adults aged 65 years or older. We recruited community-dwelling older adults who were independent in terms of the activities of daily living (ADL) in 2009. The exclusion criteria were older adults who were already ADL-dependent and were eligible to receive benefits from LTCI services. The subjects were followed prospectively for 2 years. During the follow-up period, 226 subjects died or moved; thus, we analyzed 8063 elderly adults. This study was conducted in accordance with the guidelines of the Declaration of Helsinki, and the study protocol was reviewed and approved by the Ethics Committee of the Kyoto University Graduate School of Medicine.

2.2. Serum creatinine and albumin

The serum creatinine and albumin levels of the subjects were measured. The estimated glomerular filtration rate (eGFR) was calculated using a formula reported by Matsuo et al. (2009): eGFR $(\text{mL/min}/1.73\ \text{m}^2) = 194 \times \text{Scr}^{-1.094} \times \text{Age}^{-0.287} \times 0.739$ (if female). This equation originated from the MDRD study group (Coresh, Astor, Greene, Eknoyan, & Levey, 2003) arranged for Japanese individuals, and it is recommended by the Japanese Society of Nephrology. The study cohort was divided into 4 groups according to serum albumin and eGFR quartiles.

2.3. Frailty checklist

The frailty checklist included simple yes/no questions concerning lifestyle (questions 1–5), motor abilities (questions 6–10), nutrition (questions 11–12), oral functions (questions 13–15), seclusion (questions 16–17), forgetfulness (questions 18–20), and emotions (questions 21–25) (Table 1). The total score on the frailty checklist is useful for predicting the risk of being newly certified as needing LTCI services (Coresh et al., 2003). Furthermore, physical exercise is an effective means of improving the total score on the frailty checklist (Imai et al., 2007).

2.4. Body mass index

The patients' height and weight were measured to calculate their body mass index (BMI).

2.5. Outcome measure

The outcome measure was new LTCI service need certification over a 2-year period. The selection process for classifying dependent older adults first involves a questionnaire that evaluates the person's current mental and physical condition (74 items), which is analyzed using a computerized algorithm. A long-term care approval board reaches a final decision based on the algorithm-aided analysis of the questionnaire, a doctor's recommendation, and a home visit report. Individuals who become certified as dependent older adults are subdivided into seven levels (support levels 1 and 2 and care levels 1–5), depending on their conditions. They are provided home and community-based or institutional services according to their care needs. Individuals who are not eligible for long-term care or support care may utilize preventive care services.

2.6. Statistical analysis

The baseline characteristics of the subjects who were certified or non-certified as needing LTCI services were compared. Differences in the demographic variables between the 2 groups were analyzed using Student's *t*-test or a chi-square test. In addition, differences in the demographic variables among the 4 groups stratified by eGFR quartile were examined using an analysis of variance (ANOVA) and a post hoc test. Kaplan-Meier survival curves were calculated for the group newly determined to need LTCI services and were stratified by eGFR quartile. Cox proportional hazards models were used to estimate the hazard ratios (HR) and 95% confidence intervals (CI) of the relationships between

Table 1
The frailty checklist used in Japan.

Domain	Question	Items	Yes	No
Lifestyle	1	Do you ride the bus or train alone?	0	1
	2	Do you buy household goods for everyday use?	0	1
	3	Do you withdraw and deposit savings?	0	1
	4	Do you visit your friends' homes?	0	1
	5	Do you give advice to family and friends?	0	1
Motor abilities	6	Can you climb stairs without holding onto a handrail or the wall?	0	1
	7	Can get up from a chair without grabbing something?	0	1
	8	Are you able to keep walking for about 15 min?	0	1
	9	Have you fallen in the past year?	1	0
	10	Are you very worried about falling?	1	0
Nutrition	11	Have you ever lost more than 2–3 kg of weight in a 6-month period?	1	0
	12	BMI is less than 18.5.	1	0
Oral function	13	I cannot eat hard foods as well as 6 months ago.	1	0
	14	Have you ever choked on tea or soups?	1	0
	15	Are you concerned with being thirsty?	1	0
Seclusion	16	Do you leave your home at least once a week?	0	1
	17	Compared to last year, has the number of times you go out decreased?	1	0
Forgetfulness	18	Are you told that you are forgetful or you always tell me the same thing?	1	0
	19	Do you look up phone numbers and make phone calls yourself?	0	1
	20	Do you sometimes forget the date and month?	1	0
Emotions	21	(In the past 2 weeks) I do not feel fulfillment in my daily life.	1	0
	22	(In the past 2 weeks) The activities I used to enjoy are no longer enjoyable.	1	0
	23	(In the past 2 weeks) The activities I used to carry out with ease have become troublesome.	1	0
	24	(In the past 2 weeks) I do not think I am a useful person.	1	0
	25	(In the past 2 weeks) I feel tired for no reason.	1	0

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Table 2
Baseline characteristics of the study subjects in both groups.

	Certified for LTCI requirement (n = 536)			Non-certified for LTCI requirement (n = 7527)			
	Mean	SD	Min–max	Mean	SD	Min–max	P-Value
Age (years)	80.8	7.4	66–100	76.7	6.5	65–102	<0.001
Gender (female)	332 (61.9%)	4405 (58.5%)	0.043				
BMI (kg/m^2)	22.4	3.5	13.8–35.8	22.8	3.2	12.7–39.8	0.073
Frailty checklist (points)	6.5	4.9	0–23	4.3	4.0	0–24	<0.001
Serum albumin (g/dl)	4.2	0.3	3.2–5.0	4.3	0.3	2.6–5.4	<0.001
eGFR (ml/min/1.73 m^2)	68.5	20.7	22.2–121.3	71.4	17.2	20.3–123.8	<0.001

eGFR quartile and the time to new LTCI service need certification in univariate and multivariate analyses. Multivariate analyses were performed for each covariate and were adjusted for gender, BMI, frailty checklist score, and serum albumin level, factors that are known to be associated with frailty (Levey et al., 2006; Tomata et al., 2011; Yamada, Arai, Sonoda, & Aoyama, 2012). Survival time was defined as the time between enrollment (the date of the baseline measurements) and either the new LTCI service need certification or the end of the follow-up period (March 31, 2011). The data were analyzed using PASW (Windows version 18.0, SPSS, Inc., Chicago, IL). A P value <0.05 was considered statistically significant for all the analyses.

3. Results

During the 2-year follow-up, 536 subjects (6.6%) became newly certified as needing LTCI services (Table 2). Those who were certified for LTCI need were significantly older (80.8 ± 7.4 vs. 76.7 ± 6.5, $P < 0.001$) and had higher frailty checklist scores (6.5 ± 4.9 vs. 4.3 ± 4.0, $P < 0.001$), lower serum albumin levels (4.2 ± 0.3 vs. 4.3 ± 0.3, $P < 0.001$), and lower eGFR values (68.5 ± 20.7 vs. 71.4 ± 17.2, $P < 0.001$) than those who were not certified. More women than men became certified in this cohort (female: 61.6% vs. 58.5%, $P = 0.043$). However, the BMIs were not different between the two groups ($P = 0.073$) (Table 2). We also examined whether eGFR was associated with BMI, frailty checklist score, or serum albumin level. We found that the subjects with eGFR < 60.0 ml/min/1.73 m^2 were significantly older and had lower BMIs, higher frailty checklist scores, and lower serum albumin levels ($P < 0.05$) (Table 3).

Next, we examined the relationship between each variable and new LTCI need certification. The subjects with BMIs <20.5 exhibited a significantly elevated risk of LTCI service need according to multivariate analyses using a BMI of 22.7–24.7 as the reference (adjusted hazard ratio: 1.41 [95% CI 1.11–1.78]) (Table 4). The mean BMI was 22.7 ± 3.3, with a range from 12.7 to 39.8; 1975 participants (24.5%) had BMIs <20.5. The subjects with frailty checklist scores >6 had a significantly elevated risk of LTCI service need according to multivariate analyses using frailty checklist scores <2 as the reference (adjusted hazard ratio: 2.24 [95% CI 1.73–2.90]) (Table 4). The mean frailty checklist score was 4.5 ± 4.1, with a range from 0 to 24; 2042 participants (25.3%) had frailty checklist scores >6. Participants with serum albumin levels <4.1 g/dl tended to exhibit an elevated risk of LTCI service need according to multivariate analyses using a serum albumin level >4.4 g/dl as the reference (adjusted hazard ratio: 1.25 [95% CI 0.97–1.62]). However, the univariate analysis indicated that subjects with serum albumin levels <4.1 g/dl had an elevated risk of LTCI service need (Table 4). The mean serum albumin level was 4.2 ± 0.3 g/dl, with a range from 2.6 to 5.4; 1722 participants (21.3%) had serum albumin levels <4.1 g/dl.

Fig. 1 shows the Kaplan-Meier survival curves according to new LTCI service need certification, with the subjects stratified into 4 groups according to eGFR quartile. Individuals with eGFR values <60.0 ml/min/1.73 m^2 had a significantly elevated risk of LTCI service need according to multivariate analyses using an eGFR value of 71.4–83.6 ml/min/1.73 m^2 as the reference (adjusted hazard ratio: 1.44 [95% CI 1.12–1.86]) (Table 4). The mean eGFR was 71.2 ± 17.4 ml/min/1.73 m^2, with a range from 20.3 to 123.8 ml/min/1.73 m^2; 1963 participants (24.3%) had eGFR values <60 ml/min/1.73 m^2.

4. Discussion

In this study, we found that approximately 25% of adults aged 65 years or over had eGFR values <60 ml/min/1.73 m^2, which indicates that CKD is common among older Japanese adults. The multivariate analyses demonstrated eGFR values <60.0 ml/min/1.73 m^2 were independently associated with new certifications for LTCI service need. Thus, our data indicate that CKD is a critical marker of frailty in older adults.

According to the multivariate analyses, lower BMIs (less than 20.5), and higher frailty checklist scores (more than 6) were associated with certification for LTCI service need. These results are consistent with those of previous studies (Levey et al., 2006; Tomata et al., 2011; Yamada et al., 2012), which revealed that the subjects with the lowest BMIs had an elevated risk of requiring care and that frailty checklist scores were strongly associated with new LTCI service need certifications (Levey et al., 2006). Thus, it is important to assess nutrition, cognitive function, mood, and ADL for care prevention, and the frailty checklist includes these items.

In terms of nutrition, however, our study failed to demonstrate that serum albumin levels were significantly associated with new LTCI service need certification after adjusting for other frailty-related factors, although the univariate analysis demonstrated that

Table 3
Demographic differences according to eGFR quartile.

	eGFR (ml/min/1.73 m^2)									
	Q1: <60.0		Q2: 60.0–71.3		Q3: 71.4–83.6		Q4: >83.6		P-value	Post hoc
Gender (female)	1122 (57.2%)		1153 (54.2%)		1066 (54.2%)		1429 (71.2%)		<0.001	Q2,3 < Q1 < Q4
BMI (kg/m^2)	23.1	3.3	22.7	3.2	22.9	3.1	22.4	3.4	<0.001	Q1 > Q4 > Q2,3
Frailty checklist (points)	5.2	4.6	4.0	3.9	3.2	3.6	3.9	3.8	<0.001	Q1 > Q2 > Q4 > Q3
Serum albumin (g/dl)	4.11	0.27	4.16	0.26	4.21	0.25	4.21	0.26	<0.001	Q1 < Q2 < Q3,4

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Table 4
Predictors of new LTCI service need certification during a 2-year follow-up period.

