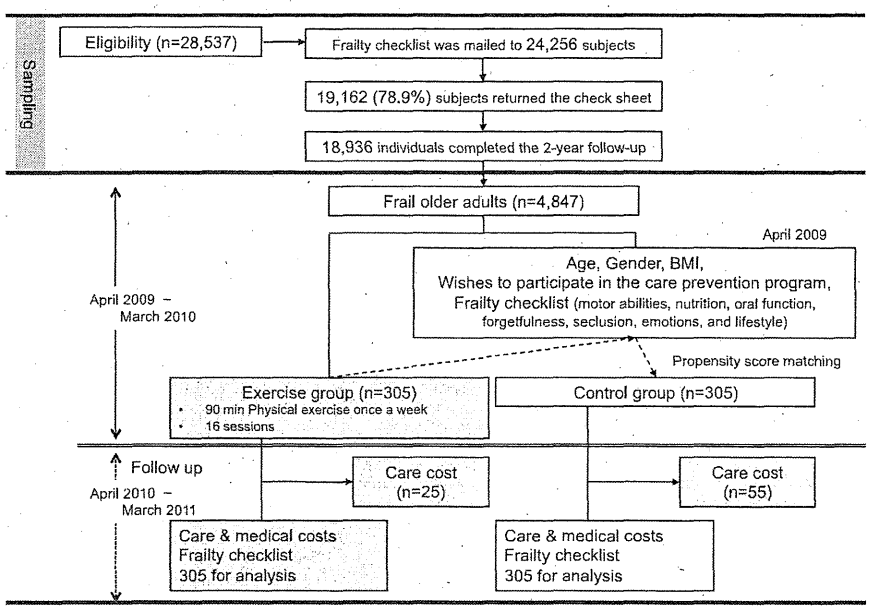

Fig. 2. A flow chart showing the distribution of subjects throughout the trial.

independent in ADLs in 2 cities (Maibara City in Shiga Prefecture and Maizuru City in Kyoto Prefecture) (Figure 1). The exclusion criteria were older adults who were already ADL-dependent and were eligible to receive benefits from LTCI services.

A total of 28,537 residents were eligible for this study in April 2009. The self-administered frailty checklist was mailed to 24,256 subjects, and the response rate was 78.9%. We further excluded individuals who died or moved from the cities in the 2-year follow-up, and analyzed 18,936 elderly. Subjects for the care prevention program were recruited using direct mail. We screened subjects in an initial interview and recruited frail older adults 65 years or older.

This study was conducted in accordance with the guidelines proposed by the Declaration of Helsinki, and the study protocol was reviewed and approved by the Ethics Committee of Kyoto University Graduate School of Medicine.

Frailty Checklist

The frailty checklist includes simple yes/no questions concerning lifestyle (questions 1 to 5), motor abilities (questions 6 to 10), nutrition (questions 11 to 12), oral functions (questions 13 to 15), seclusion (questions 16 to 17), forgetfulness (questions 18 to 20), and emotions (questions 21 to 25) (Table 1). We calculated the scores in each of these 7 domains.

Table 2
Baseline Characteristics of the Study Subjects in Exercise and Control Groups

	Exercise Group (n = 305)		Control Group (n = 305)		P Value
	Mean	SD	Mean	SD	
Age, y	79.7	6.3	80.3	6.6	.275
Gender, female	231 (75.4%)		238 (78.0%)		.560*
Height	151.5	8.0	151.1	8.3	.509
Weight	53.1	10.0	51.8	10.2	.128
BMI, kg/m^2	23.0	3.4	22.6	3.5	.129
Falls in past year	107 (35.1%)		114 (37.4%)		.670*
Total scores of frailty checklist	7.41	3.98	7.34	4.27	.814

BMI, body mass index.
*Chi-square test.

Impaired physical condition was defined as having 3 points or more in motor ability items according to the Japanese Ministry of Health, Labor, and Welfare. Malnutrition was defined as having 2 points in nutrition items, poor oral health as having 1 point or more in oral function items, seclusion as having 1 point or more in seclusion items, cognitive decline as having 1 point or more in forgetfulness items, and depressive mood as having 2 points or more in emotion items. Frailty was defined by scores of 10 or more points on questions 1 to 20.

Definition of Frail Older Adults in this Study

In this study, we defined frail older adults as those who need to maintain or to improve daily functions. These individuals are not eligible for the LTCI service requirement as defined by the government, but have a high risk of becoming dependent based on the results of the frailty checklist.[5] Those older adults are defined as having impaired motor abilities, malnutrition, poor oral health, or impaired lifestyle as described in the previous paragraph.

Care Prevention Program

The subjects received 90 minutes of group training sessions once a week for 16 consecutive weeks. The exercise class was supervised by a physiotherapist. The exercise sessions were conducted according

Table 3
Comparison of New LTCI Service Requirement Certification Between the 2 Groups

	Exercise Group, n (%)	Control Group, n (%)	RR	95% CI
LTCI requirement	25 (8.1%)	55 (18.0%)	2.16	1.46–3.20
Support level				
1	11	15		
2	7	14		
Care level				
1	4	13		
2	3	7		
3	0	3		
4	0	3		
5	0	0		

CI, confidence interval; LTCI, long term care insurance; RR, relative risk.

Table 4
Frailty Checklist Scores in Each Group at Baseline and After Intervention

	Baseline		After Intervention		Group × Time Interaction	
	n (%)	P Value	n (%)	P Value	F Value	P Value
Motor ability domain score						
Exercise (n = 305)	181 (59.5)	.414	177 (58.0)	.087		
Control (n = 305)	185 (60.7)		158 (51.7)			
Nutrition domain score						
Exercise (n = 305)	10 (3.4)	.348	11 (3.5)	.364		
Control (n = 305)	13 (4.3)		8 (2.6)			
Oral function domain score						
Exercise (n = 305)	114 (37.5)	.210	113 (37.0)	.073		
Control (n = 305)	104 (34.0)		94 (30.7)			
Forgetfulness domain score						
Exercise (n = 305)	139 (45.6)	.430	120 (39.3)	.037		
Control (n = 305)	142 (46.7)		145 (47.6)			
Seclusion domain score						
Exercise (n = 305)	66 (21.6)	.349	19 (6.2)	<.001		
Control (n = 305)	61 (20.0)		50 (16.5)			
Emotions domain score						
Exercise (n = 305)	144 (47.3)	.407	133 (43.6)	.008		
Control (n = 305)	140 (46.0)		167 (54.7)			
Lifestyle domain score						
Exercise (n = 305)	47 (15.5)	.517	36 (11.7)	.003		
Control (n = 305)	46 (15.1)		64 (21.0)			
Total score						
Exercise (n = 305)	7.41 ± 3.98		7.11 ± 4.00		12.84	<.001*
Control (n = 305)	7.34 ± 4.27		8.02 ± 4.81			

*Two-way analysis of variance adjusted for age and gender.

to a standardized format consisting of 20 minutes of moderate-intensity aerobic exercise, 30 minutes of progressive strength training, 20 minutes of flexibility and balance exercises, and 20 minutes of cool-down activities. The aerobic exercise was composed of global movement of the legs, trunk, and arms involving all joints and major muscle groups in activities such as dance. Strength training consisted of progressive resistive exercises using an elastic band. A sequence of progressively difficult exercises was also performed to improve static and dynamic balance. The control group received screening evaluation only.

Propensity Score Matching

We used propensity score matching to assemble a cohort of the exercise group, then the 2 groups would be well matched on all measured baseline characteristics, such as age, gender, body mass index, wishes to participate in the care prevention program, motor abilities, nutrition, oral function, forgetfulness, seclusion, and emotions. We estimated the scores of the exercise group for each subject using a multivariable logistic regression model. We were able to match 305 pairs of exercise and control subjects who had similar propensity scores.

Outcome Measures

Primary outcome was the new LTCI service requirement certification at 1 year after the conclusion of the intervention. Secondary outcomes were changes of frailty checklist, LTCI cost, and medical cost. The LTCI cost indicates use of home care services, nursing care, or day care services and nursing home. The utilization records of LTCI benefit services during 1 year were collected from the local governmental office. The medical cost covers almost all medical treatment, including diagnostic tests, medications, surgery, supplies and materials, physicians, and other personal cost.

Statistical Analysis

Baseline characteristics of the intervention and control groups were examined for comparability of the 2 groups. Differences in the demographic variables between the 2 groups were analyzed using the Student *t* test or chi-square test. Relative risk was then calculated, and the chi-square test was used to evaluate the effect of the care prevention program on the new LTCI service requirement and the influence on each domain of frailty checklist. Analysis of covariance was used to determine the effect of the care prevention program on total points of frailty checklist, using age as covariates. Post hoc Tukey tests were used to assess whether group or time periods showed significant differences. Multiple logistic regressions using a stepwise method was performed to investigate which of age, gender, or the decline in frailty checklist for each category was independently associated with the change of frailty checklist (improvement, maintenance, or deterioration). Finally, differences in the care and medical cost between the 2 groups were analyzed using the Student *t* test. Data were entered and analyzed using the Predictive Analytics Software (Windows version 18.0, SPSS, Inc., Chicago, IL). A *P* value less than .05 was considered statistically significant for all analyses.

Table 5
Change of Each Domain in Frailty Checklist After Exercise Intervention

Dependent Variables	Adjusted Odds Ratio (95% Confidence Interval)						
	Motor Abilities	Nutrition	Oral Functions	Forgetfulness	Seclusion	Emotions	Lifestyle
Change in checklist	2.29 (1.58–3.31)	5.32 (1.52–18.62)	—	1.77 (1.22–2.57)	—	—	—

1 = improvement, 0 = maintenance or deterioration.

Table 6
Comparison of Long Term Care Insurance and Medical Costs Between the 2 Groups

	Exercise Group, n = 305	Control Group, n = 305	P Value
	Mean ± SD	Mean ± SD	
Care costs*			
dollars	1126.8 ± 1797.9	4430.7 ± 6324.7	<.001
Medical costs			
dollars	2458.7 ± 1968.7	3458.0 ± 5847.1	<.001

One dollar = 88 yen.
*Exercise group: n = 25, control group: n = 55.

Results

Of the 610 individuals, all subjects completed the 1-year follow-up: 305 in the exercise group, and the others in the control group (Figure 2). All 16 scheduled intervention sessions were completed. The median relative adherence was 100% (25th–75th percentile, 88%–100%) in the exercise group. No fall incidents or health problems, such as cardiovascular or musculoskeletal complications, occurred during training sessions or testing. Minor problems were muscle ache and fatigue. All problems were managed easily using adjustment of the intervention, and they improved during the intervention. Subjects in the exercise and control groups were comparable and well matched with regard to their baseline characteristics (Table 2).

