Characteristics of non-participants in comprehensive health examinations ("Otasha-kenshin") among an urban community dwelling elderly: Basic research for prevention of the geriatric syndrome and a bed-ridden state

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Key words : Community-dwelling elderly, Non-participation in comprehensive health examinations, Cognitive function, Prevention of long-term care status

Purpose The present study was conducted to identify the characteristics of non-participants in secondary comprehensive health examinations among community-dwelling elderly.

Methods The subjects were 728 men and 984 women aged 70 years and over who had participated in comprehensive health examinations in 2002. Multiple logistic regression analysis was performed to assess the characteristics associated with non-participation in comprehensive health examinations after 2 years (in 2004).

Results The rates of participation in follow-up health examinations were 66.3% for men and 67.3% for women. Logistic regression analysis showed that male non-participants had low cognitive function (odds ratio (OR) = 2.19, 95% confidence interval (CI) = 1.07 − 4.49), low education (OR = 1.58, 95% CI = 1.22 − 2.22), and suffered from health problems (OR = 1.82, 95% CI = 1.27 − 2.59), and that female non-participants had low cognitive function (OR = 2.01, 95% CI 1.13 − 3.59), tended to be smokers (OR = 2.05, 95%, CI = 1.13 − 3.72), and had no hobby (OR = 0.68, 95% CI = 0.50 − 0.92).

Conclusion Poor cognitive function, health problems, and unfavorable lifestyle factors are related to non-participation in comprehensive health examinations.

Proposal It is necessary to devise various approaches to encourage participation of such individuals.

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Cognitive performance as a predictor of functional decline among the non-disabled elderly dwelling in a Japanese community: A 4-year population-based prospective cohort study

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Abstract

This study longitudinally examined the relationships between the specific domains of cognitive performance and functional decline among the community elderly. The study population was 119 men and 194 women aged 70–84 at baseline, who were examined at both baseline and in a 4-year follow-up survey. Katz's Index and the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) were used for measuring the functional capacities of basic activities of daily living (BADL) and higher-level competence, respectively. For the purpose of analyses, declines in each subscale of functional capacity during the follow-up period were used as outcome variables; and specific domains of cognitive performances, including information processing speed, executive function, orientation, and episodic memory at baseline, were used as independent variables. Multiple logistic regression analyses, adjusted for the potential confounders, showed that information processing speed and orientation were associated independently and inversely with BADL decline, and that information processing speed and executive function were related independently and inversely to higher-level competence decline. These results suggested that information processing speed and orientation are reliable predictors for decline in BADL, and information processing speed and executive function are also reliable predictors for decline in higher-level competence among the community elderly.

Keywords: Functional decline; BADL; Higher-level competence; Cognitive performance; Prospective cohort study; Community elderly

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1. Introduction

Along with the worldwide graying of populations, the maintenance of functional capacity among the elderly has become a major issue in geriatrics and gerontology (Aguero-Torres et al., 1998; Stuck et al., 1999). Functional capacity is regarded as a critical component of ability in order for older people to live independently in their everyday lives. Functional capacity contains two major components: "BADL" and "higher-level competence." BADLs include basic level activities, such as walking, eating, bathing, dressing, and toileting. Higher-level competence, indicating higher-level functional capacity above BADLs, corresponds to the fifth, sixth, and seventh sublevels of Lawton's hierarchical model of behavioral competence (Lawton, 1972) and includes activities such as preparing meals, managing money, taking medications, writing forms, and visiting the homes of friends.

To better understand the nature of functional capacity, previous studies have identified the following predictors for declining functional capacity among the elderly (Stuck et al., 1999): cognitive functioning, depression, comorbidity, functional limitation in the lower limbs, physical activity, social contact, smoking, and vision impairment, etc. Recent longitudinal studies have confirmed the relationship of level of cognitive performance to functional decline (Moritz et al., 1995; Aguero-Torres et al., 1998; Ishizaki et al., 2006; McGuire et al., 2006) among cognitively normal older people dwelling in a community. However, most of these previous studies used relatively simple cognitive scales (e.g., the Mini-Mental State Examination (MMSE)) (Folstein et al., 1975; Ishizaki et al., 2006) and the Short Portable Mental Status Questionnaire (SPMSQ) (Pfeiffer, 1975; Moritz et al., 1995) to evaluate the relationship (Gill et al., 1997). Further exploration to confirm which specific domains of cognitive performance more closely predict functional decline may be needed to facilitate the development of effective and efficient strategies for preventing or slowing functional decline among the elderly.

The present study therefore examined the relationship of specific domains of cognitive performance (information processing speed, executive function, orientation, and episodic memory) and functional decline (declining in BADL and higher-level competence) among community dwelling, non-disabled older people using a 4-year prospective, population-based approach.

2. Subjects and methods

2.1. Participants

The source of data for the present study was the Longitudinal Interdisciplinary Study on Aging conducted by the Tokyo Metropolitan Institute of Gerontology (Shimonaka et al., 1997; Iwasa et al., 2007). The study was administered in Itabashi ward, which is located in the north part of Tokyo. As of 1991, a sample of 4440 residents (aged 50–74 years) had been obtained systematically from the municipal resident registration files (*Juumin Kihon Daichou* in Japanese) in the area. We acquired 3097 completed sets of data in the first round of home-visit surveys in 1991. We then conducted follow-up interviews every succeeding

year. The 10th follow-up survey, conducted in 2001, was regarded as the baseline for the current analysis because it was the first assessment that included cognitive performance measures for the elderly. For that survey, 854 people aged 70–84 who lived in the target region were invited to participate, and 438 people (168 men and 270 women) took part in the survey voluntarily (51.3% participation) (Iwasa et al., 2007).

Among the 438 individuals who participated in the baseline survey, 322 participated in the follow-up survey in 2005. The remaining 116 people did not take part in the survey because 23 of them had died during the 4-year follow-up period, 19 had moved to a different part of Japan, 57 declined to participate, 4 had been institutionalized, and 13 were unable to be contacted due to long-term absence. Of the 322 people who did participate in the follow-up survey, 9 were excluded from this analysis; 6 had missing cognitive performance data at baseline, 2 were considered to have severe cognitive impairment (MMSE < 21) (Folstein et al., 1975) at baseline, and the number of years of education of 1 could not be determined. In total, therefore, 313 participants (119 men and 194 women) with a complete set of data remained, and their data were used for this analysis. Compared with these participants, those without follow-up data tended to be older (mean age: 76.0 vs. 74.7 years, $p = 0.02$) at baseline, almost identical with regard to the rate of women (60.3% vs. 62.4%, $p = 0.992$), and similar in the number of years of education (10.2 vs. 10.6 year, $p = 0.169$).

2.2. Measurements of functional capacity

Functional capacity was measured using self-reported BADL and higher-level competence scales.