		Certified for LTCI requirement		Non-certified for LTCI requirement		Univariate analysis			Multivariate analysis		
						HR	95%CI	P-value	HR	95%CI	P-value
Gender	Female	332	7.0%	4405	93.0%	ref			ref		
	Male	204	6.1%	3122	93.9%	0.88	0.76–1.03	0.11	0.98	0.83–1.17	0.86
BMI	Q1: <20.5	179	9.1%	1796	90.9%	1.53	1.21–1.92	<0.01	1.41	1.11–1.79	<0.01
	Q2: 20.5–22.6	120	5.9%	1915	94.1%	1.00	0.78–1.29	1.00	1.01	0.78–1.30	0.92
	Q3: 22.7–24.7	121	6.0%	1892	94.0%	ref			ref	-	
	Q4: >24.7	140	6.9%	1900	93.1%	1.13	0.88–1.44	0.35	1.09	0.85–1.39	0.51
Frailty checklist	Q1: <2	91	4.1%	2106	95.9%	ref			ref		
	Q2: 2–3	105	5.5%	1802	94.5%	1.36	1.03–1.80	0.03	1.30	1.30–1.73	0.13
	Q3: 4–6	117	6.1%	1800	93.9%	1.51	1.15–1.99	<0.01	1.41	1.06–1.86	0.01
	Q4: >6	247	12.1%	1795	87.9%	3.04	2.38–3.87	<0.01	2.63	2.05–3.39	<0.01
Serum albumin	Q1: <4.1	167	9.7%	1555	90.3%	1.75	1.36–2.24	<0.01	1.36	1.05–1.75	0.02
	Q2: 4.1–4.2	150	6.7%	2076	93.3%	1.19	0.92–1.53	0.18	1.04	0.81–1.35	0.75
	Q3: 4.3–4.4	140	6.0%	2200	94.0%	1.09	0.84–1.40	0.52	1.01	0.78–1.31	0.93
	Q4: >4.4	101	5.6%	1694	94.4%	ref			ref		
eGFR	Q1: <60.0	191	9.7%	1772	90.3%	1.99	1.55–2.54	<0.01	1.63	1.26–2.09	<0.01
	Q2: 60.0–71.3	142	6.7%	1983	93.3%	1.37	1.06–1.77	0.02	1.25	0.96–1.62	0.10
	Q3: 71.4–83.6	97	4.9%	1871	95.1%	ref			ref		
	Q4: >83.6	128	6.4%	1879	93.6%	1.29	0.99–1.68	0.06	1.17	0.89–1.53	0.26

The multivariate analysis was adjusted for gender, BMI, frailty checklist score, and serum albumin level.

a significantly larger number of subjects in the first quartile were certified as needing LTCI. Furthermore, previous studies have indicated that lower serum albumin levels are associated with future functional decline in older adults (Kalyani et al., 2012; Kane, Shamliyan, Talley, & Pacala, 2012). We assume that this result was caused by our study lacking sufficient power to demonstrate a contribution of low serum albumin to new LTCI service need certifications and by the small number of subjects with malnutrition in this cohort. Nonetheless, CKD was found to be significantly associated with new LTCI service need certification. Therefore, it should be noted that CKD may independently predict new LTCI service need certification in older adults.

We found that the subjects with the highest eGFR values (4th quartile) tended to have a higher risk of new LTCI service need certification, lower BMIs, and higher checklist scores than those in the 3rd quartile, although this difference was not statistically significant. Because eGFR is calculated using serum creatinine levels, a higher eGFR may indicate lower muscle mass, especially in older adults. Therefore, it should be noted that older adults with elevated eGFR values may be frail. Further research is required to address the role of eGFR in frailty.

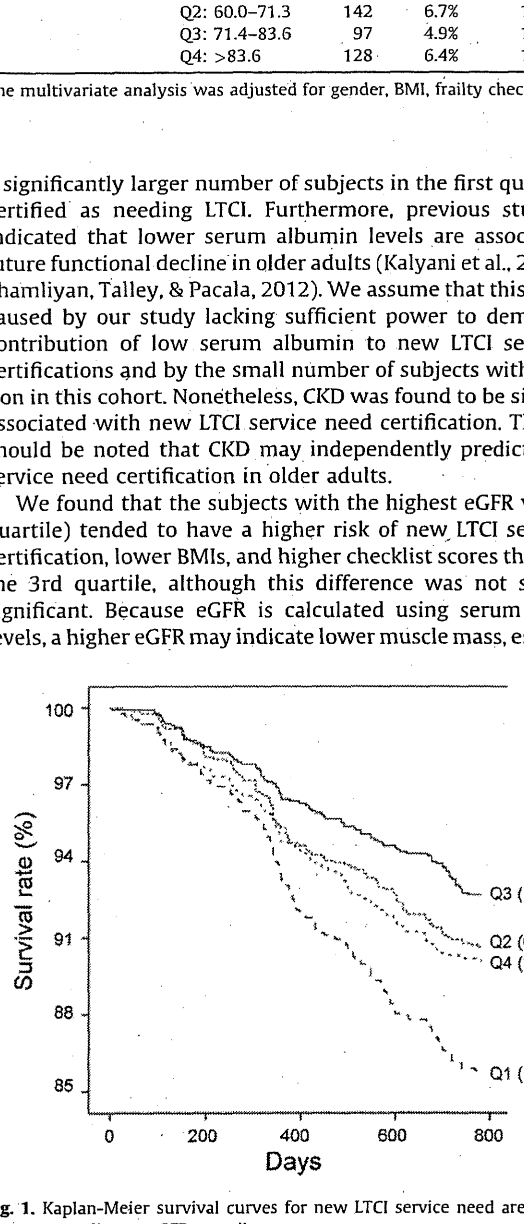

Fig. 1. Kaplan-Meier survival curves for new LTCI service need are shown for 4 groups according to eGFR quartile.

Malnutrition is known to be associated with frailty. Several studies have suggested that vitamin D deficiencies are common among patients with CKD (Reuben et al., 2002; Zuliani et al., 2001). Both vitamin D2 and D3 are first converted to 25-hydroxyvitamin D by hepatic vitamin D-25-hydroxylase and are then converted to the active form, 1,25-hydroxyvitamin D, by renal 1α-hydroxylase (Zuliani et al., 2001). Reduced activation of vitamin D has been associated with the development of hypertension, left ventricular hypertrophy, heart failure, and vascular calcification (Holick, 2007). In addition, vitamin D deficiency has been associated with sarcopenia, falls, fractures, and dementia (Bischoff-Ferrari, 2012; Chonchol, Kendrick, & Targher, 2011; Cozzolino & Ronco, 2011). Therefore, we hypothesized that CKD was a risk factor for new LTCI service need certification.

Two limitations of this study warrant mention. First, we did not collect information about the subjects' comorbidities. Therefore, the effects of comorbidities on the risk of new certifications for LTCI service need remain unclear. Second, the study participants may have had a greater motivation and interest in health issues than the non-participants. Therefore, it is possible that the non-participants had a higher prevalence of CKD and frailty.

In conclusion, this is the first study to demonstrate that CKD is independently associated with new certifications for LTCI service need. In addition, a relatively high percentage of the subjects had moderate to severe CKD (eGFR <60 ml/min/1.73 m^2). Intervention studies are needed to explore whether treating CKD may delay or prevent new certifications for LTCI service need among older adults.

Conflicts of interest

None of the authors have conflicts of interest or financial disclosures.

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References

Akiba, T., Nakai, S., Shinzato, T., Yamazaki, C., Kitaoka, T., Kubo, K., et al. (2000). Why has the gross mortality of dialysis patients increased in Japan? *Kidney International, 57*, S60–S65.

Bischoff-Ferrari, H. A. (2012). Relevance of vitamin D in muscle health. *Reviews in Endocrine and Metabolic Disorders, 13*, 71–77.

Brogan, D. J., Haber, M., & Kutner, N. G. (2000). Functional decline among older adults: Comparing a chronic disease cohort and controls when mortality rates are markedly different. *Journal of Clinical Epidemiology, 53*, 847–851.

Campbell, J. C., & Ikegami, N. (2000). Long-term care insurance comes to Japan. *Health Affairs, 19*, 26–39.

Chonchol, M., Kendrick, J., & Targher, G. (2011). Extra-skeletal effects of vitamin D deficiency in chronic kidney disease. *Annals of Medicine, 43*, 273–282.

Coresh, J., Astor, B. C., Greene, T., Eknoyan, G., & Levey, A. S. (2003). Prevalence of chronic kidney disease and decreased kidney function in the adult US population: Third National Health and Nutrition Examination Survey. *American Journal of Kidney Diseases, 41*, 1–12.

Cozzolino, M., & Ronco, C. (2011). The impact of paricalcitol on left ventricular hypertrophy. *Contributions to Nephrology, 171*, 161–165.

Ensrud, K. E., Lui, L. Y., Taylor, B. C., Ishani, A., Shlipak, M. G., Stone, K. L., et al. (2007). Renal function and risk of hip and vertebral fractures in older women. *Archives of Internal Medicine, 167*, 133–139.

Gallagher, J. C., Rapuri, P. B., & Smith, L. M. (2007). An age-related decrease in creatinine clearance is associated with an increase in number of falls in untreated women but not in women receiving calcitriol treatment. *Journal of Clinical Endocrinology and Metabolism, 92*, 51–58.

Holick, M. F. (2007). Vitamin D deficiency. *New England Journal of Medicine, 357*, 266–281.

Imai, E., Horio, M., Nitta, K., Yamagata, K., Iseki, K., Hara, S., et al. (2007). Estimation of glomerular filtration rate by the MDRD study equation modified for Japanese patients with chronic kidney disease. *Clinical and Experimental Nephrology, 11*, 41–50.

Imai, E., Horio, M., Watanabe, T., Iseki, K., Yamagata, K., Hara, S., et al. (2009). Prevalence of chronic kidney disease in the Japanese general population. *Clinical and Experimental Nephrology, 13*, 621–630.

Kalyani, R. R., Tian, J., Xue, Q. L., Walston, J., Cappola, A. R., Fried, L. P., et al. (2012). Hyperglycemia and incidence of frailty and lower extremity mobility limitations in older women. *Journal of the American Geriatrics Society, 60*, 1701–1707.

Kane, R. L., Shamliyan, T., Talley, K., & Pacala, J. (2012). The association between geriatric syndromes and survival. *Journal of the American Geriatrics Society, 60*, 896–904.

Kurella, M., Ireland, C., Hlatky, M. A., Shlipak, M. G., Yaffe, K., Hulley, S. B., et al. (2004). Physical and sexual function in women with chronic kidney disease. *American Journal of Kidney Diseases, 43*, 868–876.

Kurella, M., Yaffe, K., Shlipak, M. G., Wenger, N. K., & Chertow, G. M. (2005). Chronic kidney disease and cognitive impairment in menopausal women. *American Journal of Kidney Diseases, 45*, 66–76.

Landau, M., Kurella-Tamura, M., Shlipak, M. G., Kanaya, A., Strotmeyer, E., Koster, A., et al. (2011). Correlates of insulin resistance in older individuals with and without kidney disease. *Nephrology, Dialysis, Transplantation, 26*, 2814–2819.

Levey, A. S., Coresh, J., Greene, T., Stevens, L. A., Zhang, Y. L., Hendriksen, S., et al. (2006). Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Annals of Internal Medicine, 145*, 247–254.

Matsuo, S., Imai, E., Horio, M., Yasuda, Y., Tomita, K., Nitta, K., et al. (2009). Revised equations for estimated GFR from serum creatinine in Japan. *American Journal of Kidney Diseases, 53*, 982–992.

Reuben, D. B., Cheh, A. I., Harris, T. B., Ferrucci, L., Rowe, J. W., Tracy, R. P., et al. (2002). Peripheral blood markers of inflammation predict mortality and functional decline in high-functioning community-dwelling older persons. *Journal of the American Geriatrics Society, 50*, 638–644.

Shanahan, C. M. (2005). Mechanisms of vascular calcification in renal disease. *Clinical Nephrology, 63*, 146–157.

Tomata, Y., Hozawa, A., Ohmori-Matsuda, K., Nagai, M., Sugawara, Y., Nitta, A., et al. (2011). Validation of the Kihon Checklist for predicting the risk of 1-year incident long-term care insurance certification: The Ohsaki Cohort 2006 Study. *Nihon Koshu Eisei Zasshi, 58*, 3–13.

Tsutsui, T., & Muramatsu, N. (2005). Care-needs certification in the long-term care insurance system of Japan. *Journal of the American Geriatrics Society, 53*, 522–527.

Wiswell, R. A., Hawkins, S. A., Jaque, S. V., Hyslop, D., Constantino, N., Tarpenning, K., et al. (2001). Relationship between physiological loss, performance decrement, and age in master athletes. *Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 56*, M618–M626.

Yamada, M., Arai, H., Sonoda, T., & Aoyama, T. (2012). Community-based exercise program is cost-effective by preventing care and disability in Japanese frail older adults. *Journal of American Medical Directors Association, 13*, 507–511.

Zuliani, G., Romagnoni, F., Volpato, S., Soattin, L., Leoci, V., Bollini, M. C., et al. (2001). Nutritional parameters, body composition, and progression of disability in older disabled residents living in nursing homes. *Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 56*, M212–M216.

