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Relationships between Middle-Aged and Elderly People's Awareness of Fall-Related Environmental Risks, Mobility, and Cognitive Function

Fujiwara Kazumi[1,2], Matsuda Nobuko[2], Hatta Takeshi[1]

Abstract

In the present study, we created a list of risks associated with living environment and behavior that may cause fall-related accidents; examined the relationships between middle-aged and elderly people's awareness of fall-related environmental risks, mobility, and cognitive function; and analyzed the effect of risk awareness on fall-related accidents. The subjects were 205 community-dwelling peoples (mean age: 62.90 years), including 85 males and 120 females, who had undergone community health checkups in Town Y, Hokkaido. An analysis of the covariance structure was performed to examine the relationships between subject fall-risk awareness, cognitive function, mobility, and number of falls. The results suggested that decreases in subject mobility (standardized coefficient = −0.23, p = 0.020) and cognitive function (standardized coefficient = −0.24, p = 0.003) were associated with improved fall-risk awareness. Risk awareness was also related to the incidence of falls (standardized coefficient = 0.28, $p < 0.001$). In the present study, factors affecting awareness regarding fall-related environmental risks among the middle-aged and elderly peoples were associated with decreased mobility and cognitive functions, suggesting that changes in physical and cognitive functions can be assessed using these factors.

Key Words

fall, environment, fall- risk awareness, analysis of covariance structure

INTRODUCTION

It has been reported that a large number of elderly peoples with a high level of independence require nursing care after fall-related accidents. Fracture type is an important factor associated with a bedridden state, and the incidence of femoral neck fractures has increased among individuals aged 75 years or older, 90% of which are attributed to falls due to stumbling, slipping, and other causes[1)].According to review articles published in Japan and other countries, the causes of falls and risk factors for falls include physical disorders, medication, and decreased muscle strength[2,3)]. Moreover, Luria and Merian suggested that decreased physical strength and function can be considered as part of the disuse syndrome due to problems with the motor system or be attributed to the degenerative changes brain[4)]. The frontal association area of the brain is responsible for the appropriate allocation of required attention. This attention allocation function enables individuals to move their body[5)].It is believed that the ability to walk is influenced by reduction in the attention allocation function[6)]. Previous studies have suggested elderly individuals with a history of fallshave experienced reduction in the attention allocation function[7,8)].Studies on the relationship between the cognitive executive function and lower extremity function also identified fall-related risk factors [9)]. Taken together, these results suggest that it is important to examine the relations between physical function and cognitive abilities for preventing fall-related accidents.

In addition to these considerations, the design of physical environments-in particular, housing-is another external factor important for fall prevention. Falls are the second next most common type of

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accident (after suffocation) that the elderly experience at home[10]. According to a previous study, the incidence of accidents at home, including those inside the house and in the garden, is 57.4% for elderly women[11]. Lord et al suggested that the risk of fall-related accidents at home is related to the interactions between the environment and physical abilities[12].The guidelines on fall prevention published by the Gerontological Society of America and the British Geriatrics Society state that the risks for falls include a history of falls, decreased muscle strength, and difficulty walking and maintaining balance. These guidelines recommend that home environments should be improved for the community-dwelling elderly[13].Furthermore, previous studies have reported the effectiveness of home environment assessment and advice given by health professionals visiting the homes of elderly individuals needing nursing care who had a high fall risk[14,15].Westmead Home Safety Assessment[16]is a living-environment assessment tool developed for rehabilitation staff and other professionals. This tool consists of 72 items to identify fall hazards in individuals'living environment.Previous studies using the tool reported that implementation of the suggested modifications was effective in elderly peoples with Parkinson's diseases, cerebrovascular diseases, and cognitive impairment, who were at a high risk of falls or who fell often[17,18].In Japan, a similar program has been developed to help elderly individuals recognize unsafe areas in their houses and increase the awareness of their home environment[19].

The living environments of independent, community-dwelling elderly who are at risk for fall-related accidents vary between individuals. Therefore, to prevent falls, the elderly should be able to recognize environmental risks and changes in their own physical abilities, maintain and improve their cognitive and other physical functions, and modify their living environment when necessary.Accordingly, the Japanese Orthopedic Association proposed to increase public awareness of locomotive syndrome in 2007 for the early prevention of motor dysfunction[20].The association published a simple self-check tool, the "Seven loco checks," to identify the risks of locomotive syndrome and recommended preventive training. Motor dysfunction can progress to a state requiring nursing care, and using the self-check tool to identify the risks for this condition helps the elderly view themselves as "potential patients."According to the health belief model (HBM) theory, this attitude is a factor that promotes health behaviors[21].To decrease the risk of falling, it is important for elderly peoples to undergo physical checkups and identify risks in their living environment. Although checklists designed to examine the design of home environments are available[22,23],no checklist has been developed to assess the awareness of fall risk in specific environments. In addition, no studies have been conducted to examine the relationships between such checklists, falls, and physical functions.

