6 (hard or very hard exercise, regularly, several times a week, where physical exertion is great, such as jogging or skiing) (24).

Statistical analyses were performed using STATISTICA (Version 10, Statsoft Inc., Tulsa, OK). Repeated measurement analysis of variance (ANOVA) was used to compare the gait conditions (comfortable speed, maximal speed and dual task). The significance level was set at $p < 0.01$ to adjust for multiple ANOVAs. When significant main effects were found, Tukey's range test was used for *post hoc* analysis between gait conditions, whereas the unequal *N post hoc* test was used for between group comparisons. The Pearson product moment correlation (r) and the coefficient of determination (R^2) were used to investigate the relationship between gait conditions and age, FES-I and SF-36, whereas the Spearman product moment correlation (r_s) was used to investigate the relationship between the same gait characteristics and level of physical activity, in each gait condition. The strength of r_s was classified according to Munro (25): 0.00–0.25, little if any; 0.26–0.49, low; 0.50–0.69, moderate; 0.70–0.89, high and 0.90–1.00, very high correlation.

Results

Results showed that older individuals with osteoporosis and fear of falling were able to significantly ($p < 0.001$) increase their gait speed with 0.33 m/s from walking at comfortable to maximal speed (i.e. increased cadence, step length and swing phase duration; decreased duration in double support and stance phase, Table II). When walking with a dual task, significant main effects showed that the step width increased ($F(2, 156) = 4.85$, $p = 0.009$), together with the step length variability ($F(2, 156) = 29.70$, $p < 0.001$), whereas the cadence decreased ($F(2, 156) = 77.41$, $p < 0.001$) compared with single-task walking.

Dividing the data into three different age groups and exploring divergences within and between groups showed a significant main effect ($p = 0.006$) in groups at maximal speed, indicating that the 80+ group walked with shorter steps than both the 65–69 ($p = 0.041$) and the 70–79 ($p = 0.033$) years groups. Moreover, the oldest age group showed tendencies to walk slower than the two younger groups at maximal gait speed, 0.23 m/s slower than age 65–69 and 0.18 m/s than the 70–79 years group. ($p = 0.017$). However, there were no between group divergences regarding the performance of the cognitive task ($F(2, 76) = 0.442$, p = 0.644).

Between-age group comparisons of the velocity during dual-task walking showed a significant main effect ($p = 0.002$), indicating that the 80+ group walked slower than both the 65–69 ($p = 0.012$) and the 70–79 ($p = 0.024$) years groups, as shown in Figure 1. During dual-task walking, compared with single-task, the only parameter affected in the 60–69 years group was increased step length variability, whereas both step width and step length variability was increased in the 70–79 years group, and the 80+ years group showed decreased velocity and cadence as well as increased variability of step length and step width. We also found an indication ($p = 0.012$) that the oldest group walked with shorter steps when performing a dual task. Investigating the effects of age on gait velocity and step length suggested that older age was related both to a decrease of gait speed ($r = -0.44$) and step length ($r = -0.38$).

The mean FES-I score in the current study was 28 (range 19–46) (Table I). Regarding SF-36, the mean physical component score was 38.7 (range 18.4–58.2), and the mean score of the physical functioning scale was 62.7 (range 15–95). The Frändin–Grimby scale showed a median of 3 (low to moderate leisure activity level), ranging from 1 to 5. The correlations between gait characteristics (velocity and step length) and FES-I, SF-36 and Frändin–Grimby scale in the three gait

Table II. Temporal and spatial characteristics during three gait conditions (at comfortable and maximal speed, and walking with a dual task), in all subjects and after subdivision into different age groups.