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DIETARY VITAMIN D INTAKE IS ASSOCIATED WITH SKELETAL MUSCLE MASS IN COMMUNITY-DWELLING OLDER JAPANESE WOMEN

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Abstract: *Background & purpose:* Recently, several studies have suggested that low serum 25-hydroxyvitamin D levels are associated with sarcopenia (age-related loss of skeletal muscle mass). However, the relationship between dietary vitamin D intake and skeletal muscle mass in older adults remains unclear. The purpose of this cross-sectional study was therefore to determine whether dietary vitamin D intake is associated with muscle mass in community-dwelling older Japanese women. *Methods:* Ninety-one older Japanese women (mean age, 73.0 ± 5.5 years) participated in this cross-sectional study. We measured the skeletal muscle mass index(SMI) of the participants using bioelectrical impedance, the intake of several dietary nutritional factors using a food-frequency questionnaire, and physical activity. *Results:* The SMI correlated with level of vitamin D intake($r=0.208$, $p=0.037$) and body mass index ($r=0.330$, $p=0.001$). Regression analysis revealed that vitamin D ($\beta=0.308$; 95% confidence interval, 0.022–0.303) was a significant and independent determinant of the SMI ($p<0.001$). *Conclusion:* Dietary vitamin D intake is associated with the SMI in older, community-dwelling Japanese women.

Key words: Sarcopenia, vitamin D, nutrition, muscle mass, older adults.

Introduction

Sarcopenia, the age-related loss of skeletal muscle mass, is prevalent in older adults (1) and results in increased risk of falls and fractures, physical disability, mobility disorders, and mortality (2-4).The physiopathological causes of sarcopenia include increasing age, muscle disuse, endocrine function, neurodegenerative diseases, and malnutrition (5).Therefore, resistance training, as well as better nutrition, such as sufficient protein intake, is important for the prevention of sarcopenia (6).

Dietary protein intake is important for the maintenance of muscle mass and strength in community-dwelling older adults (7-8). In fact, a protein or amino acid supplement has been shown to increase muscle mass (9-11). However, vitamin D is also important in preventing sarcopenia.

Vitamin D levels are measured clinically using serum 25-hydroxyvitamin D (25(OH)D). Recently, several studies suggested that a low 25(OH) D level is associated with muscle mass, lower muscle strength, declined physical performance, and activity of daily living (ADL) disability (7, 12-14). Thus, patients with low 25(OH) D levels may require vitamin D replacement (15). Older adults are at risk for low vitamin D levels because the vitamin D production capacity of the skin at the age of 70 is reduced to only 30% of that of a 20-year-old person (16, 17) Thus, dietary vitamin D intake should be recommended in older adults. However, the relationship between dietary vitamin D intake and skeletal muscle mass in older adults remains unclear.

The purpose of this cross-sectional study was to determine whether dietary vitamin D intake is associated with muscle mass in community-dwelling older Japanese women.

Methods

Participants

Participants were recruited through a local press requesting healthy community-dwelling volunteers. A total of 91Japanese participants, aged 65 years and older (mean age, 73.0 ± 5.5 years), living in Kyoto city enrolled in this study in September 2011. The interview was then used to exclude participants based on the following

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exclusion criteria: severe cognitive impairment (Rapid Dementia Screening Test score of 4 or less) (18); severe cardiac, pulmonary, or musculoskeletal disorders; and comorbidities associated with greater risk of falls, such as Parkinson disease and stroke. Written informed consent was obtained from each participant in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1995.

Skeletal muscle mass index (SMI)

A bioelectrical impedance data acquisition system (Inbody 720; Biospace Co, Ltd, Seoul, Korea) was used to determine bioelectrical impedance (19). This system also uses electrical current at multi-frequencies (5, 50, 250, 500, and 1000 kHz) to directly measure the amount of extracellular and intracellular water. Participants stood on 2metallic electrodes and held metallic grip electrodes. Using segmental body composition and muscle mass, a value for the appendicular skeletal muscle mass was determined and used for further analysis. Muscle mass was converted to the skeletal muscle mass index (SMI) by dividing by height squared (kg/m^2). This index has been used in several epidemiological studies (4, 20).

Assessment of dietary nutrient intake

Dietary nutrient intake was assessed using the food frequency questionnaire (FFQ) (21). However, there is possibility of recall bias in the FFQ by older adults. Therefore, in the current study, participants were asked to record the intake of dietary foods on a calendar at 7 consecutive days. The intake of dietary foods was converted to the FFQ by one of the authors (K.T.). The output included averaged daily estimates for total energy intake and for 29 dietary nutrients including protein and vitamin D. In present study, we defined sarcopenia as coexistence of low muscle mass. Japanese women criteria for sarcopenia by SMI were less than 5.46kg/m^2 (22).

Measurement of physical activities

Measurement of step counts was conducted by pedometer, YamaxPowerWalker EX-510 (Yamasa Co, Ltd, Tokyo, Japan) which measures free-living step counts (23), and has a 30-day data storage capacity. Participants were instructed to wear the pedometer in the pocket of their dominant leg for 7 consecutive days, except when bathing, sleeping, and performing water-based activities. We calculated the average of the daily step count per week for each subject.

Statistical analyses

The relationship between the SMI and demographic data, physical activity, and nutritional factors (total energy, protein, and vitamin D) was assessed by Pearson's correlation coefficient. A multivariate analysis by means of multiple regressions was performed to investigate whether age, physical activity, total energy, protein, and vitamin D were independently associated with the SMI of the subjects. A p value <0.05 was considered statistically significant for all analyses. Differences in the data of nutritional factors variables between the Sarcopenia and non-Sarcopenia groups were analyzed by the Student's t–test. The utility of the nutritional factors for distinguishing between Sarcopenia and non-Sarcopenia was tested using receiver operating characteristic (ROC) curves for cut-off points on dietary nutrient intake. Data were analysed using the Statistical Package for Social Science (Windows version 18.0, SPSS, Inc., Chicago, IL).

Results

The characteristics of the study population are shown in Table 1. We used Pearson's correlation coefficients to determine the association of the SMI with subject demography, physical activity, and nutritional factors. The SMI was correlated with vitamin D (r=0.208,p=0.037) and body mass index(r=0.330,p=0.001;Table 2). Regression analysis revealed that vitamin D (β=0.308, 95% confidence interval,0.022–0.303) was a significant and independent determinant of the SMI (p<0.001). The Sarcopenia group had significantly worse scores than the non-Sarcopenia group in the dietary intake of vitamin D (Sarcopenia=5.66±1.74μg/day, non-Sarcopenia= 6.70±2.06μg/day, p=0.018). In the ROC curve, the area under the curve was 0.655 and the Sarcopenia-related cut-off value for dietary intake of vitamin D was determined to be 5.93μg/day (sensitivity = 62.5%, specificity = 66.7%).

Table 1
Demographic characteristics of the participants

	Mean	SD	(Min - Max)
Age (y)	73.0	5.5	(65 - 90)
Height (cm)	151.0	5.1	(139 - 164)
Weight (kg)	50.8	7.0	(35.2 - 71.8)
BMI	22.3	2.8	(16.5 - 30.9)
PA (steps/d)	6581.8	3675.6	(1865 - 26167)
SMI (kg/m^2)	6.44	1.01	(4.57 - 9.63)
Total energy (kcal/d)	1630.6	300.6	904.5 - 2366)
Protein (g/d)	57.0	11.3	(24.2 - 84.5)
Vitamin D (μg/d)	6.35	1.91	(1.0 - 10.5)

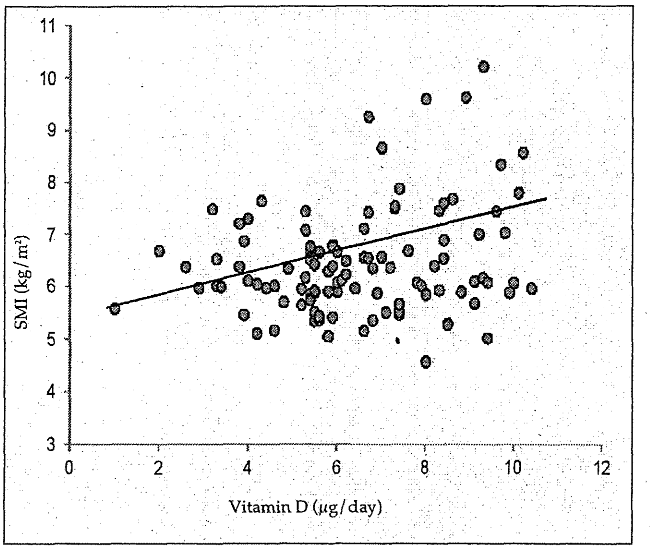
BMI: body mass index; PA: physical activity; SMI: skeletal mass

Table 2
Pearson's correlation coefficients between SMI and demographic data, physical activity, and nutritional factors

	age	BMI	PA	SMI	Total energy	Protein	Vitamin D
SMI	-.060	.330**	.034		.068	.074	.208*
Total energy	.207*	-.077	.176	.068		.877**	.404**
Protein	.202*	-.038	.184	.074	.877**		.607**
Vitamin D	.013	.013	.050	.208*	.44**	.607	

BMI: body mass index; PA: physical activity; SMI: skeletal mass; *: p<0.005; **: p<0.01

Figure 1
Dietary vitamin D intake is associated with the SMI in older Japanese women



Discussion

This study showed that dietary vitamin D intake may be related to the SMI in community-dwelling older Japanese women. Regression analysis revealed that dietary intake of vitamin D was a significant and independent determinant of the SMI. Furthermore, the Sarcopenia-related cut-off value for dietary intake of vitamin D was determined to be 5.93μg/day. Taken together, these findings led us to conclude that measuring dietary vitamin D intake is potentially important to assess the SMI in community-dwelling older women.

Vitamin D can be obtained from dietary intake and can be produced by the skin. In serum, bound to a vitamin D-binding protein, vitamin D3 is transported to the liver. In the kidneys, 25(OH) D 3 is further metabolised into the biologically active form of vitamin D (24, 25). However, vitamin D nuclear receptors were identified on muscle cells, and their abundance decreases with increasing age (26). Vitamin D deficiency may lead to loss of type 2 muscle fibres and thus to atrophy of proximal muscles (27). In addition, older adults have various risk factors for vitamin D deficiency, such as decreased sunlight exposure, reduced skin thickness, decreased dietary intake, impaired intestinal absorption, and impaired hydroxylation in the liver and kidneys (28). Specifically, older adults are at risk for low vitamin D levels because the vitamin D production capacity of the skin at the age of 70 is reduced to only 30% of that of a 20-year-old person (16, 17). Therefore, dietary vitamin D intake is very important for maintenance of muscle mass in community-dwelling older adults.

However, the current study suggests that dietary protein intake is not related to the SMI in community-dwelling older adults. Previous studies reported that dietary protein intake is important for maintenance of muscle mass in community-dwelling older men and women (7, 8). The reasons for this discrepancy remain unclear; however, the previous studies were not performed on Japanese subjects (7, 8). Differences in the ethnic origin of the study population could therefore be a reason for the disagreement of data.

There were several limitations of this study. First, our limited sample size may introduce some error of inference, reduce the power of the analysis, and limit generalization. Second, dietary vitamin D intake may not be predictive of sarcopenia in older adults as this study had a cross-sectional design. Third, the serum 25 (OH) D was not measured. Therefore, the relationship between SMI and 25 (OH) D is unclear. Fourth, the measurement of SMI estimated using BIA. The validation study of the BIA that is referred to was performed in not Japanese older women, and the validation study in Japanese older women is needed.

In conclusion, to the best of our knowledge this is the first study to indicate that dietary vitamin D intake is associated with the SMI in community-dwelling older Japanese women. A larger survey is needed to confirm and extend the present study.

