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Effects of Fall Risk Factors on the Extent of Fall-related Injuries in the Elderly Living in Community Dwellings

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Abstract The elderly with more fall risk factors might have high fall incidence. This study examined the relationships between fall risk factors among the elderly living in community dwellings and the extent of fall-related injuries. We used fall risk questionnaire given by Demura et al. (2011) to analyze 1,265 elderly individuals who experienced falls in the past year. We examined fall-related injuries, extent of injuries, and fall characteristics (fall cause and direction), noting the associated high risk factors in each case. We defined risk groups 0, 1, 2, and 3 based on the number of risk factors—0, 1, 2, and 3 or 4, respectively. The fall rate was significantly higher in groups with more risk factors. The rate of injuries, except for fractures, in each fall risk group was 68.4, 61.5, 58.7, and 60.4%, and the rate of fracture was 10.5, 12.8, 6.5, and 9.7%. There was no correlation between injuries or fracture rates and the number of fall risk factors. Injures happened most frequently after forward falls caused by tripping. However, no association between fracture and fall characteristics was observed. The risk of injuries (approximately 60% in all groups) or severe injuries (fracture; about 10%) after a fall might not be related to the number of fall risks. We observed that a certain tendency is not observed in fall characteristics with fractures. Injuries (except for fractures) mainly occurred after forward falls caused by tripping.

Keywords: *fall cause, fracture, fall risk*

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1. Introduction

At least 20-35% of elderly people over 65 years of age living in community dwellings experience falls for 1 year [1-6]. Approximately 5-10% of those experience falls resulting in severe injuries or fractures [1,7,8]. Primary prevention is very important as such events relate closely to the decrease in the quality of life and the increase in primary nursing care, medical disorders, mortality, and morbidity [9-15].

Several risk factors such as disease, medication, changes in physical function with age, and the environment are related to falls, as reported by many previous studies [1,16-21]. Tinetti et al. have reported that the incidence of falls is approximately 27% for community-dwelling elderly persons with one or fewer risk factors [1]. However, it increases to 78% for people with four or more risk factors. It is believed that the elderly with more risk factors have higher fall incidence [1,22,23].

Although it has been reported that falls might have severe psychological consequences, accelerating the decline in functional capacities [7], in cases with no severe injuries, the risk of becoming bedridden or needing primary nursing care is not very high. However, injuries caused by falls vary in severity, from negligible injuries such as abrasion and bruises to transcervical or upper limb fractures and traumatic brain injuries [24]. Thirty percent of the elderly who experience falls with transcervical fracture die within a year. Even if they recover completely, physical function level decreases markedly [10]. However, satisfactory recovery can be expected in cases without severe injuries. Bergland and Wyller have reported that rheumatism, decrease in mobility, recurrent falls, and cognitive impairment are the associated risk factors that induce falls with severe injuries [25]. As stated above, multiple risk factors are associated with fall incidence; the elderly with more related risk factors might also have high severe injury incidence.

This study examines the relationships between fall risk factors and the extent of fall-related injuries in the elderly living in community dwellings.

2. Methods

2.1. Subjects

The elderly who live independently in community dwellings were asked to participate in this survey. The

questionnaires were posted to 1,387 subjects who had consented to take part in this study, and 1,317 questionnaires were retrieved (recovery: 95.0%). The questionnaires with gaps in survey items, age, or sex were excluded from the analysis. Data of 1,265 subjects, 436 males (age of 71.0 ± 7.3 years) and 829 females (70.8 ± 7.3 years old), were obtained (valid response rate: 96.1%). The study protocol was approved by the Ethics Committee on Human Experimentation of the Faculty of Education, Kanazawa University, Japan (authorization number: 19-18).