During 1 year after the intervention, 25 subjects (8.1%) in the exercise group and 55 (18.0%) in the control group were newly certified for the LTCI service requirement. Therefore, the relative risk for new LTCI service requirement in the control group compared with the exercise group was 2.16 (95% confidence interval [CI] = 1.46–3.20) (Table 3).

At baseline, all domains of the frailty checklist were not significantly different between the 2 groups (Table 3). Subjects in the exercise group had significant improvements in total scores of the frailty checklist compared with the control group that worsened after 1 year (exercise group: from 7.41 ± 3.98 to 7.11 ± 4.00, control group: from 7.34 ± 4.27 to 8.02 ± 4.81, $F = 12.84$, $P < .001$) (Table 4) as well as in forgetfulness, seclusion, emotion, and daily life domains ($P < .05$); however, the other domains were not significantly different between them ($P > 0.05$).

Stepwise logistic regression analysis revealed that motor ability domain (OR = 2.29, 95% CI 1.58–3.31), nutrition domain (OR = 5.32, 95% CI 1.52–18.62), and forgetfulness domain (OR = 1.77, 95% CI 1.22–2.57) were significant and independent determinants of the change in frailty checklist ($P < .001$) (Table 5).

Finally, we calculated the cost-effectiveness of this intervention, and found that subjects in the exercise group spent significantly lower care cost than the control group (exercise group: $1126.8 ± 1797.9, control group: $4430.7 ± 6324.7, $P < .001$) (Table 5), whereas subjects in the exercise group spent significantly less on medical costs than the control group (exercise group: $2458.7 ± 1968.7, control group: $3458.0 ± 5847.1, $P < .001$) (Table 6).

Discussion

In this study, we addressed the role of the physical exercise program for frail older adults, and have shown that the subjects who received physical exercise sessions demonstrated a lower incidence of new LTCI service requirement, improved frailty checklist, and reduced care and medical costs.

The current results indicated that the care prevention program had a beneficial effect on frailty in older adults. Specifically, the physical exercise program showed more beneficial effects on older adults with impaired motor ability, malnutrition, and forgetfulness. Previous studies also confirmed the benefits of physical exercise training on frail older adults.[6,7] In addition, a systematic review by Daniels and colleagues[2] suggested that multicomponent exercise programs have a positive effect on ADL and instrumental ADL disability for community-living moderate physically frail older adults. These reports and our findings suggested that the physical exercise program is effective in preventing frailty.

Moreover, our results indicated that the care prevention program could reduce health care costs. Owing to the positive effect on cognition, seclusion, depression, and instrumental ADLs, the program might also be associated with fewer medical costs. In addition, intervention by the prevention program showed a lower incidence of new LTCI service requirement certification, resulting in lower care costs. On the other hand, Frick and colleagues[8] reported that the physical exercise program was not cost-effective by evaluating the cost-effectiveness of fall-prevention programs for fall-related hip fractures in older adults. These results suggest that all the physical exercise programs are not always cost-effective. Further study is required to determine how to perform cost-effective interventions in frail older adults.

There were several limitations of this study that warrant mention. First, we did not measure physical performance, and used only the frailty checklist to define frailty. There is a possibility that the frailty checklist may not be the best instrument to define frailty, such as the Short Physical Performance Battery that evaluates balance, gait, strength, and endurance by examining an individual's ability.[9] Second, our study design was not a randomized controlled trial. Therefore, these findings should be interpreted with caution.

This is the first study to demonstrate that the care prevention program is effective to improve the scores of the frailty checklist. In addition, subjects who received the care prevention program demonstrated a lower incidence of new certification of LTCI service requirement with a lower cost during the follow-up period. These results implicated the importance of care prevention programs to reduce care and disabilities in older adults. A larger study is needed to confirm the present results and to evaluate the most effective exercises for the prevention of disability in older adults.

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References

1. Wiswell RA, Hawkins SA, Jaque SV, et al. Relationship between physiological loss, performance decrement, and age in master athletes. J Gerontol A Biol Sci Med Sci 2001;56:M618–M626.
2. Daniels R, van Rossum E, de Witte L, et al. Interventions to prevent disability in frail community-dwelling elderly: A systematic review. BMC Health Serv Res 2008;30:278.
3. Campbell JC, Ikegami N. Long term care insurance comes to Japan. Health Aff (Millwood) 2000;19:26–39.
4. Tsutsui T, Muramatsu N. Care-needs certification in the long-term care insurance system of Japan. J Am Geriatr Soc 2005;53:522–527.
5. Tsutsui T, Muramatsu N. Japan's universal long-term care system reform of 2005: Containing costs and realizing a vision. J Am Geriatr Soc 2007;55:1458–1463.
6. Faber MJ, Bosscher RJ, Chin A, et al. Effects of exercise programs on falls and mobility in frail and pre-frail older adults: A multicenter randomized controlled trial. Arch Phys Med Rehabil 2006;87:885–896.
7. Ferrucci L, Guralnik JM, Studenski S, et al, Interventions on Frailty Working Group. Designing randomized, controlled trials aimed at preventing or delaying functional decline and disability in frail, older persons: A consensus report. J Am Geriatr Soc 2004;52:625–634.
8. Frick KD, Kung JY, Parrish JM, Narrett MJ. Evaluating the cost-effectiveness of fall prevention programs that reduce fall-related hip fractures in older adults. J Am Geriatr Soc 2010;58:136–141.
9. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85–M94.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Faster decline of physical performance in older adults with higher levels of baseline locomotive function

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Aim: The purpose of this longitudinal study was to determine whether the rate of decline in community-dwelling older adults varies according to baseline locomotive function levels.

Methods: This longitudinal study was conducted in community-dwelling older adults in Kyoto, Japan. In addition to information about falls, physical performance was assessed using a series of tests, including 10-m walking time, timed up and go (TUG) test, functional reach, one-leg stand test, and five chair stand test. The outcomes for each patient were measured once in 2009 and then followed up 1 year later. The change in physical performance was then determined. We divided the participants into tertiles (T1, T2, and T3) according to timed up and go test results, and the differences among the three groups were compared.

Results: Of the 252 individuals who were enrolled in the study, 231 (91.6%) completed the 12-month follow-up: 77 in the T1 group; 78 in the T2 group; and 76 in the T3 group. The T1 group showed a significantly larger decrease than the T2 and T3 groups in the 10-m walking time and TUG tests ($P < 0.05$). However, there were no significant differences in functional reach, one-leg standing test, or five chair stand test among the three groups. In the T1 group, the number of falls and elderly who had developed fear of falling increased during the study period.

Conclusions: This study demonstrated that elderly with the highest baseline performances were more likely to show a greater decline in locomotive performance than the other groups. Further study is required to elucidate the mechanism of faster physical functional decline in robust elderly. **Geriatr Gerontol Int 2012; 12: 238–246.**

Keywords: level of frailty, locomotive function, longitudinal study, robust elderly.

Introduction

Maintenance of physical performance in later life is an important component of healthy aging.[1] Walking speed has been identified as one of the most influential physical performances associated with deterioration in activity of daily living among older adults.[2] The timed up and go test (TUG) is a simple tool developed to screen basal mobility performance, which has been shown to be significantly associated with activity of daily living in frail older adults.[3] Thus, evaluating walking speed and TUG is important for predicting the risk of functional decline.

Several cross-sectional studies have shown that a gradual decline in physical performance is significantly

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associated with age.[4,5] Several longitudinal studies have also found a time-dependent decline in the physical performance of community-dwelling older adults.[6,7] However, few studies have addressed the factors involved in longitudinal change in physical performance. Therefore, we conducted several studies to demonstrate that the differential factors are related to daily activities and depend on community-dwelling older adults' level of frailty.[8] Our data suggests that a resistance training program is effective for improving physical performance in frail elderly, but not in non-frail elderly,[9] indicating a difference in the effect of physical training on elderly persons with varying levels of physical fitness. Therefore, it is important to examine longitudinal changes in the physical performance of elderly persons with varying levels of physical fitness.

The purpose of this longitudinal study was to determine whether the rate of decline in older adults differs according to baseline locomotive function levels.

Methods

Participants

Study participants were recruited through ads in the local press requesting healthy community-dwelling volunteers. A total of 252 Japanese participants, 65 years and older living in Kyoto city, were included in the baseline survey in October 2009. One year later in October 2010, the second survey was conducted. We screened 332 people, and 252 who agreed to participate were enrolled. Of the 252 individuals, 231 (91.7%) completed the 12-month follow-up (Fig. 1).

The screening process was used to exclude participants based on the following criteria: severe cardiac, pulmonary, or musculoskeletal disorders; comorbidities associated with an increased risk of falling such as Parkinson's disease and stroke; and use of psychotropic drugs. Written informed consent was obtained from each participant for the trial in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Helsinki, 1996.

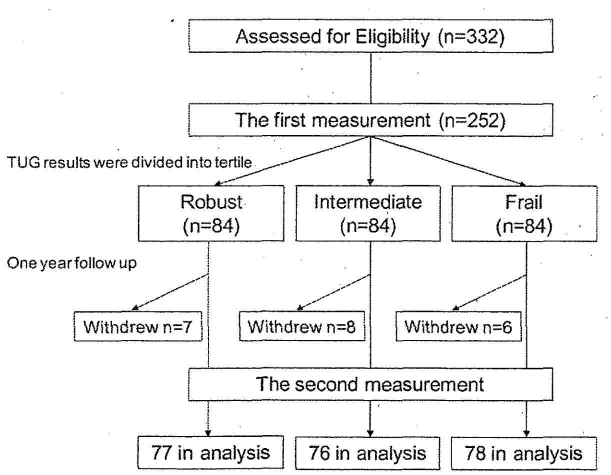

Figure 1 A flow chart showing the distribution of participants.

Outcome measures

All participants underwent five tests for measurements: 10-m walking time,[10] TUG test,[3] functional reach (FR),[11] one-leg standing (OLS) test,[12] and five chair stand (5CS) test.[13] Outcome measures were conducted in October 2009 and October 2010. No exercise program was prescribed to participants during the interim period. Before the study started, all researchers were trained by one of the authors (MY) on correct protocols for administering the assessment measures. If a participant normally used a walking aid, this aid was used during the 10-m walking time and TUG tests.