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Conflict of Interest: None

Sponsor's Role: None

References

1. Chien MY, Huang TY, Wu YT (2008). Prevalence of sarcopenia estimated using a bioelectrical impedance analysis prediction equation in community-dwelling elderly people in Taiwan. J Am GeriatrSoc 56: 1710–1715.
2. Rolland Y, Czerwinski S, Abellan Van Kan G et al (2008). Sarcopenia: its assessment, etiology, pathogenesis, consequences and future perspectives. J Nutr Health Aging 12: 433–450.
3. Topinkova E (2008). Aging, disability and frailty. Ann NutrMetab 52: 6-11.
4. Janssen I, Baumgartner RN, Ross R et al (2004). Skeletal muscle cutpoints associated with elevated physical disability risk in older men and women. Am J Epidemiol 159:413-421.
5. Cruz-Jentoft AJ, Baeyens JP, Bauer JM et al (2010). European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing 39:412-423.
6. Boirie Y (2009). Physiopathological mechanism of sarcopenia. J Nutr Health Aging. 13: 717-723
7. Houston DK, Nicklas BJ, Ding Jet al (2008). Health ABC Study. Dietary protein intake is associated with lean mass change in older, community-dwelling adults: the Health, Aging, and Body Composition (Health ABC) Study. Am J ClinNutr 87:150-155.
8. Meng X, Zhu K, Devine A et al (2009). A 5-year cohort study of the effects of high protein intake on lean mass and BMC in elderly postmenopausal women. J Bone Miner Res 24:1827-1834.
9. Meredith CN, Frontera WR, O'Reilly KP et al (1992). Body composition in elderly men: effect of dietary modification during strength training. J Am Geriatr Soc 40: 155-162.
10. Kim HK, Suzuki T, Saito K et al (2012). Effects of exercise and amino acid supplementation on body composition and physical function in community-dwelling elderly Japanese sarcopenic women: a randomized controlled trial. J Am Geriatr Soc 60: 16-23.
11. Solerte SB, Gazzaruso C, Bonacasa R et al (2008). Nutritional supplements with oral amino acid mixtures increases whole-body lean mass and insulin sensitivity in elderly subjects with sarcopenia. Am J Cardiol 101:69E-77E.
12. Visser M, Deeg DJ, Lips P (2003). Longitudinal Aging Study Amsterdam. Low vitamin D and high parathyroid hormone levels as determinants of loss of muscle strength and muscle mass (sarcopenia): the Longitudinal Aging Study Amsterdam. J Clin Endocrinol Metab 88: 5766-5772.
13. Hirani V, Primatesta P (2005). Vitamin D concentrations among people aged 65 years and over living in private households and institutions in England: population survey. Age Ageing 34:485-491.
14. Houston DK, Cesari M, Ferrucci L et al (2007). Association between vitamin D status and physical performance: the InCHIANTI study. J Gerontol A BiolSci Med Sci 62:440-446.
15. Morley JE, Argiles JM, Evans WJ et al (2011).Nutritional recommendations for the management ofsarcopenia. J Am Med DirAssoc 11:391-396.
16. Holick MF, Matsuoka LY, Wortsman J (1989). Age, vitamin D, and solar ultraviolet. Lancet 2:1104-1105.
17. MacLaughlin J, Holick MF (1985). Aging decreases the capacity of human skin to produce vitamin D3. J Clin Invest 76:1536-8.
18. Kalbe E, Calabrese P, Schwalen S et al (2003). The Rapid Dementia Screening Test (RDST): a new economical tool for detecting possible patients with dementia. Dement GeriatrCognDisord 16: 193-199.
19. Gibson AL, Holmes JC, Desautels RL, et al (2008). Ability of new octapolarbioimpedance spectroscopy analyzers to predict 4-component-model percentage body fat in Hispanic, black, and white adults. Am J ClinNutr 87:332-338.
20. Janssen I (2006). Influence of sarcopenia on the development of physical disability: the Cardiovascular Health Study. J Am GeriatrSoc 54:56-62.
21. Sone H, Yoshimura Y, Tanaka S et al (2007). Japan Diabetes Complications Study (JDCS) Group. Cross-sectional association between BMI, glycemic control and energy intake in Japanese patients with type 2 diabetes. Analysis from the Japan Diabetes Complications Study. Diabetes Res ClinPract 77: 23-29.
22. Sanada K, Miyachi M, Tanimoto M et al (2010). A cross-sectional study of sarcopenia in Japanese men and women: reference values andassociation with cardiovascular risk factors. Eur J Appl Physiol 110: 57-65.
23. Crouter SE, Schneider PL, Karabulut Met al (2003). Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. Med Sci Sports Exerc 35: 1455-1460.
24. Omdahl JL, Garry PJ, Hunsaker LA et al (1982). Nutritional status in a healthy elderly population: vitamin D. Am J ClinNutr 36:1225-1233.
25. Holick MF (1995). Environmental factors that influence the cutaneous production of vitamin D. Am J ClinNutr 61:638-645.
26. Bischoff-Ferrari HA, Borchers M, Gudat F et al (2004). Vitamin D receptor expression in human muscle tissue decreases with age. J Bone Miner Res 19:265-269.
27. Sato Y, Inose M, Higuchi I et al (2002). Changes in the supporting muscles of the fractured hip in elderly women. Bone 30:325-330.
28. Janssen HC, Samson MM, Verhaar HJ (2002). Vitamin D deficiency, muscle function, and falls in elderly people. Am J ClinNutr 75:611-615.

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Original article

Urban-rural differences in physical performance and health status among older Japanese community-dwelling women

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ABSTRACT

Background/Purpose: Assessment of physical performance allows the identification of health and functional independence among older adults. Several factors, such as environmental conditions, influence the results; therefore our objective was to compare the physical performance and the health status between older Japanese women living in urban and rural communities.
Methods: The Japanese women were aged ≥65 years, and recruited in urban ($n = 41$, age = 73.8 ± 3.92 years) and rural ($n = 54$, age = 73.8 ± 4.15 years) locations through the local press. Physical performance was assessed by the Timed Up and Go (TUG), one leg stand (OLS), repeated chair stands (CS) and handgrip strength (HGS) tests. Health status was investigated using socio-demographic characteristics; anthropometric measures and body composition; physical activity, a pedometer, Life-Space Assessment (LSA); Geriatric Depression Scale; incidence of falls, fear of falling; and medical information. Variables were compared by χ^2 test, Independent-Samples *t* test and Mann Whitney U-test.
Results: Rural individuals presented a better performance in the HGS test ($p = 0.01$) than urban individuals, who had a better performance in the CS test ($p < 0.001$). No statistical differences were found in the TUG or OLS tests. Rural women also had a higher body mass index ($p = 0.04$), waist circumference ($p < 0.01$), and body fat percentage ($p = 0.014$) than urban women, who showed higher scores in LSA ($p < 0.001$). Concerning medical information, more rural women complained of low back pain ($p = 0.01$) and gastrointestinal problems ($p = 0.02$).
Conclusion: Our findings showed that the physical performance and health status varied according to the place. Rural individuals had worse results in the CS test, but a better performance in the HGS test than urban individuals. We emphasize that health interventions should address the specific demand of each location.

1. Introduction

Japan has the world's highest average life expectancy, reaching 86.4 years for women, according to the 2010 records.[1] However, specialists have defended that the process of aging "well", such as remaining healthy, vigorous, and free of disability, is as important as the absolute number of years achieved.[2]

One of the enemies to the process of aging well is a sedentary lifestyle; a key risk of premature morbidity and mortality. Following this concept, the assessment of physical performance is receiving special attention, because it allows an early identification of older adults at risk of health and functional decline, situations that typically precede the onset of disability.[3,4] Moreover, physical performance measures are predictors of functional, psychological, and social health,[4,5] and additionally, in this complex relationship, they are influenced by several factors, such as environmental conditions.

Studies have shown that physical activity levels differ according to the environment; in rural communities, the physical activity level could be expected to be lower than that in urban neighborhoods.[6,7] A study conducted in Japan examined the association between the neighborhood environment and physical activity among Japanese adults[8]; however, to our knowledge, no study has directly compared the physical performance and the health status

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between older urban and rural community-dwelling adults yet. Therefore, we aimed to compare the physical performance and the health status between older Japanese women living in urban and rural communities.

2. Methods

2.1. Study participants

The participants were older Japanese women, recruited in urban ($n = 41$) and rural ($n = 54$) locations through the local press, by requesting healthy, community-dwelling volunteers to collaborate in this research. The inclusion criteria were age ≥65 years and the ability to perform the physical tests, to fill the questionnaires, and to give consent to participation in the study. Data was collected from November 2011 to March 2012.

Rural and urban locations were defined and classified directly with emphasis on the morphology of their settlements and the wider geographic context of such settlements. This approach ensured that the focus remained clearly on the most physical aspects of these environments, as described elsewhere.[9] The participants in an urban location lived in Kyoto city (1.47 million people), while the population in rural environments was <9000, in an area of 15.2 km^2. For this categorization, we also considered factors beyond the population size, such as differentiation by economic field, in which rural residents used the land as a direct source of income or wealth generation.

2.2. Physical performance

In the Timed Up and Go (TUG) test, participants were asked to stand up from a standard chair, walk 3 meters, turn, and sit down again; a shorter measured time indicated better ability. In the one leg stand (OLS) test, participants were instructed to stand unassisted on one leg, eyes opened and arms by the side of the trunk; the OLS was timed not exceeding 30 seconds, with a longer time indicating better balance ability. In the repeated chair stands (CS), participants were asked to stand up and sit down five times from a chair as quickly as possible, keeping their arms folded across the chest. Finally, the handgrip strength (HGS) was tested with a standard handheld dynamometer (HHD) (mTas F-1; ANIMA, Tokyo, Japan). The participant was asked to stand up and hold the dynamometer with arms parallel to the body; the HGS was measured for both hands once on each side, and the higher value was used to characterize the maximum muscle strength of the participant, as previously described.[10] HGS was expressed in kg.

2.3. Health status

Socio-demographic characteristics, such as age, living structure, educational level and current work; anthropometric measures, such as body mass index (BMI), waist circumference (WC); and body composition features, such as body fat percentage (BF%), skeletal muscle mass index (SMMI), arm muscle mass, and leg muscle mass—collected by bioelectrical impedance analysis (Inbody 430; Biospace Co, Ltd, Seoul, Korea)—were obtained.

Regarding the bioelectrical impedance, the instrument makes use of eight tactile electrodes: two are in contact with the palm and thumb of each hand and two with the anterior and posterior aspects of the sole of each foot. The individual stands with their soles in contact with the foot electrodes and grabs the hand electrodes. Resistance of arms, trunk, and legs was measured at frequencies of 5, 50 and 250 kHz. Examination provided values for skeletal muscle mass, BF% and segmental muscle mass (right and left arms and legs, and trunk). From these measurements, skeletal muscle mass was then adjusted by height and for segmental muscle mass. This bioelectrical impedance method had previously been validated as having a strong correlation to muscle volume and fat mass, as measured by dual energy X-ray absorptiometry.[11]

Moreover, regular practice of physical activity (PA) was collected by a self-administered questionnaire and was characterized by moderate walking, gymnastics, resistance training, yoga, golf, and other activities. Then, pedometer data (Yamax Powerwalker EX-510; Yamasa Co., Ltd., Tokyo, Japan), and Life-Space Assessment (LSA)[12] were also collected. Concerning the pedometer, the participants were recommended to wear the instrument in the morning and to register the number of steps in a diary at the end of the day. After 1 week, they were requested to send the pedometers by mail to researchers, including the diary record. The diary record was then matched with the pedometer memory and an average of steps counting in 1 week was used in analysis.

For psychological characteristics, the Geriatric Depression Scale (GDS-15) was used. Finally, information about the incidence of falls in a 1 year period, fear of falling, medical information, such as medical consultation frequency and hospitalization history in the last 6 months, medications, and comorbidities were also collected. Through a self-administered questionnaire, individuals were asked about the presence or absence of low back pain, diabetes, osteoporosis, hypertension, hyperlipidemia, arthropathy and gastrointestinal problems; their report was considered positive when they were assumed to be using prescribed medication for the specific comorbidity.

The study protocol was approved by the Kyoto University Graduate School of Medicine Ethics Committee (No. E1245, 2011). All participants were informed of the purpose and procedures of the study and a written consent was obtained.

2.4. Statistical analysis

Aiming to verify the normality of the data, the Shapiro-Wilk test was used. Participants' characteristics were investigated using a descriptive analysis. Socio-demographic and categorical health-status variables were compared by living environment, using the χ^2 test, while continuous variables were analyzed by the Independent-Samples t test, if normally distributed, or the Mann Whitney U-test, if skewed. Concerning the functional performance tests, only the CS was analyzed by the Independent-Samples t test, while for the others, the Mann Whitney U-test was used. The considered level of significance was $p < 0.05$. For data analysis, the Statistical Package for the Social Science (SPSS, IBM Inc., Chicago, IL, USA), version 15.0 was used.

3. Results

In total, 95 older women (urban $n = 41$, age 73.7 ± 3.92 years; rural $n = 54$, age 73.7 ± 4.15 years) participated in this study. Socio-demographic characteristics are shown in Table 1. Despite no statistical differences in their characteristics, an environmental difference was observed. Those in rural areas lived in groups of three persons or more (52.8%), while those in urban environments had the same proportion in all categories of living alone, living with a spouse, or three persons or more (33%). Moreover, rural participants showed a slightly lower educational level, in which most of them studied until junior high school (40%), while urban women studied until high school (34.3%) or university (20%). Additionally, rural women did not work (45.1%) or were engaged in farm work (37.3%), and the majority of urban women were retired (67.5%).

As shown in Table 2, participants living in rural neighborhoods presented a better performance in HGS ($p = 0.01$) than urban participants. In contrast, urban participants had a better

Table 1
Socio-demographic characteristics of older women living in urban and rural communities.