In this context, the present study aimed to identify fall risk associated with living environments and behaviorin middle-aged and elderly individuals,examined the relationships between the awareness of environmental fall risk,mobility, and cognitive function, and efficacy of the examined factors for preventing falls.

DEFINITIONS ADOPTED IN THE PRESENT STUDY

On the basis of the definition by Lamb et al, a "fall" in the present study refers to "an incident in which the hands and/or knees of a person touch the ground or something at a lower level against his/her will"[24]. The fall-risk awareness is defined as "a person's recognition of fall risk in relation to the environment or his/her behaviors."

METHODS

1. Subjects

The subjects of the present study were community-dwelling peoples who had undergone health checkups conducted in Town Y, Hokkaido, in August 2012. All 248 potential subjects had undergone general health, motor system, and cognitive function examinations; exhibited the ability to walk on their own; and demonstrated a level of visual acuity required to complete questionnaires. Subjects were excludedon the basis of refusal to undergo assessment of cognitive function, mobility, or stabilometry ;failure to complete all required fields of the survey form; or a Mini-Mental State Examination (MMSE, a test for cognitive function) score of 23or less , indicating possible dementia. Among the individuals available for selection, 205 individuals, including 85 males (41.5%) and 120 females (58.5%), were selected for study enrollment. The mean age of the subjects was 62.90years[standard deviation(*SD*) = 9.79], and subject age ranged from 40 to 92 years.

2. Survey items

Survey items included the following: (1) fall-risk awareness questionnaire, (2) fall history, (3) falls self-efficacy, and (4) visual analog scale (VAS) scores to assess pain.

1) Questionnaire

(1) Questionnaire items related to fall-risk awareness were developed so that they could be applied to a wide variety of living environments. The questionnaire consisted of items to assess anxiety about unsafe areas within their houses (i.e., their living environments) and about the ability to move, according to the findings of a survey on fall-related accidents among community residents who had undergone health checkups in Town Y in August 2011[25]. The questionnaire was developed on the basis of Johnson's fall-risk short scale (Home-Screen), the reliability and validity of which have been established[26].The following 12 items related to unsafe areas within and around the home: "small variations in floor level in tatami (grass mat) rooms, including thresholds"; "darkness at floor levelin halls and stairwells"; "slippery floor at the house entrance,kitchen, and other locations"; "edges of carpets,bath mats, or kitchen mats in the walking area"; "cushions and blankets for kotatsu tables in the walking area"; "electrical cords on the floor"; "newspapers and magazines on the floor"; "necessity to use a staircase"; "uneven roads"; "slippery roads on rainy and snowy days"; "bumpy roads"; and "carrying baggage using both hands." Subjects reported fall risk with a four-grade scale: "severe risk" (4 points), "moderate risk" (3 points), "almost no risk" (2 points), and "no risk" (1 point). The range of possible total scores was 12–48 points. Cronbach's alpha coefficient of reliability, which estimates the internal consistency of the data, was 0.90 for the 12 items related to fall-risk awareness. Exploratory factor analysis(principal factor method, varimax rotation, eigenvalue of 1.0 or higher) was conducted to determine the internal validity of the data for these 12 items. The questionnaire had a one-factor structure, and the contribution rate was 67.6%. The total score was 12–48 points.

(2) The definition of a fall (given in Section 2) was provided in the questionnaire. The subjects were questioned about their fall history (i.e., the number of falls they experienced in the past year), and asked to select "0," "1,"or "2 or more."

(3) A definition for fall self-efficacy proposed by Tinetti et al(1990)was used as an index of self-confidence for performing activities of daily activities (ADL) without falling[27]. The questionnaire consisted of items 12 assessed with a four-grade scale:"high self-confidence" (4 points), "moderate self-confidence" (3 points), "almost no self-confidence" (2 points), and "no self-confidence" (1 point). The range of possible total scores was 10–40 points.