2.2. Determining the Number of High Risk Factors

High risk factors for falling were screened using a questionnaire proposed by Demura et al. [26,27]. The questionnaire contains questions regarding previous fall experience and 50 other fall risk assessment items. The following five risk factors were assessed: potential for falling, physical function (muscle strength, leg muscle strength, upper limbs function, and gait), disease and physical symptoms (dizziness/syncope, medication, cognition/vision, cerebrovascular disease, joint/bone disease, and metabolic disease), environment (surroundings and clothing), and behavior and character (disability, incontinence, fear of falling, and risk behavior). Subjects responded to all questions with "yes" or "no." The fall risk for each subject and each risk factor were evaluated using the number of answers indicating the risk of falling. Namely, subjects were judged to have a high fall risk for each risk factor when the number of positive responses was more than one for "potential for falls," 13 for "physical function," six for "disease and physical symptoms," and three for both "behavior and character" and "environment" [27]. For each subject, high risk factors for falling were screened for the above four factors (except for the potential for falling), and the number of high risk factors was determined. There were 963 elderly with no high risk factors (risk group 0). We found 189 subjects with one of the four factors (risk group 1), 89 with two (risk group 2), and 24 with three or four factors (risk group 3). There was only one person with four high risk factors.

2.3. Procedure

Subjects entered basic attributes such as the date of registration, birthday, name, sex, and age. They answered questions regarding fall incidence and the extent of injuries caused by the fall. Information on fall incidents, their cause, direction, region, and the extent of injuries was used for the evaluations. Subjects were instructed to respond to the question, "Did you fall within the past year?" with "yes" or "no." Types of fall were listed as "trip-fall with knee down," "fall on the buttocks," "fall from the stairs," and "fall with deliquium animi and blackout." Fall causes were as follows: "leg backlash," "tripping," "slipping," "dizziness and staggering," and "other (open question)". Fall direction was also surveyed ("forward fall," "backward fall," "sideways fall," and "other (open question)". The injured region was classified as "upper limb injuries (shoulder, arm, or hand)," "lower limb injuries (lumber, leg, or foot)," "trunk injuries (back, abdominal, or chest)," "head injuries (head, neck, or face)," and "other (open question)." Types of injuries were categorized as "fracture," "sprain," "contusion or cut and graze," "no injuries," and "other (open question)." The questions were selected following Haga et al. [28] and Yasumura et al. [29]. The subjects also responded to fall risk assessment questionnaire proposed by Demura et al. [26,27].

2.4. Statistical Analysis

The differences between mean ages in the four risk groups were tested by one-way independent analysis of variance. Tukey's HSD was used for the post-hoc test. In addition to the differences between the frequencies of falls and lack of falls in the various risk groups, the differences between the frequencies of falls with and without injuries or fracture were tested using chi-squared test. Ryan's method was used for the post-hoc test. Goodness-of-fit test (GFT) was applied to analyze the differences in the frequencies of various fall causes and directions among the subjects with fracture and injuries (except for fractures). A probability level $p < 0.05$ was used for statistical significance and was adjusted using Bonferroni's method.

3. Results

Table 1 shows the results of one-way analysis of variance and multiple comparisons for age in each group. A mean age was significantly higher in the risk groups 2 and 3 than in other groups and higher in the risk group 1 than in the group 0.

Table 1. Mean age of each eiderly group regarding the number of high risk factor of falling

		Age			F	*p*	post-hoc
		n	Mean	SD			
Number of high risk factor of falling	0	963	69.5	6.5	70.7	*< 0.001*	3-4,2>1>0
	1	189	73.4	7.0			
	2	89	78.5	7.4			
	3-4	24	78.7	9.6			

Table 2 shows the frequencies of subjects with (FS) and without (NFS) falls in the risk groups 0-3 and the test results for the differences between their ratios and multiple comparisons. Some significant differences were found. The number of FSs in the risk group 3 was significantly greater than in the groups 1 and 2, and greater in groups 2 and 3 than in the group 0.

Table 2. Frequencies of fallers and nonfallers in each risk group and the test results of falling

		Fall experience			χ^2	*p*	post-hoc
		Yes	No	Total			
Number of high risk factor of falling	0	134 (13.9)	829 (86.1)	963	112.6	*< 0.001*	3,2>0 3>2,1
	1	46 (24.3)	143 (75.7)	189			
	2	39 (43.8)	50 (56.2)	89			
	3-4	19 (79.2)	5 (20.8)	24			
		238	1027	1265			

Values in parentheses indicate the ratio

Table 3 and Table 4 show the frequencies of injuries and fractures and the results of testing the differences between the ratios. No significant differences were found between the frequencies of injuries and fractures in the various risk groups. The rates for injuries and fractures were 58.7-68.4% and 6.5-12.8%, respectively. Table 5 shows the results of GFT for the fall direction in cases of injuries (except for fractures). Significant differences were found for the frequencies of the fall directions; more subjects fell forward than in other directions. Table 6 shows the results of GFT for the fall causes in cases of injuries (except for fractures). The number of the elderly who fell by tripping was significantly more than of those who slipped or staggered.