Variable	Urban	n	Rural	n	p
Age (y)[a]	73.7 ± 3.92	41	73.7 ± 4.15	54	0.99
Living structure[b]					
Alone	33.3	39	15.1	53	0.07
With spouse	33.3		32.1		
With 3 persons or more	33.3		52.8		
Education[b]					
Elementary school	11.4	35	6	50	0.17
Junior high school	20		40		
High school	34.3		26		
Technical school	14.3		20		
University	20		8		
Work[b]					
Does not work	67.5	40	45.1	51	0.23
Integral period	2.5		3.9		
Part-time work	2.5		2		
Autonomous work	2.5		2		
Farm work	12.5		37.3		
Volunteer work	7.5		7.8		
Other	5		2		

[a] Mean ± SD.
[b] Percentage.

performance in CS ($p < 0.001$). No statistical differences were found in TUG or OLS.

According to anthropometric measures, rural women had a higher BMI ($p = 0.04$), WC ($p < 0.01$) and BF% ($p = 0.01$) than urban women. A tendency to more engagement in physical activity ($p = 0.05$) and higher scores in LSA ($p < 0.001$) was found in urban participants, even though a statistically insignificant higher average pedometer count was found in rural participants.

The median found in the GDS was low (urban = 1 vs. rural = 2); most urban women had ≥ seven medical consultations (30%) in the last 6 months, while rural women had five or six (24.5%); 7.5% of urban versus 5.6% of rural participants were hospitalized in the last 6 months; and 80% of urban and 81.5% of rural participants took medications. With regards to the above mentioned factors, no statistical differences were found between the two groups, however more rural women complained of low back pain (rural = 27.8% vs. urban = 7.3%, $p = 0.01$) and gastrointestinal problems (rural = 16.7% vs. urban = 2.4%, $p = 0.02$) (Table 3).

4. Discussion

The main findings of our study were that physical performance and health status differed according to the environment; women from rural areas had a better performance in HGS and a worse performance in CS. Additionally, rural women presented higher BMI, WC, BF%, a higher prevalence of low back pain, and gastrointestinal problems, and higher weekly average step counts than urban women. By contrast, those living in urban areas showed higher regular physical activity engagement and higher scores in LSA.

Table 2
Physical performance measurements of older women living in urban and rural communities.

Variable	Urban	n	Rural	n	p
Timed Up and Go (s)[a]	6.44 (5.9–7.35)	41	6.59 (6–7.55)	54	0.44
One Leg Stand (s)[a]	23.35 (10–30)	41	28.31 (12.3–30)	54	0.38
Handgrip Strength (kg)[a]	22 (19–26)	40	25 (21.7–26.5)	54	0.01
Five Chair Standing (s)[b]	7.43 ± 1.75	41	8.97 ± 2.18	54	<0.001

[a] Median (interquartile).
[b] Mean ± SD.

Table 3
Health status measurements of older women living in urban and rural communities.

Variable	Urban	n	Rural	n	p
BMI (kg/m^2)[a]	21.9 ± 2.50	41	23.2 ± 3.45	54	0.04
Waist Circumference (cm)[a]	72.2 ± 5.78	39	76.7 ± 8.14	54	<0.01
Body Fat Percentage[a]	29.0 ± 6.49	39	32.5 ± 6.67	54	0.01
SMMI (kg/m^2)[b]	8.28 (7.63–8.6)	39	8.01 (7.67–8.63)	54	0.91
Arm muscle mass (kg/m^2)[b]	1.36 (1.2–1.51)	39	1.42 (1.33–1.61)	54	0.06
Leg muscle mass (kg/m^2)[b]	4.59 (4.29–4.98)	39	4.41 (4.1–4.71)	54	0.08
Pedometer[b]	5791 (3992–7634)	35	6734 (5447–7794)	53	0.07
Physical activity[c]					
No	17.9	39	35.4	48	0.05
Almost everyday	20.5		6.3		
2 or 3 per week	46.2		52.1		
1 or 2 per month	15.4		6.3		
Life-space assessment[a]	97.0 ± 17.7	32	73.2 ± 19.9	53	<0.001
Geriatric Depression Scale[b]	1 (0–3)	33	2 (0.75–4)	54	0.19
Fear of falling[c]	45.7	35	40.7	54	0.64
Fell in past year[c]	35.1	37	24.1	54	0.25
Medical consultation[c]					
No	17.5	40	18.9	53	0.36
1~2 times	27.5		20.8		
3~4 times	15		17		
5~6 times	10		24.5		
7 or more	30		18.9		
Hospitalization[c]	7.5	40	5.6	54	0.70
Medications[c]	80	40	81.5	54	0.99
Low back pain[c]	7.3	41	27.8	54	0.01
Diabetes[c]	4.9	41	13	54	0.18
Osteoporosis[c]	24.4	41	25.9	54	0.86
Hypertension[c]	43.9	41	38.9	54	0.62
Hyperlipidemia[c]	26.8	41	35.2	54	0.38
Arthropathy[c]	24.4	41	22.6	54	0.84
Gastrointestinal problems[c]	2.4	41	16.7	54	0.02

SMMI = skeletal muscle mass index.
[a] Mean ± SD.
[b] Median (interquartile).
[c] Percentage.

Even though no statistical difference was found, rural participants had a slightly greater arm muscle mass and urban participants a higher leg muscle mass. One possible explanation for this difference is regarding their lifestyle routine (e.g., rural women were more involved in farm work, which usually requires hand and general strength, while urban women seem to be more engaged in physical activity and had higher scores in LSA). However, this is only a hypothesis, as lifestyle factors were not investigated in detail.

Concerning the CS, rising from a chair is a complex task involving movement of all body segments from head to foot; the activity requires coordinated joint mobility, strength and balance to enable the center of mass to be transferred forward and upward from the seated position to erect standing.[13] One could say that the lower performance in CS in rural participants may be linked with the higher incidence of low back pain, as this comorbidity was identified by Janssen et al (2002) as a subject-related determinant for CS in a review study. Additionally, in our research, the CS was done with arms folded across the chest; studies have verified that standing without using armrests requires different kinematics and kinetics, and older adults usually do trunk flexion to keep the balance. Beginning the movement from a position different from erect is also related with increased time movement[14] and could be influenced by low back pain as well. In our studied rural sample, the farm work might be a possible cause for this comorbidity[15] as a kyphotic or squatting position is frequently required in agriculture.

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Moreover, the class of medications usually prescribed for low back pain includes nonsteroidal antiinflammatory drugs, skeletal muscle relaxants and opioid analgesics; unfortunately, we did not investigate the classes of the medication that the participants used, however, there is evidence supporting the fact that some of this class of medications may be related with their gastrointestinal problems as well.[16]

The values for HGS and CS in urban individuals were similar to previous studies developed in urban communities in Japan[10,17]; however, our studied rural group had higher HGS and lower CS in comparison.

A study aimed at identifying HGS cutoffs for women and its results showed the threshold of 21 kg at any level of BMI, with values below the cutoff indicating mobility limitations.[18] Another study verified that poor HGS is a predictor of accelerated dependency in activities of daily living (ADL) and cognitive decline in the oldest old[5] and predicts cause-specific mortality in middle-aged and elderly individuals.[19]

Additionally, individuals from rural environments had higher BMI, WC and BF% than those from the urban cohort, however, both groups are inside the cutoff values for BMI, according to the World Health Organization (normal range = 18.5–24.99 kg/m^2)[20] and specific WC (80 cm) for the diagnosis of metabolic syndrome in Japanese women.[21] Such differences on anthropometric features are also linked with lifestyle factors, however, as we did not investigate dietary habits, we cannot extend our conclusions to this point.

TUG has been used as a screening of fall risk.[22] The values we found were better in comparison with other studies; Herman et al (2011) verified a mean score of 9.5 $\pm$ 1.7 seconds, ranging from 5.4 to 15.6 seconds, however, their study involved both genders. Another study developed in Japan, with only women (mean age = 78.6 years), found a mean score of 10.3 seconds for TUG,[23] and a review study referenced an Australian research that found a mean score of 8.5 $\pm$ 1.6 seconds for women aged 70–79 years.[24]

Another review study conducted by Michikawa et al (2009) identified reference values for OLS time in elderly participants, and stated that this measure of balance can be used as a practical marker to screen the elderly for frailty. Because various procedures are used, the measured values varied widely from study to study, with a mean of 6.9 to 32.9 seconds reported for women aged 70–79 years (considering the maximum time of 60 seconds). Clearly, this variation may be due to individual, as well as procedural, differences. Also, many studies provided combined data for men and women. In their original research, the authors found a median value of 27.8 seconds for women aged 75–79 years, also considering the maximum time of 60 seconds execution.[25] Despite the different methodology, our results are similar to theirs.

In our study, rural women showed lower scores in LSA and a tendency to be less engaged in physical activity. Our results were consistent with another urban–rural comparison study conducted in the United States, which showed that rural older women had a higher BMI and less engagement in physical activity than their urban counterparts.[7] Consistently, another study showed that rural participants had less engagement in physical activity and less active transportation.[6] In Japan, a study was conducted to examine the association between the neighborhood environment and physical activity among Japanese adults; it was reported that people living in neighborhoods with a high residential density, good access to shops, the presence of sidewalks, and the presence of bike lanes, had higher physical activity levels.[8] Furthermore, Peel et al (2005), in a study about the measure of mobility for older community-dwelling adults, found that rural participants also had lower physical performance and function, but higher scores in LSA than urban participants. The authors justified their findings, stating that rural individuals usually travel farther to accomplish tasks, and some community services enabling residents to stay at home, may be unavailable in rural communities.[26]

A study conducted by Van Dyck et al (2010) showed additional evidence regarding pedometer data, in which they concluded that rural individuals took fewer average steps per day than urban ones, contrasting with our results, which showed a higher weekly average step count in individuals from a rural environment; however, their sample was younger (mean age = 42.4 years) than ours.[6] A national survey conducted in Japan showed 5823 steps per day, on average, in people aged 65–74 years, similar to our findings from an urban community, but lower than those observed in the rural community.[27] We may explain our results by the socio-demographic data, that participants from the rural community were more engaged in work and farm activities, even though no statistical differences were found. When performing these daily activities, it is expected that they will take more steps per day. Additionally, we may reinforce the results of LSA supposing that, if participants from rural communities had lower scores, they do not travel farther and use less transportation than urban ones. Aiming to move through the community or going to work, they may do it on foot. Consequently, they accumulated more steps per day/week. Moreover, they may walk to nearby fields for agriculture work.

LSA is an important measure of frailty, as it allows early verification of mobility restriction, which may permit the identification of persons in the course of disability development and at a time when such disability can be prevented. This approach in community dwelling older adults showed strong correlations with age,[28] physical performance measures,[12] daily activities,[12,28] comorbid conditions,[12,28] depressive symptoms,[12] social activities,[28] self-reported health,[12,28] and poor psychological well-being.[28]

Our findings should be useful in targeting and evaluating interventions that enable people to maintain independent mobility and physical performance in their living environment. We emphasize that health interventions should address the specific demand of each location.

To our knowledge, no study has been done to show a direct comparison regarding physical performance and general health status in older urban and rural Japanese women, and our study is the first that shows some evidence about these variables. However, it has several limitations, such as the small sample size, a different number of respondents in each assessment, and it includes only one gender. Therefore, further studies with a variability of geographic settings and a larger sample are needed to continue the investigation concerning differences in the environment to confirm our findings.

Disclosure statement

None of the authors have conflicts of interest or financial disclosures.

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References

1. Statistics Bureau Japan, *Ministry of Internal Affairs and Communications Website.* http://www.stat.go.jp/english/data/handbook/c02cont.htm; 2010 [accessed May 2012].
2. Curb JD, Ceria-Ulep CD, Rodriguez BL, Grove J, Guralnik J, Willcox BJ, et al. Performance-based measures of physical function for high-function populations. *J Am Geriatr Soc* 2006;**54**:737–42.

