Aging Clin Exp Res 17: 211-216, 2005

Relationship between falls and physical performance measures among community-dwelling elderly women in Japan

Masaharu Morita[1,2], Noboru Takamura[1], Yosuke Kusano[1], Yasuyo Abe[1], Kazuhiko Moji[3], Tai-ichiro Takemoto[4], and Kiyoshi Aoyagi[1]

[1]Department of Public Health, Nagasaki University Graduate School of Biomedical Sciences, [2]Department of Physical Therapy, Fukuoka International College of Health and Welfare, [3]Information and Reference Center of Tropical Medicine, Nagasaki University, Institute of Tropical Medicine, [4]Department of Health and Nutrition, Nagasaki International University, Faculty of Health Management, Nagasaki, Japan

ABSTRACT. ***Background and aims:*** *The relationship between falls and physical performance has focused on the frail elderly who have several health problems, particularly those in nursing homes or care facilities. It is important to clarify the relationship between falls and physical performance among the community-dwelling elderly.* ***Methods:*** *We examined the relationship between falls and physical performance measures (grip strength, chair stand time, functional reach, usual walking speed) among 402 community-dwelling Japanese elderly women aged 60 years and over.* ***Results:*** *Overall prevalence of falls was 21.1%, and increased with age. In univariate analysis, grip strength and functional reach were not significantly different between women who did and did not fall. Chair stand time of women who fell was longer than that of women who did not (*p=*0.05), and the usual walking speed of women who fell was significantly slower than that of women who did not fall (*p<*0.0001). Physical functioning significantly decreased with age; grip strength, functional reach and usual walking speed decreased, and chair stand time increased. Logistic regression analysis, adjusting for age and other covariates, showed that slower usual walking speed was significantly associated with falls, but grip strength and functional reach were not. Increased chair stand time had a borderline association (*p=*0.1).* ***Conclusions:*** *Our findings indicate that poor lower extremity function, especially walking ability, is an important risk factor for falls in elderly Japanese community-dwelling women.*
(Aging Clin Exp Res 2005; 17: 211-216)

INTRODUCTION

Falls are major health problems among the elderly because of the risk of morbidity and mortality (1). Approximately 20 to 40% of people aged 65 years and over living in the community experience falls each year (2-6) and this incidence increases with age (4). One study reported that 6% of the falls resulted in major injury (7). Even when no physical injury occurs, falls can lead to fear of falling, activity limitations, and loss of confidence, mobility and independence (2, 8, 9).

Much attention has been paid to the problem of falls and related injuries in the expanding elderly population, and standardized physical performance measures have been applied in geriatric assessments and aging research (10, 11). Previous studies have demonstrated that poor physical performance is associated with increased risk of falls (8, 9), and physical performance measures are also associated with health status, such as medical condition and physical functioning (11).

The relationship between falls and physical performance has focused mainly on the frail elderly who have several health problems, particularly those in nursing homes or care facilities (12, 13). The usefulness of each test of physical performance in predicting falls varies, depending on the health status and level of function of the elderly person being tested. Findings among the elderly in nursing homes or care facilities cannot be extrapolated to those in the community.

It would be important to clarify the relationship between falls and physical performance among the community-dwelling elderly. However, there have only been a few studies in Western countries (8, 9, 14) and none in

Key words: Elderly, falls, physical performance, women.

Correspondence: K. Aoyagi, Department of Public Health, Nagasaki University Graduate School of Biomedical Sciences, 1-12-4 Sakamoto, Nagasaki, Japan 852-8523.
E-mail: kiyoshi@net.nagasaki-u.ac.jp

Received November 4, 2003; accepted in revised form October 14, 2004.

Aging Clin Exp Res 17: 211-216, 2005

Japan. The purpose of this study was to examine the relationship between falls and physical performance measures (grip strength, chair stand time, functional reach, usual walking speed) among community-dwelling elderly women aged 60 years and over in Japan.