(4) The VAS test was used to describe the level of pain subjects experienced in the lower back, legs, and knees. Subjects marked"×" on 10cm lines representing the range of pain: "0" (no pain) to "10" (the most severe pain).

2) Assessment of cognitive functions

The Nagoya University Cognitive Assessment Battery (NU-CAB) was developed to assess the cognitive function of community residents undergoing health checkups[28] and the reliability and

validity of this assessment battery have been established[29-32].The following NU-CAB items were adopted for this analysis:

(1) MMSE was conducted to assess cognitive impairment.

(2) The digit cancellation task (D-CAT) was conducted to assess the speed of information processing and attentional and executive system functions (i.e., the attention allocation function)[33].Subjects were asked to identify three specified numbers from a table of randomly arranged numbers (50 ×12) and cross the identified numbers off as quickly and accurately as possible.

(3) The Stroop test was performed to assess attentional and executive system functions. This test uses two A4-sized sheets: one sheet presents five rows and eight columns of colored circles with a diameter of 2.5 cm (patch patterns) and the other sheet presents colored letters (Gothic, 36points). The circles and letters are printed in four colors, i.e.,red, blue, yellow, and green, in a random arrangement. The colors of the circles and letters do not match the colors expressed by the words. The subjects were asked to state the actual colors printed on the sheets as accurately and quickly as possible. The examiner recorded the response time required to recognize and state the colors and the number of errors.

(4) The verbal fluency test (letter) was used to assess language function. The subjects were asked to name as many common nouns starting with the Hiragana characters “ka” or “shi” as they could. The time limit was 1min, and they were instructed name a word only once. The number of named common nouns was recorded as a score; two or more naming of one common noun were counted as one point.

(5)The Money road map Test developed by Butters, Soeldner, and Fedio, was used to assess spatial cognition[34]. The test examines to pographical spatial orientation to assess mental rotation skills (required to develop psychological images).Subjects were asked to follow2-cm-wide lines that branch randomly at four (preliminary test) or12(main test) points and state whether they would turn left or right at each point. In addition, they were instructed to maintain their posture and not to move the head. The subjects received one point for each correct statement (at each branch point), and the possible total score range was 1–12 points.

3) Stabilometry

Envelopment area was calculated using a G-620 stability meter (Anima) by asking the subjects to gaze at an eye-level target for 60 s.

4) Mobility

The health of the lower limbs was assessed with the 10-m walking test, maximum stride length, and 40-cm step test. The efficacy of these data as a fall-screening method has been established [35].

(1) For the 10-m walking test, subjects were asked to walk along a straight path and the time required to walk 10 m was recorded. An additional 2 m before and 2 m after the course was provided to allow acceleration and deceleration so that the time recorded reflected walking speed alone.

(2) For the maximum stride length, the subjects were asked to stand straight with both feet side by side, take as large a step forward as possible, and bring the lagging foot next to the leading foot. The distance between the start and end positions was recorded.

(3) For the 40-cm step test, subjects were asked to step on a 40-cm-tall stool without using a handrail, stand straight up on the stool with feet side by side, and step forward to descend on the other side of the stool safely. Performance was graded using a three-grade scale: “I had no difficulty”(0 points), “I wobbled when I stepped down off the stool” or“I was barely able to perform the task by putting my hand on the knee” (1 point), and “I could not perform the task at all” (2 points).

5) Grip strength

To assess physical state, the grip strength of each hand was measured once using a grip dynamometer (Yagami DM-100), and the best performance was adopted. For the measurement, subjects were asked to stand straight, place their feet shoulder-width apart, and place the arms by the

sides of the body with them being extended at the elbow.

3. Analysis methods

Fall-risk awareness data were analyzed with a t-test to detect gender differences and with one-way analysis of covariance structure to examine the relationship with the number of falls.A chi-square test was performed to compare differences in 12 items related to fall-risk awareness between groups of subjects who did or did not have a history of falls. To examine the relationships between fall-risk awareness and assessment items, an analysis using Pearson's correlation coefficient was performed. Covariance structural analysis was performed to examine the relationships between fall-risk awareness, cognitive function, mobility, and number of falls. The goodness of fit of the established model was determined using the goodness-of-fit index (GFI) and the adjusted goodness-of-fit index (AGFI). Both of these commonly used indices are believed to not be influenced by the sample size. Root mean squares error of approximation (RMSEA)[36]were calculated from the difference between model and actual distributions.PASW20.0 and Amos20.0 software (SPSS) were used for analyses, and the significance level was set at 5% or lower.

