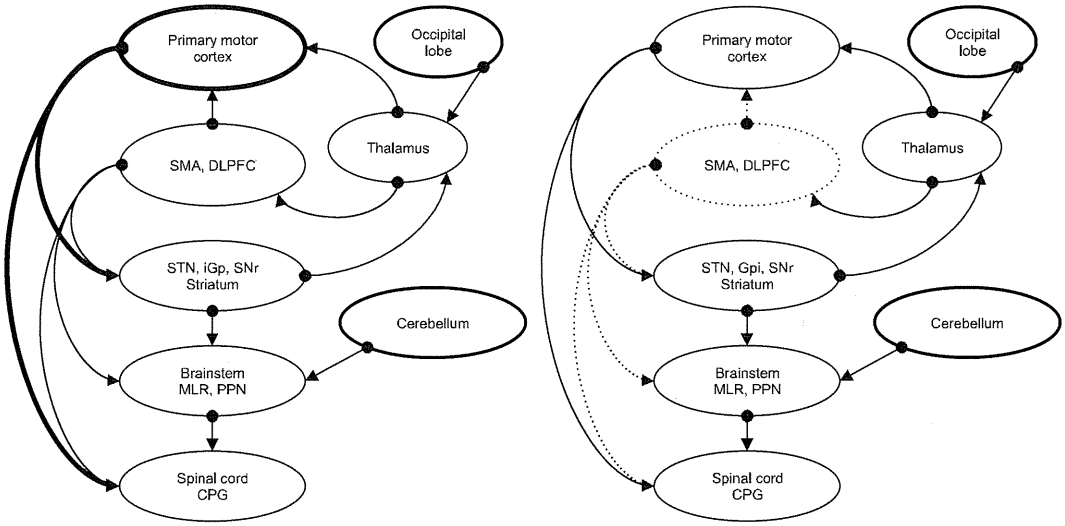

Fig. 2. Differences in neural mechanisms controlling treadmill walking in LSV compared to HSV individuals. Multiple channels from the 'basal ganglia–thalamo-cortical system' and 'basal ganglia–brainstem system' are both involved in regulating the central pattern generator (CPG) in the spinal cord. The primary motor cortex and non-primary motor areas such as supplementary motor areas constitute multiple parallel circuits with the basal ganglia counterparts. (a) Left panel displays our hypothesized neural network for the LSV group. The projections from M1 increased during walking to adapt to the unaccustomed environment (treadmill walking). (b) Right panel displays our hypothesized neural network for the HSV group. The HSV group deactivated FDG uptakes in SMA during treadmill walking and the deactivations may lead to dysfunction of 'basal ganglia–thalamo-cortical system' and 'basal ganglia–brainstem system'. *Abbreviations*: STN, subthalamic nucleus; iGP, internal segment of globus pallidus; SNr, substantia nigra pars reticulata; MLR, midbrain locomotor region; PPN, pedunculopontine nucleus.

cuneus (BA 17) and precuneus (BA 7/31), is believed to play a role in visuomotor coordination. The areas which showed relative activation were compatible with those reported in a previous activation study using FDG–PET [10]. In addition, online visual feedback was the requisite for locomotor adaptation [26] and was thought to override internal model predictions of control during locomotion [27]. Our study further supports the hypothesis that locomotor adaptation requires neuronal activation in the region related to visuomotor coordination.

In the HSV group, relative deactivations in FDG uptake were observed over a broad area of the prefrontal cortex, including the supplementary motor area and the dorsolateral prefrontal cortex. Cortical locomotor commands originating from the premotor and supplementary motor cortices are conveyed to the brainstem locomotor centers via the basal ganglia. The structure of the dorsolateral prefrontal cortex is important for selecting and planning voluntary movements [28] or simulating motor actions [29]. The relative deactivation of the supplementary motor area and dorsolateral prefrontal cortex may be associated with the finding that the participants in the HSV group might have found it difficult to adapt to an unfamiliar environment, i.e., treadmill walking.

Detailed group comparison revealed that the LSV group had a more prominent relative activation in the primary sensorimotor area compared to the HSV group and that the HSV group exhibited relative deactivation in the hippocampus compared to the LSV group during treadmill walking. The relative activation of the primary motor area may improve projection to the basal ganglia and to the CPG in the spinal cord, thus facilitating the strengthening of the basal ganglia–thalamocortical system during walking (Fig. 2). Regarding relative deactivation in the hippocampus, Zimmerman et al. (2009) found that increased variability in step length was associated with poorer hippocampal metabolism in elderly individuals. The authors suggested

Table 3
A region of interest analysis based on the standardized uptake value as the relative difference in gait-induced glucose uptake changes between groups.

	LSV group Mean (SD)	HSV group Mean (SD)	*p* value
Walk>Rest			
Primary sensorimotor area (BA 3, 4)	13.56 (3.01)	10.93 (2.16)	0.02
Occipital lobe (BA 17, 18, 19)	11.42 (4.29)	9.25 (3.55)	0.19
Cerebellum (vermis, anterior and posterior lobe)	17.18 (4.85)	17.36 (4.07)	0.92
Rest>Walk			
Orbitofrontal cortex (BA 11)	3.85 (3.18)	3.67 (2.94)	0.89
Superior frontal gyrus (BA 10)	4.16 (2.54)	4.76 (2.83)	0.59
Dorsolateral prefrontal cortex (BA 9, 46)	3.16 (2.09)	4.45 (2.25)	0.16
Supplementary motor area (BA 6, 8)	3.79 (1.74)	4.12 (1.83)	0.65
Middle and superior temporal gyrus white matter	1.85 (1.45)	3.07 (1.15)	0.03
Posterior cingulate cortex (BA 31)	3.01 (2.16)	3.67 (3.58)	0.59
Pons	2.40 (1.89)	1.84 (0.94)	0.37
Hippocampus	1.24 (1.31)	2.44 (1.29)	0.03

LSV: high step-length variability; HSV: low step-length variability.

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that the hippocampus plays an important role in the timing or rhythmicity of locomotion, which may be compromised in elderly adults [30]. Additionally, PET study showed that imagined walking with obstacles was associated with increased prefrontal and parahippocampal activation, suggesting that higher brain centers become progressively engaged when the locomotor task demands increased cognitive and sensory information processing [31]. Beauchet et al. (2003) reported that stride-to-stride variability increased significantly in older subjects with the interfering task of counting, although there was no significant change in young subjects. The authors suggested the involvement of higher cortical regions for the motor control of gait under a dual-task in older adults [32]. Our findings therefore support and extend previous research via the identification of an association between FDG–PET activation/deactivation and gait *variability* in an unfamiliar environment in elderly adults. Walking task used a treadmill, as a stimulator to increase cognitive demand may be beneficial tool for identifying the involvement of cortical regulation in gait of the older adults.

Limitations of our study were that the sample was drawn from a larger study of community-dwelling adults over the age of 75 years, and we were not able to examine the relationships between brain activity and cognitive functions across the entire adult lifespan.

In conclusion, FDG PET revealed that the most prominent relative activations during treadmill walking were the primary sensorimotor areas, occipital lobe, and cerebellar areas. The high step-length variability group exhibited a lesser relative activation in the primary sensorimotor area and a greater relative deactivation in the white matter of the middle and superior temporal gyrus and hippocampus during treadmill walking than the low step-length variability group. These results suggested the involvement of cortical regulation in gait adaptation of the older adults. Additional studies are necessary to examine the longitudinal sequence and relationships of gait, cognitive status, and presynaptic functional changes that emerge across the spectrum from normal aging to advanced functional decline.

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Conflict of interest statement

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The sponsors had no role in the design or conduct of the study, the collection, management, analysis, or interpretation of the data, or the preparation, review, or approval of the manuscript.

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Original Study

Combined Prevalence of Frailty and Mild Cognitive Impairment in a Population of Elderly Japanese People

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Keywords:
Function
MCI
disability
dementia
old

A B S T R A C T

Objective: Preventive strategies for frailty and mild cognitive impairment (MCI) are important for avoiding future functional decline and dementia in older adults. The purpose of this study was to use a population-based survey to ascertain the single and combined prevalence of frailty and MCI and to identify the relationships between frailty and MCI in older Japanese adults.
Design: Cross-sectional study.
Setting: General community.
Participants: A total of 5104 older adults (aged 65 years or older, mean age 71 years) who were enrolled in the Obu Study of Health Promotion for the Elderly (OSHPE).
Measurements: Each participant underwent detailed physical and cognitive testing to assess frailty and MCI. We considered the frailty phenotype to be characterized by limitations in 3 or more of the following 5 domains: mobility, strength, endurance, physical activity, and nutrition. Screening for MCI included a standardized personal interview, the Mini-Mental State Examination, and the National Center for Geriatrics and Gerontology-Functional Assessment Tool (NCGG-FAT), which included 8 tasks used to assess logical memory (immediate and delayed recognition), word list memory (immediate and delayed recall), attention and executive function (tablet version of Trail Making Test-part A and B), processing speed (tablet version of digit symbol substitution test), and visuospatial skill (figure selection).
Results: The overall prevalence of frailty, MCI, and frailty and MCI combined was 11.3%, 18.8%, and 2.7%, respectively. We found significant relationships between frailty and MCI (the odds ratio adjusted for age, sex, and education was 2.0 (95% confidence interval 1.5–2.5).
Conclusions: Using the OSHPE criteria, we found more participants with MCI than with frailty. The prevalence of frailty and MCI combined was 2.7% in our population. Future investigation is necessary to determine whether this population is at increased risk for disability or mortality.