Assessment of BADL was administered at both the baseline and follow-up period. BADLs, comprised of basic self-care tasks necessary for an adult to live independently, were measured using the following five items: walking, eating, bathing, dressing, and toileting. Participants were asked to judge whether or not they were independent (able to do without any help from another person or special equipment) with respect to the five tasks listed above. Only those participants who reported being independent in all BADLs were regarded as BADL independent. Those subjects who were dependent with respect to one or more BADLs were regarded as BADL dependent.

The TMIG-IC (Koyano et al., 1991) was performed at both the baseline and follow-up periods. The TMIG-IC is a multidimensional 13-item scale that assesses higher-level competence on the basis of Lawton's hierarchical model of behavioral competence (Lawton, 1972). Participants were asked to judge whether they were independent with respect to the 13 tasks shown in Table 1. Higher scores reflect a higher-level competence. In this study, a cut-off score of 10/11 (meaning that scores of 10 and below were classified as higher-level competence dependent) was used to judge whether participants were dependent with respect to higher-level competence (Koyano et al., 1993).

2.3. Measurements of cognitive performance

Cognitive performance tests were performed in four domains. Digit symbol substitution, from the Wechsler Adult Intelligent Scale-Revised (Wechsler, 1981), was

Table 1
Tokyo Metropolitan Institute of Gerontology Index of Competence

1	Can you use public transportation (bus or train) by yourself?
2	Are you able to shop for daily necessities?
3	Are you able to prepare meals by yourself?
4	Are you able to pay bills?
5	Can you handle your own banking?
6	Are you able to fill out forms for your pension?
7	Do you read newspapers?
8	Do you read books or magazines?
9	Are you interested in news stories or programs dealing with health?
10	Do you visit the homes of friends?
11	Are you sometimes called on for advice?
12	Are you able to visit sick friends?
13	Do you sometimes initiate conversations with young people?

used for "information processing speed." Verbal fluency was used for "executive function." Time and place orientation from the MMSE was used for "orientation," and delayed recall, also from the MMSE, was used for "episodic memory."

Digit symbol substitution is comprised of a paper-and-pencil task. The participants receive a test sheet paper and are asked to do a timed translation of numbers to symbols using a cue given at the top of the test page and write as many symbols as possible into the empty boxes below each digit. The test is scored as the number of correct translations completed within 90 s, with a potential range of 0–93. The task evaluates the domain of "information processing speed," which refers to the cognitive ability to quickly and accurately process newly input information from outside and retrieve materials held in memory storage (Barberger-Gateau et al., 1999).

Verbal fluency requires participants to generate aloud as many words as possible that belong to particular categories semantically and phonologically during a certain period of time. In this study, two tasks were administered as verbal fluency tasks. The participants were given 60 s to say as many words as possible belonging to the category of animals and beginning with the Japanese *kana* syllabary letter of "*ka*". The task score was the number of acceptable words produced in the two tasks. For the domain of "executive function," this test reflects a set of cognitive abilities involved in the planning, initiation, sequencing, and monitoring of goal-directed activities (Chaves et al., 2006).

Time and place orientation is comprised of summing up the number of correct answers to the 10 items of the "orientation to time and place" subscale of the MMSE. It thus has a score range of 0–10. The task assesses the domain of "orientation," which reflects the mental ability to grasp basic circumstances and understand fundamental information like time and place in order to live independently.

Delayed recall is a subscale of the MMSE with a score range of 0–3 that records the number of objects correctly recalled. The task assesses the domain of "episodic memory," which reflects the long-term memory storage system that deals with everyday experiences encoded in a particular time and place. It enables the conscious recollection of personal events and episodes from one's personal past (Tulving, 1983).

2.4. Other measurements

Data for age, gender, the number of years of education, self-rated health, living alone, presence of chronic diseases, and depressive status (Sheehan et al., 1998), were used to describe the characteristics of the study participants. Self-rated health was scored from responses to the question, "Would you say your health in general is excellent, good, poor, or very poor?" Moreover, in the analysis these responses were dichotomized into two categories: "Excellent/Good" and "Poor/Very Poor." The presence of chronic diseases was defined as having at least one disease from among stroke, heart disease, and diabetes mellitus. Data for age, gender, the number of years of education, presence of chronic diseases, and depressive status were used as covariates in analyzing for independent associations between cognitive performance and functional decline.

2.5. Procedure

The participants took part in a face-to-face interview in a comprehensive health examination (*Otasha-Kenshin*) (Iwasa et al., 2007) at baseline and in a door-to-door interview in the follow-up period. Trained research assistants administered the instruments to obtain the data described above. The study was approved by the Ethics Committee of the Tokyo Metropolitan Institute of Gerontology. We were given access to the municipal resident registration files by the Itabashi ward authorities. The study was explained to all participants, and all were advised that: (1) their participation would be entirely voluntary; (2) they could withdraw from the study at any time; and (3) if they chose not to participate or to withdraw, then they would not be disadvantaged in any way.

2.6. Statistical analysis

To examine the relationships between cognitive function and functional decline, only subjects who had no functional dependency at baseline in each subscale of functional capacity (BADL and higher-level competence) were followed-up. "Functional decline" was defined as the new onset of functional dependency during the 4-year follow-up period.

Logistic regression analyses were performed to test the associations by each cognitive performance test. Crude odds ratio [OR] estimates and the confidence intervals [CI] corresponding to the four cognitive performance domains were initially computed, and then adjusted OR estimates controlling for age, gender, number of years of education, presence of chronic diseases, and depressive status were calculated. One OR unit in the cognitive tests corresponded to a 1S.D. decrease (9.9, 6.6, 0.8, and 0.9 points for information processing speed, executive function, orientation, and episodic memory in BADL decline model, respectively; 9.7, 6.7, 0.6, and 0.8 points for information processing speed, executive function, orientation, and episodic memory in higher-level competence decline model, respectively). All statistical procedures were performed using SAS Version 9.1 software (SAS Institute Inc., Cary, NC, USA).

Table 2
Characteristics of participants at baseline ($N = 313$)

Age (mean ± S.D.)	74.7 ± 3.7
Gender (% women)	62.0
Number of years of education (mean ± S.D.)	10.6 ± 2.7
Living alone (%)	18.5
Self-rated health (% poor/very poor)	19.8
Presence of chronic diseases[a] (%)	19.2
Depression (%)	3.2
Information processing speed (mean ± S.D.)[b]	37.6 ± 9.9
Executive function (mean ± S.D.)[b]	23.5 ± 6.6
Orientation (mean ± S.D.)[b]	9.6 ± 0.8
Episodic memory (mean ± S.D.)[b]	2.2 ± 0.9
BADL dependent (%)	0
Higher-level competence dependent (%)	13.1

[a] Presence of chronic diseases was defined as having at least one disease from among stroke, heart disease, and diabetes mellitus.

[b] Actual range for information processing speed (6–70), for executive function (8–42), for orientation (6–10), and for episodic memory (0–3).