4. Ethical consideration

Prior to analysis, the subjects read a statement that their participation in all examinations must be according to their own free will, that data would be processed concealing identities of individuals, and that measurements would be tabulated only to provide basic data to promote the health of community residents. The present study was conducted with the approval of the Ethics Committee of Kobe University Graduate School of Health Sciences (No.160).

RESULTS

1. Basic attributes of the subjects

The 205 subjects included 85 males (41.5%) and 120 females (58.5%). The total mean age was 62.90 years (SD = 9.79), and the age range was 40–92 years. The mean age for male and female subjects were 65.32 years (SD = 8.92) and 61.19 years (SD = 10.05), respectively.Fifty-nine (28.8%) of the subjects reported they sustained a fall once in the previous year, and 20 (9.8%) that sustained falls twice or more.

2. History of falls and risk awareness

The mean score for fall-risk awareness was 22.99 points (SD = 8.73). The mean scores for male and female subjects were 20.39 points (SD = 8.25) and 24.83 points (SD = 8.62), respectively, with the difference being significant (t =−3.72, p < 0.001). The mean score for fall-risk awareness was 21.56 points (SD = 8.62) for subjects who reported no falls in the previous year, 25.13 points (SD = 7.77) who reported one fall, and 29.20 points (SD= 7.98) who reported twice or more falls. Higher number of falls correlated with greater fall-risk awareness (F = 8.82, p < 0.001). Subjects indicatedthat outdoor locations, including "slippery roads on rainy and snowy days" (63.4%), "bumpy roads (lawn, gravel roads)" (36.1%), and "uneven roads" (34.1%), pose a high or moderate risk. A chi-square test was usedto compare differences in the fall-risk awareness between subjects with and without a history of falls. Analysis revealed that awareness regarding the following 11 items was significantly higher in the group experiencing falls than in the no-fall group: "a small differences in floor level in tatami rooms, including thresholds" (p = 0.023), "darkness at floor level in hall and stairwells" (p = 0.007), "slippery floor at the house entrance, in the kitchen, and in other locations" (p = 0.008), "cushions and blankets for kotatsu tables in the walking area" (p = 0.016), "electrical cords on the floor" (p < 0.001), "newspapers and magazines on the floor" (p = 0.001), "necessity to use a staircase" (p = 0.007), "uneven roads" (p = 0.006), "slippery roads on rainy and snowy days" (p < 0.001), "bumpy roads" (p = 0.016), and "carrying baggage using both hands" (p = 0.022). No significant differences were noted in their awareness of fall riskfor the "edges of carpets and bath or kitchen mats in the walking area."

3. Relationships between fall-risk awareness, falls, mobility, and cognitive function

Correlations between fall-risk awareness and assessment items were analyzed to examine the relationships between awareness, mobility, and cognitive function (Table 1). The correlation between fall-risk awareness and the assessment items was greater for older subjects ($r = 0.23$, $p = 0.001$). Low Stroop test scores ($r = 0.25$, $p < 0.001$) and low grip strength ($r = -0.25$, $p < 0.001$) correlated to higher fall-risk awareness. A moderate negative correlation was observed for falls self-efficacy and the fall-risk awareness ($r = -0.53$, $p < 0.001$). In summary, low self-efficacy concerning fall-related accidents correlated to higher fall-risk awareness. In contrast, no correlation was noted between fall-risk awareness and pain in the lower back, legs, or knees.

Table 1.
Comparison and Correlation between fall-risk awareness and assessment items

		no-fall group (n=146)			one more-fall group (n=59)					
		Mean	±	SD	Mean	±		*p*	*r*	*p*
Risk awareness		21.56	±	8.62	26.51	±	8.01	**		
Age		63.15	±	8.97	62.29	±	11.65	n.s.	0.23	**
D-CAT		171.65	±	38.73	164.94	±	42.11	n.s.	-0.19	**
Money		9.86	±	2.44	10.07	±	2.30	n.s.	-0.16	*
Stroop	(sec)	42.33	±	6.77	43.71	±	17.01	n.s.	0.25	**
Verbal fluency		12.45	±	15.95	12.88	±	4.35	n.s.	-0.10	n.s.
MMSE		28.12	±	1.96	28.24	±	1.88	n.s.	-0.06	n.s.
Stride length	(cm)	118.14	±	14.23	118.10	±	14.24	n.s.	-0.19	**
Walking 10m	(sec)	5.30	±	1.09	5.30	±	0.86	n.s.	0.19	**
ENV AREA	(cm2)	2.96	±	1.87	3.16	±	2.31	n.s.	0.08	n.s.
Grip strengeth	(kg)	32.30	±	10.08	32.34	±	11.43	n.s.	-0.25	**
Falls self-efficacy		37.40	±	4.15	35.49	±	5.07	*	-0.53	**