Table 7 and Table 8 show the results of GFT for the cause and direction of falls in cases of fracture. No significant differences were found for the frequencies of fall causes and directions.

Table 3. Frequencies of the eiderly with injury by falls in each risk group and the test results of the differents of their ratios

		Injury with falls			χ^2	*p*
		Yes	No	Total		
Number of high risk factor of falling	0	81 (60.4)	53 (39.6)	134	0.6	*0.905*
	1	27 (58.7)	19 (41.3)	46		
	2	24 (61.5)	15 (38.5)	39		
	3-4	13 (68.4)	6 (31.6)	19		
		145	93	238		

Values in parentheses indicate the ratio

Table 4. Frequencies of the eiderly with fracture by falls in each risk group and the test results of the differents of their ratios

		Fractures with falls			χ^2	*p*
		Yes	No	Total		
Number of high risk factor of falling	0	13 (9.7)	121 (90.3)	134	1.0	*0.806*
	1	3 (6.5)	43 (93.5)	46		
	2	5 (12.8)	34 (87.2)	39		
	3-4	2 (10.5)	17 (89.5)	19		
		23	215	238		

Values in parentheses indicate the ratio

Table 5. The results of the test of goodness of fit for the fall direction of the eiderly with injury exceept for fracture by falling

			χ^2	*p*	post-hoc
Fall direction	Forward (F)	77 (67.0)	59.3	*0.000*	F>L,B
	Backward (B)	15 (13.0)			
	Lateral (L)	23 (20.0)			
	Total	115			

Values in parentheses indicate the ratio. Other (n = 7) was excluded.

Table 6. The results of the test of goodness of fit for the fall cause of the eiderly with injury exceept for fracture by falling

			χ^2	*p*	post-hoc
Fall cause	leg backlash (LB)	25 (23.6)	50.9	*0.000*	LB>S,DG
	tripping (T)	56 (52.8)			
	slipping (S)	19 (17.9)			
	dizziness and staggering (DG)	6 (5.7)			
	Total	106			

Values in parentheses indicate the ratio. Other (n = 16) was excluded

Table 7. The results of the test of goodness of fit for the fall direction of the eiderly with fracture by falling

			χ^2	*p*
Fall direction	Forward (F)	10 (47.6)	2.0	*0.368*
	Backward (B)	5 (23.8)		
	Lateral (L)	6 (28.6)		
	Total	21		

Values in parentheses indicate the ratio. Other (n = 2) was excluded.

Table 8. The results of the test of goodness of fit for the fall cause of the eiderly with fracture by falling

			χ^2	*p*	post-hoc
Fall cause	leg backlash (LB)	3 (15.8)	7.7	*0.052*	
	tripping (T)	9 (47.4)			
	slipping (S)	6 (31.6)			
	dizziness and staggering (DG)	1 (5.3)			
	Total	19			

Values in parentheses indicate the ratio. Other (n = 4) was excluded.

4. Discussion

The ratio of the elderly who experienced a fall within a year increased linearly with increasing number of fall risks (Table 1). Tinetti et al. have surveyed the fear of falling, physical function (flexibility, balance, and gait), and residential environment of 336 elderly people (aged 75 and older) to clarify the risk factors for fall incidence [1]. They reported that 108 elderly people fell at least once during a year follow-up, 24% and 6% of them were injured severely or suffered fractures, respectively. Moreover, the authors extracted the use of sedatives (28.3), cognitive impairment (5.0), disabilities of the lower extremities (3.8), abnormalities of balance and gait (1.9), and foot problems (1.8) as factors predisposing for falls (odds ratios indicated in parentheses). They reported that the risk of falling increased linearly with the number of risk factors: 8% with none, 19% with one risk factor, 32% with two risk factors, and 78% with four or more risk factors. Tinetti et al. (1988) have investigated high risk factors for falling in relation to physical function levels

based on performance tests. Our assessment was based on the questionnaire results. The study of Tinetti et al. (1988) also differed from our research in that they used medication and cognitive function as risk factors. However, the results of the two studies were similar: fall incidence increased with the number of fall risks. We can also infer that even the healthy elderly, living independent lives, might be subject to high fall risk factors, and their fall incidence will increase with the increasing number of such factors.