3. Results

Table 2 gives the characteristics of the members of the follow-up cohort (e.g., age, proportion of women, number of years of education, proportion of living alone, self-rated health, presence of chronic diseases, and proportion of depression), cognitive performance (information processing speed, executive function, orientation, and episodic memory) and functional capacity (BADL and higher-level competence) at baseline.

During the follow-up period, the number of participants who were classified as newly BADL decline was 19 (6.1%), and the number who were classified as newly higher-level competence decline was 83 (30.5%).

Table 3 shows the associations between cognitive performance and functional decline. Multiple logistic regression analyses, adjusted for the potential confounders cited above, showed that information processing speed (OR (for a 1S.D. decrease) = 2.22, 95% CI: 1.26–4.12) and orientation (OR = 1.59, 95% CI: 1.13–2.22) were associated significantly, independently, and inversely with BADL decline, and that information processing speed (OR = 1.45, 95% CI: 1.08–1.96) and executive function (OR = 1.38, 95% CI: 1.04–1.83) were related significantly, independently, and inversely to higher-level competence decline. Episodic memory was neither associated with BADL decline nor higher-level competence decline.

4. Discussion

The present study was conducted in order to examine the relationships among specific domains of cognitive function and longitudinal change in functional capacity among non-disabled, community dwelling older people. Our findings indicated that information processing speed and orientation inversely predicted BADL decline, and that information

Table 3
Crude and adjusted [OR] of 1S.D. decrease in cognitive performance to functional decline during a 4-year follow-up[a,b,c]

	BADL ($N = 313$)						Higher-level competence ($N = 272$)					
	Crude model			Adjusted model[d]			Crude model			Adjusted model[d]		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Information processing speed	2.56	1.51–4.55	<0.001	2.22	1.26–4.12	0.008	1.45	1.11–1.93	0.008	1.45	1.08–1.96	0.015
Executive function	1.39	0.86–2.35	0.192	1.34	0.82–2.31	0.263	1.36	1.04–1.79	0.028	1.38	1.04–1.83	0.026
Orientation	1.72	1.26–2.33	<0.001	1.59	1.13–2.22	0.007	1.23	0.96–1.59	0.095	1.22	0.95–1.58	0.123
Episodic memory	1.14	0.71–1.75	0.577	0.99	0.61–1.54	0.954	1.12	0.73–1.23	0.692	0.93	0.71–1.21	0.593

[a] During the follow-up period, the number of participants who were classified as newly BADL decline was 19 (6.1%), and the number who were classified as newly higher-level competence decline was 83 (30.5%).

[b] One OR unit in cognitive performance corresponds to a 1S.D. decrease (9.9, 6.6, 0.8, and 0.9 points for information processing speed, executive function, orientation, and episodic memory in BADL decline model, respectively; 9.7, 6.7, 0.6, and 0.8 points for information processing speed, executive function, orientation, and episodic memory in higher-level competence decline model, respectively).

[c] Logistic regression analyses were performed by each cognitive performance test.

[d] Adjustments for age, gender, number of years of education, presence of chronic diseases (stroke, heart disease, and diabetes mellitus), and depressive status were calculated.

processing speed and executive function also inversely predicted higher-level competence decline, when adjusted for potential confounders.

Information processing speed predicted both BADL decline and higher-level competence decline in this study, suggesting that information processing speed is a comprehensive predictor of longitudinal change in both high and essential levels of functional capacity in daily life. Owsley et al. (2002) examined cross-sectionally the relationship between three domains of cognitive measures (information processing speed, episodic memory, and reasoning) and functional capacity and found that only information processing speed was associated with the instrumental activities of daily living (IADL), which are comprised of higher-level competence activities, indicating that information processing speed is integral to the rapid and efficient performance of especially higher-level daily activities among the elderly. In addition, we also confirmed the relationship of information processing speed with BADL. It is well-known that information processing speed is also a good predictor of mortality (Swan et al., 1995) and is also associated closely with physical function performance (Owsley and McGwin, 2004), indicating that information processing speed might also maintain basic levels of daily activity. For these reasons, information processing speed is a comprehensive predictor of longitudinal change in both high and essential levels of functional capacity in daily life.

Executive function predicted only higher-level competence decline in this study, suggesting that executive function is a more important predictor of higher-level competence decline compared to BADL decline. Carlson et al. (1999) found in a cross-sectional study among the community elderly that executive function had a much closer correlation to IADL than to BADL. Additionally, Cahn et al. (1998) discovered in a cross-sectional study among patients with Parkinson's disease that there was only a relationship between executive function and IADL and not simple motor functioning like finger movements and finger tapping, in contrast, simple motor function, but not executive function, was found to be associated with BADL.

Orientation predicted only BADL decline in this study, suggesting that orientation may be more of a predictor of BADL decline than higher-level competence decline. Our finding is similar to the results of previous studies (Weiler et al., 1994; Gill et al., 1997). Orientation is a sign of the early stage of cognitive impairment (Solomon et al., 1998). Older people with cognitive impairment are likely to experience BADL decline (Aguero-Torres et al., 1998). Consequently, a low level of orientation is an indicator of the incidence of cognitive impairment and can predict BADL decline. On the other hand, a relationship between orientation and higher-level competence was not found in this study. These therefore indicate that orientation may be more of a predictor of BADL decline than higher-level competence decline.

Episodic memory predicted neither BADL decline nor higher-level competence decline in this study, suggesting that there is a possibility that episodic memory itself could be unimportant and employed not so much for daily life among the community elderly because of following three reasons. First, there are a few cross-sectional studies that did not find a significant relationship between episodic memory and functional capacity (Carlson et al., 1999; Cahn-Weiner et al., 2000; Owsley et al., 2002). Second, older people are likely to take notes to memorize information, and read recordings on

books and newspapers to recollect detailed information about past events in everyday life. Third, it is guessed that "prospective memory", which is concerned with memory function for future intensions, may be more reliable predictor of functional decline in daily life, compared to episodic memory. Ability to remember to do at the right time has important implications for older people's everyday functioning, because, for instance, failing to take medication or attend a medical appointment could potentially have very serious consequences (Crawford et al., 2006). On the other hand, there are previous studies that discovered a significant relationship between episodic memory and functional decline (Gill et al., 1997; Dodge et al., 2006). Thus, further detailed examinations of the relationship are needed.

The mechanism related to the association between the components of cognitive performance and functional decline was unable to be clarified in this study. Nonetheless, we can suggest two possible types of association between cognitive function and functional decline. First, cognitive functioning may be an indicator of the influence of the other critical risk factors for functional decline, such as physical and mental health status, socio-economic status, and social integration, etc. (Stuck et al., 1999). However, this possibility should be noted as being relatively weak as the present study managed to adjust for possible confounding factors in the association. Second, cognitive function may also have a direct effect on functional decline, namely, aging-related cognitive decline and the incidence of cognitive impairment may directly determine functional decline in old age. Regardless of the type of mechanism, however, in this study we could confirm that cognitive performance is a crucial predictor for functional decline, and, moreover, our findings are useful for the prevention of functional decline in health promotion settings of the community elderly.