MMSE: Mini Mental State Examination , ENV AREA: envelopment area
* p < .05 ** p < .01 n.s. : not significant
r: Speaman's rank correlation coefficient

4. Analysis of covariance structure

Factor analyses of the assessment items were performed for the constructs "cognitive functions" and "mobility." Exploratory factor analyses (principal factor method, varimax rotation, eigenvalue of 1.0 or higher) were performed using five subordinate cognitive function tests (MMSE, D-CAT, Stroop test, verbal fluency test, and Money road map Test), to examine "cognitive functions." A one-factor structure was extracted, and the cumulative rate was 36.78%. The results of four examinations, i.e., MMSE, D-CAT, Stroop test and verbal fluency test, were adopted as observation variables, excluding Money road map Test results for which factor loadings were lower than 0.4. To examine "mobility," exploratory factor analyses (principal factor method, varimax rotation, eigenvalue of 1.0 or higher) of maximum stride length and scores from the 10-m walking and 40-cm step tests were performed. A one-factor structure was extracted, and the cumulative rate was 51.78%. Maximum stride length values and scores for the 40-cm step and 10-m walking tests were adopted as observation variables. Furthermore, the hypothetical model "The fall-risk awareness is influenced by cognitive functions and mobility, and related to fall-related accidents" was developed for analysis; the "envelopment area as perceived with the eyes open" and grip strength were also regarded as "mobility" in relation to stabilometry. Paths without significant correlations were excluded to create the final model (Figure 1). In an analysis using the final model, cognitive functions and mobility, as two potential factors, influenced fall-risk awareness, which affected fall history and falls self-efficacy. The analysis results suggested that fall-risk awareness was significantly influenced by both cognitive functions and mobility: decreases in mobility (standardized coefficient = −0.23, $p = 0.020$) and cognitive functions (standardized coefficient =

−0.24, p = 0.003, respectively) increased fall-risk awareness. The level of fall-risk awareness influenced the incidence of falls (standardized coefficient = 0.28, $p < 0.001$). Although fall-related self-efficacy was significantly affected by the level of fall-risk awareness (standardized coefficient = 0.40, $p < 0.001$), it was not influenced by mobility. Age was only related to a decrease in cognitive functions (standardized coefficient = 0.64, $p < 0.001$) and did not affect mobility. The goodness of fit of the model was determined to be appropriate: GFI = 0.944, AGFI = 0.917, RMSEA = 0.044.

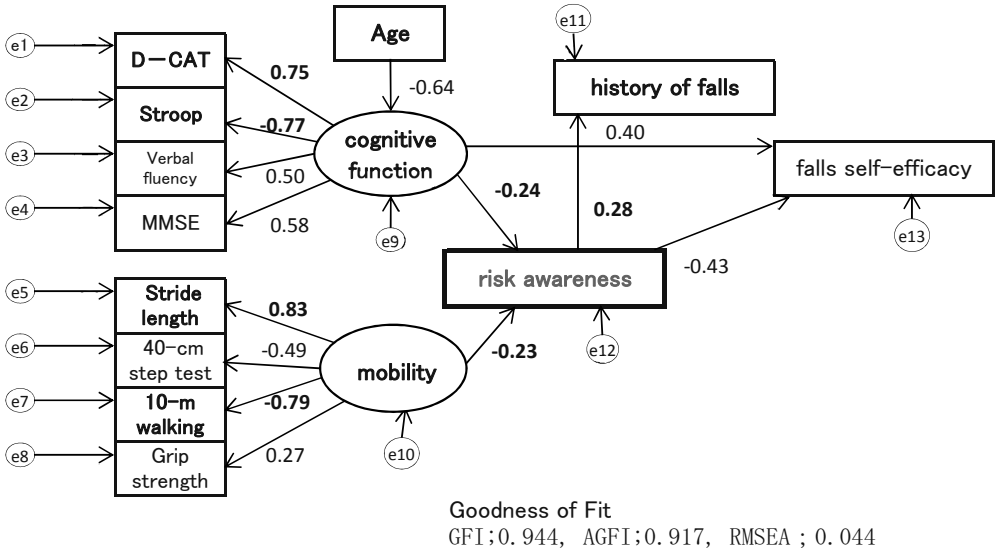

Figure1.
Relationships between fall-risk awareness, falls, mobility, and cognitive

DISCUSSION

In the present study, we created a list of risks for living environments and behavior that may cause fall-related accidents;examined the relationships between middle-aged and elderly individuals' awareness of environmental fall risk, mobility, and cognitive function;and examined the effect of fall-risk awareness on fall history.