The rate of frailty and mild cognitive impairment (MCI), which increases with age, is a major risk factor for dependency, institutionalization, and mortality.[1,2,3,4] Individuals with disabilities have greater health care needs compared with those without.[5] The elderly population is highly heterogeneous, such that elderly people in the same age range may have a widely varied risk of disability. To prevent disability, population-based intervention programs should be targeted at those in the population with an increased risk of frailty and MCI.

Many studies have worked within research and clinical settings to identify target populations with frailty and MCI. For instance, the Interventions on Frailty Working Group assessed various methods for screening, recruiting, evaluating, and retaining frail elderly individuals in clinical trials.[6] They reported that most researchers focused on the following domains when identifying physical frailty: mobility,

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such as lower-extremity performance and gait abnormalities; muscle weakness; poor exercise tolerance; unstable balance; and factors related to body composition, such as weight loss, malnutrition, and muscle loss.[6] Participants with MCI in a community cohort were described by a group of investigators from the Mayo Clinic in 1999, who then produced a series of diagnostic criteria.[7] A conference of international MCI experts then revised these criteria,[8] and the National Institute on Aging joined the Alzheimer's Association to revise the diagnostic criteria for the symptomatic predementia phase of Alzheimer disease (AD). They outlined the following factors for the identification of MCI: concern regarding a change in cognition, impairment in one or more cognitive domains, preservation of independence in functional abilities, and absence of dementia.[9]

Using the frailty criteria developed by the Cardiovascular Health Study (CHS), the overall prevalence of frailty in community-dwelling adults aged 65 or older in the United States has been found to range from 7% to 12%. In the CHS, the prevalence of frailty increased with age from 3.9% in the 65 to 74 age group to 25.0% in the 85+ age group, and was greater in women than in men (8% vs 5%).[10] Using the MCI criteria in the CHS cognition study, the overall prevalence of MCI was found to be 18.8%, and the prevalence increased with age from 18.8% in participants younger than 75 years to 28.9% in those older than 85 years.[11]

Several cross-sectional studies have reported an association between physical frailty and cognitive function.[6,10,12,13] In addition, longitudinal studies have revealed that a higher level of physical frailty is associated with an increased risk of incident AD[14] and MCI.[15] These studies suggest that in some older adults, physical frailty is associated with the development of MCI. Older adults who show signs of both physical frailty and MCI may be more likely to exhibit functional decline than those with either frailty or MCI. However, the combined prevalence of frailty and MCI and the relationships between frailty and MCI in the Japanese population has not been clearly established. Thus, the purpose of this study was to ascertain the combined prevalence of frailty and MCI and to identify the relationships among frailty, MCI, and demographics including age, sex, and education in the Japanese population, using a community-based survey.

Methods

Participants

Our national study assessed 5104 individuals 65 years and older (mean age 71 years) who were enrolled in the Obu Study of Health Promotion for the Elderly (OSHPE). Each individual was recruited from Obu, Japan, which is a residential suburb of Nagoya. Inclusion criteria required each participant to be 65 years or older at the time of examination (2011 or 2012), and to reside in Obu city. Based on previous reports, we excluded participants with a history of Parkinson disease, stroke, or Mini-Mental State scores less than 18, as these conditions could produce characteristics of frailty.[3,10,16] We also excluded participants who had participated in similar studies, those with severe disabilities, and those with missing data values regarding determinants for frailty and MCI. In the present study, we examined the prevalence of frailty in 4745 participants, MCI in 5025 participants, and the combined prevalence of frailty and MCI in 4681 participants. Informed consent was obtained from all participants before their inclusion in the study, and the Ethics Committee of the National Center for Gerontology and Geriatrics approved the study protocol.

Measurements

The assessments were conducted by well-trained staff who had nursing, allied health, or similar qualifications. Before commencement of the study, all staff received training from the authors in the correct protocols for administering the assessment measures.

Operationalization of the Frailty Phenotype in OSHPE

We considered the frailty phenotype to be characterized by limitations in 3 or more of the following 5 domains: mobility, strength, endurance, physical activity, and nutrition. Mobility was measured in seconds using a stopwatch. Participants were asked to walk on a flat and straight surface at a comfortable walking speed. Two markers were used to indicate the start and end of a 2.4-meter walk path, with a 2-meter section to be traversed before passing the start marker so that participants were walking at a comfortable pace by the time they reached the timed path. Participants were asked to continue walking for an additional 2 meters past the end of the path to ensure a consistent walking pace while on the timed path. A low level of mobility was established according to a cutoff (<1.0 m/s). Grip strength was measured in kilograms using a Smedley-type handheld dynamometer (GRIP-D; Takei Ltd., Niigata, Japan). Low grip strength was established according to a sex-specific cutoff (male: <26 kg, female: <17 kg). Endurance was assessed via a self-report of exhaustion, which included questions from the Geriatric Depression Scale,[17] such as: "Do you feel full of energy?" If participants answered "no" to this question, we classified them as low endurance. We evaluated the role of physical activity by asking the following questions about time spent engaged in sports and exercise: (1) "Do you engage in moderate levels of physical exercise or sports aimed at health?" and (2) "Do you engage in low levels of physical exercise aimed at health?" If participants answered "no" to both of these questions, we considered them to be physically inactive. Nutritional status was established according to self-reports of weight loss in response to the following question: "In the past 2 years, have you lost more than 5% of your body weight irrespective of intent to lose weight?" Patients with impairments in at least 3 of the 5 domains were considered to be frail.

Operationalization of the MCI in OSHPE

We defined MCI based on previous studies,[18,19,20] using the following criteria: subjective memory complaints, cognitive impairment (indicated by an age-adjusted score at least 1.5 SDs below the reference threshold of any of the tests, all of which are commonly used for detailed neuropsychological assessments); no evidence of functional dependency (no need for supervision or external help in performing activities in daily life); and exclusion from the clinical criteria for dementia. Screening for MCI included a standardized personal interview for collection of sociodemographic, lifestyle, medical history, and functional status (activities of daily living) data, along with cognitive screening that was conducted using the Mini-Mental State Examination (MMSE)[21] and the National Center for Geriatrics and Gerontology-Functional Assessment Tool (NCGG-FAT).[22] Individuals with 23 or fewer points on the MMSE were considered to have a general cognitive impairment.[23] The NCGG-FAT consists of 8 tasks used to assess logical memory (immediate and delayed recognition), word list memory (immediate and delayed recall), attention and executive function (tablet version of Trail Making Test-part A and B), processing speed (tablet version of Digit Symbol Substitution Test), and visuospatial skill (figure selection). The participants were given 20 to 30 minutes to complete the battery, which consisted of the previously mentioned 8 tasks. High test-retest reliability and moderate to high validity were confirmed in community-dwelling older adults for all task components of the NCGG-FAT.[22] All tests used in this study had previously established

standardized thresholds for the definition of impairment in the corresponding domain (score <1.5 SDs below the age-specific mean) for population-based OSHPE cohort consisting of older adults.

Statistical Analysis

We compared age-, sex-, and education-specific prevalence, as well as the combined prevalence rates of frailty and MCI using χ^2 tests. The prevalence of frailty and MCI were explored in 4745 and 5025 participants, respectively. In calculating the combined prevalence, we found that 4681 participants did not meet the exclusion criteria for frailty or MCI. A multivariate logistic regression model was used to determine the odds ratios of MCI or frailty with respect to age category, sex, and education level. Participants with low general cognitive function were excluded from the multivariate analysis. As a result, the multivariate analysis included data from 3497 participants. All data management and statistical computations were performed using the IBM SPSS Statistics 19.0 software package (SPSS Inc., Chicago, IL).

Results

The OSHPE identified 538 (11.3%) elderly participants who had symptoms of frailty and 945 (18.8%) who had MCI (Table 1). Figures 1 and 2 show our findings regarding the prevalence of frailty and MCI, respectively. We found that the prevalence of frailty increased with advancing age. Of the 538 participants who were classified as frail, 192 (34.9%) were 80 years and older. The prevalence of frailty was higher in women than in men ($P < .05$), and a lower level of education was significantly associated with prevalence of frailty ($P < .01$). Participants who reported 9 or fewer years of education had a 16.4% rate of frailty, whereas in those who reported at least 13 years of education, this rate was 7.7% (Table 1 and Figure 1).

The OSHPE found young-old, 65 to 74 years, participants to have a higher rate of MCI than old-old, 75 years and older, participants. Educational level was significantly associated with MCI ($P < .01$). Participants who reported 9 or fewer years of education had a 23.4% rate of MCI, whereas this rate was reduced to 14.1% in participants who reported at least 13 years of education (Table 1 and Figure 2). The OSHPE found no significant sex-specific differences in the prevalence of MCI.