In the 10-m walking time test, participants walked 15 m at a comfortable pace, as determined by the individual. A stopwatch was used to record the time required to reach the 10-m point that was marked in the middle of the path. The test-retest reliability using the intertrial correlation coefficient (ICC; 1.1) was 0.943. The better performance of the two trials was used as the walking time score in the analysis. In the TUG test, participants were asked to stand up from a standard chair with a seat height of 40 cm, walk a distance of 3 m at a maximum pace, turn, walk back to the chair, and sit down. The test-retest reliability using the ICC (1.1) was 0.929. The TUG score was defined as the better performance of the two trials. In the FR test, each participant was positioned next to a wall with one arm raised at 90° and fingers extended. A meterstick was mounted on the wall at shoulder height. The distance that a participant could reach while extending forward from an initial upright posture to the maximal anterior leaning posture, without moving or lifting the feet, was measured in centimeters according to the position of the tip of the third finger against the mounted meterstick. The distances measured in the two trials were averaged to obtain the FR score. The test-retest reliability using the ICC (1.1) was 0.915. In the OLS test, participants were instructed to start from a standing position with a comfortable base as support with their eyes open and arms at their sides. They were then instructed to stand unassisted on either leg. OLS was measured in seconds from the time one foot was lifted from the floor to when it touched the ground or the standing leg. The test-retest reliability using the ICC (1.1) was 0.905. The participants stopped the OLS if the time exceeded 60 s. In 5CS, participants were asked to stand up and sit down five times as quickly as possible. They were timed from the initial sitting position to the final standing position

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at the end of the fifth stand. The test-retest reliability using the ICC (1.1) was 0.954. The 5CS score was defined as the better performance of the two trials. The percent change for physical performance was calculated as follows:

Percent change (%) = 100 × (2010 measurement − 2009 measurement)/2009 measurement

Falls and the fear of falling

Participants were interviewed about falling during the past year and their fear of falling in 2009 and 2010. Falls were defined as all situations in which a participant suddenly and involuntarily came to rest upon the ground or a surface lower than their original station.[14] Falls resulting from extraordinary environmental factors (e.g. traffic accidents or falls while riding a bicycle) were excluded.

We assessed participants' fear of falling by asking a single yes-or-no question with a high test-retest reliability, "Are you afraid of falling?"[15] This question was asked during the interviews in 2009 and 2010. The test-retest reliability using the kappa coefficient was 0.960.

Statistical analysis

We divided the participants into tertiles (T1, T2, and T3) according to TUG test results. TUG was chosen for several reasons. First, it is a simple measure of physical function that involves lower extremity strength, dynamic balance, gait, and agility. Second, TUG has been shown to identify physical function limitations in geriatric patients in a clinical setting.[16,17]

We analyzed the outcome measurements using a two-way ANOVA. Tukey tests were used for post-hoc analysis. Differences in the physical variables between elderly who had or had not fallen and between those with or without a fear of falling were analyzed by two-way ANOVA. Data were analyzed using SPSS v. 18.0 for Windows (Chicago, IL, USA). A P-value of <0.05 was considered statistically significant for all analyses.

Results

Of the 252 individuals, 231 (91.7%) completed the 12-month follow-up: 77 in T1 group (91.7%), 78 in T2 group (92.9%) and 76 in T3 group (90.5%) (Fig. 1). There were no significant differences in all performance measurements and age between men and women.

Baseline characteristics

There were significant differences in age (T1, 73.9 ± 6.6; T2, 79.1 ± 7.0; T3, 82.0 ± 6.9; F = 25.2, $P < 0.001$), walking time (T1, 7.4 ± 1.4 sec; T2, 9.7 ± 2.8 sec; T3, 12.7 ± 2.6 sec; $P < 0.05$), TUG (T1, 6.9 ± 0.9 sec; T2, 9.2 ± 0.9 sec; T3, 12.7 ± 1.3 sec; $P < 0.05$), FR (T1, 29.0 ± 7.0 cm; T2, 26.5 ± 6.7 cm; T3 21.3 ± 7.1 cm; $P < 0.05$), OLS (T1, 19.5 ± 13.6 sec; T2, 10.0 ± 10.7 sec; T3, 5.4 ± 5.5 sec; $P < 0.05$), and 5CS (T1, 8.5 ± 2.4 sec; T2, 10.4 ± 2.1 sec; T3, 13.5 ± 3.8 sec; F = 28.0, $P < 0.001$). There were no significant differences in height or weight (Table 1).

Follow-up measures

There were significant differences in walking time (T1, 8.0 ± 1.9 sec; T2, 9.3 ± 2.0 sec; T3, 12.3 ± 2.7 sec; $P < 0.001$), TUG (T1, 7.5 ± 1.5 sec; T2, 9.3 ± 1.8 sec; T3, 13.0 ± 3.2 sec; $P < 0.001$), FR (T1, 30.2 ± 8.8 cm; T2, 27.6 ± 8.4 cm; T3, 21.0 ± 6.5 cm; $P < 0.001$), OLS (T1, 19.0 ± 12.8 sec; T2, 8.7 ± 9.4 sec; T3, 4.3 ± 3.8 sec; $P < 0.001$), and 5CS (T1, 7.4 ± 2.0 sec; T2, 9.5 ± 3.2 sec; T3, 13.6 ± 5.5 sec; $P < 0.001$) (Table 1, Fig. 2).

Group-time interactions are summarized in Table 1. A statistically significant group-time interaction was observed for walking time and TUG ($P < 0.05$).

Falls and fear of falling

In the T1 group, the number of falls and elderly who had developed a fear of falling increased between baseline and follow-up (falls, 19.5% to 27.2%; fear of falling, 13.0% to 26.0%). There were no significant differences in FR, OLS, or 5CS. In T2 and T3 groups, the number of falls and elderly who had developed fear of falling did not change between baseline and follow-up (Table 1).

Characteristics of elderly with or without falls

Group-time interactions are summarized in Tables 2, 3, and 4. In T1 group, a statistically significant group-time interaction was observed for TUG and 5CS ($P < 0.05$). However, we did not find any significant differences in T2 and T3 groups (Tables 2, 3 and 4).

Characteristics of elderly with or without fear of falling

Group-time interactions are summarized in Tables 2, 3, and 4. In T1 group, a statistically significant group-time interaction was observed for TUG ($P < 0.05$) (Table 2). In T2 group, a statistically significant group- time interaction was observed for TUG and 5CS ($P < 0.05$) (Table 3). In T3 group, there were no significant differences (Table 4).

Discussion

In the current study, we have shown that elderly with the highest baseline performances are more likely to show a decline in locomotive performance than the

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Table 1 Comparison of outcome measurements among the three groups

	T1 (≤8.2) (*n* = 77)	T2 (8.3–10.9) (*n* = 76)	T3 (≥11.0) (*n* = 78)	F-value	*P*-value	*Post-hoc*
Age	73.9 ± 6.6	79.1 ± 7.0	82.0 ± 6.9	25.2	<0.001	†‡§
Height (cm)	157.1 ± 9.0	155.0 ± 8.1	155.8 ± 10.9	0.5	0.620	–
Weight (kg)	57.7 ± 9.8	56.5 ± 8.3	54.5 ± 10.1	0.7	0.492	–
Gender, female	57 (74.0)	60 (78.9)	60 (76.9)			–
Falls, *n* (%)						
2009	15 (19.5)	20 (26.3)	26 (33.3)			
2010	21 (27.2)	22 (28.9)	28 (35.9)			
Fear of falling, *n* (%)						
2009	10 (13.0)	29 (38.2)	36 (46.2)			
2010	20 (26.0)	30 (39.5)	37 (47.4)			
Walking time (sec)						
2009	7.4 ± 1.4	9.7 ± 2.8	12.7 ± 2.6	9.227	<0.001	†‡§
2010	8.0 ± 1.9	9.3 ± 2.0	12.3 ± 2.7			†‡§
Change (%)	5.3 ± 17.6	–5.1 ± 25.2	–3.4 ± 20.1			†‡
Timed up and go (sec)						
2009	6.9 ± 0.9	9.2 ± 0.9	12.7 ± 1.3	3.361	0.037	†‡§
2010	7.5 ± 1.5	9.3 ± 1.8	13.0 ± 3.2			†‡§
Change (%)	5.8 ± 14.1	2.4 ± 16.2	2.6 ± 22.6			†‡
Functional reach (cm)						
2009	29.0 ± 7.0	26.5 ± 6.7	21.3 ± 7.1	1.254	0.291	
2010	30.2 ± 8.8	27.6 ± 8.4	21.0 ± 6.5			
Change (%)	5.5 ± 28.0	5.8 ± 28.1	–3.3 ± 37.9			
One-leg standing (sec)						
2009	19.5 ± 13.6	10.0 ± 10.7	5.4 ± 5.5	0.906	0.439	
2010	19.0 ± 12.8	8.7 ± 9.4	4.3 ± 3.8			
Change (%)	–5.3 ± 41.4	–2.9 ± 31.2	–6.7 ± 32.8			
Five chair stand (sec)						
2009	8.5 ± 2.4	10.4 ± 2.1	13.5 ± 3.8	0.217	0.885	
2010	7.4 ± 2.0	9.5 ± 3.2	13.6 ± 5.5			
Change (%)	–10.0 ± 24.5	–6.4 ± 33.3	1.0 ± 31.7			

†T1 *versus* T2. ‡T1 *versus* T3. §T2 *versus* T3.