Generalization from our findings is limited in one major way. There is the possibility that the representativeness of the data set may have been restricted because out of the 438 individuals who participated in the baseline survey, 116 (26.5%) did not take part in the follow-up survey due to reasons including death, loss of follow-up contact information, and declining to participate, etc.

5. Conclusion

This study longitudinally examined associations between specific domains of cognitive performance and functional decline among the community elderly. We found that information processing speed and orientation are reliable and inverse predictors of BADL decline, and that information processing speed and executive function are reliable and inverse predictors for higher-level competence decline. Further research is needed to better understand the mechanism involved in the relationships reported herein.

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Low Serum 25-Hydroxyvitamin D Levels Associated With Falls Among Japanese Community-Dwelling Elderly

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ABSTRACT: Previous studies have shown that low serum 25-hydroxyvitamin D [25(OH)D] level is a risk factor for falls among the elderly in European and North American populations. We used a cross-sectional community-based survey to study the association of serum 25(OH)D level and falls among Japanese community-dwelling elderly. A total of 2957 elderly persons (950 men and 2007 women) 65–92 yr of age who participated in mass health examinations for the prevention of geriatric syndrome for the elderly underwent an interview, blood analysis, and physical performance testing. Experience of falls over the previous year was assessed in an interview. Physical performance tests of handgrip strength, stork standing time with the eyes open, and normal waking speed as risk factors for falls among the elderly were conducted. Serum albumin and 25(OH)D concentrations were analyzed. Mean 25(OH)D concentration was significantly lower in women than in men ($p < 0.001$). Women showed a significant decline of 25(OH)D level with increased age ($p < 0.001$). There was also a significant difference in the prevalence of 25(OH)D insufficiency [25(OH)D level < 20 ng/ml] between the sexes ($p < 0.001$). The rate of falls was significantly higher in the lowest quartile of 25(OH)D level in women ($p = 0.02$) and in women with 25(OH)D insufficiency ($p = 0.001$). Women also showed significant declines in all three fall-related physical performance tests. Multiple logistic regression analysis showed significant and independent associations between 25(OH)D level and experience of falls in women only ($p = 0.01$). Low 25(OH)D level was significantly associated with a high prevalence of falls in Japanese elderly women because of their inferior physical performance. Low serum 25(OH)D levels appear preventable and easily treated; there is an evident need for greater awareness to screen and thus prevent this condition.
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Key words: 25-hydroxyvitamin D, fall, physical performance, community elderly

INTRODUCTION

THE IMPORTANCE OF vitamin D for skeletal health is well known.[1,2] Through the regulation of calcium and phosphorus levels in the blood by promoting their absorption from food in the intestines, vitamin D promotes bone formation and mineralization for the development of a strong skeleton. Vitamin D deficiency, which can result from inadequate intake coupled with inadequate sunlight exposure, plays an important role in the development of osteoporosis because of the induction of a secondary hyperparathyroidism that mobilizes calcium from the bone.

Vitamin D deficiency results not only in impaired bone mineralization, but also in myopathy in the elderly.[3,4] It has also been shown recently to be associated with a decline of muscle strength,[5–8] sarcopenia,[7] and functional limitations and disability,[5,8] and probably because of these phenomena, with falls in the elderly.[9–11] We have studied and reported that concomitant low serum 25-hydroxyvitamin D [25(OH)D] and albumin were associated with decreased objective physical performance among Japanese community-dwelling elderly from a nutritional point of view.[12] However, falls were not taken into account in the previous study.

The aim of this study was to investigate the association between serum 25(OH)D levels and falls, and the associated physical performance among community-dwelling Japanese elderly who in some previous studies have been reported to have stronger muscle strength and lower fall rates than whites.[13,14] We hypothesized that low 25(OH)D levels (1) correlate with poor muscle strength, balance, and walking capability and (2) are consequently associated with the occurrences of falls among community-dwelling Japanese elderly.

MATERIALS AND METHODS

Subjects

The participants were 2957 residents (950 men and 2007 women) ≥65 yr of age living in Itabashi ward in Tokyo, Japan, who had participated in mass health checkups for the community elderly (Otasha-Kenshin) conducted in October/November 2004 and 2005. Otasha-Kenshin, which means "health checkups for successful aging" in Japanese, is a comprehensive mass health examination for commu-

The authors state that they have no conflicts of interest.

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nity-dwelling elderly that aims to prevent "geriatric syndrome" including falls and fractures, incontinence, poor oral health, mild cognitive impairment, depression, and undernutrition. The overall aim is to prevent the loss of independence and the need for long-term care in later life. Details of Otasha-Kenshin, including participant details, investigation methods, and its contents, have been described in our earlier papers.[15–17] None of the subjects analyzed in this study had a history of malignant diseases, current treatment of vitamin D, chronic renal failure, or other serious diseases affecting vitamin D regulation. All participants were essentially ambulatory, lived independently in their homes, and had sound functional capacity. Participants provided written informed consent to participate in the study, which was approved by the Institutional Review Board and Ethic Committee of the TMIG (Accepted No. 5, July 1, 2004).

Data collection

Interviews were conducted to assess the age, physical activity, and chronic disease conditions of subjects. History of chronic diseases was self-reported and included hypertension, stroke, heart disease, diabetes, and renal failure. Heart disease included angina pectoris, acute myocardial infarction, congestive heart failure, and various arrhythmias. Renal failure was defined as chronic renal failure under treatment including hemodialysis, which can affect the regulation and metabolism of serum vitamin D levels.

We also assessed fall experience over the previous year. A fall was defined as an unintentional change in position resulting in coming to rest at a lower level or on the ground. The subjects were asked about their falls in the same manner as in our previous study.[18] That is, they were asked the question, "Have you experienced any falls during the previous 12 months?" Those who reported one or more falls were asked about the circumstances and consequences of each fall (i.e., the time, reason and place of the fall, the presence or absence of injury, and whether they visited a doctor).

Previous population-based studies have confirmed that physical performance characteristics, including those based on handgrip strength, stork standing time with the eyes open, and normal walking speed, are risk factors for falls among the community elderly in Japan.[18–20] Moreover, these three variables have also been confirmed by a covariance structure model as the essential factors underlying physical performance measures for Japanese elderly living in a community.[21]

Handgrip strength

The peak handgrip force (kg) of each hand was measured by Smedley's hand dynamometer (Yagami, Tokyo, Japan). The test was performed twice, and the higher of the two measurements made on the dominant hand was recorded.