SUBJECTS AND METHODS

Subjects

The Hizen-Oshima Study is a prospective population-based cohort study on musculoskeletal conditions (osteoporosis, osteoarthritis). We recruited community-dwelling women aged 40 years and over living in the town of Oshima, Nagasaki Prefecture, Japan. Oshima has a population of approximately 5800 (2850 men, 2950 women), in which the number of women aged 40 years and over is approximately 2000. All women aged 40 and over were invited to participate, and baseline examination was performed at the Oshima Health Center between 1998 and 1999. A total of 586 women participated. In this study, we selected 402 elderly women (36% of those eligible) aged 60 years and over. We compared the age distribution of participants *vs* non-participants. In total, the mean age of participants (69.0±5.8 years) was significantly younger than that of non-participants (71.6±8.0 years). The participation rate of each age group was 45% at 60-69 years, 39% at 70-79 years, and 15% at 80 years and over.

Although Oshima has a shipyard, it is mainly a rural (farming/fishing) district. Approximately half of the women who participated in the study continue to grow rice and vegetables by manual labor, sometimes using machinery. The information about the amount of each task was not available. At study entry, none of the participants were institutionalized and all lived independently. All participants gave their written informed consent before examination. Additional details of this study have been published previously (15, 16).

Assessment of falls

A fall was defined as falling and landing on the floor or ground, or falling and hitting something like a table or stairs (17). Information on falls was obtained by questionnaire, participants being asked: "Did you fall and land on the floor or ground?" or "Have you fallen and hit something like a table or stairs during the previous 12 months? (yes/no)". We did not obtain this information on the total number of falls in this study.

Measures

Height and weight were measured in light clothing and without shoes. The body mass index (BMI) was calculated as weight (kg)/height $(m)^2$. The physical activity index was calculated using a validated questionnaire (18).

Measures of physical performance included grip strength, chair stand time, functional reach, and usual walking speed according to the previous report (19). Grip strength of the dominant hand was measured using a hydraulic dynamometer (Jamar Hydraulic Hand Dynamometer, Jafayette Instrument Company, Inc., IN, USA) and calculated as the average of two trials. Chair stand time was measured as the time it took (average of two trials) to stand up from a standard chair five times; subjects were asked not to use their arms for assistance. Functional reach was calculated as the difference between two measurements (average of three trials). Subjects first stood comfortably upright, facing forward, hand in a fist, with their arm extended next to a yardstick mounted on a wall. They then reached forward as far as possible without stepping or losing their balance. Usual walking speed was calculated from the time required for subjects to walk a 6-meter course bounded by two lines at their usual pace (average of two trials), and the number of steps taken to cover the course was also recorded. Step length was calculated as the 6-meter length of the course divided by the number of steps. Subjects were asked to stand one meter behind the starting line and to walk all the way one meter past the end line before stopping; subjects entered the course in usual walking condition.

Statistical analysis

Statistical analysis was performed using SAS version 6.12 software (SAS Institute, Cary, NC, USA). Student's *t*-test for continuous variables and the chi-square test for categorical variables were used to determine the significance of differences between women who did and did not fall. Correlations between age, physical activity index and physical performance measures were examined using Pearson's correlation analysis. Logistic regression analysis was used to explore the association of falls with physical performance measures after adjustment for age and other covariates.

RESULTS

Table 1 shows the prevalence of falls among women in each age group during a 12-month period. Overall prevalence of falls was 21.1%, and increased with age.

As shown in Table 2, no differences in age, height, weight, BMI, or physical activity index were found between women who did and did not fall. Physical performance measures of women who did and did not fall are shown in Table 3. Grip strength and functional reach were

Table 1 - *Prevalence of falls among women for each age group.*

Age group (years)	Participants No.	Women who fell No.	%
60-69	221	42	19.0
70-79	157	36	22.9
80+	24	7	29.2
Total	402	85	21.1

Table 2 - *Characteristics of women who did and did not fall.*

Characteristic	Overall (n=402)	Fell (n=85)	Did not fall (n=317)	*p*-value*
Age (years)	69.0±5.8	70.0±6.4	68.8±5.6	ns
Height (cm)	148.0±5.4	147.4±6.1	148.2±5.2	ns
Weight (kg)	51.4±8.5	51.8±7.8	51.3±8.7	ns
Body Mass index (kg/m^2)	23.4±3.4	23.8±3.0	23.3±3.5	ns
Physical activity Index (METs†)	52.2±13.6	50.0±13.2	52.7±13.7	ns

Values are means ± standard deviation. *p-value for comparison between women who did and did not fall. †METs: metabolic equivalents.