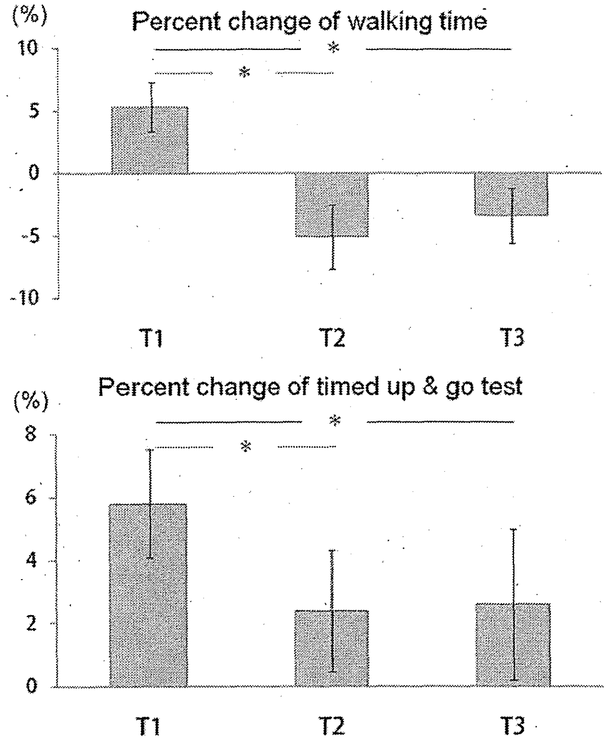

Figure 2 Percent change in the walking time and timed up and go tests among the three groups. The means ± SEM in T1, T2, and T3 groups are shown. $*P < 0.05$.

others. These results are quite unexpected. However, Koster *et al.* compared the leg strength of octogenarians and septuagenarians, and found more rapid decline in leg strength in septuagenarians.[18] Moreover, it has been reported that active community-dwelling elderly men and women respectively lose 0.8% and 0.7% of lean leg mass per year on average.[18] These characteristics of the aging process might account for why the T1 group showed a greater decrease in locomotive functions. Yet, it is possible that a floor effect may account for this longitudinal maintenance of physical performance in the T2 and T3 groups. Previous cross-sectional studies have shown an age-dependent gradual decline in locomotive function,[4,5] while longitudinal studies have shown a time-dependent decline in locomotive function in community-dwelling older adults.[6,7] The subjects of these studies were community-dwelling older adults with a relatively high level of performance, presumably equivalent to our study's T1 or T2 groups. However, participants in our study had a wider range of physical performance levels. For example, the reference values for TUG were 8.1 s for persons aged 60 to 69 years old, 9.2 s for persons aged70 to 79 years, and 11.3 s for persons aged 80 to 99 years.[19] The reference values for the T1 group was 6.9 s, 9.2 s for the T2 group, and 12.7 s for the T3 group. Thus, the level of physical performance may have affected our results.

The T1 group showed a significantly larger decrease in 10-m walking time and TUG than the other groups. An earlier longitudinal study indicated that the age-related decline was accelerated in lower extremity performance.[7] Walking speed, in particular, is a good predictor for the onset of functional dependence in a Japanese community population.[2] In the same manner, TUG has been shown to be significantly associated with activities of daily living function in frail older adults.[3] Thus, physical training, such as resistance training, maintains level of activity of daily living in healthy elderly is very important.

The T1 group showed an increase in falls (19.5% to 27.2%) and fear of falling (13.0% to 26.0%) in 2010. In general, at least one-third of people aged 65 and older fall at least once annually.[20,21] In addition, the major risk factor for fear of falling is shown to be history of at least one fall.[22] In the T1 group, elderly with a fear of falling were more likely to show a decline in locomotive performance than elderly without a fear of falling. Several studies have indicated that people who are afraid of falling appear to enter a debilitating spiral of loss of confidence, restricted physical activities, physical frailty, lack of social participation, falls, and loss of independence.[23–28] Therefore, it is possible that the increased fear of falling is associated with decreased locomotive function in T1 group.

There were several limitations of this study that warrant mention. First, although we used TUG to define frailty, TUG may not be sufficient to define frailty. The Edmonton Frail Scale adopts eight other domains such as cognition, general health status, functional independence, social support, medication use, nutrition, mood, and continence other than TUG.[29] Further study is required to test the levels of these domains in this cohort. Second, the standard deviations for the percent change values are quite large, which shows major individual differences. These factors may have affected the current results. Third, the results of men and women were combined in this research because of the relatively small sample size. A larger sample size is required to analyze in each gender. Finally, participants were probably more motivated and showed greater interest in health than the general population of older adults.

This was a longitudinal study to demonstrate that the participants with the highest baseline levels of performance were more likely to show a greater decline in locomotive performance than the other groups. Further study is needed to explore the mechanism of a faster decline in physical performance in the robust elderly. Future work should also be done to determine whether the effects of a training program on physical performance differ according to the level of physical well-being.

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Table 2 Characteristics of elderly who have or have not fallen and with or without a fear of falling in T1 group

	Falls (2010)				Fear of falling (2010)			
	Falls (2010) ($n = 21$)	No falls ($n = 56$)	F-value	*P*-value	Fear ($n = 20$)	No fear ($n = 57$)	F-value	*P*-value
Age	76.0 ± 6.6	73.1 ± 6.5		0.08†	74.1 ± 7.5	73.9 ± 6.3		0.90†
Height (cm)	155.5 ± 9.7	157.6 ± 8.8		0.49†	158.7 ± 9.7	156.1 ± 8.5		0.34†
Weight (kg)	61.0 ± 14.1	56.2 ± 7.2		0.26†	62.0 ± 10.5	55.0 ± 8.6		0.08†
Gender, female	15 (71.4%)	42 (75.0%)		0.48‡	13 (65.0%)	44 (77.2%)		0.22‡
Walking time (sec)								
2009	7.3 ± 1.5	7.4 ± 7.5	0.03	0.88	7.6 ± 1.6	7.4 ± 1.6	0.11	0.74
2010	8.4 ± 2.5	7.8 ± 1.2			8.9 ± 1.9	7.6 ± 1.8		
Change (%)	8.9 ± 18.6	3.8 ± 15.9			12.3 ± 17.5	2.4 ± 15.4		
Timed up and go (sec)								
2009	7.0 ± 0.9	6.8 ± 0.7	4.34	0.04	7.0 ± 1.1	6.9 ± 0.8	23.22	0.00
2010	7.9 ± 1.6	7.3 ± 1.2§			8.2 ± 1.1	7.1 ± 0.9§		
Change (%)	8.8 ± 15.1	4.6 ± 13.2			12.4 ± 16.9	3.5 ± 11.8		
Functional reach (cm)								
2009	27.7 ± 6.9	29.5 ± 7.0	0.80	0.37	27.9 ± 6.1	29.4 ± 7.3	0.65	0.42
2010	26.7 ± 7.6	30.5 ± 8.9			28.0 ± 7.4	31.0 ± 9.2		
Change (%)	−1.2 ± 24.5	8.2 ± 29.1			4.7 ± 32.8	5.8 ± 26.2		
One-leg standing (sec)								
2009	23.6 ± 32.4	20.5 ± 14.0	0.21	0.65	23.8 ± 14.1	20.7 ± 24.4	0.35	0.56
2010	15.0 ± 11.7	21.0 ± 12.9			22.7 ± 14.9	17.8 ± 11.7		
Change (%)	−11.2 ± −47.2	2.8 ± 39.3			−14.3 ± 27.9	−1.4 ± 46.1		
Five chair stand (sec)								
2009	8.2 ± 2.5	8.6 ± 2.3	6.33	0.02	8.6 ± 2.2	8.5 ± 2.5	0.44	0.51
2010	8.0 ± 2.4	7.1 ± 1.8§			7.5 ± 2.2	7.3 ± 1.9		
Change (%)	−6.1 ± −25.4	14.1 ± 16.4			−10.6 ± 22.1	−13.1 ± 17.2		

†Student's *t*-test. ‡χ^2 test. §As calculated by group comparison.

Table 3 Characteristics of elderly who have or have not fallen and with or without fear of falling in T2 group

	Falls (2010)				Fear of falling (2010)			
	Falls (2010) ($n = 22$)	No falls ($n = 54$)	F-value	P-value	Fear ($n = 30$)	No fear ($n = 46$)	F-value	*P*-value
Age	79.9 ± 6.6	78.8 ± 7.2		0.57†	79.5 ± 7.9	78.9 ± 6.5		0.72†
Height (cm)	155.0 ± 8.9	155.0 ± 8.0		0.99†	154.6 ± 7.1	155.2 ± 8.9		0.83†
Weight (kg)	58.0 ± 8.5	56.0 ± 8.4		0.62†	57.9 ± 6.8	55.7 ± 9.2		0.54†
Gender, female	17 (77.3%)	43 (79.6%)		0.52‡	22 (73.3%)	38 (82.6%)		0.25‡
Walking time (sec)								
2009	10.3 ± 1.8	9.5 ± 3.0	0.09	0.76	10.1 ± 2.0	9.6 ± 3.1	0.10	0.75
2010	9.8 ± 1.7	9.2 ± 1.9			10.0 ± 2.0	9.0 ± 1.6		
Change (%)	−6.4 ± 0.1	−4.5 ± 0.3			−1.8 ± 15.0	−7.2 ± 30.0		
Timed up and go (sec)								
2009	9.4 ± 0.7	9.3 ± 0.7	2.70	0.11	9.5 ± 0.7	9.3 ± 0.7	4.31	0.05
2010	9.9 ± 1.5	9.2 ± 1.9			10.1 ± 1.9	8.9 ± 1.6§		
Change (%)	3.1 ± 0.1	−4.8 ± 0.2			4.3 ± 14.2	−7.3 ± 16.7		
Functional reach (cm)								
2009	25.4 ± 6.4	26.9 ± 6.8	0.43	0.52	24.2 ± 5.7	28.0 ± 6.9	0.36	0.56
2010	24.2 ± 6.2	27.9 ± 8.9			24.7 ± 6.9	29.4 ± 8.9		
Change (%)	−4.9 ± 0.3	6.3 ± 0.3			6.3 ± 29.9	5.5 ± 27.1		
One-leg standing (sec)								
2009	7.7 ± 9.1	11.1 ± 14.4	0.00	0.99	11.1 ± 17.4	9.5 ± 9.7	0.01	0.93
2010	6.3 ± 4.9	10.1 ± 11.1			5.8 ± 5.3	11.0 ± 11.4		
Change (%)	−1.4 ± 0.4	−0.1 ± 0.3			−13.8 ± 30.8	7.7 ± 35.1		
Five chair stand (sec)								
2009	10.6 ± 3.1	10.3 ± 1.5	0.01	0.93	10.7 ± 1.5	10.2 ± 2.4	5.84	0.02
2010	10.4 ± 4.2	9.2 ± 2.8			11.3 ± 3.0	8.2 ± 2.7§		
Change (%)	−8.9 ± 0.1	−12.4 ± 0.2			2.6 ± 17.7	−22.0 ± 16.8		

†Student's *t*-test. ‡χ^2 test. §As calculated by group comparison.