Table 1 shows the distribution of the combined prevalence of frailty and MCI by age, sex, and educational level. The OSHIPE revealed 126 (2.7%) participants with a combined incidence of frailty and MCI. Combined prevalence increased with age, with the highest rate found in the age group containing participants who were 80 years and older (6.9%). Participants with a low educational level had a higher rate of MCI combined with frailty (4.4% for 9 or fewer years) than those with higher education (1.3% for 13 years and more). No clear pattern emerged for any sex-specific differences in the prevalence of combined frailty and MCI (Table 1).

Our multivariate analysis found 3497 participants from the OSHPE cohort who did not meet the exclusion criteria for frailty and MCI and who maintained objective cognitive function. We found several significant relationships between frailty and MCI (odds ratio [OR] = 2.0, 95% confidence interval [95% CI] 1.5–2.5). In terms of the relationship between frailty and sociodemographics, participants aged 65 to 69 years were less likely to be frail than older participants (OR = 2.7, 95% CI 1.9–3.8, for the group 75 to 79 years of age, and OR = 6.9, 95% CI 4.9–9.7, for the group 80 years and older). There were no significant associations observed between frailty and sex. Participants with 9 or fewer years of education had a higher OR (1.4) than participants with at least 13 years of education (Table 2).

In terms of the relationship between MCI and sociodemographics, female participants had a significantly lower OR (0.8, 95% CI 0.7–1.0) than male participants. There was an evident relationship between MCI and educational level. In comparison with participants with at least 13 years of education, participants with a lower level of education were more likely to have MCI (OR = 1.5, 95% CI 1.2–1.8, for those with 10–12 years of education, and OR = 3.2, 95% CI 2.5–4.0, for those with 9 or fewer years of education) (Table 2).

Discussion

This study presents original data regarding vulnerability for physical and cognitive decline in a sample of 5104 elderly community dwellers in Japan. To our knowledge, this is the first study about frailty and MCI in this region of the world. Japan has a rapidly aging population in comparison with North, Central, and South America, as well as Europe. An examination of the differences in levels of frailty and MCI between countries may be useful in developing health care policies, especially in countries where the population is expected to rapidly age in the near future.

Growing evidence has indicated that there is a connection between frailty and cognitive impairment. Several studies have reported a longitudinal association between frailty and rate of MCI in elderly community-dwelling individuals. Boyle et al[15] reported, in an assessment that used 12 years of annual follow-up data, that physical frailty was associated with a high risk of MCI, such that each 1-unit (grip strength, timed walk, body composition, and fatigue) increase in physical frailty was associated with a 63% increase in the risk of MCI. Auyeung et al[24] identified that physical frailty, as indicated by

Table 1
Number of Participants and Prevalence of Frailty and Mild Cognitive Impairment (MCI)

	Frailty (n = 4745)			MCI (n = 5025)			Combined (n = 4681)
	Without Frailty	With Frailty	Prevalence	Without MCI	With MCI	Prevalence	Prevalence
All participants	4207	538	11.3%	4080	945	18.8%	2.7%
Age, y			$P < .01$			$P < .02$	
65–69	1794	106	5.6%	1583	390	19.80%	1.6%
70–74	1344	105	7.2%	1221	307	20.10%	2.2%
75–79	711	135	16.0%	771	145	15.80%	3.4%
≥80	358	192	34.9%	505	103	16.90%	6.9%
Sex			$P < .05$			$P < .05$	
Females	2157	302	12.3%	2073	489	19.10%	3.0%
Males	2050	236	10.3%	2007	456	18.50%	2.4%
Educational level, y			$P < .01$			$P < .01$	
≤9	1420	279	16.4%	1414	431	23.40%	4.4%
10–12	1812	179	9.0%	1712	357	17.30%	2.0%
≥13	963	80	7.7%	943	155	14.10%	1.3%

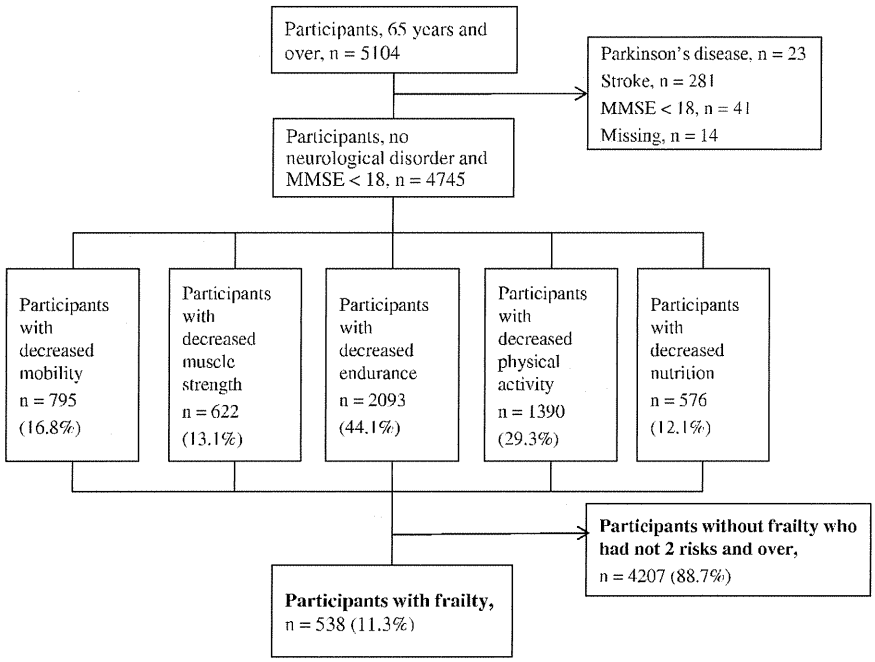

Fig. 1. Participants' flow to find frail older adults.

low body weight, weaker grip strength, slower performance in the chair-stand test, and shorter step-length in men and weaker grip strength in women, was associated with a decline in MMSE score over a 4-year period. Similarly, low cognitive function was independently associated with an increased risk of frailty in older adults. Raji et al. reported that nonfrail participants with a poor MMSE score (<21) at baseline had a 9% probability per year of becoming frail over a 10-year period, compared to individuals with normal cognition (MMSE

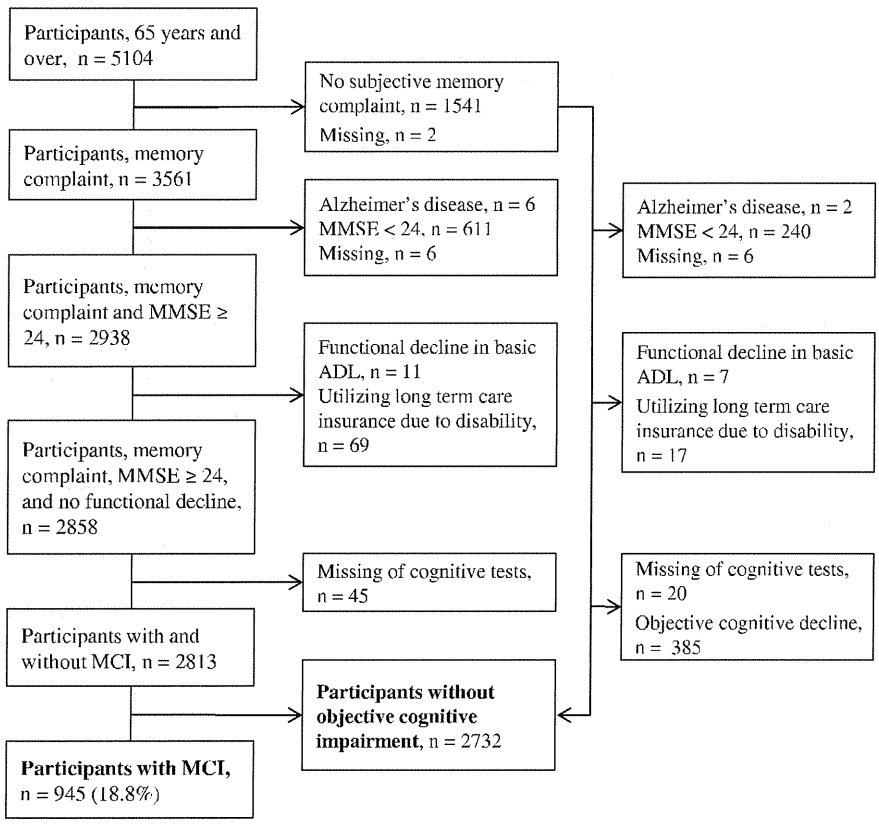

Fig. 2. Participants' flow to find MCI older adults.