Table 3 - *Comparison of physical performance measures for women who did and did not fall.*

Physical performance measure	Overall (n=402)	Fell (n=85)	Did not fall (n=317)	*p*-value*
Grip strength (kg)	22.4±4.7	22.0±5.3	22.5±4.6	ns
Chair stand time (sec)	10.1±3.3	10.8±4.0	9.9±3.1	0.05
Functional reach (cm)	23.5±6.7	23.1±8.1	23.7±6.2	ns
Usual walking speed (m/sec)	1.18±0.25	1.08±0.31	1.21±0.23	<0.0001

Values are means ± standard deviation. *p-value for comparison between women who did and did not fall.

not significantly different between women who did and did not fall. Chair stand time of women who fell was longer than that of women who did not (p=0.05), and the usual walking speed of women who fell was significantly slower than that of women who did not (p<0.0001).

Physical functioning significantly decreased with age; grip strength (r=–0.49, p<0.0001), functional reach (r=–0.33, p<0.0001) and usual walking speed (r=–0.52, p<0.0001) decreased, and chair stand time (r=0.44, p<0.0001) increased (the longer time required to complete the test represents a decline in function). Physical functioning significantly increased with the higher physical activity index; grip strength (r=0.15, p=0.003), functional reach (r=0.12, p=0.014) and usual walking speed (r=0.19, p<0.0001) increased, and chair stand time (r=–0.14, p=0.005) decreased.

Logistic regression analysis was conducted to examine the independent contributions of each physical perfor-

Table 4 - *Adjusted odds ratio and 95% confidence interval for fall at each physical performance measure.*

	Unit	Odds ratio	95% confidence interval
Grip strength			
Age adjusted	5.0 kg decreased	1.01	0.76-1.36
Age and height adjusted	5.0 kg decreased	0.99	0.73-1.35
Age and weight adjusted	5.0 kg decreased	1.04	0.77-1.41
Age and BMI adjusted	5.0 kg decreased	1.03	0.77-1.39
Chair stand time			
Age adjusted	5.0 sec increased	1.36	0.94-1.96
Age and height adjusted	5.0 sec increased	1.45	0.94-1.98
Age and weight adjusted	5.0 sec increased	1.35	0.93-1.95
Age and BMI adjusted	5.0 sec increased	1.35	0.93-1.95
Functional reach			
Age adjusted	5.0 cm decreased	1.01	0.83-1.23
Age and height adjusted	5.0 cm decreased	1.00	0.81-1.22
Age and weight adjusted	5.0 cm decreased	1.02	0.84-1.23
Age and BMI adjusted	5.0 cm decreased	1.00	0.83-1.22
Usual walking speed			
Age adjusted	0.5 m/sec decreased	3.14	1.75-5.63
Age and height adjusted	0.5 m/sec decreased	3.13	1.74-5.63
Age and weight adjusted	0.5 m/sec decreased	3.10	1.72-5.58
Age and BMI adjusted	0.5 m/sec decreased	3.06	1.70-5.52

BMI: body mass index.

Aging Clin Exp Res 17: 211-216, 2005

mance measure to falls. Table 4 shows the odds ratio (OR) and 95% confidence interval (CI) in physical performance measures, adjusting for age and other covariates. Slower usual walking speed was associated with falls, but grip strength and functional reach were not. Increased chair stand time had a borderline association (p=0.1).