		Comfortable			Maximal			Dual task			% change comfortable vs. maximal speed		% change single vs. dual task	
Variable	Age group	Mean	Min–max	SD	Mean	Min–max	SD	Mean	Min–max	SD	%	*p*-value	%	*p*-value
Velocity (m/s)	All ($n = 79$)	1.17	0.70–1.89	0.20	1.50	0.93–2.22	0.28	1.08	0.33–1.77	2.7	+28.2	**0.000**	−17.7	**0.001**
	65–69 ($n = 13$)	1.23	0.97–1.60	0.16	1.60	1.08–2.22	0.28	1.22	0.84–1.77	0.25	+30.1	**0.000**	−10.8	0.974
	70–79 ($n = 43$)	1.21	0.70–1.89	0.23	1.55	0.93–2.01	0.28	1.13	0.49–1.61	0.25	+28.1	**0.000**	−16.6	0.318
	80+ ($n = 23$)	1.08	0.74–1.47	0.21	1.37	0.98–1.81	0.23	0.93	0.33–1.34	0.26	+26.9	**0.000**	−113.9	**0.001**
Cadence (steps/min)	All	114	93–155	11	132	111–167	12	104	31–135	20	+15.8	**0.000**	−18.8	**0.000**
	65–69	116	104–130	8	133	118–154	11	111	83–135	17	+14.9	**0.000**	−14.4	0.236
	70–79	114	93–155	10	133	111–167	13	106	52–135	19	+16.7	**0.000**	−17.0	0.100
	80+	111	93–134	11	130	111–153	10	97	31–134	23	+17.1	**0.000**	−112.6	**0.001**
Step length (cm)	All	61.7	39.6–77.7	8.3	68.1	47–86.7	9.4	62.4	41.0–86.5	9.6	+10.3	**0.000**	+1.2	0.383
	65–69	63.6	48.9–76.5	7.5	71.6	51.9–86.7	9.5	66.2	51.1–79.9	8.9	+12.6	**0.000**	+4.1	0.066
	70–79	62.9	39.6–77.7	8.3	69.7	47.0–84.1	9.1	63.8	41.0–82.1	8.7	+10.8	**0.000**	+1.4	0.506
	80+	58.3	45.6–71.0	8.0	63.0	50.1–78.1	8.3	57.6	42.9–86.5	10.2	+8.1	**0.000**	−11.2	0.782
Step width (cm)	All	7.9	1.5–15.3	3.1	8.1	1.1–16.9	3	8.6	1.5–21.7	3.9	+2.4	0.677	+9.0	**0.007**
	65–69	7.1	1.5–15.3	3.5	6.9	1.1–15.0	3.2	7.5	2.9–18.3	3.8	−12.8	0.222	+5.6	0.222
	70–79	7.7	2.3–13.5	2.9	8.2	2.3–16.9	2.9	8.8	1.5–21.7	4.0	+6.5	0.346	+14.3	**0.005**
	80+	8.7	3.7–13.7	3.1	8.6	2.4–13.9	3.0	8.8	2.2–14.5	3.8	−11.1	0.838	+1.1	0.838
Swing phase (% GC)	All	38.3	34.0–42.7	1.7	39.8	34.5–52.2	2.3	38.4	32.2–42.9	2.1	+4.1	**0.000**	+0.4	0.660
	65–69	38.2	35.0–41.4	1.6	39.9	35.3–44.0	2.0	38.7	35.4–42.9	1.9	+2.8	**0.000**	+0.8	0.169
	70–79	38.3	34.7–42.4	1.8	39.9	36.3–52.2	2.6	38.4	34.5–42.7	1.9	+2.8	**0.000**	+0.3	0.811
	80+	38.3	34.0–41.2	1.9	39.5	34.5–43.2	2.1	38.3	32.2–42.7	2.6	+1.9	**0.002**	0	1.000
Stance phase (% GC)	All	61.8	57.6–66.1	1.7	60.2	50.1–65.6	2.2	61.6	57.1–67.9	2.1	−12.5	**0.000**	−10.3	0.581
	65–69	61.8	58.6–65.0	1.6	60.1	56.1–64.7	2.0	61.3	57.1–64.7	1.9	−14.5	**0.000**	−11.3	0.161
	70–79	61.8	57.6–65.4	1.8	60.1	50.1–63.8	2.3	61.6	57.4–65.5	1.9	−12.6	**0.000**	−10.3	0.877
	80+	61.7	58.7–66.1	1.9	60.5	56.8–65.6	2.1	61.7	57.4–67.9	2.6	−13.1	**0.002**	0	1.000
Double support (% GC)	All	23.7	15.5–32.3	3.4	21.4	12.9–54.6	5.3	23.5	15.1–34.1	2.1	−19.7	**0.000**	−11.0	0.843
	65–69	23.9	17.9–30.2	3.0	20.5	12.9–29.7	4.0	23.1	16.2–29.4	3.4	−114.2	**0.000**	−13.3	0.236
	70–79	23.7	15.5–31.1	3.5	21.8	15.2–54.6	6.1	23.5	15.1–32.5	3.9	−18.0	0.026	−10.8	0.949
	80+	23.6	17.8–32.3	3.7	21.2	13.6–30.9	4.2	23.6	15.6–34.1	5.0	−110.2	**0.001**	0	1.000
Step length variability (cm)	All	2.3	1.4–5.1	0.7	2.4	1.2–6.7	0.8	3.3	0.8–9.0	1.5	+1.7	0.965	+40.9	**0.000**
	65–69	1.9	1.4–2.5	0.4	2.1	1.2–3.0	0.5	2.9	0.8–5.4	1.3	+10.5	0.797	+31.6	**0.004**
	70–79	2.3	1.4–5.1	0.6	2.3	1.4–3.7	0.5	3.2	1.4–7.2	1.6	0	0.966	+39.1	**0.000**
	80+	2.6	1.5– 4.9	0.9	2.7	1.5–6.7	1.1	3.6	1.9–9.0	1.6	+3.8	0.897	+38.5	**0.001**
Step width variability (cm)	All	3.0	1.1–10.6	2.1	2.4	1.1–8.2	1.2	3.5	1.2–14.4	2.6	−119.6	0.093	+15.3	0.231
	65–69	2.2	1.5–4.5	0.8	2.1	1.2–3.9	0.7	3.0	1.7–8.8	1.9	−14.5	0.873	+36.4	0.121
	70–79	3.3	1.2–10.6	2.5	2.4	1.1–7.8	1.2	3.1	1.2–14.4	2.4	−127.3	0.040	−6.1	0.768
	80+	2.8	1.1–8.8	1.8	2.7	1.1–8.2	1.4	4.5	1.8–11.0	3.0	−13.6	0.989	+60.7	0.011

