Differential association of frailty with cognitive decline and sarcopenia in community-dwelling older adults

Running Title: Frailty with cognitive decline and sarcopenia

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Keywords: Frailty, cognitive decline, sarcopenia, community-dwelling older adults
Abstract:

Objectives: Frailty in older adults is a serious problem due to various adverse health outcomes in many countries with aging populations, such as Japan. The purpose of this study was to determine whether frailty and pre-frailty are associated with cognitive decline and sarcopenia in community-dwelling older adults.

Design: This is a cross-sectional study.

Setting: Japan.

Participants: The participants were 273 Japanese community-dwelling older women aged 65 years and older.

Measurements: We used the frailty criteria developed by the Cardiovascular Health Study to define physical frailty. We divided the cohort into non-frail, pre-frail, and frail according to frailty scores. Cognitive decline and memory decline were defined by using the Mini-Mental State Examination and Scenery Picture Memory Test, respectively. Sarcopenia was defined according to the diagnostic algorithm recommended by the Asian Working Group for Sarcopenia.

Results: In the multivariate logistic regression analysis by using non-frail participants as the reference, pre-frail elderly individuals were significantly more likely to have sarcopenia than non-frail elderly individuals (odds ratio [OR]: 2.77, 95% confidence interval [CI]: 1.05–9.26), but not cognitive decline or memory decline. Frail elderly individuals were significantly more likely to have cognitive decline (OR: 5.76, 95% CI: 1.20–27.6), memory decline (OR: 5.53, 95% CI: 1.64–18.7) and sarcopenia (OR: 19.1, 95% CI: 3.73–98.0) than non-frail elderly individuals.

Conclusions: Sarcopenia was associated with pre-frailty and frailty, while cognitive decline was
associated only with frailty.
Highlights

- We studied the association of physical frailty with cognitive decline and sarcopenia.
- We focused on the level of frailty in community-dwelling older adults.
- Frailty, but not pre-frailty, was associated with cognitive and memory decline.
- Both frailty and pre-frailty were associated with sarcopenia.
Introduction

Frailty in older adults is a serious concern in countries with aging populations, such as Japan. In general, frailty is defined as a vulnerable state that places older adults at high risk for adverse health outcomes, such as falls, hospitalization, and mortality. 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%, and was greater in women than in men. In Japanese, the prevalence of frailty in community-dwelling adults aged 65 or older was 11.3%, and it increased with aging. Frail older adults are considered to have a substantially increased risk of disability, dependency, and need for long-term care insurance. Therefore, prevention and early detection of frailty is important for addressing age-related health care issues.

The causes of frailty are not clearly defined, but it has been suggested that age-related physical changes are the main causes of frailty. Sarcopenia, defined as progressive loss of skeletal muscle mass, strength, and physical function, is regarded as a key component of physical frailty. The Interventions on Frailty Working Group assessed various methods for screening, recruiting, evaluating, and retaining frail elderly individuals in clinical trials. They reported that most researchers focused on the following domains when identifying 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. Age-dependent loss of skeletal muscle mass is a multifactorial process; contributing factors include physical inactivity, malnutrition, oxidative stress, changes in endocrine function, and...
increases in inflammatory cytokines.\textsuperscript{5} Thus, the domains of frailty overlap with the factors related to sarcopenia, and both frailty and sarcopenia mutually result in adverse health outcomes \textsuperscript{5, 6}.

Of note, some definitions of frailty include cognitive function and dementia \textsuperscript{4, 8}. Several cross-sectional studies have reported an association between physical frailty and cognitive function \textsuperscript{1, 7, 9, 10}. In addition, longitudinal studies have revealed that a higher level of physical frailty is associated with increased risk of incident Alzheimer’s disease (AD)\textsuperscript{11} and mild cognitive impairment (MCI) \textsuperscript{12}. It has been indicated that frailty is associated with AD pathology \textsuperscript{13} and its biological mechanisms \textsuperscript{14}. However, not all dementia patients become frail; therefore, the association between frailty and cognitive impairment warrants further study.

Frailty is associated with sarcopenia and cognitive decline. Furthermore, frailty has been considered to include other aspects, such as psychosocial issues and comorbidities \textsuperscript{15}. However, it is unclear whether the associations between frailty and cognitive decline as well as between frailty and sarcopenia are different according to the level of frailty. Therefore, the purpose of this study was to determine whether frailty and pre-frailty are associated with cognitive decline and sarcopenia in community-dwelling older adults.
Methods

Participants

Participants for this study were recruited through the local press; 273 Japanese women aged 65 years and older (mean age 73.0 ± 5.4 years) responded. We included community-dwelling older adults who were independent in activities of daily living (ADLs). Participants were interviewed and excluded if they met any of the following criteria: severe cardiac, pulmonary, or musculoskeletal disorders; severe neurological disorders, such as Parkinson disease and stroke; and participation in Japan’s long-term care service. The following data were collected from each participant: age, height, weight, and number of medications being consumed.