DISCUSSION

The number of community-dwelling elderly women in Japan is increasing (20). Falls are reported to be a major risk for morbidity and mortality among the elderly (1). The elderly who fall are less mobile and have more difficulty in activities of daily living than those who do not fall (6). In community-dwelling elderly women aged 65 years and over, the prevalence of falls in the previous year was reported to be approximately 30-40% in Western countries (4-6) and approximately 20% in Japan (2, 3). Our result was lower than that of published community studies in Western countries (4-6) but similar to other Japanese studies (2, 3). These findings suggest that the difference in prevalence of falls may partly be related to lifestyle (environmental) factors and/or ethnicity (genetics). Two factors which may account for the reduced risk of falling among Japanese compared with people in Western countries are better neuromuscular function due to sitting directly on the floor (a traditional Japanese custom) plus the shorter legs of Japanese people (at least partly related to genetics) (21).

Previous studies showed that grip strength (19, 22), functional reach (19, 23), usual walking speed (19, 24) decreased and chair stand time (11, 19) increased with age, which were consistent with our results. We also found a positive relationship between physical activity index and physical performance measures. People with a higher level of physical activity have good physical functioning (and vice versa), which may contribute to preventing falls.

Poor physical performance on the neuromuscular tests such as chair stand time and usual walking speed was associated with an increased risk of falls in our study. Inability to perform the chair stand has been reported as a risk factor for falls (9), as is slower walking speed (8). Length of lower extremities and step length can affect walking speed. Since the length of lower extremities was not available in our study, we examined the association using height as surrogate. Usual walking speed had a significant positive association with height (r=0.29, p<0.0001) and step length (r=0.83, p<0.0001). Step length was significantly shorter in women who fell than in women who did not (0.52±0.086 *vs* 0.55±0.065, respectively, p=0.003). Narrower step length may result from poor walking ability. Several studies have found strong associations between shorter step length and the likelihood of falls among frail elderly in nursing homes or intermediate care facilities (12, 13), which is consistent with our results, which indicate that poor physical performance on lower extremity function can predict the likelihood of falls.

Although grip strength (8) and functional reach (9) were reported to be available to confirm the risk of falls, they were not associated with falls in our study. This relationship may be complex, and was inconclusive.

We selected performance measures according to the previous report (19). However, recent studies have reported that the "Get up and Go" test is also a reliable and valid test quantifying functional mobility, and is frequently used in community-dwelling population studies (14, 25-27). It is considered to be a good measure of combined physiological attributes (power, speed, agility, balance), which reflects the common mobility and gait maneuvers required in independent living (26). However, although it would be another good predictor of falling, it was not available in this study. Future study will be needed to determine the role of this test in predicting falls among our cohort.

Physical performance measures may be useful in primary health care and clinical practice because they are simple to administer and safe to perform. The practitioner can recreate situations in which falls are likely to occur and provide a dynamic, integrated assessment of physical capacity for the elderly (10). In recent studies, the elderly with poor physical performance were found to suffer musculoskeletal pain (28), disability in activities of daily living (29), and had chronic medical conditions such as arthritis and the results of hip fracture (11). These findings indicate that physical performance measures capture information about several physical factors.

With advancing age, most people experience a decline in lower extremity function such as decrease in walking speed (24) and muscle strength (30). This decline is one of the most important risk factors for falls (12). Efforts to improve lower extremity function serve to decrease the risk of falls (31). Intervention studies among community-dwelling elderly show that the "stand-up/step-up" procedure improves strength and balance (32) and low-intensity training with resistance bands and putty strengthens the knee extensor muscle (31).

Self-reported pain in the knee and hip joints and foot is reported to be associated with increased risk of falls (28), and arthritis of the lower extremities was the most frequent reason for disability in our cohort (33). We had also reported that physical disability or limited activity increased the risk of falls (2). A population-based study has found an increasing prevalence of osteoarthritis of the knee with aging (34), indicating that knee osteoarthritis is an important risk factor for falls among the elderly.

Our study has several limitations. First, although we attempted to obtain a representative sample of the population, our subjects had to be mobile enough to attend the study center. Only 15% of eligible women aged 80 and over participated in our study, which is a potential source

of selection bias. Women with the most severe symptoms and disability may not have participated. Second, there may be inaccuracies in subject recall about falls in the previous 12 months. Cummings et al. (35) found that surveying falls during the past 12 months at a single point in time underestimated the true number of falls by 13%. Among the cognitively impaired especially, falls may be forgotten or reported more than once. We did not obtain information about our subjects' cognitive status. When subjects had cognitive problems, information on their falls was provided by their family members, which may have influenced the results to some extent.