Table 2
Relationships Between Frailty, Mild Cognitive Impairment (MCI), and Sociodemographics

	Frailty		MCI	
	Odds Ratio (95% Confidence Interval)	*P*	Odds Ratio (95% Confidence Interval)	*P*
MCI	2.0 (1.5–2.5)	<.01		
Frailty			2.0 (1.5–2.5)	<.01
Age, y	*P* for trend	<.01	*P* for trend	>.05
65–69	1		1	
70–74	1.2 (0.9–1.7)	.30	1.0 (0.8–1.2)	.95
75–79	2.7 (1.9–3.8)	<.01	0.7 (0.6–0.9)	.01
≥80	6.9 (4.9–9.7)	<.01	0.9 (0.7–1.2)	.54
Sex				
Males	1		1	
Females	1.1 (0.9–1.4)	.45	0.8 (0.7–1.0)	.04
Educational level, y	*P* for trend	.02	*P* for trend	<.01
≥13	1		1	
10–12	1.0 (0.7–1.4)	.85	1.5 (1.2–1.8)	<.01
≤9	1.4 (1.0–2.0)	<.05	3.2 (2.5–4.0)	<.01

21+).[25] Although the criteria for determining frailty and MCI vary slightly between studies, our results were in accordance with previous findings, and thus add support to the association between frailty and MCI.

The prevalence of frailty was 11.3% in our participant group, a rate slightly higher than that of previous studies that also used the CHS frailty criteria. In the American Cardiovascular Health Study, the prevalence of frailty among 5317 community-dwelling men and women aged 65 years and older was 6.9%, and frailty was associated with older age, male gender, being African American, having lower education and income, poorer health, and higher rates of comorbid chronic disease and disability.[10] The French Three-City Study demonstrated a frailty prevalence of 7% among 6078 community-dwelling men and women aged 65 years and older, and frailty was associated with older age, female gender, lower education, lower income, a poorer self-reported health status, and more chronic disease in addition to incident disability.[26] The Hertfordshire Cohort Study (HCS), UK, reported that the prevalence of frailty, as defined by CHS frailty criteria, among 638 community-dwelling participants aged 64 to 74 years was 8.5% for women and 4.1% for men.[27] The principal difference in the frailty criteria used by the CHS and OSHPE is the cutoff point for walking speed: in the CHS it is set at 0.65 m/s (height ≤173 cm) and in the OSHPE it is 1.0 m/s. This difference may be one explanation for the higher prevalence observed in studies using the OSHPE. The Survey of Health, Aging, and Retirement in Europe (SHARE) studied 16,584 men and women aged 50 years and older, and found that the prevalence of frailty in the nondisabled population aged 65 years and over ranged from 3.9% to 21.0%. The SHARE study demonstrated a higher prevalence of frailty in southern (9.3% to 21.0%) compared with northern Europe (<9.0%).[28] The SHARE study defined slowness using the following 2 questions regarding mobility: "Because of a health problem, do you have difficulty [expected to last more than 3 months] walking 100 meters" and "... climbing 1 flight of stairs without resting." Gait velocity has consistently been reported to differentiate between participants with and without functional decline, as frail elderly individuals walk significantly slower than their nonfrail peers.[29,30] Thus, gait velocity has been found to be a strong predictor of adverse events, such as disability,[31-37] mortality,[32,33,38,39] hospitalization,[32,33,35,40] and falls.[40,41] The cutoff point for walking speed in the present study was 1.0 m/s, which appears to be a critical point for predicting future functional decline in community-dwelling elderly individuals.[32,33,35,36,37] These results suggest that walking speed may be the most useful measurement for determining frailty and predicting future functional decline in older adults.[42,43]

It is likely that the reported prevalence of MCI varies between studies as a result of different diagnostic criteria, as well as different sampling and assessment procedures. Despite some methodological differences, most previous studies report prevalence figures for MCI or for cognitive impairment without dementia ranging from 11% to 23%. The Women's Cognitive Impairment Study used global and domain-specific cognitive measures and found the prevalence of MCI or cognitive impairment without dementia to be 23.2% in a sample of 1299 participants aged 85 years and older.[19] The Mayo Clinic Study of Aging diagnosed 329 of 1969 study participants (16.7%) with MCI or cognitive impairment without dementia using the Clinical Dementia Rating Scale, a neurologic evaluation, and neuropsychological testing to assess 4 cognitive domains: memory, executive function, language, and visuospatial skills.[44] A study from Leipzig, Germany, that used a 55-point composite instrument found the overall prevalence of MCI or cognitive impairment without dementia to be 19.3% in participants aged 75 years and older.[45] The Cardiovascular Health Study found the overall rate of MCI or cognitive impairment without dementia to be 19% in participants aged 75 years and older.[11] In the Aging, Demographics, and Memory Study, an estimated 5.4 million people (22.2% of the total population of the country) in the United States aged 71 years or older were found to have cognitive impairment without dementia.[46] In a Japanese study, MCI was diagnosed in 271 of 1433 study participants (18.9%).[47] In the above-mentioned study, a diagnosis of MCI was contingent on cognitive performance 1.0[44,45,47] or 1.5 SDs[11,19,46] below at least one test measure. In the present study, we found the prevalence of MCI to be 18.8%, which is similar to previous studies that used multiple cognitive tests to detect MCI.

In the present study, we found the combined prevalence of frailty and MCI to be 2.7% among 4681 community-dwelling elderly participants. Our analyses of the relationships among frailty, MCI, and sociodemographics revealed a significant relationship between frailty and MCI (OR 2.0). These results suggest that frailty may coincide with MCI in older adults who exhibit vulnerability factors for both conditions. Many researchers believe that the definition of frailty should include mental health as well as physical functioning. The Frailty Operative Definition-Consensus Conference Project reported that experts agreed on the importance of a more comprehensive definition of frailty that should include assessment of physical performance, including gait speed and mobility, nutritional status, mental health, and cognition.[48] The results of the present study were in line with the new concept of frailty, which included cognition. Individuals with a co-occurrence of frailty and MCI may face a higher risk of incidence disability than healthy older adults or older adults with either frailty or MCI. The French Three-City Study established that frail persons with a cognitive impairment are significantly more likely to develop disabilities in activities of daily living (ADL) and instrumental ADL disabilities.[49] Moreover, the Hispanic Established Populations for the Epidemiologic Study of the Elderly demonstrated that frailty and cognitive impairment affect mortality differently when they occur independently compared with when they are present together. For instance, individuals with cognitive impairment and frailty had higher mortality compared with individuals with either frailty or cognitive decline.[50] Further longitudinal study is needed to clarify the ways in which frailty and MCI might affect vulnerability among older adults.

Our multivariate analysis indicated that the participants with the highest risk of developing frailty were 80 years and older or had received fewer than 9 years of education. Many studies have reported relationships among frailty, age, and education. For instance, the Women's Health Initiative Observational Study found

that age is significantly correlated with incident frailty. In contrast, the previously mentioned study found no clear relationship between MCI and age. The MCI criteria in the OSHPE is based on cognitive score (ie, <1.5 SDs below the age-specific mean of healthy peers). Our inability to find a relationship between MCI and age may have been because of our use of age-specific criteria.

Our logistic model revealed that participants with the highest risk of MCI were predominantly male and had received 9 or fewer years of education. The Mayo Clinic Study of Aging reported that the prevalence OR for MCI in men was 1.54 (95% CI 1.21–1.96; adjusted for age, and education). Several other studies have reported a higher rate of MCI in older adults who received fewer years of education.[19,20,44,51] In one study, this result remained essentially unchanged after adjusting for several demographic and clinical variables, as well as the Apolipoprotein E genotype, suggesting that this association is not due to comorbid conditions or to a differential rate of MCI in men compared with women.[44] Our results support these previous discoveries while adding the finding that ethnic differences do not explain the higher prevalence of MCI in men than in women. There is a clear relationship between educational level and prevalence of MCI. Indeed, our results suggest that educational level is more closely associated with MCI risk than age in the OSHPE criteria.

One strength of the present study is the size of the cohort assessed in a specific community. Our findings are backed by comprehensive geriatric assessments intended to identify frailty and cognitive impairments. To our knowledge, this is the first study to demonstrate the combined prevalence of frailty and MCI in a large sample of older adults. We identified MCI using the NCGG-FAT, which is useful for multidimensional cognitive screening in population-based samples to assess the risk of cognitive decline. In a hospital setting, psychologists, neurologists, and other specialists are available to perform psychological tests. It can be difficult to assemble specialists in Japan for assessments in a community setting. The NCGG-FAT is easily administered using a tablet PC with the instructions shown on the display. Therefore, it is not necessary for those collecting the data to have a thorough knowledge of neurocognitive measures, and the identity of the person administering the questionnaire will not strongly affect the results.

An important limitation of our study is that participants were not recruited randomly to complete the OSHPE. This may lead to an underestimation of the prevalence of frailty and MCI, as the participants were relatively healthy elderly persons who were able to access the health checkup from their homes. Second, for some participants, we were not able to contact an informant, such as family member, to verify medical records, lifestyle information, and asymptomatic aberrant behavior.

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Performance-based assessments and demand for personal care in older Japanese people: a cross-sectional study

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ABSTRACT

Objectives: To identify appropriate clinical tests for determining the demand for personal care in older Japanese people.