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Table 4 Characteristics of elderly who have or have not fallen and with or without fear of falling in T3 group

	Falls (2010)				Fear of falling (2010)			
	Falls (2010) ($n = 28$)	No falls ($n = 50$)	F-value	P-value	Fear ($n = 37$)	No fear ($n = 41$)	F-value	P-value
Age	82.0 ± 6.4	82.0 ± 7.3		0.99†	83.9 ± 7.6	80.1 ± 6.8		0.02†
Height (cm)	155.6 ± 9.8	155.9 ± 11.5		0.94†	153.2 ± 10.8	161.5 ± 8.0		0.07†
Weight (kg)	49.2 ± 5.4	56.3 ± 10.8		0.14†	52.0 ± 11.6	59.5 ± 8.4		0.09†
Gender, female	20 (71.4%)	40 (80.0%)		0.17‡	28 (75.7%)	32 (78.0%)		0.35‡
Walking time (sec)								
2009	11.87 ± 2.01	12.99 ± 2.94	3.53	0.07	12.6 ± 2.7	12.6 ± 2.7	0.14	0.71
2010	12.47 ± 2.89	12.27 ± 2.54			12.3 ± 2.2	12.4 ± 3.1		
Change (%)	2.91 ± 14.69	−7.09 ± 21.47			−3.6 ± 22.4	−3.4 ± 17.2		
Timed up and go (sec)								
2009	12.92 ± 1.08	12.73 ± 1.21	0.52	0.47	12.9 ± 1.2	12.7 ± 1.1	0.36	0.55
2010	12.91 ± 2.58	13.28 ± 4.03			13.3 ± 3.5	13.0 ± 3.7		
Change (%)	−3.17 ± 17.78	2.40 ± 26.53			2.0 ± 23.7	3.4 ± 23.8		
Functional reach (cm)								
2009	22.42 ± 7.11	20.69 ± 7.06	0.37	0.55	22.4 ± 7.5	20.3 ± 6.6	0.01	0.92
2010	22.92 ± 5.56	20.11 ± 6.72			21.6 ± 5.9	20.3 ± 7.0		
Change (%)	5.68 ± 25.46	−2.01 ± 43.44			−5.1 ± 37.1	1.4 ± 39.3		
One-leg standing, sec								
2009	4.47 ± 3.28	5.29 ± 5.80	0.16	0.69	4.7 ± 4.0	5.3 ± 6.0	0.49	0.49
2010	3.67 ± 2.92	4.29 ± 4.08			3.6 ± 3.2	4.6 ± 4.2		
Change (%)	−8.63 ± 38.58	−0.62 ± 45.06			−2.7 ± 41.0	−1.4 ± 45.9		
Five chair stand (sec)								
2009	14.89 ± 3.39	12.90 ± 3.94	0.41	0.53	13.1 ± 3.4	14.3 ± 4.6	1.79	0.19
2010	15.72 ± 6.70	12.57 ± 4.67			14.1 ± 6.3	12.7 ± 3.8		
Change (%)	3.44 ± 24.64	−4.73 ± 30.54			1.6 ± 30.8	−8.0 ± 24.5		

†Student's t-test. ‡χ^2 test.

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References

1 Guralnik JM, Ferrucci L, Pieper CF *et al.* Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *J Gerontol A Biol Sci Med Sci* 2000; **55**: M221–M231.
2 Shinkai S, Watanabe S, Kumagai S *et al.* Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. *Age Ageing* 2000; **29**: 441–446.
3 Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991; **39**: 142–148.
4 Isles RC, Choy NL, Steer M, Nitz JC. Normal values of balance tests in women aged 20–80. *J Am Geriatr Soc* 2004; **52**: 1367–1372.
5 Bohannon RW. Comfortable and maximum walking speed of adults aged 20–79 years: reference values and determinants. *Age Ageing* 1997; **26**: 15–19.
6 Onder G, Penninx BW, Lapuerta P *et al.* Change in physical performance over time in older women: the Women's Health and Aging Study. *J Gerontol A Biol Sci Med Sci* 2002; **57**: M289–M293.
7 Furuna T, Nagasaki H, Nishizawa S *et al.* Longitudinal change in the physical performance of older adults in the community. *J Jpn Phy Ther Assoc* 1998; **1**: 1–5.
8 Yamada M, Arai H, Nagai K, Uemura K, Mori S, Aoyama T. Differential determinants of physical daily activities in frail and non-frail community-dwelling older adults. *J Clin Gerontol Geriatr* 2011; **2**: 42–46.
9 Yamada M, Arai H, Uemura K *et al.* Effect of resistance training on physical performance and fear of falling in elderly with different levels of physical well-being. *Age Ageing* 2011; **40**: 637–641.
10 Lopopolo RB, Greco M, Sullivan D, Craik RL, Mangione KK. Effect of therapeutic exercise on gait speed in community-dwelling elderly people: a meta-analysis. *Phys Ther* 2006; **86**: 520–540.
11 Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. *J Gerontol* 1990; **45**: M192–M197.
12 Vellas BJ, Wayne SJ, Romero L, Baumgartner RN, Rubenstein LZ, Garry PJ. One-leg balance is an important predictor of injurious falls in older persons. *J Am Geriatr Soc* 1997; **45**: 735–738.
13 Guralnik JM, Simonsick EM, Ferrucci L *et al.* A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994; **49**: M85–M94.
14 Koski K, Luukinen H, Laippala P, Kivela SL. Physiological factors and medications as predictors of injurious falls by elderly people: a prospective population-based study. *Age Ageing* 1996; **25**: 29–38.
15 Reelick MF, van Iersel MB, Kessels RP, Rikkert MG. The influence of fear of falling on gait and balance in older people. *Age Ageing* 2009; **38**: 435–440.
16 Miller ME, Rejeski WJ, Reboussin BA, Ten Have TR, Ettinger WH. Physical activity, functional limitations, and disability in older adults. *J Am Geriatr Soc* 2000; **48**: 1264–1272.
17 Stuck AE, Walthert JM, Nikolaus T, Büla CJ, Hohmann C, Beck JC. Risk factors for functional status decline in community-living elderly people: a systematic literature review. *Soc Sci Med* 1999; **48**: 445–469.
18 Koster A, Ding J, Stenholm S *et al.*; for the Health ABC study. Does the amount of fat mass predict age-related loss of lean mass, muscle strength, and muscle quality in older adults? *J Gerontol A Biol Sci Med Sci* 2011; **66A**: 888–895.
19 Bohannon RW. Reference values for the timed up and go test: a descriptive meta-analysis. *J Geriatr Phys Ther* 2006; **29**: 64–68.
20 Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988; **319**: 1701–1707.
21 Lord SR, Ward JA, Williams P, Anstey KJ. An epidemiological study of falls in older community-dwelling women: the Randwick Falls and Fractures Study. *Aust J Public Health* 1993; **17**: 240–245.
22 Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooji SE. Fear of falling: measurement strategy, prevalence, risk factors and consequences among older persons. *Age Ageing* 2008; **37**: 19–24.
23 Friedman SM, Munoz B, West SK, Rubin GS, Fried LP. Falls and fear of falling: which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. *J Am Geriatr Soc* 2002; **50**: 1329–1335.
24 Lachman ME, Howland J, Tennstedt S, Jette A, Assman S, Peterson EW. Fear of falling and activity restriction: the survey of activities and fear of falling in the elderly (SAFE). *J Gerontol B Psychol Sci Soc Sci* 1998; **53**: P43–P50.
25 Arfken CL, Lach HW, Birge SJ, Miller JP. The prevalence and correlates of fear of falling in elderly persons living in the community. *Am J Public Health* 1994; **84**: 565–570.
26 Howland J, Peterson EW, Levin WC, Fried L, Pordon D, Bak S. Fear of falling among the community-dwelling elderly. *J Aging Health* 1993; **5**: 229–243.
27 Cumming RG, Salkeld G, Thomas M, Szonyi G. Prospective study of the impact of fear of falling on activities of daily living, SF-36 scores, and nursing home admission. *J Gerontol A Biol Sci Med Sci* 2000; **55**: M299–M305.
28 Delbaere K, Crombez G, Vanderstraeten G, Willems T, Cambier D. Fear-related avoidance of activities, falls and physical frailty. A prospective community-based cohort study. *Age Ageing* 2004; **33**: 368–373.
29 Rolfson DB, Majumdar S, Tsuyuki RT, Tahir A, Rockwood K. Validity and reliability of the Edmonton Frail Scale. *Age Ageing* 2006; **35**: 526–529.

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NUTRITIONAL SUPPLEMENTATION DURING RESISTANCE TRAINING IMPROVED SKELETAL MUSCLE MASS IN COMMUNITY-DWELLING FRAIL OLDER ADULTS

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Abstract: *Objective:* Sarcopenia, the age-related loss of skeletal muscle mass, is highly prevalent in older adults. The aim of this study was to investigate the effects of the combination of resistance training and multinutrients supplementation (including vitamin D and protein) on muscle mass and physical performance in frail older adults. *Methods:* This trial was conducted in Japanese frail older adults (n=77), which underwent a standardized protocol of a 3-month physical exercise intervention. The sample population was divided into two groups, according to the adoption (S/Ex: n = 38) or not (Ex: n = 39) of the additional multinutrient supplementation. The outcome measures of interest for the present analyses were the skeletal muscle mass index (SMI) and several physical performance tests. *Results:* Participants in S/Ex group had significant improvements for the outcome measures, including SMI and maximum walking time (P<0.05), compared to those in Ex group. The prevalence of sarcopenia decreased from 65.7% to 42.9% in S/Ex group, while that in Ex group remained unchanged (68.6% to 68.6%) (relative risk = 1.60, 95% CI: 1.03-2.49). *Conclusion:* The results of this study suggest that the combination of resistance training and multinutritional supplementation may be more effective at improving muscle mass and walking speed than an intervention only based on resistance training.

Key words: Sarcopenia, vitamin D, protein, resistance training, muscle mass, older adults.

Introduction

Sarcopenia, the age-related loss of skeletal muscle mass, is highly prevalent in older adults (1). Multiple operational definitions have been proposed for this condition in literature. In the present study, we defined sarcopenia as coexistence of low muscle loss and slow walking speed according to consensus statement released by the Society of Sarcopenia, Cahexia and Wasting Disorders (SSCWD) (2). Sarcopenia is associated with the risk of falls and fractures, physical disability, mobility disorders, and mortality (3-5). The possible causes of sarcopenia are numerous and include increasing age, muscle disuse, endocrine dysfunction, neurodegenerative diseases, and malnutrition (6). In particular, given the strong relationship existing between nutritional status and skeletal muscle, it has been hypothesized that the combination of exercise and nutritional supplementation may be particularly important for adequately targeting sarcopenia (7).