Stork standing

While standing on a square (0.4 × 0.4 m), each subject stood on one foot while watching a point set at eye level 1 m away and tried to maintain this posture. A stopwatch measured the duration in seconds, up to a maximum of 1 min, and the longer of two attempts was recorded.

Normal walking speed

A flat walking path of 11 m was marked with tape at the 3- and 8-m points. A stopwatch measured the time taken to walk 5m, from the time when a foot first touched the ground after the 3-m line to when a foot touched the ground after the 8-m line. The participants were asked to take the test by walking at their normal or preferable speed. The test was repeated and the faster speed recorded.

Because of the possibility of a high correlation among the three physical performance tests, after confirmation by Pearson's correlation coefficient (r), normal walking speed was selected as the representative independent variable for the multiple logistic regression model.

Measurement of serum levels of albumin and 25(OH)D

Blood samples were collected in a nonfasting state and in a sitting position. Analyses were carried out centrally in one laboratory (Special Reference Laboratories, Tokyo, Japan). Serum 25(OH)D levels are commonly used as a measure of vitamin D status,[22–24] and these were measured with an RIT 2 kit (Dia Sorin, Stillwater, MN, USA). The RIT 2 method is based on an antibody specific to 25(OH)D; using this method, the CV was <1%. We summarized the serum 25(OH)D levels of these subjects into quartiles, and used the 25 percentile cut-off to compare groups of subjects with higher and lower 25(OH)D. Lower serum 25(OH)D was defined as 25.0 ng/ml (62.5 nM) or below for men and 21.0 ng/ml (52.5 nM) or below for women. For a definition of vitamin D insufficiency, based on studies performed in the United States and Australia[25,26] showing that a serum 25(OH)D level of at least 15–20 ng/ml is needed to achieve optimum PTH levels, we defined a 25(OH)D level of <20 ng/ml as insufficiency.

Statistical analysis

All data were analyzed with SPSS software for Windows, version 13.0 (SPSS, Chicago, IL, USA); the level of significance was set at 5%.

Means and SDs (for continuous variables) along with proportions (for categorical variables) were calculated for all participants. Differences between men and women were assessed using t-tests for continuous variables and χ^2 tests for categorical data. Differences in serum 25(OH)D levels were analyzed among the four age groups by one-way ANOVA in both sexes. Furthermore, comparisons of fall-related variables by 25(OH)D level were performed using analysis of covariance (ANCOVA) controlled for age in continuous variables, and Mantel-Haenszel χ^2 tests were used to adjust for age in categorical variables in both sexes.

To analyze the association of serum albumin and 25(OH)D level with physical performance (i.e., handgrip strength, stork standing time with the eyes open, and normal walking speed), multiple regression analysis was conducted with age adjustment. To study the association of falls and 25(OH)D levels, logistic regression analysis was

TABLE 1. CHARACTERISTICS OF STUDY PARTICIPANTS

Characteristics	*Male (n = 950)*	*[Min–Max]*	*Female (n = 2007)*	*[Min–Max]*	*p*
Age (yr, mean ± SD)	74.5 ± 5.1	[65–89]	75.4 ± 4.7	[65–92]	<0.001*
Fall experience over the previous year (yes, %)	103 (10.8)		372 (18.5)		<0.001†
Hand grip strength (kg, mean ± SD)	31.4 ± 6.6	[10–52]	18.8 ± 4.6	[1–38]	<0.001*
Stork standing time with eyes open (s, mean ± SD)	37.1 ± 22.5	[1–95]	35.8 ± 23.3	[1–88]	0.152*
Normal walking speed (m/s, mean ± SD)	1.23 ± 0.26	[0.40–2.08]	1.18 ± 0.29	[0.15–2.00]	<0.001*
Serum albumin (g/dl, mean ± SD)	4.35 ± 0.23	[3.4–5.0]	4.31 ± 0.21	[3.3–5.0]	<0.001*
Serum 25(OH)D level (ng/ml, mean ± SD)	28.5 ± 5.0	[8–42]	24.2 ± 4.9	[9–38]	<0.001*
Age group	(n)		(n)		
65–69	(173) 28.4 ± 4.5		(163) 26.8 ± 3.8		
70–74	(314) 28.5 ± 5.3		(763) 24.2 ± 4.6		
75–79	(320) 28.6 ± 4.9		(675) 24.0 ± 5.1		
80+	(143) 28.4 ± 5.5	$p = 0.97$‡	(406) 23.6 ± 5.3	$p < 0.001$‡	
Quartile [cut-off value of 25(OH)D for each percentile]	(ng/ml)		(ng/ml)		
25 percentile	25.0		21.0		
50 percentile	29.0		24.0		
75 percentile	32.0		28.0		
Insufficient (<20 ng/ml, %)	4.8		17.7		<0.001†

* Student's *t*-test for continuous variables between males and females.
† χ^2 test for categorical variables between males and females.
‡ ANOVA in both males and females.

conducted using "fall experience over the previous year" as a dependent variable and other variables [age, physical performance test, serum albumin, and 25(OH)D levels] as independent variables.

RESULTS

The basic characteristics of the subjects, including age, handgrip strength, stork standing with the eyes open, normal walking speed, serum albumin level, and 25(OH)D level, are shown in Table 1. Mean ages were 74.5 ± 5.1 yr in men and 75.4 ± 4.7 yr in women ($p < 0.001$). Concerning fall experience, the numbers (percentage) of individuals who experienced a fall over the previous year were 103 (10.8%) in men and 372 (18.5%) in women. The prevalence of falls was significantly higher in women than men ($\chi^2 = 28.30$, $p < 0.0001$). The number of falls varied from one to five. Sixty-one men (59.2%) and 259 women (69.8%) had experienced only one fall, whereas 42 men and 113 women had recurrent falls of two or more times. The predominant cause of falling was "tripping" in both sexes, followed by "slipping" and "missing a step." The consequences of falling, that is, the conditions of injury, were clearly different between men and women. Although "bruise" (38.7%) and "scratch" (26.1%) were frequent among women, "no injury" accounted for nearly one half (44.7%) of men.

The mean 25(OH)D concentrations were 28.5 ± 5.0 ng/ml in men and 24.2 ± 4.9 ng/ml in women ($p < 0.001$). Only in women was there a significant decline of 25(OH)D concentration with increasing age by ANOVA ($p < 0.001$). Forty-six (4.8%) men and 356 (17.7%) women had a 25(OH)D level of <20 ng/ml (50 nM; $p < 0.001$).