1. Fall-risk awareness and fall history

Previous studies reported that a history of falls is a significant predictor of fall-related accidents[2,37]. In the present study, fall-risk awareness was high among middle-aged and elderly peoples with a history of falls. Analysis of covariance structure also suggested that fall-risk awareness is influenced by mobility and cognitive functions and is related to fall history. Cognitive functions that affected fall-risk awareness included those assessed by MMSE, D-CAT, Stroop test, and verbal fluency test.

Stroop and D-CAT scores were particularly associated with cognitive function (standardized coefficient = −0.77, $p < 0.001$ and standardized coefficient = 0.75, $p < 0.001$, respectively). The Stroop test assesses the functions of maintenance, selection, and allocation of attention as hierarchical elements[38], whereas D-CAT assesses the level of attention[33].The level of cognitive function, which is significantly influenced by these attention functions, affected fall-risk awareness. This finding suggests that fall-risk awareness is increased by differences in floor levels and darkness inside and outside the house, which may pose obstacles to walking, as well as reduction in the ability to pay attention to obstacles, such as newspapers and electrical cords. It is reported that atrophy of the quadriceps and psoas major often worsens in individuals in their 60s and 70s[39], and

that decreases in muscle mass and strength decrease power and stamina in this age group contribute to fall-related accidents[40].The results of the present study suggested that mobility, assessed by the maximum stride length and 40-cm step and 10-m walking tests, also influenced risk awareness. Low maximum stride length is believed to be related to tripping when stepping over an obstacle, and low 40-cm step scores are believed to be associated with the difficulty when using stairs or other steps. In the present study, fall-risk awareness scores for thresholds, cushions and blankets for kotatsu tables, uneven roads, and stairs were high in the group experiencing falls, which suggests that decreases in the maximum stride length and scores for the 40-cm step and 10-m walking tests might indicate improved fall-risk awareness in daily life. An increased fall-risk awareness associated with decreased mobility and cognitive functions was associated with a history of falls.

2. Fall-risk awareness and falls self-efficacy

According to Tinetti et al, self-efficacy related to falls is an effective variable to estimate current physical function[41].In the present study, falls self-efficacy was influenced by cognitive functions but not by mobility. Decrease in fall-risk awareness caused by changes in cognitive functions and mobility, decreased falls self-efficacy. Motor function decreases with age, and deterioration accelerates after 75 years[42].However, in the present study, mobility was not directly related to falls self-efficacy, presumably because the mean age of the subjects was approximately 63 years.

Because physical, cognitive, and other functions of the elderly decrease as they become older, they may not be able to adjust their movements in their living environments according to the level of their physical abilities unless they accurately recognize reduction in physical functions. Our results suggest that assessment of fall-risk awareness, designed to examine risks in internal and external environments of middle-aged and elderly peoples, was influenced by decreases in both mobility and cognitive functions. This suggests that assessment of fall-risk awareness might be used to identify changes in mobility and cognitive functions. To prevent fall-related accidents, it is necessary to examine the awareness of environmental fall risk among middle-aged and elderly peoples as well as others at a high risk for falling,decrease fall risk in the environment, and decrease the rate of decline of mobility functions.

Psychosocial variables that could influence the risk of falling, including ADL, emotional state, and social interactions, were not determined in this study. It has been reported that individuals who are afraid of fall-related accidents refrain from participating in activities, resulting further decrease in physical and psychological functions, which, in turn, leads to more falls[43].The present study only examined the relationships between the fall-risk awareness and variables in a cross-sectional manner. For a comprehensive examination, it is necessary to conduct a longitudinal study on the relationship between fall-risk awareness and fall history, examine changes in cognitive function and mobility over time, as well as their causal relationships with fall-risk awareness and fall history. In addition, it is necessary to increase the efficacy of the assessment as a checklist to determine the appropriate time to intervene for fall prevention. Furthermore, intervention studies should be conducted to assess the effects of fall-prevention activities incorporating the fall-risk awareness.

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