In fact, resistance and/or aerobic exercise are important for the prevention and management of sarcopenia. A recent meta-analysis showed that the resistance training is effective at improving strength (8) and eliciting muscle mass gains in older adults (9). In a previous study, we demonstrated that leg muscle mass and physical performances are improved by a 1-year resistance training protocol in frail older adults (10). In addition, our 6-month pedometer-based walking program showed to effectively increase physical activity, improve physical performance, and augment leg muscle mass in sedentary older adults (11).

On the other hand, nutritional supplementation is similarly important to counteract the detrimental age-related effects on skeletal muscle. In particular, a proper protein intake is important at older age. Dietary protein intake is relevant for the maintenance of muscle mass and strength in community-dwelling older adults (12-13). Protein supplementation has been shown to enhance the muscle strengthening effect of resistance exercise (14-15). Similarly, amino-acids supplementation (crucial for protein synthesis (16)) has shown beneficial effects on muscle mass (17).

Recently, vitamin D has attracted a growing interest of researchers and clinicians in the field of geriatrics. The deficiency of such hormone is quite common in older adults. Several studies suggested that a low 25-hydroxyvitamin D (25(OH) D) concentration is associated with lower muscle strength, reduced physical performance, and increased disability (12, 18-19). Bischoff-Ferrari and colleagues showed that a high daily dose of supplemental vitamin D reduced the risk of falling; however, a low dose of supplemental vitamin D in older adults with vitamin D sufficiency may not reduce the fall risk (20).

The Society for Sarcopenia, Cahexia, and Wasting Disease recently recommended the combination of exercise with protein and/or vitamin D supplementation for reducing the age-related skeletal muscle decline (7). Evidence is still limited with only

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few trials having tested the effectiveness of nutritional supplementation in sarcopenia (21-23). The aim of the present study is to investigate the effects of the combination of resistance training with a multinutrient supplementation (including vitamin D and proteins) on muscle mass and physical performance in frail older adults with low muscle mass. We hypothesized that muscle mass and physical performance might better benefy from the combined intervention compared to when only resistance training is adopted.

Methods

Participants

Participants were recruited by an advertisement in the local press and public ads. We recruited 96 community-dwelling older adults from two communities with similar environment in Kyoto city. Participants of one community were allocated to a resistance training intervention (Ex); subjects from the other community received the same resistance training intervention and the additional nutritional supplementation (S/Ex).

The following inclusion criteria were verified during the initial interview:
- Frailty status as certified by the long-term care insurance service;
- Presence of low muscle mass (defined as appendicular muscle mass divided by squared height lower than 6.87 kg/m2 in men, and lower than 5.46 kg/m2 in women [24])
- Age of 65 years and older;
- Living in the community;
- No severe cognitive impairment (defined as a Rapid Dementia Screening Test score higher than 4) [25];
- Ability to independently walk (even with a cane);
- No regular supplementation of vitamin D and protein during the previous 12 months.

The exclusion criteria adopted in the present study were:
- Severe cardiac, pulmonary, or musculoskeletal disorders;
- Presence of comorbidities associated with an increased risk of falls, such as Parkinson's disease or stroke;
- Use of psychotropic drugs.

Written informed consent was obtained from each subject in accordance with the guidelines approved by the Kyoto University Graduate School of Medicine and the Declaration of Human Rights, Helsinki, 1975.

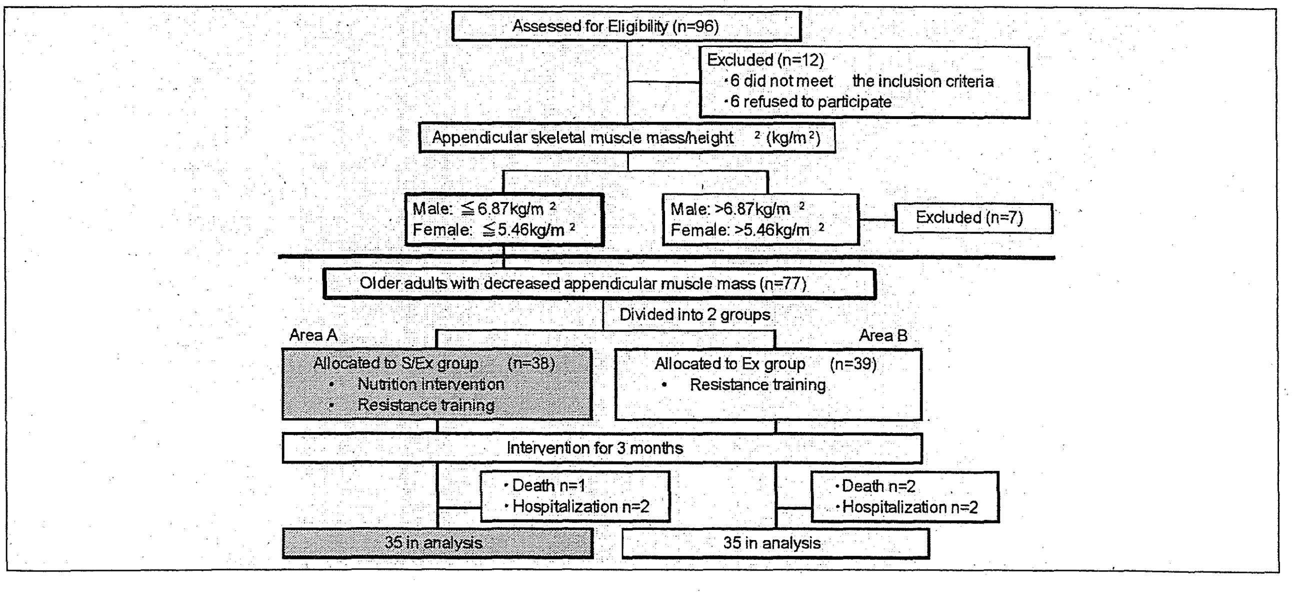
Of the total 96 screened community-dwelling older adults, 19 were excluded. The remaining 77 older adults with low muscle mass were divided into the 2 groups: nutritional supplementation during resistance training (S/Ex: n = 38) group and resistance training alone (Ex: n = 39) group (Figure 1).

Interventions

Multinutrient supplementation

A multinutrient supplementation, particularly aimed at increasing vitamin D and protein intakes, was provided 3 times a week for 3 months to participants in the S/Ex group. A detailed description of the adopted product (Resource PemPal Active®; 12.5 μg of vitamin D, 10.0 g of protein with branched chain amino acids; 200kcal, 41% carbohydrate, 37% fat, 20%

Figure 1
Flow chart describing the study design



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protein, 2% oligosaccharide, Nestle Japan Ltd. Tokyo, Japan) is provided in the Appendix.

Resistance training

Participants performed 90 minutes of group training sessions 3 times a week for the 3 months of the study. Each exercise class used a standardized format that included 10 minutes of warm-up exercises, 60 minutes of progressive strength training, 10 minutes of flexibility and balance exercises, and 10 minutes of cool-down activities. The warm-up exercise consisted of movement of legs, trunk, and arms to include all joints and major muscle groups in activities such as mild dancing. Strength training consisted of progressive resistive exercises using an elastic band and exercise machines.

Participants performed biceps curls, double-arm pull downs, seated row, leg press, leg curl, and leg extension exercises on the resistance training machines. Training loads were chosen using the 10-repetition maximum (10-RM, the maximal weight that can be lifted 10 times). Participants used the 10-RM for 3 sets of 10 repetitions for each machine exercise. Participants were required to adjust the training weight to ensure failure at the 10-RM.

A sequence of progressively more difficult exercises was also performed to improve static and dynamic balance. Although exercises could be performed in a sitting position, the importance of performing in a standing position to improve balance was encouraged. Physiotherapists evaluated each participant twice during the study period to ensure adherence to the exercise protocols during classes.

Outcome measurements

A physiotherapist blinded about the group allocation of each subject administered the test of interest at the baseline visit, and later at the completion of the 3-month intervention. All baseline measures were completed before group allocation. Before the study started, all staff members received training by one of the authors (MY) about the correct protocols to administer the measures included in this study.

Skeletal muscle mass index (SMI)

Bioelectrical impedance analysis (BIA; Physion MD; Physion Co. Ltd, Kyoto, Japan) was performed to determine body composition (26). This system applies a constant current of 800 mA at 50 kHz through the body. Participants were assessed in supine position with their arms and legs extended and relaxed. Using segmental body composition and muscle mass, a value for the appendicular skeletal muscle mass was determined and used for the present analysis. Muscle mass was converted to the skeletal muscle mass index (SMI) by dividing appendicular skeletal muscle mass by squared height (kg/m^2). This index has been used in several epidemiological studies (5, 27).

Measurement of physical performances

For all participants, the following 6 measurements were obtained: 10-m maximum walking time (28), the timed up and go (TUG) test (29), the functional reach (FR) test (30), the five chair stand (5CS) test (31), the hand grip strength (HGS) (32), and the knee-extension strength (KES) (33). If a walking aid was normally used at home, this aid was used during the TUG test and 10-m walking.

In the maximum walking, participants were asked to walk 15 m at a maximum pace. A stopwatch was used to record the time required to reach the 10 m point (marked in the course). The time recorded in 2 trials was averaged to obtain the parameter used in the present analyses.

In the TUG test, participants were asked to stand up from a chair with a seat height of 40 cm, walk a distance of 3 m at a maximum pace, turn, walk back to the chair, and sit down. The time recorded from 2 trials was averaged to obtain the parameter used in the present analyses.

In the FR test, each participant was positioned next to a wall with one arm raised at 90° and fingers extended. A meter stick was placed on the wall at shoulder height. The distance that a participant could reach while extending forward from an initial upright position to the maximal anterior leaning position without moving or lifting the feet was visually measured in centimetres according to the position of the tip of the third finger against the placed meter stick. The distances measured in 2 trials were averaged to obtain the variable used in the present analyses.

In the 5CS, participants were asked to stand up and sit down five times as quickly as possible, and they were timed from the initial sitting position to the final standing position at the end of the fifth stand. The5CS score was defined as the better performance of two trials.

In the HGS, participants used a hand-held dynamometer with the arm by the side of the body. The participants squeeze the dynamometer with maximum isometric effort. No other body movement was allowed. The HGS score was defined as the better performance of their two trials.

The KES was measured with hand-held dynamometer (HHD; mTas F-1; ANIMA, Tokyo, Japan) during isometric contraction of the knee extensor. In a sitting position, the subject kept the hip and knee at 90° angle. The maximal isometric strength was measured after adequate pre-

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measurement trials. The HHD was placed 25 cm distal to the knee joint. Torque was calculated by multiplying strength by the arm (25 cm) and expressed at the percentage of bodyweight (Nm/kg). The KES score was defined as the better performance of two trials.