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3. Gardner AW, Montgomery PS. Differences in exercise performance and leisure-time physical activity in older men and women. *Clin Med Geriatr* 2008;**1**:9–15.
4. Viccaro LJ, Perera S, Studenski SA. Is timed up and go better than gait speed in predicting health, function, and falls in older adults? *J Am Geriatr Soc* 2011;**59**: 887–92.
5. Taekema DG, Gussekloo J, Maier AB, Westendorp RGJ, Craen AJM. Handgrip strength as a predictor of functional, psychological and social health. A prospective population-based study among the oldest old. *Age Ageing* 2010;**39**: 331–7.
6. Van Dyck D, Cardon G, Deforche B, De Bourdeaudhuij I. Urban–rural differences in physical activity in Belgian adults and the importance of psychosocial factors. *J Urban Health Bull N Y Acad Med* 2010;**88**:154–66.
7. Wilcox S, Castro C, King AC, Housemann R, Brownson RC. Determinants of leisure physical activity in rural compared with urban older and ethnically diverse women in the United States. *J Epidemiol Community Health* 2000;**54**: 667–72.
8. Inoue S, Murase N, Shimomitsu T, Ohya Y, Odagiri Y, Takamiya T, et al. Association of physical activity and neighborhood environment among Japanese adults. *Prev Med* 2009;**48**:321–5.
9. Bibby P, Shepherd J. *Developing a new classification of urban and rural areas for policy purposes – the methodology*. London, UK: DEFRA; 2005.
10. Yoshimura N, Oka H, Muraki S, Akune T, Hirabayashi N, Matsuda S, et al. Reference values for hand grip strength, muscle mass, walking time, and one-leg standing time as indices for locomotive syndrome and associated disability: the second survey of the ROAD study. *J Orthop Sci* 2011;**16**:768–77.
11. Malavolti M, Mussi C, Poli M, Fantuzzi AL, Salvioli G, Battistini N, et al. Cross-calibration of eight-polar bioelectrical impedance analysis versus dual-energy X-ray absorptiometry for the assessment of total and appendicular body composition in healthy subjects aged 21–82 years. *Ann Hum Biol* 2003;**30**: 380–91.
12. Baker PS, Bodner EV, Allman RM. Measuring life-space mobility in community-dwelling older adults. *J Am Geriatr Soc* 2003;**51**:1610–4.
13. Fotoohabadi MR, Tully EA, Galea MP. Kinematics of rising from a chair: image-based analysis of the sagittal hip-spine movement pattern in elderly people who are healthy. *Phys Ther* 2010;**90**:561–71.
14. Janssen WGM, Bussmann HBJ, Stam HJ. Determinants of the sit-to-stand movement: a review. *Phys Ther* 2002;**82**:866–79.
15. Dean SG, Hudson S, Hay-Smith EJC, Milosavljevic S. Rural workers' experience of low back pain: exploring why they continue to work. *J Occup Rehabil* 2011;**21**:395–409.
16. Chou R, Huffman LH. Medications for acute and chronic low back pain: a review of the evidence for an American Pain Society/American College of Physicians Clinical Practice Guideline. *Ann Intern Med* 2007;**147**:505–14.
17. Tsubaki A, Kubo M, Kobayashi R, Jigami H, Takahashi HE. Age-related changes in physical function in community-dwelling people aged 50–79 years. *J Phys Ther Sci* 2010;**22**:23–7.
18. Sallinen J, Stenholm S, Rantanen T, Heliövaara M, Sainio P, Koskinen S. Hand-grip strength cut points to screen older persons at risk for mobility limitation. *J Am Geriatr Soc* 2010;**58**:1721–6.
19. Sasaki H, Kasagi F, Yamada M, Fujita S. Grip strength predicts cause-specific mortality in middle-aged and elderly persons. *Am J Med* 2007;**120**:337–42.
20. World Health Organization Website. *Global Database on Body Mass Index an interactive surveillance tool for monitoring nutrition transition*. http://apps.who.int/bmi; 2006 [accessed May 2012].
21. Ogawa D, Kahara K, Shigematsu T, Fujii S, Hayakawa N, Okazaki M, et al. Optimal cut-off point of waist circumference for the diagnosis of metabolic syndrome in Japanese subjects. *J Diabetes Invest* 2010;**1**:117–20.
22. Herman T, Giladi N, Hausdorff JM. Properties of the "Timed Up and Go" Test: more than meets the eye. *Gerontology* 2011;**57**:203–10.
23. Shimada H, Kim H, Yoshida H, Yoshida Y, Saito K, Suzukawa M, et al. Factors associated with the Timed Up and Go Test score in elderly women. *J Phys Ther Sci* 2010;**22**:273–8.
24. Bohannon RW. Reference values for the Timed Up and Go Test: a descriptive meta-analysis. *J Geriatr Phys Ther* 2006;**29**:64–8.
25. Michikawa T, Nishiwaki Y, Takebayashi T, Toyama Y. One-leg standing test for elderly populations. *J Orthop Sci* 2009;**14**:675–85.
26. Peel C, Baker PS, Roth DL, Brown CJ, Bodner EV, Allman RM. Assessing mobility in older adults: the UAB study of aging Life-Space Assessment. *Phys Ther* 2005;**85**:1008–19.
27. Ministry of Health, Labour and Welfare of Japan Website. *The National Health and Nutrition Survey*. [In Japanese] Available at: http://www.mhlw.go.jp/bunya/kenkou/eiyou07/01.html; 2005 [accessed May 2012].
28. Murata C, Kondo T, Tamakoshi K, Yatsuya H, Toyoshima H. Factors associated with life space among community-living rural elders in Japan. *Public Health Nurs* 2006;**23**:324–31.

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Research paper

The correlation between the plenitude of fall prevention programs and fall incidents in community-level: A J-MACC study

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ABSTRACT

Objective: The purpose of this study was to examine the relationship between the number of participants partaking in fall prevention-related programs and fall rates in the community.
Method: A cross-sectional survey was conducted in Sakyo Ward, Kyoto City, Japan as part of the Japan Multi-center Aging Cohort for Care prevention study. Data from 6423 healthy community-dwelling elderly adults living in 20 districts were used to identify the districts with high fall rates. An alternate survey was conducted to collect information on fall prevention-related programs held in each district between April 2010 and March 2011. Using the Mantel-Haenszel chi-square test, we identified districts with high fall rates and compared the number of participants in each fall prevention-related program between districts with high fall rates and other districts using the Mann-Whitney U test and chi-square test.
Results: The districts determined as "non-high fall rate" had significantly more participants in exercise and education programs than the "high fall rate" districts ($p = 0.02$). The "non-high fall rate" districts also had more participants than the "high fall rate" districts in public group exercise, private volunteer-led group exercise, and pamphlet distribution; however, this number was not significant.
Conclusion: Interventions with exercise and educational aspects may be effective in preventing falls at the community level.

1. Introduction

Falls are a major public health problem among the elderly population. Approximately 28–35% of the community-dwelling elderly population over the age of 65 fall each year [1]. Falls lead to reduced levels of independence and poor quality of life [2,3]. Moreover, 24% of community-dwelling elder adults sustain serious injuries from their falls [4], and half of older adults' injury-related hospitalizations are related to falls [5].

Through a systematic review, Tinetti and Kumar reported that the highest risk factors for falling include previous falls; impairments to strength, gait, and balance; and the use of specific medications [6]. Although the risk of falling increases with the number of risk factors [4], healthy elder adults are also vulnerable to falls [7,8]. Combining programs, such as strength, gait, and balance training; environmental adaptation and/or modification; reviewing and reducing medications; managing vision problems and orthostasis are effective in preventing falls [9,10]. Population-based interventions include coordinated activity programs in which the focus of strategies and countermeasures is on the whole community rather than individuals within the community [11]. These population-based, multi-strategy interventions are cost-effective and provide a significant reduction (or downward trend) in fall-related injuries ranging from 6–33% [11,12]. Larsson et al. concluded that preventing falls at the community level might be more cost-efficient than preventing falls only among groups identified as being at a high risk of falling [13].

In Japan, local governments and organizations have been implementing programs dealing with preventive care associated with fall prevention [14], but the effectiveness of these programs at the community level has not yet been determined. A previous study reported that health behavior could spread within a social network (e.g., family or friend groups) [15,16]. This suggests that an individual might gain positive health benefits from others through information sharing with their social ties [17]. Access to fall prevention resources (e.g., local exercise programs) and specific behaviors that maintain or improve health or build fall prevention skills (e.g., footwear, simple exercises, home hazards) could expand from the community to the resident through social sharing. The purpose of this study was to examine if the number of participants within fall prevention-related programs differs between communities with high fall rates and low fall rates.

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2. Methods

2.1. Setting and design

We analyzed data from a cross-sectional study entitled "The Japan Multi-center Aging Cohort for Care prevention (J-MACC)." The study was performed in Sakyo Ward, Kyoto City; we chose the district as the unit of comparison to maintain the anonymity of people living in those districts while, at the same time, ensuring an adequate number of sampling units. Anonymity was necessary because informed consent was not feasible. The practitioners of the fall prevention-related preventive care programs were identified through discussion with the administrator of the Sakyo Ward Office, Welfare Department, Support Division. The Kyoto University Graduate School of Medicine approved our study protocol and informed consent procedure, and our protocol conforms to the Declaration of Human Rights, Helsinki, 1975. The committee understood and agreed that informed consent from the participating practitioners—but not from each subject—was required.

2.2. Data source and sample

Sakyo comprises 24 administrative districts with over 169,000 residents (National Census 2008). Of the 24 districts, those with less than 1% of Sakyo's total population were excluded, resulting in 20 districts: districts A–T, which were considered for this study.

Residents' data were drawn from the "Kihon Checklist" (a frailty checklist), a survey conducted by Kyoto City from April to August 2011. The survey consists of 25 items to screen for frail elderly, and it is based on the Long-term Care Insurance (LTCI) system [18]. The survey was mailed to 24,964 healthy, community-dwelling elderly adults aged 65 years or older. These adults were not certified as a support or care requirement according to their care needs and certification assessment from the LTCI system [19]. All potential participants were living in the Sakyo region of Kyoto City; 6970 residents responded (response rate: 27.9%). Seventy-four samples from the four excluded districts and 473 samples with missing values on age, gender, height, weight, or an item from the Kihon Checklist—"Do you have any history of a fall within the past year?"—were excluded from the analysis. This resulted in a final sample size of 6423.

2.3. Outcome data

Whether someone experienced a fall was based on a basic "yes or no" question from the Kihon Checklist that inquires about fall history within the past year: "Do you have any history of a fall within the past year?" The fall rate of each district was considered as the percentage of subjects who answered, "yes," within each district.

Data from the fall prevention-related preventive care programs held in Sakyo between April 2010 and March 2011 were collected from nine government referral organizations. We sent a self-report survey to each organization to determine the number of participants from each district for every program from the organizational database. The programs were grouped by the type of intervention.

Public group exercise: group exercise programs conducted by the government referral organization that were open to any healthy, community-dwelling elderly adults. Professional exercise experts supervised each program. Each program lasted 1 hour and was held once a week. Sessions covered a period ranging from one day to a maximum of three months.

Private, volunteer-led exercise: volunteer-led group exercise programs held without assistance from a government referral organization. Educated volunteers supervised the programs, and participation was often limited to group members. Each session lasted 1–1.5 hours and was held every week or once every 2 weeks. Once the program started, it continued throughout the year.

Exercise and education program: combination of physical activity and education about preventive care, such as physical activity, diet, and oral health. Local volunteers ran the programs, and professionals supported the activities. Medical checkups, exercise, and dementia prevention activities were permanent features of such programs, and local professionals provided educational lectures. Each program lasted between 2 and 6 hours and was held mostly once or twice a month.

Pamphlet: disseminated written material with information on falls, how to prevent falls, and the benefits of exercise. The pamphlets were placed at local community centers and handed out to people who attended the health checkups.

Lecture: educational lectures on health awareness, preventing falls, or the benefits of exercise provided by health professionals. Each lecture was approximately 1 hour and held as a single activity.

The following procedure was used for every intervention for each district prior to statistical analysis. For "Public exercise", "Private, volunteer-led exercise", "Exercise and education program" and "Pamphlet", the number of participants in each intervention group was summed and divided by the district's area (per km^2) to normalize the geographic factor. For "Lecture", a response variable was created according to whether the district had held lectures (1 = more than once; 0 = none).

2.4. Statistical analyses

The analytic method is shown in Fig. 1. A Mantel-Haenszel chi-square test was performed to classify the districts into the following two groups: the high fall rate district group (high fall rate group: HR group) and the non-high fall rate district group (non-high fall rate group: n-HR group). Each district was compared to the district with the lowest fall rate. Districts that had a significantly high odds ratio compared to the lowest fall rate district were grouped into the HR group, and others were grouped into the n-HR group. Gender, age (≥75) and BMI (<18.5) were used to adjust for demographic and biological factors.

To examine the relationship between fall rates and intervention programs, the Mann-Whitney U test and chi-square test were conducted. The number of participants in the "Public exercise", "Private, volunteer-led exercise", "Exercise and education program" and "Pamphlet" within each district was compared to the HR group and the n-HR group using the Mann-Whitney U test. Those in the "Lecture" group were compared using the chi-square test. Statistical analyses were performed with SPSS for Windows software, version 20.0. All statistical tests were two-sided, with the level of significance defined as $p < 0.05$.