Comparisons of the rate of fall experience over the previous year, average number of falls, physical performance tests, and serum albumin levels are shown in Table 2. Subjects who were judged as not appropriate for the tests because of high blood pressure, heart failure, lumbago, knee pain, etc., were excluded from the physical performance tests. Thus, the total number of subjects who underwent the physical performance tests was 2837 (917 men and 1921 women) in the handgrip strength test, 2519 (792 men and 1727 women) in the stork standing test, and 2044 (455 men and 1589 women) in the normal walking speed test. First, comparisons were conducted between the lowest quartile group (≤25.0 ng/ml in men and ≤21.0 ng/ml in women) and the higher groups. Both hand grip strength and stork standing time were significantly different in men, and all of the measurements were significantly different in women. Furthermore, for women only, the rate of fall experience and average number of falls were significantly higher in the lowest quartile group compared with the other groups ($p = 0.02$ for the rate and $p = 0.021$ for the number). Second, comparisons were conducted between the 25(OH)D insufficiency group (<20 ng/ml) and the normal group (≥20 ng/ml). Hand grip strength and serum albumin level in men, and all measurements except hand grip strength in women, were significantly different between these two groups. Stork standing time, normal walking speed, and serum albumin level were significantly lower in the 25(OH)D insufficiency group. As for rate of fall experience and average number of falls, only women showed that the 25(OH)D insufficiency group had a significantly higher rate ($p = 0.001$) and average number ($p = 0.006$) of falls than the normal group.

Table 3 shows the associations of serum concentrations of albumin and 25(OH)D with physical performance tests by multiple regression models adjusted for age. Serum 25(OH)D level showed significant association with all three variables in the physical performances of both men and women. However, serum albumin level showed significant association only with handgrip strength in both sexes.

Calculations of Pearson's correlation coefficient (r) were

TABLE 2. SERUM 25(OH)D LEVEL AND CHARACTERISTICS FOR MALES AND FEMALES

Characteristics	Male			Female		
	Lower (≦25.0 ng/ml) (n = 249)	*Higher (≧26.0 ng/ml) (n = 701)*	*p*	*Lower (≦21.0 ng/ml) (n = 576)*	*Higher (≧22.0 ng/ml) (n = 1431)*	*p*
Fall experience over the previous year (yes, *n*, %)	27 (10.8)	76 (10.8)	0.938*	129 (22.4)	243 (17.0)	0.020*
Average number of falls (times, mean ± SD)	2.1 ± 2.4	1.7 ± 1.1	0.422†	1.6 ± 1.2	1.4 ± 0.8	0.021[b)]
Hand grip strength (kg, mean ± SD)	30.5 ± 6.7	31.7 ± 6.5	0.020[b)]	17.9 ± 4.6	19.2 ± 4.6	0.002[b)]
Stork standing time with eye open (s, mean ± SD)	34.6 ± 22.5	38.2 ± 22.5	0.046[b)]	31.7 ± 23.5	37.7 ± 23.0	<0.001†
Normal walking speed (m/s, mean ± SD)	1.19 ± 0.26	1.25 ± 0.26	0.061†	1.12 ± 0.28	1.21 ± 0.27	<0.001†
Serum albumin (g/dl, mean ± SD)	4.34 ± 0.24	4.35 ± 0.26	0.616†	4.28 ± 0.23	4.33 ± 0.21	<0.001†
	Insufficiency (<20.0 ng/ml) (n = 46)	*Normal (≧20.0 ng/ml) (n = 904)*	*p*	*Insufficiency (<20.0 ng/ml) (n = 356)*	*Normal (≧20.0 ng/ml) (n = 1651)*	*p*
Fall experience over the previous year (yes, *n*, %)	3 (6.5)	100 (11.1)	0.454*	92 (25.8)	280 (17.0)	0.001*
Average number of falls (times, mean ± SD)	2.7 ± 0.6	1.8 ± 1.5	0.338†	1.7 ± 1.3	1.4 ± 1.5	0.006†
Hand grip strength (kg, mean ± SD)	28.5 ± 6.4	31.5 ± 6.5	0.003†	18.1 ± 4.7	19.0 ± 4.6	0.420[b)]
Stork standing time with eye open (s, mean ± SD)	31.4 ± 22.9	37.5 ± 22.5	0.124†	29.8 ± 22.9	37.2 ± 23.2	<0.001†
Normal walking speed (m/s, mean ± SD)	1.16 ± 0.79	1.24 ± 0.26	0.138†	1.11 ± 0.29	1.20 ± 0.27	<0.001†
Serum albumin (g/dl, mean ± SD)	4.27 ± 0.26	4.35 ± 0.22	0.027†	4.27 ± 0.23	4.32 ± 0.21	<0.002†

* The Mantel-Haenszel χ^2 test adjusted for age.
† ANCOVA adjusted for age.

TABLE 3. ASSOCIATION OF SERUM ALBUMIN AND 25(OH)D LEVELS WITH PHYSICAL PERFORMANCE FOR MALES AND FEMALES

	Handgrip strength			*Stork standing time*			*Normal walking speed*		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Men									
Albumin	0.096	0.852	0.001	0.002	3.644	0.947	0.025	0.053	0.576
25(OH)D	0.067	0.037	0.020	0.075	0.152	0.030	0.111	0.002	0.012
Women									
Albumin	0.109	0.459	<0.001	0.037	2.502	0.106	0.045	0.030	0.051
25(OH)D	0.062	0.020	0.003	0.109	0.105	<0.001	0.143	0.001	<0.001

Values are adjusted for age. *p* values are derived from multiple regression analysis.
β, standardized regression coefficient.

carried out to confirm the correlation among the three physical performance tests. The results showed high and significant intercorrelation for these three variables; correlation coefficients were from 0.23 (handgrip strength and stork standing time) to 0.35 (stork standing time and normal walking speed) in men and from 0.31 (handgrip strength and stork standing time) to 0.47 (stork standing time and normal walking speed) in women, and all were significant at $p < 0.001$. Therefore, we adopted only "normal walking speed" to represent the physical performance tests as well as the independent variable for the final multiple logistic regression model.

Table 4 shows the associations of fall experience over the previous year with normal walking speed, serum albumin, and 25(OH)D levels by multiple logistic regression models with age adjustment. Normal walking speed (unit = 0.1 m/s) showed a significant protective effect against falls in

TABLE 4. MULTIPLE LOGISTIC REGRESSION MODEL OF FACTORS ASSOCIATED WITH FALL EXPERIENCE OVER THE PREVIOUS YEAR

Risk factor	Male			Female		
	OR	*95% CI*	*p*	*OR*	*95% CI*	*p*
Age (yr)	1.02	0.95–1.10	NS	1.02	0.99–1.06	NS
Normal walking speed (0.1 m/s)	0.87	0.77–0.97	0.015	0.92	0.88–0.97	0.001
Albumin (g/dl)	1.69	0.45–6.33	NS	1.60	0.88–2.90	NS
25(OH)D (ng/ml)	1.00	0.95–1.06	NS	0.97	0.94–0.99	0.010

Dependent variable was "fall experience over the previous year" (yes = 1, no = 0).
The unit of normal walking speed was transferred from meters per second to 0.1 m/s in this final multiple logistic regression model.
NS, not significant.

both men (OR = 0.87, 95% CI = 0.77–0.97) and women (OR = 0.92, 95%CI = 0.88–0.97). Serum 25(OH)D level (unit = 1 ng/ml) also had a significant and independent protective effect for falls found only in women (OR = 0.97, 95% CI = 0.94–0.99, $p = 0.01$).