Design: Cross-sectional observation study.

Setting: Obu Study of Health Promotion for the Elderly (Obu, Aichi) and Tsukui Ordered Useful Care for Health (241 day-care centres) cohorts in Japan.

Participants: A total of 10 351 individuals aged 65 years or older (6791 with personal care and 3560 without personal care) participated in the study.

Measures: Physical performance tests included grip strength, the chair stand test, walking speed at a comfortable pace, and the timed up-and-go test. Personal care was defined as participants who had been certified in the national social long-term care insurance in Japan.

Results: Individuals who received personal care showed a significantly poorer performance than those without personal care for all physical performance tests ($p<0.001$). Gait speed was the most useful of the physical performance tests to determine the demand for personal care (receiver operating characteristic curve statistics: men, 0.92; women, 0.94; sensitivity: men, 86; women, 90; specificity: men, 85; women, 85). After adjustment for age, sex, cognitive impairment and other physical tests, all physical performance tests were individually associated with the demand for personal care. A slow gait speed (<1 m/s) was more strongly correlated with the demand for personal care than other performance measures (gait speed OR: 5.9; 95% CI: 5.0 to 6.9).

Conclusions: Clinical tests of physical performance are associated with the demand for personal care in older people. Preventive strategies to maintain physical independence may be required in older adults who show a gait speed slower than 1 m/s. Further research is necessary to confirm these preliminary results.

ARTICLE SUMMARY

Article focus

- Measures of physical performance may identify older persons with a preclinical stage of disability.
- However, it is unclear which performance test and cut-point are the most useful to screen for risk of functional dependence in older Japanese people.
- The purpose of this study was to identify appropriate clinical tests for determining the risk of functional dependence in older Japanese people.

Key messages

- Clinical tests of physical performance were associated with a functional decline in older people.
- Preventive strategies to avoid personal care may be required in older adults who show a gait speed slower than 1 m/s.

Strengths and limitations of this study

- Strengths of this study include a large sample size and performance-based assessment, which could determine actual physical capacity and predict subsequent physical disability in older people living in the community.
- We analysed cross-sectional data. Therefore, further investigation of the validity of these tests in predicting the risk of disability in older people using a prospective study design is recommended.

INTRODUCTION

Japan is the fastest ageing society on earth and the first large country in the history to have its population start shrinking rapidly from natural causes. The life expectancy of Japanese people (mean age: men, 79.4 years; women, 85.9 years) is at the highest level in the world. The population of Japan, which currently stands at 127 million, is expected to fall to just under 100 million in the next 40 years. By 2050, 4 of 10 adults in Japan will be older than 65 years of age. Japan implemented the national social long-term care insurance (LTCI) system on 1 April 2000. Every Japanese person aged 65 and older is eligible for benefits based strictly on physical and mental frailty or disability.[1] In June 2006, the Japanese government implemented a major LTCI reform that focused on preventive benefits for the

population at high risk of disability (ie, physical and/or cognitive frailty), to contain the skyrocketing costs of the LTCI.[2]

Physical frailty increases with advancing age and is a major risk factor for dependency, institutionalisation, and mortality.[3–5] People with a disability have higher healthcare needs and use compared with those without a disability.[6] Although the biggest risk factor for future frailty is advancing age, other factors that are possibly modifiable through interventions should not be ignored. For the purpose of targeting risk factors for future frailty, adequate assessment of individual people may be required. One of the main characteristics of the elderly population is its heterogeneity, with elderly people in the same age range showing a wide variance with regard to their risk of disability. To prevent frailty or disability, population-based intervention programmes should be targeted at the population at risk. A feasible and valid screening tool available for research and clinical settings is required to identify target populations. The Interventions on the Frailty Working Group developed recommendations to screen, recruit, evaluate and retain frail older persons in clinical trials.[7] They reported that most researchers focus on the following domains for identification of physical frailty: mobility, such as lower extremity performance and gait abnormalities; muscle weakness; poor exercise tolerance; unstable balance and factors related to body composition, such as weight loss, malnutrition and muscle loss.[7]

In an effort to select tailored preventive programmes in the Japanese LTCI system, those at high risk for subsequent disability are identified by a basic functional status questionnaire. Although the questionnaire is relatively quick to administer, a performance-based assessment could determine actual physical capacity and more accurately predict subsequent physical disability in community-living older people. Guralnik *et al*[8] reported that measures of physical performance may identify older persons with a preclinical stage of disability who may benefit from interventions to prevent the development of frank disability. A previous study identified that a rapid gait test was more likely than other mobility performance tests to discriminate older women at high risk of frailty based on the Japanese LTCI system.[9] However, which performance tests including upper and lower limb muscle functions and which cut-points are the most useful to screen for the demand for personal care are not clear. This study investigated the relationships between performance-based physical assessments and demand for personal care in older people using two large sample cohorts in Japan.

METHODS

Participants

We performed a national study of 10 351 individuals aged 65 years and older who had received personal care (n=6791) and those who had not received personal care (n=3560). The study included individuals who were enrolled in the Obu Study of Health Promotion for the Elderly (OSHPE) and the Tsukui Ordered Useful Care for Health (TOUCH) programme. To enrol in the OSHPE, an individual was recruited from Obu, Japan, which is a residential suburb of Nagoya. Inclusion criteria required that the participant was aged 65 years or older at examination in 2011 or 2012, lived in Obu, and had not participated in another study. Exclusion criteria stipulated that participants be certified as needing support or care by the Japanese public LTCI system, had disability in basic activities of daily living, and could not carry out performance-based assessments. To enrol in the TOUCH programme, an individual had to be 65 years or older and certified as needing support or care from the Japanese public LTCI system. Detailed information was provided in a previous study.[10] In brief, TOUCH sites (241 day-care centres) are located throughout Japan and provide comprehensive, facility-based day-care services (eg, bath, lunch, physical and cognitive recreational activities and physical exercise). Most TOUCH clients have some physical disability and frailty, defined as the presence of weakness, low physical activity and/or slow gait speed, in accordance with the widely accepted definition of frailty.[7]

A total of 10 351 older participants (mean age, 78.8±8.0 years) underwent performance-based assessments. Informed consent was obtained from all participants prior to their inclusion in the study, and the Ethics Committee of the National Centre for Geriatrics and Gerontology approved the study protocol.

Performance-based assessment

The assessment measures were conducted by well-trained staff who had nursing, physiotherapy, occupational therapy or similar qualifications. Prior to start of the study, all staff received training from the authors in the correct protocols for administering all of the assessment measures. The assessment included several physical tests. Upper and lower limb muscle functions were assessed with the grip strength (GS) and the chair stand test (CST), respectively.[11] Gait function was assessed with walking time tests conducted at a comfortable pace (comfortable walking speed, CWS) and with the timed up-and-go (TUG) test.[12]

GS was measured in kilograms in the participant's dominant hand using a Smedley-type handheld dynamometer (GRIP-D; Takei Ltd, Niigata, Japan). The CST involved sitting down and standing up five times, using a chair without an armrest. The score was the time taken to complete the task in seconds. Participants were asked to exert their maximum effort in GS and CST. CWS was measured in seconds with a stopwatch. Participants were asked to walk on a flat and straight surface at their CWS. Two markers were used to indicate the start and end of the path, and a 2 m and over approach was allowed before reaching the start marker so that participants can walk at their comfortable pace within the timed path. They were instructed to continue walking past the end

of the path for a further 2 m and over to ensure that the walking pace was consistent throughout the task. The TUG test involved rising from a chair, walking 3 m, turning around, walking back to the chair and sitting down.[12] The TUG test is one of the most frequently used tests of balance and gait, and is often used to assess fall risk in older people.[13] The time to complete the TUG test was measured, in seconds, at each participant's usual pace. Both walking tests were measured once, and if a walking aid was nomally used inside the home, this aid was used during the tests.

Cognitive function

The Mini-Mental State Examination (MMSE)[14] for the OSHPE population and the Mental Status Questionnaire (MSQ) for individuals enrolled in the TOUCH programme were used to measure cognitive functioning, and were used as potential confounders in the association between performance-based physical assessments and functional dependence.[15] Individuals with 23 or fewer points on the MMSE and three or more errors on the MSQ were considered to have cognitive impairment.[15 16]

Statistical analysis

Demographic and clinical variables were compared between the participants with and those without personal care using Student t tests for continuous variables and χ^2 tests for categorical variables. To compare the predictive ability of the study measures, receiver-operated characteristic (ROC) curves were inspected to determine cut-points for each test that best discriminated between the individuals with and those without personal care. Cut-points for maximising the sensitivity and specificity for each test were determined using the Youden index.[17] The area under the curve (AUC), sensitivity and specificity were then calculated for the cut-points. We used multivariate logistic regression analyses to determine ORs and 95% CIs, and to assess independent associations of the cut-points of physical performance measures for demand for personal care. The participants were divided into two groups according to the cut-point of the performance-based physical assessments. Covariates were added sequentially to the logistic model to evaluate the associations at different levels of adjustment. Model 1 included each performance-based physical assessment, and model 2 included the model 1 variables plus age, sex and cognitive impairment as determined by the MMSE or MSQ. Model 3 included all performance-based physical assessments plus age, sex and cognitive impairment. The participants were then divided into five groups as follows: individuals with no risk and those with 1, 2, 3 or 4 risks, according to the number of risks identified by the cut-points of the performance-based physical assessments. The ORs and 95% CIs for the number of risks were calculated adjusted for age, sex and cognitive impairment. All statistical contrasts were made at the 0.05 level of significance, and all data management and statistical computations were performed using the IBM SPSS Statistics V.19.0 software package (SPSS Inc, Chicago, Illinois, USA).