However, we found no relationship between the number of high risk factors and injuries caused by falls (Table 2). Stalenhoef et al. have constructed a fall risk model and conducted 36 weeks prospective cohort study using 311 elderly people (aged 70 and older) to determine predictive factors for recurrent falls [8]. They have reported that during follow-up, there were 197 falls among 33% of the elderly; 45% of these were injured, 6% had a fracture, and 39% were slightly injured. Moreover, they included an abnormal postural sway (3.9), two or more falls in the previous year (3.1), low scores for hand-grip strength (3.1), and depression (2.2) in their fall risk model. They reported low fall incidence among the elderly with no risk or one risk factor, but very high rate among those with three or more risk factors. The rates of FS (18.8%) and injured FS individuals (60.9%) in our study were different from those reported by Stalenhoef et al. [8]; they reported higher rate of FSs and lower rate of injuries than those in our study. In their study, 33% of the subjects fell and approximately half of them fell recurrently; it is possible that the physical function levels of that group were impaired, which might have caused the observed differences. However, both studies show that approximately half of the subjects experiencing a fall suffer from injuries.

We found that the rate of individuals with fractures did not depend on the number of fall risk factors (Table 3). Speechley and Tinetti have conducted a one-year follow-up survey for 336 elderly [30]. They were categorized into frail (n = 67), normal (n = 182), and vigorous (n = 87) groups; the study has reported that the rate of injured individuals in the vigorous group was significantly greater than in the frail and normal groups (vigorous: 33% vs frail: 6% and normal: 16%). The authors have concluded that fall prevention is important to prevent severe injuries regardless of physical function level. In our study, severe injuries analyzed were restricted to fractures. As a result, the frequency of the elderly with severe injuries may have been lower in comparison with that reported by Speechley and Tinetti [30]. However, considering that the subjects of both studies lived independently, the probability of fracture might be approximately 10%, regardless of the number of fall risks.

We found that more than half of the elderly injured in a fall (except for fractures) fell forward by tripping (Table 4 and Table 5), but this tendency was not found in the subjects with fractures (Table 6 and Table 7). The causes of falls are associated with fall direction [26]; we can assume that the body parts subjected to shock are similarly affected. It has been pointed out that the impact to the region of hip joints during a lateral fall increases the risk of hip fracture by 3-5 fold [20,31,32,33]. Smeesters et al. have examined the fall direction, impacted parts, and the speed of the impact to the pelvis in falls triggered by three different causes (syncope, slipping, and step-down) with three gait speeds (fast, normal, and slow), using 14 young adults [34]. The results have shown that almost all subjects fell forward by tripping or step-down regardless of gait speed, and the front of the body was hit. In cases of fast gait, almost all falls were forward falls caused by slipping and syncope, with similar effect. However, in cases of slow gait, slipping induced lateral backward falls, and hip joints or hips were impacted. Most of the lateral falls caused by syncope affected areas around hip joints. These data suggest that falls caused by slipping at low gait speed or by syncope are likely to result in a substantial impact to hip joints and increase the chance of hip fracture. The subjects of our study had relatively high level of physical function and lived independently; their injuries, except for fractures, were caused by forward falls after tripping. However, no clear tendency was found for fall characteristics of the subjects with fractures. Our findings may be attributed to the relatively high level of physical function in these individuals. Even when the causes are the same, the forward falls carry low hip fracture risk, and lateral or backward falls have a high risk of such an injury. The relationship between the fall cause and the activity during the incident still needs to be studied in detail.

5. Conclusion

The risk of injuries (approximately 60% in all groups) or severe injuries (fracture; approximately 10%) after a fall might not be related to the number of fall risks. We observed that a certain tendency is not observed in fall characteristics with fractures. Injuries (except for fractures) mainly occurred after forward falls caused by tripping.

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