In conclusion, our results show that decreased usual walking speed is associated with increased risk of falls, and that increased chair stand time had a borderline association, suggesting that poor lower extremity function, especially gait ability, is an important risk factor for falls. However, the cross-sectional design of our study makes it difficult to establish cause and effect, and a prospective study is needed to investigate this issue further. Physical functioning generally decreases with age, but maintaining or improving lower extremity function may be useful in preventing falls in the elderly (36). Poor muscle strength in the upper or lower extremities may be used to identify people who are dependent in activities of daily living, and maintaining muscle strength may reduce the risk of dependence in activities of daily living (37). Interventions to reduce the risk of falls among community-dwelling elderly should target physical factors, especially lower extremity function, that are likely to cause falls (31).

ACKNOWLEDGEMENTS

The study was partly supported by the Japan Society for the Promotion of Science (Grant in Aid for Scientific Research (C) #11670374). The authors thank Drs. Yoshisada Shibata and Sumihisa Honda (Department of Radiation Epidemiology, Atomic Bomb Disease Institute, Nagasaki University Graduate School of Biomedical Sciences) for their valuable comments, and Yuichiro Yahata (Department of Community Health & Epidemiology, Akita Prefectural Institute of Public Health) for assistance with data analysis. We thank the staff of the Oshima Health Center for their valuable assistance in conducting the study, and are also grateful to all participants for their kind cooperation.

REFERENCES

1. Sattin RW. Falls among older persons: a public health perspective. Annu Rev Public Health 1992; 13: 489-508.
2. Aoyagi K, Ross PD, Davis JW, Wasnich RD, Hayashi T, Takemoto T. Falls among community-dwelling elderly in Japan. J Bone Miner Res 1998; 13: 1468-74.
3. Yasumura S, Haga H, Nagai H, Suzuki T, Amano H, Shibata H. Rate of falls and the correlates among elderly people living in an urban community in Japan. Age Ageing 1994; 23: 323-7.
4. Campbell AJ, Borrie MJ, Spears GF. Risk factors for falls in a community-based prospective study of people 70 years and older. J Gerontol 1989; 44: M112-7.
5. Blake AJ, Morgan K, Bendall MJ, et al. Falls by elderly people at home: prevalence and associated factors. Age Ageing 1988; 17: 365-72.
6. O'Loughlin JL, Robitaille Y, Boivin JF, Suissa S. Incidence of and risk factors for falls and injurious falls among the community-dwelling elderly. Am J Epidemiol 1993; 137: 342-54.
7. Nevitt MC, Cummings SR, Hudes ES. Risk factors for injurious falls: a prospective study. J Gerontol 1991; 46: M164-70.
8. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent nonsyncopal falls. A prospective study. JAMA 1989; 261: 2663-8.
9. Davis JW, Ross PD, Nevitt MC, Wasnich RD. Risk factors for falls and for serious injuries on falling among older Japanese women in Hawaii. J Am Geriatr Soc 1999; 47: 792-8.
10. Tinetti ME, Ginter SF. Identifying mobility dysfunctions in elderly patients. Standard neuromuscular examination or direct assessment? JAMA 1988; 259: 1190-3.
11. Perkowski LC, Stroup-Benham CA, Markides KS, et al. Lower-extremity functioning in older Mexican Americans and its association with medical problems. J Am Geriatr Soc 1998; 46: 411-8.
12. Lipsitz LA, Jonsson PV, Kelley MM, Koestner JS. Causes and correlates of recurrent falls in ambulatory frail elderly. J Gerontol 1991; 46: M114-22.
13. Tinetti ME, Williams TF, Mayewski R. Fall risk index for elderly patients based on number of chronic disabilities. Am J Med 1986; 80: 429-34.
14. Bergland A, Jarnlo GB, Laake K. Predictors of falls in the elderly by location. Aging Clin Exp Res 2003; 15: 43-50.
15. Yoshida S, Aoyagi K, Felson DT, Aliabadi P, Shindo H, Takemoto T. Comparison of the prevalence of radiographic osteoarthritis of the knee and hand between Japan and the United States. J Rheumatol 2002; 29: 1454-8.
16. Jinbayashi H, Aoyagi K, Ross PD, Ito M, Shindo H, Takemoto T. Prevalence of vertebral deformity and its associations with physical impairment among Japanese women: the Hizen-Oshima Study. Osteoporos Int 2002; 13: 723-30.
17. Gibson MJ, Andres RO, Isaacs B, Radebaugh T, Worm-Petersen J. The prevention of falls in later life. A report of the Kellogg International Work Group on the prevention of falls by the elderly. Dan Med Bull 1987.
18. Sallis JF, Haskell WL, Wood PD, et al. Physical activity assessment methodology in the five-city project. Am J Epidemiol 1985; 121: 91-106.
19. Aoyagi K, Ross PD, Hayashi T, et al. Calcaneus bone mineral density is lower among men and women with lower physical performance. Calcif Tissue Int 2000; 67: 106-10.
20. Ministry of Health, Labour and Welfare. White Paper on Health, Labour and Welfare. Tokyo: Gyousei, 2002 (in Japanese).
21. Fujita T. Osteoporosis in Japan: factors contributing to the low incidence of hip fracture. Adv Nutr Res 1994; 9: 89-99.
22. Kallman DA, Plato CC, Tobin JD. The role of muscle loss in the age-related decline of grip strength: cross-sectional and longitudinal perspectives. J Gerontol 1990; 45: M82-8.
23. Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. J Gerontol 1990; 45: M192-7.
24. Lord SR, Lloyd DG, Li SK. Sensori-motor function, gait patterns and falls in community-dwelling women. Age Ageing 1996; 25: 292-9.
25. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991; 39: 142-8.