3. Results

Population characteristics are shown in Table 1. Among the healthy elderly adults who were 65 or older, the average fall rate was 22.5%, with the lowest rate of 19.2% in district A and the highest rate being 39.0% in district C. After adjusting for gender, age and BMI, district C (odds ratio: 2.780; 95% CI: 1.605–4.813), R (odds ratio: 1.793; 95% CI: 1.011–3.180), S (odds ratio: 1.639; 95% CI: 1.039–2.585), and T (odds ratio: 2.049; 95% CI: 1.162–3.611) had significantly higher fall rates than district A, which had the lowest fall rate. The odds ratio and 95% CIs are shown in Table 2.

The n-HR group had a significantly higher number of people who participated in the "Exercise and education program" compared to the HR group ($p = 0.02$). "Public exercise", "Private, volunteer-led exercise" and, in the n-HR group, "Pamphlet" also

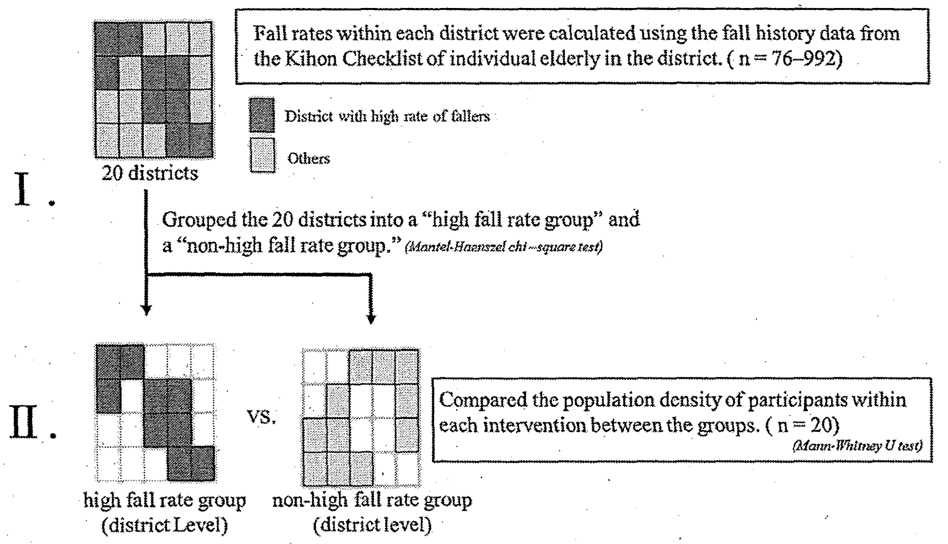

Fig. 1. Flow chart showing the analysis of the study. (I) First, the fall history of the elderly living in the district was used to calculate the fall rate of each district (n = 76–992). The districts were grouped into a high fall rate group or a non-high fall rate group according to the fall rate of the individual district. (II) Then, the population density of participants within each fall prevention intervention (lecture was compared by whether or not a lecture was held) were compared between the two groups.

had a higher number of participants, but this number was not significant. Five districts, three in the n-HR group and two in the HR group, held "Lectures" during the one-year period, but no significant differences were found between the groups (Table 3).

4. Discussion

Falls occur because of complex interactions among intrinsic and/or extrinsic factors. Intrinsic factors include demographic and biological factors, while extrinsic factors include environmental and behavioral factors [1]. At the district level, the fall rate within individual districts in Sakyo had a wide range: 19.2 to 39.5%. After adjusting fall rate by gender, age, and BMI, four districts were still considered "high rate," which was not associated with factors such as overall population density (<4000 persons/km^2) or elder population density (data not shown). Districts in which a higher number of people participated in programs that included both physical activity and education had a significantly lower fall rate. One-dimensional interventions that consisted of only exercise programs were also associated with a decrease in the fall rate, but not significantly. Previous studies report that interventions that include only exercise do prevent falls at the individual level [6,20]; however, to reduce falls at the community level, multifactorial interventions are advocated and preferred [13].

Exercise programs are more effective in reducing risk factors when they are combined with other interventions, such as home hazard management, vision improvement, and encouraging various behavioral changes [6,10,21]. The exercise and education program in the present study is a half-day program held approximately every month that includes group exercise; simple lectures on health and welfare; and physical recreation activity; these are conducted by educated volunteers or health-related

Table 1
Characteristics of the study population.

District	n	Faller	Female	Age (year)	BMI
		Total No. of persons (percent)		(Mean ± S.D.)	
All	6423	1444 (22.5)	3766 (58.6)	77.53 ± 6.04	22.16 ± 2.97
A	297	57 (19.2)	191 (64.3)	77.25 ± 6.28	22.36 ± 3.23
B	136	36 (26.5)	76 (55.9)	77.78 ± 5.69	22.68 ± 3.29
C	76	30 (39.5)	52 (68.4)	77.80 ± 5.85	21.78 ± 3.16
D	147	37 (25.2)	85 (57.8)	78.47 ± 6.56	22.42 ± 3.40
E	197	40 (20.3)	116 (58.9)	76.95 ± 5.92	22.22 ± 3.00
F	324	64 (19.8)	188 (58.0)	77.72 ± 6.06	22.16 ± 2.92
G	298	61 (20.5)	191 (64.1)	78.27 ± 5.98	21.80 ± 2.78
H	405	83 (20.5)	241 (59.5)	77.64 ± 5.84	21.91 ± 2.71
I	218	56 (25.7)	127 (58.3)	76.82 ± 6.03	22.34 ± 3.11
J	434	103 (23.7)	271 (62.4)	77.21 ± 6.22	22.09 ± 2.90
K	447	110 (24.6)	273 (61.1)	78.43 ± 6.19	21.77 ± 2.97
L	621	126 (20.3)	359 (57.8)	78.26 ± 6.05	21.96 ± 3.02
M	696	162 (23.3)	392 (56.3)	77.51 ± 5.70	22.21 ± 2.87
N	279	64 (22.9)	158 (56.6)	76.46 ± 5.72	22.31 ± 3.11
O	272	56 (20.6)	162 (59.6)	76.99 ± 6.17	22.51 ± 3.25
P	268	58 (21.6)	155 (57.8)	78.40 ± 5.77	21.57 ± 2.63
Q	992	210 (21.2)	553 (55.7)	77.15 ± 6.11	22.30 ± 2.84
R	78	24 (30.8)	43 (55.1)	75.38 ± 5.75	22.99 ± 2.78
S	78	23 (29.5)	46 (59.0)	77.08 ± 6.58	22.51 ± 3.05
T	160	44 (27.5)	87 (54.4)	77.02 ± 5.94	22.69 ± 3.07

Table 2
Adjusted likelihood of falls of the districts.

District	Odds ratios	95 %CI	p
A[a]	1.000	Reference	–
B	1.548	0.953–2.515	0.10
C	3.121	1.765–5.518	<0.001[**]
D	1.343	0.830–2.174	0.28
E	1.138	0.718–1.802	0.67
F	1.000	0.668–1.498	0.92
G	1.041	0.691–1.569	0.93
H	1.086	0.743–1.588	0.74
I	1.470	0.962–2.246	0.09
J	1.320	0.916–1.903	0.16
K	1.380	0.957–1.991	0.10
L	1.038	0.728–1.481	0.91
M	1.286	0.914–1.811	0.17
N	1.279	0.852–1.918	0.28
O	1.075	0.710–1.626	0.81
P	1.110	0.727–1.695	0.71
Q	1.154	0.831–1.602	0.44
R	1.953	1.102–3.461	0.03[*]
S	1.970	1.096–3.543	0.04[*]
T	1.626	1.030–2.569	0.048[*]

Mantel-Haenszel chi-square test was used to compare the likelihood of fallers of each district with the reference district. Gender, age (≥75), and BMI (<18.5) were used to adjust the intrinsic factors.
[a] Reference district.
[*] $p < 0.05$.
[**] $p < 0.01$.

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Table 3
Comparison of adjusted number of participants in "Public exercise", "Private, volunteer-led exercise", "Exercise and education program", "Pamphlet" and "Lecture" of non-high fall rate group (n-HR group) and high fall rate group (HR group).

	n-HR group	HR group	p
	Median		
Public exercise[a]	5.63	0.59	0.08
Private, volunteer-led exercise[a]	5.80	1.43	0.34
Exercise and education program[a]	203.75	14.02	0.02*
Pamphlet[a]	63.75	4.72	0.22
Lecture[b]			0.25

The number of participants was normalized for the district's area (per km^2).
* $p < 0.05$.
[a] Mann-Whitney U test was used to compare between the groups.
[b] Chi-square test was used to compare between the groups.

professionals. The program is a holistic one that opens the lines of communication and encourages interaction among local residents [22]. Trustworthiness, an essential component of social capital, increases knowledge sharing [23,24]. For example, at the information sessions, some participants disseminated fall prevention information [25]. This peer-delivered education might increase fall prevention awareness among people who have not previously participated in the program but have social ties with those who have [26]. In fact, peer-led exercise programs might be as effective as those led by professional instructors [27–29]. Therefore, the program can be considered efficient not only for the participants but also for others who could benefit from modifying their activities and improving their environments through social interaction and information sharing. Thus, developing a firm and trustworthy social network could be an efficient way to implement an effective community-level intervention.

A major limitation of the study was the residents' response rate. The number of subjects was enough to maintain the sample size, but the number of residents within some districts was small, and we could not obtain a representative sample from those populations. In addition, we did not collect information on other demographic factors, such as socioeconomic and educational status. Thus, we were not able to determine whether these factors had any influence on our results. Another limitation included our inability to follow individuals who had participated in the programs. In other words, we cannot determine whether participation in a program had prevented falls, or if people who did not participate in the program had received a secondary benefit through interactions with those who did participate. However, matching individual subjects who fell with those who participated in an intervention program is not always necessary when conducting population-based studies [13,30]. Nevertheless, the relationship between participation and falls must be explored to clarify the actual effect of these programs among community residents. The ultimate goal of the programs conducted by government referral organizations was to prevent the population from being dependent on long-term care services. Even though fall prevention programs were chosen selectively, a few individual sessions within the programs could have focused more on health enhancement and not directly on fall prevention. Although the study is cross-sectional and causal correlation was not established, we evaluated the effectiveness of the interventions at the local community level. Communities where these programs are being implemented have a substantially lower fall rate; this is an essential finding. However, further study examining the effectiveness for the elderly who did not participate in the program is needed to clarify the actual effects of the interventions. For health sectors to provide efficient programs to communities, further research that includes deeper evaluation of the content and cost-effectiveness of the intervention programs is required.

5. Conclusion

The districts in which exercise and educational outreach interventions were effectively implemented had a lower fall rate. The adequate conduction of these interventions has the possibility of not only prevent falls of the participants but will also reduce falls at the community level.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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References

[1] Yoshida S. A global report on falls prevention: epidemiology of falls; 2007 [Cited October 10, 2012]http://www.who.int/ageing/projects/1.Epidemiology%20of%20falls%20in%20older%20age.pdf.
[2] Fabrício SC, Rodrigues RA, da Costa Jr ML. Falls among older adults seen at a São Paulo State public hospital: causes and consequences. Rev Saude Publica 2004;38:93–9.
[3] Hawkins K, Musich S, Ozminkowski RJ, Bai M, Migliori RJ, Yeh CS. The burden of falling on the quality of life of adults with Medicare supplement insurance. J Gerontol Nurs 2011;37:36–44.
[4] Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med 1988;319:1701–7.
[5] Cripps R, Carman J. Falls by the elderly in australia trends and data for 1988; 2001 [Cited October 10, 2012]http://www.nisu.flinders.edu.au/pubs/reports/2001/eldfalls_injcat35.pdf.
[6] Tinetti ME, Kumar C. The patient who falls: "It's always a trade-off". JAMA 2010;303:258–66.
[7] Speechley M, Tinetti M. Falls and injuries in frail and vigorous community elderly persons. J Am Geriatr Soc 1991;39:46–52.
[8] Hill K, Schwarz J, Flicker L, Carroll S. Falls among healthy, community-dwelling, older women: a prospective study of frequency, circumstances, consequences and prediction accuracy. Aust N Z J Public Health 1999;23:41–8.
[9] Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Preventing falls: how to develop community-based fall prevention programs for older adults; 2008 [Cited October 10, 2012]http://www.cdc.gov/homeandrecreationalsafety/images/cdc_guide-a.pdf.
[10] Day L, Fildes B, Gordon I, Fitzharris M, Flamer H, Lord S. Randomised factorial trial of falls prevention among older people living in their own homes. BMJ 2002;325:128.
[11] McClure R, Turner C, Peel N, Spinks A, Eakin E, Hughes K. Population-based interventions for the prevention of fall-related injuries in older people. Cochrane Database Syst Rev 2005;25:CD004441.
[12] Hanley A, Silke C, Murphy J. Community-based health efforts for the prevention of falls in the elderly. Clin Interv Aging 2011;6:19–25.
[13] Larsson TJ, Hägvide ML, Svanborg M, Borell L. Falls prevention through community intervention – a Swedish example. Saf Sci 2010;48:204–8.
[14] Ogawa M. The present situation and task in grappling with disability prevention at a local office. J Phys Ther 2005;22:658–63 [Japanese].
[15] Newman MEJ. The structure and function of complex networks. SIAM Rev 2003;45:167–256.
[16] Christakis NA, Fowler JH. The collective dynamics of smoking in a large social network. N Engl J Med 2008;358:2249–58.
[17] Christakis NA. Social networks and collateral health effects. BMJ 2004;329:184–5.
[18] Campbell JC, Ikegami N. Long-term care insurance comes to Japan. Health Aff (Millwood) 2000;19:26–39.
[19] Tsutsui T, Muramatsu N. Care-needs certification in the long-term care insurance system of Japan. J Am Geriatr Soc 2005;53:522–7.