% GC, percentage of gait cycle. Bold type = significantly different from zero at $p < 0.01$.

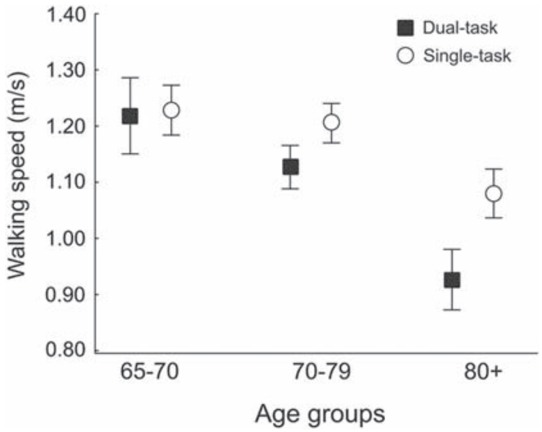

Figure 1. Illustrating the mean and ± standard error of walking speed during single and dual tasks in all age groups. At dual-task walking, a significant main effect ($F(2, 76) = 6.90$, $p = 0.002$), indicated that the 80+ years group walked slower than both the 65–69 ($p = 0.012$) and the 70–79 years ($p = 0.024$) groups.

conditions were low to moderate ($r \leq 0.55$) (Table III). The strongest correlations were found between SF-36 and step length during gait at comfortable ($r = 0.55$) and maximum ($r = 0.54$) speed, indicating interdependency between these variables of 30% ($r^2 = 0.30$).

Discussion

The results of the present study showed that, when instructed to walk at their maximal speed, older women with osteoporosis and fear of falling were able to increase their velocity, cadence, step length and swing phase, with corresponding decrease in double support and stance phase. However, when walking with a cognitive dual task, cadence was decreased, and step width and step length variability were increased compared with single-task walking. The overall gait performance, both between gait conditions and age groups, diverged most in the oldest subjects, and during dual task in particular. Moreover, correlations, although low to moderate, indicated that walking velocity and step length decreased with aging, fear of falling, lower HRQL and level of physical activity.

Dividing the subjects into three age groups, similarly to prior studies (18,19), showed that all groups were able to increase their speed when asked to walk at their maximal speed. Comparisons between the groups showed that the oldest group walked 0.18 m/s slower than the younger groups at maximal speed, which to some extent may be explained by a reduced step length. It has been shown that a gait speed of 1.2 m/s is needed to navigate urban crosswalks (26), a gait speed that the oldest women of this study were unable to achieve when walking at comfortable speed (mean 1.08 m/s). This might indicate challenges for these women in daily life situations.