DISCUSSION

Maintenance of physical performance in old age is an important factor not only for a healthy and independent life in the community but also a way to prevent falls that can lead to a marked decline in activities of daily living (ADLs). A national survey in Japan has shown that the annual frequency of falls is >20% in those >65 yr of age and that ~10% of these falls result in fractures.[27]

This study showed that the proportion of people who reported falls in the previous year increased with age and that falls were more common in women than in men.[20] These findings are consistent with the results of other studies of falls among community-dwelling elderly.[28–32] Aoyagi et al.[33] reported that the proportion of falls in the previous year after age standardization for Japanese was about one half of that of whites. Furthermore, the incidence of hip fracture among Japanese elderly was found to be much lower than that reported for whites in North America and Europe.[34] This difference is probably partly the result of the lower fall rate among Japanese, suggesting that both ethnicity (genetics) and lifestyle (environmental) factors may be involved.[14] Recently, some studies have shown that lower serum vitamin D level is a risk factor for falls and fall-associated physical performance among the elderly.[9,10,35] At present, however, there are few studies on the association between serum 25(OH)D level and falls in Japanese community elderly, whose frequency of falls is less than that observed in Europe and the United States.[6–8,13]

In this study, we found that there were significant sex differences of 25(OH)D level on average and in a pattern of decline along with aging; namely, women had significant lower serum 25(OH)D levels at any age group and showed remarkable declines with aging. One of the reasons for this sex difference may be general inactivity and lower intake of vitamin D from daily food among Japanese elderly women compared with men. One Japanese national survey showed that, compared with 39.1% of men, 32.6% of women engage in physical activity for at least 30 min two or more times a week.[36] Our previous study also reported that women had significantly lower rates of regular sports activity than men (13.8% versus 21.5%).[37] Furthermore, we recently reported that one of the significant predictors for cessation of regular activity was "female sex" as well as "smoking" and "slow walking speed" from a population-based, 2-yr follow-up study.[38] The national survey also showed that women took smaller amounts of vitamin D than men (8.6 ± 9.0 versus 8.9 ± 10.0 μg/d on average). In particular, for elderly respondents ≥70 yr of age, the average intake of vitamin D in women (8.6 ± 9.0 μg/d) was much less than that in men (10.3 ± 10.1 μg/d).[36] These factors of physical inactivity and lower intake of daily vitamin D in elderly women may have caused their observed higher frequency of 25(OH)D insufficiency compared with men. It is known that the main source of vitamin D in humans is considered to be through the skin, where vitamin D is produced during exposure to UVB sunlight.[39,40] In our study, to avoid any seasonal variation of serum 25(OH)D, data collection was carried out only during autumn (October/November), which meant that serum 25(OH)D levels would be almost stable and at an average throughout the year among a normal Japanese population.[41]

The range of serum 25(OH)D levels was 8–42 ng/ml in men and 9–38 ng/ml in women. Although it is still uncertain what an optimal 25(OH)D level is, it has been suggested that the range of 25(OH)D levels should be 32–100 ng/ml, with a lower limit somewhere between 15 and 36 ng/ml.[41–43] In this study, we defined a 25(OH)D level of <20 ng/ml as insufficiency. From this, we judged that the prevalence of 25(OH)D insufficiency was significantly predominant in women (17.7%) compared with men (4.8%; $p < 0.001$). Studies concerning the prevalence of 25(OH)D insufficiency in various populations have been challenged because of the lack of standardization of assays and different cut-off points.[44] A comparison of serum 25(OH)D level between hip fracture patients and nonhip fracture controls in Japan showed that average serum 25(OH)D concentrations were significantly different: 17.8 ng/ml in hip fracture patients and 25.8 ng/ml in nonhip fracture controls.[45] Furthermore, 62% of the hip fracture patients ($N = 50$) had 25(OH)D insufficiency, defined as having a serum 25(OH)D concentration <20 ng/ml. In this context, the elderly whose 25(OH)D levels were <20 ng/ml can be considered to be in insufficiency and at high risk of a hip fracture, which indeed has increased sharply during last two decades in Japan.[46]

In comparisons of serum 25(OH)D levels and fall-associated variables between the group of participants in the lowest quartile and the groups of the three other higher quartiles of serum 25(OH)D level, all variables but normal walking speed in men were significantly lower in the lower 25(OH)D group than in the higher group. Our findings are consistent with the results from a Swedish population-based study of 986 community-living elderly women[47] that showed that the lower 25(OH)D group was significantly correlated with inferior gait speed, inferior balance test, and lower knee extension/flexion strength results, all of which are fall-associated variables.

The rate of fall experience over the previous year by serum 25(OH)D level was significantly different only in women [i.e., 22.4% in the lower 25(OH)D group and 17.0% in the higher group ($p = 0.02$) and also 25.8% in the insufficiency group and 17.0% in the normal group ($p = 0.001$), respectively]. The average numbers of falls were also significantly different between the lower and higher groups ($p = 0.021$) and between the insufficient and normal groups ($p = 0.006$), respectively. This finding that lower serum 25(OH)D level or 25(OH)D insufficiency status is associated with falls among elderly women is consistent with many previous studies.[3,4,11] However, there is a controversy about which type of vitamin D [i.e., 25(OH)D or $1,25(OH)_2D_3$] is associated with fall risk. Faulkner et al.,[48] who examined the relationship of vitamin D supplementation and the serum concentration of vitamin D metabolites

with falls in older white, community-dwelling women (n = 389) in the Unites States, reported that only the higher serum $1,25(OH)_2D_3$ concentration was associated with a lower fall risk but that 25(OH)D concentration was not associated with falls. In our study, as one of the study limitations, serum $1,25(OH)_2D_3$ was not assessed in the participants undergoing the mass health examination.