RESULTS

Comparison between participants with and those without personal care

Table 1 shows the characteristics of the participants. The participants with personal care were significantly older (p<0.001), included a higher number of women (p<0.001) and a higher number of persons with cognitive impairment (p<0.001) than those without personal care. For the comparison of performance-based assessments, the participants with personal care had significantly lower scores on all physical tests (p<0.001) compared

Table 1 Characteristics of the participants

	Participants with personal care (n=6791)	Participants without personal care (n=3560)
Age (years)*	82.6±6.7	71.8±5.2
Sex, women, n (%)*	4720 (69.5)	1793 (50.4)
Cognitive impairments, n (%)*	2962 (43.6)	562 (15.8) [8]
GS (kg)*	16.3±6.9	27.3±7.8
CST (s)*	13.0±5.6	8.6±2.4
CWS (m/s)*	0.7±0.3	1.2±0.2
TUG (s)*	16.6±7.7	8.9±1.8
Care level in the LTCI, n (%)		
Support need level 1	804 (11.8)	0 (0)
Support need level 2	1112 (16.4)	0 (0)
Care need level 1	2057 (30.3)	0 (0)
Care need level 2	1687 (24.8)	0 (0)
Care need level 3	842 (12.4)	0 (0)
Care need level 4	257 (3.8)	0 (0)
Care need level 5	32 (0.5)	0 (0)
Disability of basic ADLs, n (%)		
Eating	105 (1.5) [136]	0 (0)
Grooming	398 (5.9) [136]	0 (0)
Bathing	1374 (20.2) [136]	0 (0)
Locomotion	745 (11.0) [136]	0 (0)
Stairs	1508 (22.2) [136]	0 (0)

Individuals with 23 or fewer points on the MMSE in the participants without personal care and with three or more errors on the MSQ in the participants with personal care are considered to have cognitive impairment. Beneficiaries of the LTCI can use multiple services for which they are eligible, according to their care plan up to the maximum amount (£382 for Support Level 1; £800 for Support Level 2; £1275 for Care Level 1; £1498 for Care Level 2; £2058 for Care Level 3; £2354 for Care Level 4; £2756 for Care Level 5), in principle, for a 10% copayment and can use more services than covered as long as they pay all the costs for the services beyond the maximum level (calculated at £1=130 yen).
*Comparison between the participants with and without personal care; p<0.001, [ ] missing value.
CST, chair stand test; CWS, comfortable walking speed; GS, grip strength; LTCI, long-term care insurance; MMSE, mini-mental state examination; MSQ, mental status questionnaire; TUG, timed up-and-go test.

Table 2 Cut-points for the risk of demand for personal care and associated sensitivity, specificity, area under the curve (AUC), and OR statistics for all participants

	Criterion	Sensitivity	Specificity	AUC
GS (kg)				
Men	<26	74	89	0.88
Women	<17	80	88	0.90
CST (s)				
Men	≥10	72	74	0.79
Women	≥10	67	77	0.78
CWS (m/s)				
Men	<1.0	86	85	0.92
Women	<1.0	90	85	0.94
TUG (s)				
Men	≥11	76	88	0.88
Women	≥11	79	89	0.90

CST, chair stand test; CWS, comfortable walking speed; GS, grip strength; TUG, timed up-and-go test.

with those in participants without personal care (table 1). The number of participants with and without personal care who used the walking aid during the walking tests were 2593 (38.2%) and 35 (1.0%), respectively.

Cut-points between participants with and those without personal care

ROC curve analysis results, showing the performance cut-points for each test and associated statistics, are shown in table 2. The Youden index determined the cut-points for the demand for personal care as follows: GS in men and women was <26 and <17 kg, respectively; CST was ≥10 s, CWS was <1.0 m/s and TUG was ≥11 s for both sexes. The CWS score had the highest AUC for discriminating the demand for personal care and displayed good sensitivity and specificity (85–90%). High AUCs were also found for GS and TUG, as well as fair to good sensitivity and specificity (74–80%).

Relationships between cut-points and risk of disability

The multiple logistic regression models showed significant relationships between physical performances and the demand for personal care (table 3). The demand for personal care was most closely related to CWS in model 1 (OR=34.7; 95% CI 30.9 to 39.0). These results remained essentially unchanged after controlling for age, sex, cognitive impairment and other physical performance tests. In the final model (model 3), the highest OR of factors related to the demand for personal care was for CWS (OR=5.9; 95% CI 5.0 to 6.9). Figure 1 shows the distribution of CWS for participants with personal care. Participants who walked 1.1 m/s and faster had the lowest amount of personal care (20%). The rate of participants with personal care increased rapidly with a CWS slower than 1.1 m/s, and 90% of participants with a CWS slower than 0.8 m/s had personal care (figure 1A). The rate of functional decline increased rapidly for individuals walking slower than 1 m/s in women (figure 1C) rather than men (figure 1B), and with the rate of functional decline reaching 90% when CWS was slower than 0.8 m/s in both sexes (figure 1B,C).

There was a significant relationship between the number of risks based on the physical performance tests and the demand for personal care. The ORs and 95% CIs for personal care in participants with 1, 2, 3 and 4 risks were 3.1 (2.6 to 3.8), 10.6 (8.7 to 13.1), 35.6 (28.6 to 44.5) and 141.3 (103.6 to 192.7), respectively, compared with participants without risks ($p<0.001$). Figure 2 shows the distributions of the number of risks for demand for personal care. The rates of participants with personal care who had no risk, 1, 2 and 3 or more risks were 8.7%, 38.5%, 75.6% and 90.0%, respectively (figure 2).

DISCUSSION

Neuromuscular function, including muscle strength, balance and gait, and cognitive function are important risk factors for disability. Performance-based assessment of these factors can be used to identify people at an increased risk of future functional decline. We examined the use of various measures to identify the most useful measure for screening the demand for personal care.

Cut-points of demand for personal care

In the current study, univariate analyses identified all physical tests as being able to discriminate between participants with and those without personal care. When performance was dichotomised for cut-points, GS, CST, CWS and TUG retained statistically significant relationships with personal care. The CWS test (cut-point, 1 m/s) displayed the highest OR in the final model, with good sensitivity and specificity with respect to

Table 3 Relationships between physical performances and the demand for personal care

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
GS (men: <26 vs ≥26 kg, women: <17 vs ≥17 kg)	20.9 (18.6 to 23.5)*	8.5 (7.4 to 9.7)*	4.1 (3.5 to 4.8)*
CST (≥10 vs <10 s)	6.6 (6.1 to 7.3)*	4.1 (3.7 to 4.7)*	1.3 (1.1 to 1.5)*
CWS (<1 vs ≥1 m/s)	34.7 (30.9 to 39.0)*	17.5 (15.3 to 20.0)*	5.9 (5.0 to 6.9)*
TUG (≥11 vs <11 s)	27.1 (24.1 to 30.5)*	15.3 (13.4 to 17.6)*	4.0 (3.4 to 4.8)*

*p<0.01.
Model 1 was crude ORs and Model 2 was adjusted for age, sex and cognitive impairment. Model 3 was adjusted for age, sex, cognitive impairment and physical performances.
CST, chair stand test; CWS, comfortable walking speed; GS, grip strength; TUG, timed up-and-go test.