However, the results of this study showed only minute deviations when compared with the results from studies on age-matched healthy women, during gait at comfortable speed (18,19) and maximal speed (19) in similar (but not identical) age groups. This diverges from previous work, where both subjects with osteoporosis and thoracic kyphosis (15) or with fear of falling (9), have been found to walk slower and with shorter steps than healthy controls. Our results could indicate that gait performance during comfortable and fast walking were age-related, rather than related to osteoporosis and/or fear of falling.

On the other hand, during walking with a dual task, as compared with single-task walking, our subjects showed significantly decreased cadence and increased step width and step length variability. Analysis of the age groups showed larger gait divergences during dual-task walking in the oldest group. To our knowledge, larger studies presenting normative data of gait characteristics during dual-task conditions are lacking, making it difficult to draw definite conclusions regarding the gait performance during this condition.

The fact that step length variability increased in all age groups when adding a cognitive dual task implies that a cognitive task while walking interferes with the normal gait pattern of these subjects. These

Table III. Correlation between the velocity and step length during comfortable walking speed, maximal walking speed and dual-task walking, and fear of falling (FES-I), health-related quality of life (SF-36) and physical activity level (Frändin–Grimby scale) in older women with osteoporosis.

	Velocity (m/s)			Step length (cm)		
Variable	Comfortable speed	Maximal speed	Dual task	Comfortable speed	Maximal speed	Dual task
FES-I	−0.44	−0.39	−0.29	−0.43	−0.41	−0.32
SF-36 (physical component)	0.50	0.45	0.25	0.55	0.54	0.45
SF-36 (physical function)	0.46	0.38	0.24	0.51	0.51	0.44
Frändin–Grimby scale	0.39*	0.39*	0.30*	0.39*	0.39*	0.39*

FES-I, Falls Efficacy Scale – International; SF-36, Short Form 36 Health Survey. *Spearman product moment correlation (r_s).

results, supported by similar results of increased step length variability during dual task in elderly subjects (5) in combination with the fact that the number of gait variables affected during dual task was increased in the older age groups, suggests that old age in combination with osteoporosis and fear of falling affects gait performance when adding a cognitive task. This may be of particular importance in this population, as increased gait variability has been linked to frailty in older persons (1) and to increased risk of falling (3), which in osteoporosis might lead to severe consequences.

According to Delbaere et al. (27) a cut-off score of ≤ 28 on the FES-I represents a high concern of falling. The majority of subjects in this study would be considered to have a high concern for falling. Correlations, although low to moderate, indicated that walking velocity and step length decreased with higher concern of falling. On the other hand, gait performance of the older women in this study was similar to what has been presented in studies in health age-matched subjects without fear of falling (18,19). Prior studies have found decreased gait performance to occur in subjects with fear of falling combined with activity limitations only (28), and in osteoporosis subjects with intense pain and fear of falling (29). Since our subjects, being relatively active and ambulatory individuals, did not report pronounced activity limitations or pain, these findings may raise the question if fear of falling alone is an adequate tool on predicting gait performance. However, future studies needs to investigate this further.

Moreover, increased HRQL and level of physical activity were moderately associated with increased velocity and step length during the gait conditions. Walking speed has earlier been suggested as a powerful indicator of health and disease (30). However, our results showed that only 30% interdependency between these variables, leaving 70% of the variation to other factors. However, our results of a moderate relationship between the physical component score of SF-36 and comfortable gait speed were in accordance with those of Imagama et al. (31).

This study has several limitations. Firstly, the lack of a control group makes it difficult to interpret fully how the results in the current study relate to age-matched subjects without osteoporosis, particularly, while walking with a dual task. Moreover, to evaluate the effects of fear of falling, it might have been valuable to compare our results with results of older persons with osteoporosis without fear of falling. However, considering the character of osteoporosis, it might be that the vast majority of individuals with osteoporosis suffer to some extent from fear of falling. We also acknowledge a limitation in the sample size, especially considering that we are dividing the population into the three age groups. Finally, based on the overall gait performance, the older subjects in this study may be considered relatively healthy older persons. The fact that the subjects of this study would go on to be randomized into an intervention study requiring subjects to be eligible for a time- and energy-consuming balance training regime makes it possible that frailer individuals might have been discouraged from participating.

In conclusion, although the overall results of the gait conditions and age groups suggest that the subjects in the current study were well functioning older women, we also found that the oldest subjects walked with an altered gait pattern under attention demanding circumstances, which has been associated to an increased risk of falling.

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