Assessment of sarcopenia

For the present study we adopted the SSCWD criteria (2). The SSCWD recommended to define sarcopenia as the concurrent presence of slow walking speed (equal to or less than 1 m/sec) and low appendicular muscle mass. Japanese criteria for sarcopenia assessed by appendicular muscle mass/squared height were less than 6.87 kg/m² in men and less than 5.46 kg/m² in women (24).

Statistical analysis

Baseline characteristics of S/Ex and Ex groups were compared to examine the comparability of the 2 groups. Differences in the physical function variables between the 2 groups were analysed using the Student's t-test or chi-square test.

Analysis of covariance (ANCOVA) was used to determine the effect of the intervention program on each outcome measure, with baseline values as covariates. Post hoc Tukey tests were used to assess which group or time periods showed significant differences.

Data were entered and analysed using the SPSS (Windows version 18.0, SPSS, Inc., Chicago, IL). A P value <0.05 was

Table 1
Baseline characteristics of study participants according to the S/Ex and Ex groups

Characteristics		S/Ex group (n=35) Mean SD	Ex group (n=35) Mean SD	P-value
Age	Mean±SD	74.4±7.3	75.6±6	.411
Height	cm, Mean±SD	156.2±9.1	157.2±8.7	.603
Weight	kg, Mean±SD	55.2±8.8	55.9±10.4	.733
BMI	kg/m², Mean±SD	22.6±3.1	22.5±3.3	.890
Gender (female)	n (%)	17 (48.5%)	19 (54.3%)	.408[a]
Medication	number, Mean±SD	5.2±2.9	5.7±3.7	.499
Walking aid user	n (%)	24 (68.6%)	25 (71.4%)	.500[a]
Fear of falling	n (%)	26 (74.3%)	24 (68.6%)	.398[a]
Falls in past year	n (%)	12 (34.3%)	14 (40.0%)	.402[a]

a. chi-square test

Table 2
Functional fitness items in each group at pre- and post-intervention

Items		Baseline Mean	Baseline SD	Post Mean	Post SD	main effect (time) F-value	main effect (time) P-value	Group _ Time Interaction F-value	Group _ Time Interaction P-value
Maximum walking time, sec	S/Ex	13.3	7.3	12.5	6.3	7.83	.01	5.98	.02
	Ex	12.5	5.2	12.5	5.3				
Timed up & go test, sec	S/Ex	15.8	8.3	14.8	7.9	.78	.38	1.87	.18
	Ex	14.2	5.0	14.5	6.7				
Functional reach, cm	S/Ex	17.7	8.3	20.3	5.8	7.84	.01	.06	.82
	Ex	20.4	6.8	23.5	6.9				
Five chair stand, sec	S/Ex	13.0	6.1	12.3	6.0	3.35	.07	.21	.65
	Ex	13.2	3.9	12.7	3.7				
Hand grip strength, kg	S/Ex	24.4	8.4	26.1	8.3	2.26	.14	.36	.55
	Ex	23.1	6.7	24.1	8.2				
Knee extension torque, Nm/kg	S/Ex	.55	.25	.63	.30	4.38	.04	.15	.70
	Ex	.61	.28	.65	.30				
Appendicular muscle mass, kg/m²	S/Ex	4.62	.87	4.87	.99	$ 17.78	<.01	8.61	<.01
	Ex	4.41	.77	4.45	.74				

Notes: Columns indicating pre- and post-intervention values are expressed as mean (SD); $ Post hoc test: S/Ex vs Ex (P<0.05)

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considered statistically significant for all analyses.

Results

A total of 96 people were screened, and 77 (80.2%) meeting the inclusion criteria of the trial and agreeing to participate were enrolled (Figure 1). Twelve participants were excluded because they did not match the inclusion criteria or refused to participate, and 7 participants were also excluded because they did not match the criteria for low muscle mass.

Among the 77 individuals selected for the study, 70 (90.9%) completed the 3-month intervention: 35 in the S/Ex group (92.1%) and 35 in the Ex group (89.7%).

All the 24 scheduled intervention sessions were completed. The median relative adherence was 83% (25th–75th percentile, 73–88%) in the S/Ex group and 77% (73–88%) in the Ex group. No fall incidents occurred during training sessions or testing. No health problems, including cardiovascular or musculoskeletal complications, occurred during training sessions or testing. Minor problems observed in both groups were muscle-ache after the first training sessions and fatigue. All problems were managed easily by adjustment of the intervention. Participants in the S/Ex and Ex groups were comparable and well matched with regard to their baseline characteristics (Table 1).

The significant time effects were found for maximum walking time, FR, KES and SMI ($P<0.05$) (Table 2). Participants in the S/Ex group had significantly greater improvements in maximum walking time and SMI ($P<0.05$) (Table 2). However, the other outcome measures were not significantly different between the 2 groups ($P > 0.05$).

At pre-intervention, the prevalence of sarcopenia was 65.7% and 68.6% in the S/Ex and the Ex groups, respectively, while at post-intervention, that was 42.9% and 68.6% in the S/Ex and the Ex groups, respectively. The relative risk was calculated as 1.60 (95% CI: 1.03-2.49).

Discussion

In this 3-month pilot trial to address the role of combination of resistance training and nutritional supplementation intervention for frail older adults with low muscle mass, we have shown that SMI and walking speed were significantly improved only in the S/Ex group. These results suggested that combination of resistance training and nutritional supplementation program may be beneficial for frail older adults to prevent and treat sarcopenia. On the other hand, the reported time effects for improved walking speed, balance function, leg strength and SMI confirm that a resistance training intervention may be able to increase physical function in older persons.

Interestingly, no significant time effects were not found for TUG, 5CS or HGS, despite previous studies showed that the resistance training is effective for improving strength (8) and eliciting gains in muscle mass in older adults (9). However, a recent meta-analysis showed that the resistance training is effective for improving maximal strength, but does not consistently improve physical performance such as walking speed (34). Longer interventions might be effective for the improvement of physical performance. Our study showed that in the Ex group, a 3-month resistance training program was not effective to improve walking speed.

In the present trial, we tested a multinutrient intervention particularly rich in vitamin D and proteins. It has been shown that vitamin D supplementation may enhance muscle strength in frail older adults with vitamin D deficiency (35). Although the primary source of vitamin D is sunlight, it still can be obtained from diet. In serum, vitamin D3 is transported to the liver by binding to a vitamin D-binding protein. In the kidney, 25(OH) D3 is further metabolised into a biologically active form of vitamin D (36, 37). However, the vitamin D production capacity of the skin at the age of 70 is reduced to only 30% of that of 20-year-old persons (38, 39), and an increased dietary intake should be recommended in older adults.

Protein supplementation has been shown to augment the muscle strengthening effect of resistance exercise (14, 40). Older adults have a high risk of inadequate protein intake (41), and their synthetic response to protein intake may be blunted (42). Several studies found a positive association between protein intake and muscle mass (43, 44). In fact, aminoacids intake has a stimulatory effect on muscle protein synthesis (45).

Despite of a short period of supplementation (3 times a week for 3 months), the intervention was effective at increasing muscle mass in frail sarcopenic older adults. Moreover, the present results showed that the nutritional supplementation provided added benefits to those from the resistance training for increasing muscle mass and physical performance. Longer interventions might turn out to be more effective, even for the other outcomes (e.g. knee extension torque and falls) for which we did not reported significant findings. Further studies are required to address the effect of nutritional supplementation and exercise on sarcopenia and physical performance.

Several limitations of the present study need to be mentioned. First, single participants were not randomized. Therefore, the evidence level is not so strong as it would be obtained from a randomized controlled trial (RCT). Second, these findings should be considered as preliminary due to the relatively small sample size. This issue may introduce some error of inference, reduce the power of the analysis, and limit

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generalization. Third, no follow-up after completion of the trial was conducted. Since there is a lack of evidence regarding the long-term effect of nutritional supplement on the treatment of sarcopenia, this issue also needs to be addressed in future specific studies. Forth, the intake of dietary food was not recorded. The nutritional supplement may have changed dietary intakes. Fifth, the measurement of SMI was estimated using the BIA which is far from the gold standard to accurately assess sarcopenia. Sixth, serum levels of 25 (OH) D were not measured. Therefore, the relationship between the nutritional supplement and 25 (OH) D cannot be determined. Finally, a control group not engaged in interventions was lacking. Participants in S/Ex group may have had higher motivation and interest in health issues than the general elderly population.

In conclusion, results of our study suggest that the combination of resistance training and nutritional supplementation program may be more effective at improving SMI and walking speed than resistance training only. These results imply the importance of these prevention programs to reduce sacropenia in older adults. A larger RCT is needed to confirm and extend the present results.

Appendix

Micro- and macro-nutrients of the adopted nutritional supplementation

		125 ml
Protein	g	10.0
Vitamin D	µg	12.5
Fat	g	8.2
Carbohydrate	g	20.6
Oligosaccharide	g	2.0
Natrium	mg	100
Fluid	g	93.5
Mineral	mg	91.7
Vitamin A	µgRE	244
Vitamin E	mg	4.5
Vitamin K	µg	11
Vitamin B1	mg	0.6
Vitamin B2	mg	0.8
Niacin	mg	9.8
Vitamin B6	mg	0.9
Vitamin B12	µg	1.3
Folate	µg	125
Pantothenic acid	mg	4.4
Vitamin C	mg	56.0
Biotin	µg	9
Unsaturated fatty acid	g	0.35