Please cite this article in press as: Yoshimura K, et al. The correlation between the plenitude of fall prevention programs and fall incidents in community-level: A J-MACC study. Eur Geriatr Med (2013), http://dx.doi.org/10.1016/j.eurger.2013.01.008

[20] Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC. Effective exercise for the prevention of falls: a systematic review and meta-analysis. J Am Geriatr Soc 2008;56:2234–43.
[21] Clemson L, Cumming RG, Kendig H, Swann M, Heard R, Taylor K. The effectiveness of a community-based program for reducing the incidence of falls in the elderly: a randomized trial. J Am Geriatr Soc 2004;52: 1487–94.
[22] Takeda T, Kondo K, Hirai H. Preventive intervention of senile dementia focusing on psychosocial factors: intervention theory based on the population health approach and its evaluation of midterm outcomes. J Jpn Occup Ther Assoc 2009;28:178–86 [Japanese].
[23] Chang CW, Huang HC, Chiang CY, Hsu CP, Chang CC. Social capital and knowledge sharing: effects on patient safety. J Adv Nurs 2011;68: 1793–803.
[24] Willem A, Scarbrough H. Social capital and political bias in knowledge sharing: an exploratory study. Hum Relat 2006;59:1343–70.
[25] Dychtwald K. Wellness and health promotion for the elderly rockville. Rockville: Aspen Systems; 1986.
[26] Deery HA, Day LM, Fildes BN. An impact evaluation of a falls prevention program among older people. Accid Anal Prev 2000;32:427–33.
[27] Waters DL, Hale LA, Robertson L, Hale BA, Herbison P. Evaluation of a peer-led falls prevention program for older adults. Arch Phys Med Rehabil 2011;92: 1581–6.
[28] Layne JE, Sampson SE, Mallio CJ, Hibberd PL, Griffith JL, Das SK, et al. Successful dissemination of a community-based strength training program for older adults by peer and professional leaders: the people exercising program. J Am Geriatr Soc 2008;56:2323–9.
[29] Modra AK, Black DR. Peer-led minimal intervention: an exercise approach for elderly women. Am J Health Behav 1999;23:52–60.
[30] Tinetti ME, Baker DI, King M, Gottschalk M, Murphy TE, Acampora D, et al. Effect of dissemination of evidence in reducing injuries from falls. N Engl J Med 2008;359:252–61.

Reliability and Validity of Gait Analysis by Android-Based Smartphone

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Abstract

Smartphones are very common devices in daily life that have a built-in tri-axial accelerometer. Similar to previously developed accelerometers, smartphones can be used to assess gait patterns. However, few gait analyses have been performed using smartphones, and their reliability and validity have not been evaluated yet. The purpose of this study was to evaluate the reliability and validity of a smartphone accelerometer. Thirty healthy young adults participated in this study. They walked 20 m at their preferred speeds, and their trunk accelerations were measured using a smartphone and a tri-axial accelerometer that was secured over the L3 spinous process. We developed a gait analysis application and installed it in the smartphone to measure the acceleration. After signal processing, we calculated the gait parameters of each measurement terminal: peak frequency (PF), root mean square (RMS), autocorrelation peak (AC), and coefficient of variance (CV) of the acceleration peak intervals. Remarkable consistency was observed in the test–retest reliability of all the gait parameter results obtained by the smartphone ($p < 0.001$)*. All the gait parameter results obtained by the smartphone showed statistically significant and considerable correlations with the same parameter results obtained by the tri-axial accelerometer (PF* $r = 0.99$*, RMS* $r = 0.89$*, AC* $r = 0.85$*, CV* $r = 0.82$*;* $p < 0.01$*). Our study indicates that the smartphone with gait analysis application used in this study has the capacity to quantify gait parameters with a degree of accuracy that is comparable to that of the tri-axial accelerometer.*

Key words: *smartphones, accelerometers, gait analysis, reliability, validity*

Introduction

Walking is a natural form of movement, and most people walk every day to perform a variety of common tasks such as shopping and traveling. This most natural capability, however, is commonly influenced by major cerebral impairments,[1] severe musculoskeletal disorders,[2] and aging.[3]

The study of human movement, an area that has been actively researched for many years, has sought to identify and characterize gait patterns. For years, the quantitative analysis of gait patterns has been studied in gait laboratories that are equipped with many sophisticated measurement and analysis devices such as ground reaction force plates and three-dimensional kinematic motion analysis systems.[4,5] However, the use of such facilities requires specialized personnel and laboratory environment. Moreover, most of the equipment is costly, and the data acquisition procedures are often cumbersome. In fact, for some time now, the use of facilities for gait analysis has been limited to field research and clinical settings.

More recently, wireless tri-axial accelerometers are being used widely for gait analysis because they are easy to use and inexpensive and they do not require a laboratory environment. Henriksen et al.[6] found the reliability of trunk accelerometric gait analysis to be satisfactory, as it yielded high values for intraclass correlation coefficient (ICC) and low values for measurement error and coefficients of variation. By conducting a personal computer analysis of the raw acceleration data collected from a person's gait, it is possible to quantify the variability, regularity, and rhythmic pattern of the person's gait.[7] Accelerometric gait analysis enables us to assess gait patterns from the perspective of gait stability, which is different from the previously used kinematic approach.

A current and quite recent trend has seen the deployment of accelerometers in off-the-shelf cellphone handsets such as smartphones, and studies of gait analysis and measurements of anticipatory postural adjustments have been attempted using a smartphone accelerometer.[8,9] Lemoyne et al.[9] performed gait analysis experiments using a smartphone that demonstrated the capacity to accurately quantify gait parameters with a sufficient level of consistency. Thus, smartphones may have the potential to assess gait patterns as competently as accelerometers. However, gait analysis using smartphones has not been explored widely, and its reliability and validity have not yet been evaluated. Therefore, the purpose of this study was to evaluate the reliability and validity of a smartphone accelerometer. In this study, gait parameters obtained by a

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smartphone were compared with those obtained by a conventional accelerometer.

Subjects and Methods

SUBJECTS

Students at Kyoto University were recruited as subjects for this study. 17 men and 13 women volunteered, none of whom reported present or previous diseases or injuries associated with gait and/or balance impairments. Informed consent was obtained from all subjects prior to their participation, in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine (approval number E1095) and the Declaration of Human Rights, Helsinki, 1975.

TEST PROCEDURES

The subjects were instructed to walk on a 25-m smooth, horizontal walkway, with a 2.5-m space at each end of the walkway for acceleration and deceleration. Thus, measurements were performed over a distance of 20 m. Subjects walked the length of this walkway three times at their preferred speeds, wearing shoes that did not influence their gait.

APPARATUS

We used two kinds of acceleration measurement terminals: One equipped with a smartphone (Xperia SO-01B, Android™ operating system version 2.1, 139 g, 119×60×13.1 mm, Sony Ericsson Co., Japan) and the other equipped with a tri-axial accelerometer (model WAA-006, 17 g, 38×39×10 mm, ATR-Promotions Co., Japan). The smartphone and the tri-axial accelerometer were taped together. With the method used by Moe-Nilssen and Helbostad,[10] the terminals were secured over the L3 region, which is close to where the body's center of mass is believed to be located during quiet standing. We developed a gait analysis application and installed it in the smartphone to measure the acceleration of the terminal. This application measured the acceleration of an Android smartphone and immediately displayed the gait analysis results on the smartphone's screen. In our gait analysis, the sampling rate of acceleration measurement for the smartphone was set at SENSOR_DELAY_FASTEST, which is the highest mode listed in the specifications for an Android smartphone. Because the sampling rate was not constant, we adjusted the sampling rate of the acceleration measurement in the smartphone to 0.03 s during interpolation. In total, 256 samples (7.68 s) of acceleration data were obtained from each measurement terminal and analyzed. For the same reasons as above, the sampling rate of the tri-axial accelerometer was set to 0.03 s.

DATA PROCESSING

We selected the following gait parameters, according to previous studies: peak frequency (PF),[11] root mean square (RMS),[10] autocorrelation peak (AC),[11,12] and the coefficient of variance (CV) of the acceleration peak intervals.[13,14]

The PF value indicates the gait cycle, which is the time taken for one step. The RMS value indicates the degree of gait instability; thus, a higher RMS value indicates a lower degree of stability. The AC value indicates the degree of gait balance, so a higher AC value indicates a greater degree of balance. The CV value indicates the degree of gait variability (i.e., the variability in the elapsed time between the first contacts of two consecutive footfalls). To calculate the gait parameters, we used the absolute values of the tri-axial acceleration data to decrease the influence of the measurement terminal posture. Let $a_{t_1:t_n} = a_{t_1}, a_{t_2}, \ldots, a_{t_n}$ denote the set of all acceleration absolute values acquired from time t_1 to t_n, for $t_1 \le t_n$. Let a_t and n, respectively, denote the acceleration absolute value at time t and the number of all acceleration absolute values acquired from time t_1 to t_n.

PF DETECTION PROCEDURE

The PF f_p of acceleration data $a_{t_1:t_n}$ was detected with high accuracy based on the PF candidate f_p', which was detected from the smoothed acceleration data in order to decrease the influence of the high-frequency measurement noise that accompanied PF detection. The PF detection procedure is shown in *Figure 1*. First, acceleration data $a_{t_1:t_n}$ were smoothed using a low-pass filter. Second, the PF candidate, f_p', was detected where the power spectrum at frequency f_p' was the highest peak in the frequency space to which the smoothed acceleration data were converted by fast Fourier transformation. Finally, PF f_p was detected in the frequency space to which acceleration data $a_{t_1:t_n}$ were converted, where the power spectrum of PF f_p had the highest peak around PF candidate f_p'.

PROCEDURE FOR CALCULATION OF RMS

The RMS of acceleration data $a_{t_1:t_n}$ was calculated as follows:

$$RMS = \left(\frac{\int_{t_1}^{t_n} a(t)^2 dt}{t_n - t_1} \right)^{\frac{1}{2}}$$

Here, let t_1 and t_n, respectively, denote the start time and the stop time of our gait analysis measurement.

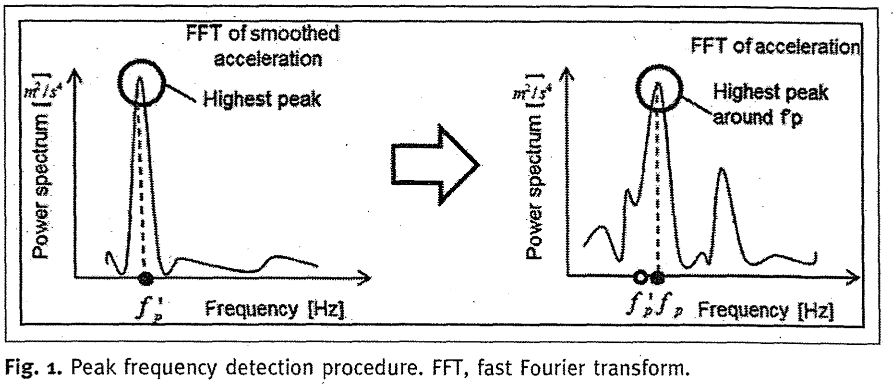

Fig. 1. Peak frequency detection procedure. FFT, fast Fourier transform.