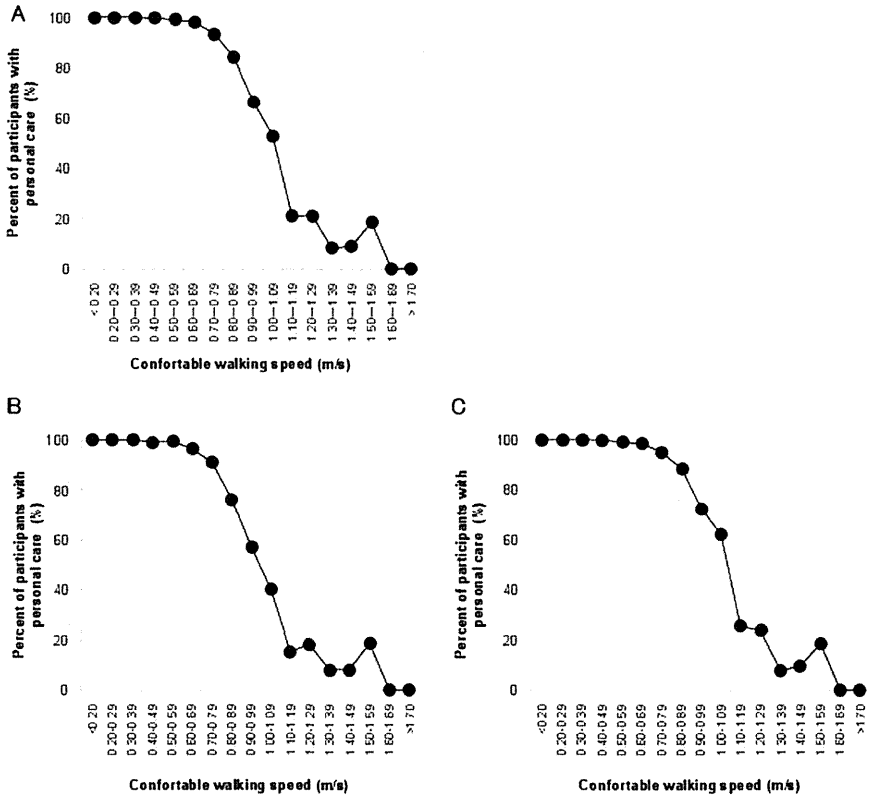

Figure 1 Comfortable walking speed distributions of participants with personal care in all participants (A), men (B) and women (C). The rate of participants with personal care markedly decreased at 1.0 m/s and faster at a comfortable walking speed.

identifying participants with personal care. At identified cut-points, GS (men, 26 kg; women, 17 kg), CST (10 s) and TUG (11 s) could also significantly discriminate participants with personal care with sensitivities and specificities of 67–89%. This result highlights what can occur when dichotomised rather than continuous data are used. There is an associated loss of information and reduced predictive accuracy as a trade-off for ease of scoring and test interpretation. These results, however, are consistent with previous findings that showed associations between measures of muscle strength and mobility and functional decline.[18]

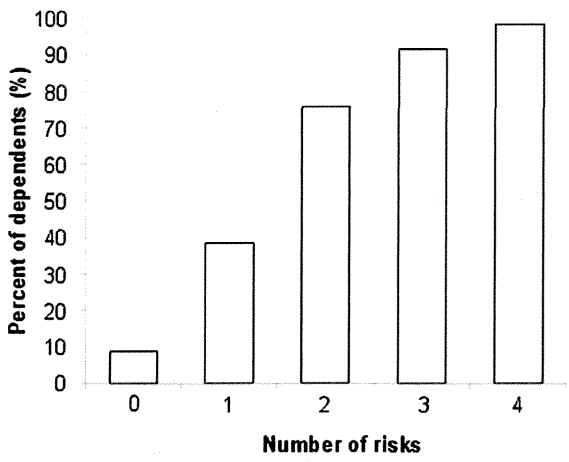

Figure 2 Participants with personal care according to the number of risks identified by cut-points of physical performance tests. Percentages of participants with personal care who had no risk, 1, 2 and 3 or more risks were 8.7%, 38.5%, 75.6% and 90%, respectively.

Gait speed and personal care

Gait velocity, as measured by the CWS test in this study, has been consistently reported to differentiate between participants with and those without personal care, with frail older persons walking significantly slower,[10 19] and has proved to be a strong predictor of adverse events, such as disability,[18 20–25] mortality,[21 22 26 27] hospitalisation[21 22 24 28] and falls.[28 29] Gait slowing, which occurs in the latest stages of life, suggests that mobility is so central to life that energy is shifted away from walking activity only when other vital activities are threatened,[30] which may lead to increased functional independence. In addition, a slower walking speed is an associated factor for subsequent dementia.[31] Dementia is one of the most important factors of health problems for functional decline in the aged population. For our study sample, the cut-point for CWS was 1 m/s, which is the critical point for future functional decline in community-dwelling older people determined by previous studies.[18 21 22 24 25] These results suggest that walking speed may be the most crucial measurement to determine the demand for personal care in older adults. Measurement of walking speed is reliable, valid,

sensitive, inexpensive, safe, quick and a simple tool. Therefore, measurement of walking speed is suitable to use in community settings as a screening tool and evaluation for the effect of a care prevention programme.

Muscle strength and mobility and personal care

In the current study, higher ORs were found for GS and TUG, as well as CWS. Hand GS is an estimate of isometric strength in the upper extremity, but also correlates with strength in other muscle groups,[32] and therefore, is considered an estimate of the overall strength. In addition, GS has proved to be a strong predictor of physical functioning and disability,[33 34] morbidity[35] and mortality.[36 37] Our findings support previous evidence and add cut-points of <26 kg in men and <17 kg in women that discriminate those at high-risk for disability in community-living older people. The TUG has been recommended as a screening tool for identifying older people who are at risk for falling.[38 39] Bischoff *et al*[40] proposed a normative cut-point of 12 s for community-dwelling elderly people between 65 and 85 years of age. In daily clinical practice, elderly persons who perform the TUG in >12 s should receive early evaluation and intervention. Our results regarding TUG cut-points are in line with these previous studies.

Strengths and limitations

Strengths of the present study include a large sample size and we used performance-based assessment, which could determine actual physical capacity and predict subsequent physical disability in community-living older people. However, the present study has a number of limitations. One of the limitations is that we analysed cross-sectional data. Therefore, further investigation of the validity of these tests in predicting the risk of disability in older people using a prospective study design is recommended. Another limitation is that many frail older people using healthcare services cannot walk because they have multiple diseases or geriatric syndromes. Non-ambulatory participants were excluded from our study. Therefore, we acknowledge that the study findings may not be generalised to this frailer group.

CONCLUSIONS

This study provides preliminary evidence that clinical tests of physical performances can predict the risk of disability in older people. Logistic regression analysis selected CWS as the best independent correlate of disability, with good sensitivity and specificity. Further investigation is required, and future research should include a prospective measurement of the risk of disability to more accurately determine the validity of screening tests for this population.

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Contributors HS designed and organised the study, analysed and interpreted the data, and drafted the manuscript. TS and MS made substantial contributions to the conception, design, analysis and interpretation of the data, and critically revised the draft. All authors took responsibility for the accuracy and integrity of the study. All authors gave the final approval of the version to be published.

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Competing interests None.

Patient consent Obtained.

Ethics approval Ethics Committee of the National Center for Gerontology and Geriatrics.

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Data sharing statement No additional data are available.

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Performance-based assessments and demand for personal care in older Japanese people: a cross-sectional study

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ORIGINAL ARTICLE

Using two different algorithms to determine the prevalence of sarcopenia

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Aim: Several operative definitions and screening methods for sarcopenia have been proposed in previous studies; however, the opinions of researchers still differ. We compared the prevalence of sarcopenia using two different algorithms: (i) the European working group on sarcopenia in older people (EWGSOP)-suggested algorithm using gait speed as the first step; and (ii) the muscle mass and strength algorithm.

Methods: A population-based, cross-sectional survey of adults aged over 65 years was carried out. Data on a total of 4811 participants were available for analysis. Gait speed, grip strength and appendicular skeletal muscle mass were assessed to determine sarcopenia. Appendicular skeletal muscle mass was estimated from bioimpedance analysis measurements and expressed as skeletal muscle mass index. Grip strength and skeletal muscle mass index were considered to be low if they fell below the threshold of the lowest 20% of values measured in a subset of healthy subjects. We compared the prevalence rates of sarcopenia determined by the two algorithms.

Results: The prevalence rate of sarcopenia in a representative sample of older Japanese adults was 8.2% for men and 6.8% for women based on the EWGSOP algorithm. The two algorithms identified the same participants as sarcopenic, the only difference being the EWGSOP algorithm classified an additional seven participants (0.15%) into sarcopenia compared with the muscle mass and strength algorithm.

Conclusion: It is debatable whether inclusion of gait speed is necessary when screening for sarcopenia in community-dwelling older adults. Future research should examine the necessity of including gait speed in algorithms and the validity of cut-off values. **Geriatr Gerontol Int 2014; 14 (Suppl. 1): 46–51.**

Keywords: aging, prevalence, sarcopenia.

Introduction

Several changes in body composition occur with the aging process (e.g. a decrease in bone and muscle mass, and an increase in the proportion of fat).[1,2] Lower muscle mass is associated with decreased strength, and might lead to the development of functional limitations and disability in old age.[3–6] Advanced skeletal muscle loss could also potentially have an impact on quality of life, the need for supportive services and ultimately the need for long-term care in older persons.[5] Thus, it is important to develop a valid and feasible method to screen older adults for sarcopenia, and to establish a preventive strategy for sarcopenia in older people.

Although operative definitions and screening methods for sarcopenia have been proposed in previous studies, the opinions of researchers have been conflicting.[3,7–10] Recently, a European working group on sarcopenia in older people (EWGSOP) published their recommendations for a clinical definition, and consensus diagnostic criteria, for sarcopenia.[10] In that report, the EWGSOP suggested an algorithm using the presence of both low muscle mass and low muscle function, including strength and gait performance, for the diagnosis of sarcopenia. Low gait performance is the first step to identify sarcopenia in the EWSOP algorithm. Thus, it is possible that older adults with high gait

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performance would not be categorized as sarcopenic, even if they had evident muscle atrophy.