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References

1. Chien MY, Huang TY, Wu YT. Prevalence of sarcopenia estimated using a bioelectrical impedance analysis prediction equation in community-dwelling elderly people in Taiwan. J Am Geriatr Soc 2008; 56: 1710–1715.
2. Morley JE, Abbatecola AM, Argiles JM, et al. Society on Sarcopenia, Cachexia and Wasting Disorders Trialist Workshop. Sarcopenia with limited mobility: an international consensus. J Am Med Dir Assoc 2011; 12: 403-409.
3. Rolland Y, Czerwinski S, Abellan Van Kan G, et al. Sarcopenia: its assessment, etiology, pathogenesis, consequences and future perspectives. J Nutr Health Aging 2008; 12: 433–450.
4. Topinkova E. Aging, disability and frailty. Ann Nutr Metab 2008; 52: 6-11.
5. Janssen I, Baumgartner RN, Ross R, et al. Skeletal muscle cutpoints associated with elevated physical disability risk in older men and women. Am J Epidemiol 2004; 159:413-421.
6. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. 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 2010; 39:412-423.
7. Morley JE, Argiles JM, Evans WJ, et al. Nutritional recommendations for the management of sarcopenia. J Am Med Dir Assoc 2011; 11: 391-396.
8. Peterson MD, Rhea MR, Sen A, et al. Resistance exercise for muscular strength in older adults: a meta-analysis. Ageing Res Rev 2010; 9: 226-237.
9. Peterson MD, Sen A, Gordon PM. Influence of resistance exercise on lean body mass in aging adults: a meta-analysis. Med Sci Sports Exerc 2011; 43: 249-258.
10. Yamada M, Arai H, Uemura K, et al. Effect of resistance training on physical performance and fear of falling in elderly with different levels of physical well-being. Age Ageing 2011; 40: 637-641.
11. Yamada M, Mori S, Nishiguchi S, et al. Pedometer-based behavioral change program can improve dependency in sedentary older adults: A randomized controlled trial. Journal of Frailty & Aging (in press)
12. Houston DK, Nicklas BJ, Ding J, et al. 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 Clin Nutr 2008; 87:150-155.
13. Meng X, Zhu K, Devine A, et al. 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 2009; 24: 1827-1834.
14. Hays NP, Kim H, Wells AM, et al. Effects of whey and fortified collagen hydrolysate protein supplements on nitrogen balance and body composition in older women. J Am Diet Assoc 2009; 109: 1082-1087.
15. Paddon-Jones D, Sheffield-Moore M, Katsanos CS, et al. Differential stimulation of muscle protein synthesis in elderly humans following isocaloric ingestion of amino acids or whey protein. Exp Gerontol 2006; 41: 215-219.
16. Paddon-Jones D, Sheffield-Moore M, Urban RJ, et al. Essential amino acid and carbohydrate supplementation ameliorates muscle protein loss in humans during 28 days bed rest. J Clin Endocrinol Metab 2004; 89: 4351-4358.
17. Solerte SB, Gazzaruso C, Bonacasa R, et al. Nutritional supplements with oral amino acid mixtures increases whole-body lean mass and insulin sensitivity in elderly subjects with sarcopenia. Am J Cardiol 2008; 101: 69E-77E.
18. Hirani V, Primatesta P. Vitamin D concentrations among people aged 65 years and over living in private households and institutions in England: population survey. Age Ageing 2005; 34: 485-491.
19. Houston DK, Cesari M, Ferrucci L, et al. Association between vitamin D status and physical performance: the In CHIANTI study. J Gerontol A BiolSci Med Sci 2007; 62: 440-446.

20. Bischoff-Ferrari HA, Dawson-Hughes B, Staehelin HB, et al. Fall prevention with supplemental and active forms of vitamin D: a meta-analysis of randomised controlled trials. BMJ 2009; 339: b3692.
21. Bonnefoy M, Cornu C, Normand S, et al. The effects of exercise and protein-energy supplements on body composition and muscle functionin frail elderly individuals: a long-term controlled randomised study. Br J Nutr 2003; 89: 731-739.
22. Price R, Daly F, Pennington CR, et al. Nutritional supplementation of very old people at hospital discharge increases muscle strength: a randomised controlled trial. Gerontology 2005; 51: 179-185.
23. Milne AC, Potter J, Vivanti A, et al. Protein and energy supplementation in elderly people at risk from malnutrition. Cochrane Database Syst Rev 2009; 15: CD003288.
24. Sanada K, Miyachi M, Tanimoto M, et al. A cross-sectional study of sarcopenia in Japanese men and women: reference values andassociation with cardiovascular risk factors. Eur J Appl Physiol 2010; 110: 57-65.
25. Kalbe E, Calabrese P, Schwalen S, et al. The Rapid Dementia Screening Test (RDST): a new economical tool for detecting possible patients with dementia. Dement Geriatr Cogn Disord 2003: 16; 193-199.
26. Miyatani M, Kanehisa H, Masuo Y, et al. Validity of estimating limb muscle volume by bioelectrical impedance. J Appl Physiol 2010; 91: 386-394.
27. Janssen I. Influence of sarcopenia on the development of physical disability: the Cardiovascular Health Study. J Am Geriatr Soc 2006; 54: 56-62.
28. Lopopolo RB, Greco M, Sullivan D, et al. Effect of therapeutic exercise on gait speed in community-dwelling elderly people: a meta-analysis. Phys Ther 2006; 86: 520-540.
29. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991; 39: 142-148.
30. Duncan PW, Weiner DK, Chandler J, et al. Functional reach: a new clinical measure of balance. J Gerontol 1990; 45: M192-M197.
31. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994; 49: M85-M94.
32. Roberts HC, Denison HJ, Martin HJ, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards astandardised approach. Age Ageing 2011; 40: 423-429.
33. Wang CY, Olson SL, Protas EJ. Test-retest strength reliability: hand-held dynamometry in community-dwelling elderly fallers. Arch Phys Med Rehabil 2002; 83: 811-815.
34. Steib S, Schoene D, Pfeifer K. Dose-response relationship of resistance training in older adults: a meta-analysis. Med Sci Sports Exerc 2010; 42: 902-914.
35. Moreira-Pfrimer LD, Pedrosa MA, Teixeira L,et al. Treatment of vitamin D deficiency increases lower limb muscle strength in institutionalized older people independently of regular physical activity: a randomized double-blind controlled trial. Ann Nutr Metab 2009; 54: 291-300.
36. Omdahl JL, Garry PJ, Hunsaker LA, et al. Nutritional status in a healthy elderly population: vitamin D. Am J Clin Nutr 1982; 36: 1225-1233.
37. Holick MF. Environmental factors that influence the cutaneous production of vitamin D. Am J Clin Nutr 1995; 61: 638-645.
38. Holick MF, Matsuoka LY, Wortsman J. Age, vitamin D, and solar ultraviolet. Lancet 1989; 2: 1104-1105.
39. MacLaughlin J, Holick MF. Aging decreases the capacity of human skin to produce vitamin D3. J Clin Invest 1985; 76: 1536-1538.
40. Paddon-Jones D, Sheffield-Moore M, Katsanos CS, et al. Differential stimulation of muscle protein synthesis in elderly humans following isocaloric ingestion of amino acids or whey protein. Exp Gerontol 2006; 41: 215-219.
41. Fulgoni VL 3rd. Current protein intake in America: analysis of the National Health and Nutrition Examination Survey, 2003-2004. Am J Clin Nutr 2008; 87: 1554S-1557S.
42. Wolfe RR, Miller SL, Miller KB. Optimal protein intake in the elderly. Clin Nutr 2008 ; 27: 675-684.
43. Vellas BJ, Hunt WC, Romero LJ, et al. Changes in nutritional status and patterns of morbidity among free-living elderly persons: a 10-year longitudinal study. Nutrition 1997; 13: 515-519.
44. Lesourd B, Decarli B, Dirren H. Longitudinal changes in iron and protein status of elderly Europeans. SENECA Investigators. Eur J Clin Nutr 1996; 50: S16-S24.
45. Kim JS, Wilson JM, Lee SR. Dietary implications on mechanisms of sarcopenia: roles of protein, amino acids and antioxidants. J Nutr Biochem 2010; 21: 1-13.

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Global brain atrophy is associated with physical performance and the risk of falls in older adults with cognitive impairment

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Aim: Falls are common in patients with cognitive disorder. The purpose of this study was to determine whether global brain atrophy is associated with cognitive function, physical performance and fall incidents in older adults with mild cognitive disorder.

Methods: A total of 31 older adults with mild cognitive disorders (mean age 78.9 ± 7.3 years) were studied, and 10 of them had experienced falls and the others had not in the past 1 year. Cognitive function and physical performance were measured in these patients. Global brain atrophy was determined by the Voxel-Based Specific Regional Analysis System for Alzheimer's Disease software.

Results: Fallers showed significantly worse scores than the non-fallers in the Global Brain Atrophy Index, Clock Drawing Test (CDT), Verbal Fluency Test (animal), maximum walking time and Timed Up & Go (TUG) Test. The Global Brain Atrophy Index was correlated with the Verbal Fluency Test (animal; $r = -0.522$), the Verbal Fluency Test with letter (ka; $r = -0.337$), CDT ($r = -0.547$), TUG ($r = 0.276$) and Five Chair Stands Test ($r = 0.303$) by age-adjusted correlation analyses. Stepwise regression analysis showed that the Global Brain Atrophy Index ($\beta = 1.265$, 95% CI 1.022–1.567) was a significant and independent determinant of falls ($R^2 = 0.356$, $P = 0.003$).

Conclusion: Global brain atrophy might be indicated as one of the risk factors for falls in older adults with mild cognitive disorders. **Geriatr Gerontol Int 2013; 13: 437–442.**

Keywords: falls, global brain atrophy, mild cognitive disorder.

Introduction

Falls are a significant cause of injuries, loss of confidence, increased morbidity and mortality in older adults.[1,2] One-third of community-dwelling older adults aged 65 years and older, and up to 50% of those aged 80 years and older experience falls each year.[3,4] It has been noted that older adults with cognitive impairment are more likely to suffer falls.[5] In fact, the fall rate in patients with Alzheimer's disease (AD) was reported to be nearly twofold higher than age-matched controls.[6] Furthermore, older adults with cognitive disorders have impaired balance and gait,[7] as well as impaired executive functions.[8]

Although patients with cognitive disorders have a higher risk of falls, few studies have been reported on the relationship between morphological changes of the brain and fall incidents. White matter lesions, frequently found in magnetic resonance imaging (MRI) of the aging brain,[9] are attributed to cerebral microangiopathic changes.[10] White matter lesions in older adults are also associated with gait and balance impairment,[11,12] cognitive impairment[13] and frequent falling.[14] A previous study suggested that periventricular white matter lesions might be related to falls in patients with a mild to moderate cognitive disorder.[15] Furthermore, white matter lesions can predict the incident of hip fracture in persons younger than 80 years-of-age.[16]

Previous reports showed that measures of cognitive performance in old age, such as scores on tests of intelligence, information processing speed and memory, are predicted by global and local brain atrophy.[17] However, there have been no studies to address the relationship between global brain atrophy and fall incidents. Therefore, the purpose of the present study was to determine whether global brain atrophy is associated with cognitive function, physical performance and fall incidents in older adults with mild cognitive disorders.

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