Further analysis on the association of serum albumin and 25(OH)D levels with the fall-associated variables in this study showed that only serum 25(OH)D level had a significant association with all three fall-associated variables in both sexes. On the other hand, serum albumin had a significant association only with handgrip strength in both sexes. The mechanism connecting serum albumin and muscle mass or power is not clear.[49,50] However, serum albumin concentration may be a marker of the protein status of an individual, with lower values indicating a diminished protein reserve and stimulated catabolic processes leading to muscle break down and also muscle strength decline.[50] Thus, low serum albumin, even within a normal range, is independently associated with weaker muscle strength and future decline in older men and women.[51,52]

Serum 25(OH)D concentration is an important determinant of muscle mass and sarcopenia. In an observational study of community-dwelling elderly in the Netherlands, incident sarcopenia, defined as a minimum of 40% decline in muscle strength and 3% decline in muscle mass, was found to be twice as likely among 25(OH)D-deficient elderly [25(OH)D level < 10 ng/ml] than among elderly with a 25(OH)D level of >20 ng/ml.[7] With respect to the role of vitamin D in muscle strength, the majority of the actions of vitamin D are mediated through $1,25(OH)_2D_3$ binding to nuclear vitamin D receptor (VDR) that can directly modulate the transcription of the gene possessing a functional binding site for VDR in its regulatory region.[8,53] Therefore, muscle strength seems to be influenced by the VDR genotype in the muscle cell. With the use of specific restriction endonucleases, several VDR polymorphisms have been determined. In nonobese, older women, a 23% difference in quadriceps strength and a 7% difference in grip strength between two homozygote types of a restriction site have been found.[54] The action of vitamin D is affected by allelic variance of the VDR. A genomic study on VDR polymorphism has shown that Japanese women had much lower frequency of homozygote BB (1.4%) than white women (16.7%).[55] In this context, if the VDR polymorphism affects not only the BMD but also muscle strength of elderly women, Japanese women in general may have an advantage with respect to their lower frequency of falls and associated hip fractures.

As for the association of serum 25(OH)D level and fall experience over the previous year by multiple logistic regression models, even after the adjustment of other fall-associated variables, serum 25(OH)D level was independently associated with falls in women as well as normal walking speed in this study. A considerable number of population-based studies have also been conducted on walking ability in relation to the occurrence of falls in the elderly.[56–60] Increased body sway, uneven distances, and uneven timing during walking were identified as risk factors for falls.[61,62] The authors have previously reported that both fall experience over the previous year and a decline in walking speed were very strong predicators of the occurrence of frequent falls in a 5-yr follow-up cohort study among Japanese community-living elderly.[18] Muscle function or strength as the single most important component for walking ability has been consistently identified as a risk factor for hip fractures as a consequence of falls in the elderly. Subclinical 25(OH)D insufficiency is also considered to be an important risk factor for hip fractures in elderly people in both white[63,64] and Japanese[45] populations. We have suggested that elderly women with lower 25(OH)D levels and with a significant decline in their fall-associated variables tend to decline in walking capability and be more vulnerable to falls even in elderly populations of Japanese women, whose fall rate has been reported to be low.

A relevant issue regarding the role of 25(OH)D in physical performance is that vitamin D supplementation has been reported to be significantly effective in maintaining or improving physical performance and preventing falls among the elderly. In a recent randomized and multiple-dose study, Broe et al.[65] reported that a high dose of vitamin D (800 IU/d) reduced the risk of falls dramatically by 72% lower (adjusted-incidence rate ratio) than participants taking a placebo over the same 5-mo period in a nursing home. However, the question of which type of vitamin D supplementation (i.e., either cholecalciferol or calciferol) is more effective at reducing falls among community-living elderly is still controversial. The association of vitamin D supplementation with better physical performance related to the risk of falls and/or reduced falls is unclear at present. For example, a meta-analysis of five randomized controlled trials provided some evidence that vitamin D supplementation might reduce falls,[10] whereas the results of a second meta-analysis of four randomized controlled trials of vitamin D found no such evidence.[66]

Our findings suggesting that there are significant relationships between serum 25(OH)D and fall-associated physical performance and with falls themselves could provide guidance about how to prevent falls and fractures, particularly hip fractures resulting from falls among community-living elderly. Two such countermeasures are to improve muscle strength, especially in the lower extremities, and to enhance balance ability.[67,68] For example, from a randomized controlled exercise intervention trial for Japanese community-dwelling elderly, we have proven that a moderate exercise intervention program in addition to a home-based program significantly improved fall-associated variables and, consequently, decreased the incidence of falls for 1.5 yr after the intervention.[67]

Another countermeasure would be to maintain a high level of serum 25(OH)D by adequate intake of foods containing vitamin D, supplementation, and exposure to sunlight. Incidentally, fish consumption seems to play an important role in maintaining adequate vitamin D nutrition among elderly Japanese.[69] In general, these countermeasures seem to be consistent with the traditional Japanese lifestyle. Our earlier study using risk factor analysis of hip fractures in elderly Japanese showed that such a traditional

Japanese lifestyle, including living on Japanese tatami mats and eating fish daily, was strongly associated with a decrease in the risk of hip fractures.[14] Living on Japanese tatami mats, including futon-style bedding, seems have great benefits for preventing falls and hip fractures by continuously strengthening the muscles of the hip girdle and lower extremities by sitting, squatting, and frequent standing over the course of many years. Furthermore, consumption of dark-meat fish, which is rich in vitamin D, also seems to be beneficial for maintaining adequate 25(OH)D levels in the elderly, especially in the winter season.[69]

Before detailing our final conclusions, some limitations of our study must be considered. (1) The subjects analyzed were not selected randomly from the study population; as well, they were relatively healthy elderly persons who were able to travel from their homes to the health checkup venue. As a result, elderly persons with lower physical functional capacity were excluded. (2) Plasma $1,25(OH)_2D_3$, albumin-corrected calcium, and PTH, which would provide information on the extent of any primary vitamin D deficiency,[8,48,70] and creatine clearance that may affect the metabolism of vitamin D through the kidney,[71] were not assessed in this study. It is well known that increased secretion of PTH is associated with decreased serum 25(OH)D levels, which may commonly occur in the elderly. However, according to a survey on the nutritional status of vitamin D among Japanese community-dwelling elderly, Nakamura et al.[72] reported that only 1.8% of the subjects had elevated intact PTH levels. (3) We did not analyze the genotype of the VDR that could influence muscle strength and, likely, the fall rate as well. (4) This study was cross-sectional and therefore did not provide cause/effect relationships, although we showed a significant correlation between physical performance and serum 25(OH)D levels in Japanese community-dwelling elderly. Therefore, a longitudinal follow-up study and controlled clinical trials would seem necessary to confirm the role of serum 25(OH)D in falls and its association with the physical performance of the elderly.

In conclusion, our findings showed that a lower serum 25(OH)D level was significantly associated with fall experience over the previous year and with fall-associated variables in Japanese women whose fall rate has been reported to be about one half that of white women. This indicates that serum 25(OH)D level has a common and positive relationship with the occurrence of falls in elderly women, and probably beyond any genetic background represented by VDR phenotype differences and anthropometric and nutritional differences.

Muscle weakness or sarcopenia, frailty, and falls, all of which can be frequent among the elderly and therefore are often categorized as geriatric syndrome, have a major impact on the elderly in terms of both morbidity and mortality. The connections between these items related to geriatric syndrome and 25(OH)D has been well established by many population-based epidemiological studies including this one. Such geriatric syndromes could be prevented by both exercise interventions and adequate levels of serum 25(OH)D; these would help maintain good physical performance and functional capacity for a high quality of life among community-dwelling elderly.

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