The term "sarcopenia" was coined by Rosenberg in 1989 to refer to the process of age-related loss of skeletal muscle mass.[11] Originally, "sarcopenia" derives from the Greek words *sarx* (meaning flesh) and *penia* (meaning loss), and this term is used to refer specifically to the gradual loss of skeletal muscle mass and strength that occurs with advancing age.[12] According to the original meaning, the definition and diagnosis of sarcopenia should be based on the reduction of muscle mass and strength. Furthermore, sarcopenia is a fundamental component of frailty, and it can be seen as one dimension of frailty. Frailty is a geriatric syndrome resulting from age-related cumulative declines across multiple physiological systems, and is characterized by the following five domains: unintended weight loss, self-reported exhaustion, weakness (reduced grip strength), slow gait speed and low levels of physical activity.[13] If sarcopenia patients are screened according to gait speed, sarcopenia becomes roughly synonymous with frailty, and it could confuse interpretation of both sarcopenia and frailty.

The purpose of the present study was to compare the difference in prevalence of sarcopenia determined using two different algorithms: (i) the EWGSOP algorithm, using gait speed as the first step; and (ii) the muscle mass and strength algorithm, and to examine whether gait speed should be a critical component for screening sarcopenia.

Methods

Participants

The present study was based on data collected as part of the Obu Study of Health Promotion for the Elderly (OSHPE), carried out in Obu, Aichi, Japan, from August 2011 to February 2012. OSHPE initially sent postal invitations to 14 313 persons aged 65 years and older, resident in the city of Obu. Individuals who had participated in previous studies, were hospitalized and/or in residential care, or were certified as requiring more than level 3 care needing support or care by the Japanese public long-term care insurance system were excluded from participation in OSHPE. A total of 5104 persons responded and agreed to participate in the present study (response rate: 35.7%). The overall survey consisted of face-to-face interviews on health status, physical and cognitive function tests, and body composition, among other items. Major chronic illnesses were assessed by nurses through face-to-face interviews. Chronic illnesses included in the study were hypertension, hyperlipidemia, diabetes mellitus, heart disease, stroke, Parkinson's disease, dementia, clinical depression, cancer, lung disease, osteoporosis and arthritis (rheumatoid and osteoarthritis).

Of the 5104 OSHPE participants, we excluded those with missing data on body composition, gait speed or muscle strength. Data on 4811 participants (94.3% of all participants, 2343 men and 2468 women) were available for this analysis. All participants were informed about the study procedures and provided written informed consent before participation. In addition, this study was carried out in accordance with the Helsinki Declaration, and was approved by the ethics committee of the National Center for Geriatrics and Gerontology.

Assessment of appendicular muscle mass

A multifrequency bioelectrical impedance analyzer (MC-980A; Tanita, Tokyo, Japan) was used to measure bioimpedance. This bioelectrical impedance analysis (BIA) instrument uses six electrical frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1000 kHz), and we calculated the impedance index, height^2 (cm) divided by resistance (Ω). The participants stood barefoot on the analyzer platform, grasping the two handgrips. Eight-point tactile electrodes made contact with the palm and thumb of each hand, and with the anterior and posterior aspects of the sole of each foot. Surface electrodes were placed on the right side of the body, on the dorsal surface of the hands and feet proximal to the metacarpal- and metatarsal-phalangeal joints, respectively, medially between the distal prominences of the radius and ulna, and between the medial and lateral malleoli at the ankle. Measurements were carried out by trained staff, and completed within 30 s.

We estimated appendicular skeletal muscle mass (ASM) using the following equations that were developed for Japanese older adults:[14]

$$\text{Men: ASM} = 0.197 \times (\text{impedance index}) + 0.179 \times (\text{weight}) - 0.019$$

$$\text{Women: ASM} = 0.221 \times (\text{impedance index}) + 0.117 \times (\text{weight}) + 0.881$$

Skeletal muscle mass index (SMI) was calculated as ASM / height.^{2}

Measurement of muscle strength

Maximal voluntary isometric strength of handgrip was measured using a hand dynamometer Grip-D (Takei, Niigata, Japan). The measurement was taken with the dominant hand in a standing position. The muscle strength test was carried out once only. Handgrip strength has been widely used to measure muscle strength and correlates well with most relevant outcomes.[15]

Measurement of gait speed

Participants were asked to walk 6.4 m (divided into two 2.0-m zones at each end, and a 2.4-m middle-zone) at their usual pace. We measured the required time (in seconds) to pass the 2.4-m middle zone to calculate gait speed (m/s). Use of a cane or walker was permitted if participants could not practice the gait test. The gait test was carried out five times, and the average value was used.

Gait speed is a valid and widely used measure of mobility limitation for both healthy and impaired older persons,[16] with high predictive validity for subsequent disability, hospitalization and mortality.[17,18]

Algorithm and cut-off values to determine sarcopenia

We used the EWGSOP-algorithm as one method to determine the individuals with sarcopenia. We also used the muscle mass and strength algorithm. The EWGSOP recommends use of normative (healthy young adult) rather than other predictive reference populations, with cut-off points (for muscle mass and strength) at two standard deviations below the mean reference value.[10] However, no reference data from a normative Japanese population were available with which to determine cut-off values for grip strength and SMI. In the absence of normative reference populations, previous studies have used healthy older adults as their reference groups (applying cut-off points derived from the lowest sex-specific quartiles[13] or quintiles[9,19]). To overcome this limitation, we selected a healthy subset of people from our study, and used their sex-specific quintile points (lowest 20%) as cut-off values. This healthy subset was defined as follows: no impairment of activities of daily living, no medical history (stroke, Parkinson's disease, Alzheimer's disease or other serious neurological diagnoses, depression), gait speed ≥1.0 m/s and Mini-Mental State Examination (MMSE) score ≥21. Participants were classified as "low level" when their grip strength or SMI values fell below the cut-off points. In the EWGSOP-algorithm, a gait speed at 0.8 m/s is used as the cut-off value.[10]

Statistical analysis

Differences in age, body mass index (BMI), SMI, gait speed, grip strength, and MMSE score were compared between those with and without sarcopenia using *t*-tests by sex. The prevalence of major chronic illnesses was also compared between those with and without sarcopenia using χ^2-tests. All analysis was carried out using commercially available software, IBM SPSS statistics (version 19; SPSS, Chicago, IL, USA), and the level of significance was as set at $P < 0.05$.

Results

Determination of the cut-off values for sarcopenia

A total of 3810 (74.6% of all participants, 1848 men and 1962 women, mean age 71.2 ± 4.9 years) were included in the healthy subset of people used to determine cut-off values. Cut-off values of grip strength were set at 28.8 kg and 18.2 kg for men and women, respectively. Similarly, cut-off values of SMI were set at 7.09 kg/m^2 in men and 5.91 kg/m^2 in women.

Prevalence and characteristics of sarcopenia

Data on a total of 4811 participants (94.3% of all participants, 2343 men and 2468 women) were available for analysis. The mean age was 72.2 ± 5.5 years in men and 72.1 ± 5.7 in women. The mean SMI was 7.71 ± 0.79 kg/m^2 in men and 6.51 ± 0.70 kg/m^2 in women.

According to the EWGSOP-algorithm, 7.5% (n = 360) of all participants were classified as having sarcopenia. The prevalence of sarcopenia was 8.2% for men and 6.8% for women, but this difference was not significant ($P = 0.09$). The prevalence of sarcopenia increased with age in both men and women, with people aged 80 years and older having the highest prevalence rates (25.0% in men and 12.2% in women, Fig. 1).

The characteristics of normal and sarcopenic participants are summarized in Table 1. Compared with the normal participants, both male and female sarcopenic participants were significantly older ($P < 0.01$) and had lower BMI ($P < 0.01$). In addition, there were significant differences in the proportions of participants with hypertension ($P < 0.01$) and osteoporosis ($P < 0.01$).

We also calculated the prevalence of sarcopenia using the muscle mass and strength algorithm, and compared the prevalence of sarcopenia determined using the two methods (Fig. 2). The present results showed that the two algorithms produced similar overall estimates of sarcopenia prevalence (7.5% *vs* 7.3% using the

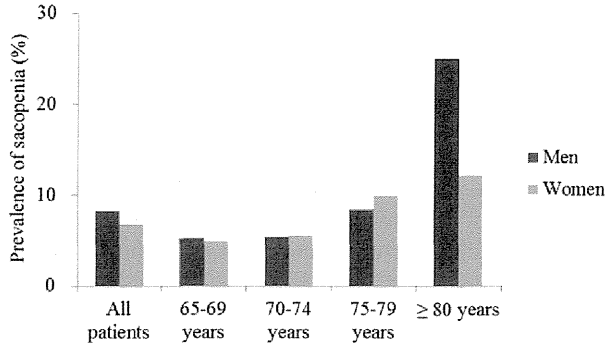

Figure 1 The prevalence of sarcopenia by age category and sex.