Aging Clin Exp Res 17: 211-216, 2005

26. Rikli RE, Jones CJ. Development and validation of a functional fitness test for community-residing older adults. J Aging Phys Act 1999; 7: 129-61.
27. Rikli RE, Jones CJ. Functional fitness normative scores for community-residing older adults, ages 60-94. J Aging Phys Act 1999; 7: 162-81.
28. Leveille SG, Bean J, Bandeen-Roche K, Jones R, Hochberg M, Guralnik JM. Musculoskeletal pain and risk for falls in older disabled women living in the community. J Am Geriatr Soc 2002; 50: 671-8.
29. Ensrud KE, Nevitt MC, Yunis C, et al. Correlates of impaired function in older women. J Am Geriatr Soc 1994; 42: 481-9.
30. Csuka M, McCarty DJ. Simple method for measurement of lower extremity muscle strength. Am J Med 1985; 78: 77-81.
31. Tinetti ME, Baker DI, McAvay G, et al. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. N Engl J Med 1994; 331: 821-7.
32. Reinsch S, MacRae P, Lachenbruch PA, Tobis JS. Attempts to prevent falls and injury: a prospective community study. Gerontologist 1992; 32: 450-6.
33. Morita M, Aoyagi K, Yahata Y, et al. Prevalence of disabilities of the upper and lower extremities among community-dwelling middle-aged and elderly women. Jpn J Public Health 2001; 48: 889-95 (in Japanese - English summary).
34. Felson DT, Naimark A, Anderson J, Kazis L, Castelli W, Meenan RF. The prevalence of knee osteoarthritis in the elderly. The Framingham osteoarthritis study. Arthritis Rheum 1987; 30: 914-8.
35. Cummings SR, Nevitt MC, Kidd S. Forgetting falls. The limited accuracy of recall of falls in the elderly. J Am Geriatr Soc 1988; 36: 613-6.
36. Myers AH, Young Y, Langlois JA. Prevention of falls in the elderly. Bone 1996; 18: 87S-101S.
37. Rantanen T, Avlund K, Suominen H, Schroll M, Frandin K, Era P. Muscle strength as a predictor of onset of ADL dependence in people aged 75 years. Aging Clin Exp Res 2002; 14 (Suppl. 3): 10-5.