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

Assessment of frailty

We measured physical frailty domains determined in a previous study. As in that study, we considered the frailty phenotype to be characterized by limitations in the following five domains by using frailty criteria developed by the CHS: slowness, weakness, exhaustion, low activity, and shrinking. To measure slowness, each participant’s 10-m normal walking speed (m/s) was calculated, and a slow walk was defined as <1.0 m/s. To measure weakness, low grip strength was established according to a sex-specific cutoff of the average grip strength in each arm (women:
Exhaustion was assessed via self-report by using the Geriatric Depression Scale [16] i.e., exhaustion was defined as a negative (“no”) answer to the question “do you feel full of energy?” 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 a participant answered “no” to both of these questions, then we considered their physical activity to be low. Shrinking 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?” If a participant answered “yes” to this question, then we considered them to have shrunk. We calculated the number of affected domains and classified participants as follows: pre-frailty = 1 or 2, frailty > 3.

**Measurement of cognitive function**

Participants’ cognitive function was measured by using two neuropsychological tests: the Mini-Mental State Examination (MMSE) [17] and the Scenery Picture Memory Test (SPMT) [18].

Global cognitive function was assessed by using the MMSE, a standard test in cognitive aging research to assess mental status. The MMSE tests five areas of cognitive function: orientation, registration, attention and calculation, recall, and language. It has 11 questions and a possible maximum score of 30. We divided the participants into a normal or a cognitive decline group based on a cut-off of 23/24 as the MMSE score [19].

The SPMT is a simple memory test that assesses visual memory combined with verbal
responses. This test uses a line drawing of a living room in a house with 23 objects commonly observed in daily life on an A4 piece of paper. The examinee is instructed to look at the picture for 1 minute and remember the items. After this encoding period, participants are distracted by completing a brief digits forward test. Participants are then asked to recall the objects in the picture without a time limitation. The recall usually takes approximately 2 minutes. The number of items recalled is the score for the SPMT. We divided the participants into a normal or memory decline group based on a cut-off of 9/10 as the SPMT score. 

**Definition of sarcopenia**

We defined sarcopenia by using the diagnostic algorithm recommended by the Asian Working Group for Sarcopenia (AWGS), which assesses the presence of both low muscle function (low physical performance or low muscle strength) and low muscle mass. A bioelectrical impedance data acquisition system (Inbody 430; Biospace Co, Ltd, Seoul, Korea) was used to perform bioelectrical impedance analysis. This system uses electrical current at multiple frequencies (5, 50, 250, 500, and 1000 kHz) to directly measure the amount of extracellular and intracellular water. Participants stood on two metallic electrodes and held metallic grip electrodes. Using segmental body composition, appendicular skeletal muscle mass was determined and used for further analysis. Skeletal muscle mass index (SMI) was calculated by dividing muscle mass by height squared in meters (kg/m²). This index has been used in several epidemiological studies. If a participant had both low muscle function (slow walking speed, ≤0.8 m/s; low grip strength for women, ≤18 kg) and low SMI (low muscle mass for women, ≤5.7 kg/m²), then they were defined as...
having sarcopenia

Statistical analysis

Prior to the analysis, we classified participants into the following three groups according to their frailty score: non-frailty, pre-frailty, and frailty. Differences in the demographic variables, MMSE, SPMT, and SMI among the three groups were examined by using the analysis of variance (ANOVA). When a significant effect was found, differences were determined with the Tukey-Kramer post-hoc test. Differences in the prevalence of cognitive decline, memory decline, and sarcopenia among the three groups were evaluated by using the chi-square test. In addition, multivariate logistic regression analyses, adjusted for age, BMI, and medications, were performed to determine whether physical frailty was associated with cognitive decline, memory decline, or sarcopenia. For this analysis, cognitive decline, memory decline, and sarcopenia were dependent variables, while the three frailty groups (dummy coded with non-frailty group as the reference group) were independent variable. Subsequent multivariate logistic regression analyses were performed to determine the independent association between each level of frailty and the risk of cognitive decline or sarcopenia. In these subsequent analyses (adjusted for age and medications), the frailty groups were the dependent variables, and cognitive decline and sarcopenia were independent variables. Odds ratios (ORs) with 95% confidence intervals (CI) were presented. Statistical analyses were carried out by using SPSS Statistics for Windows, version 20.0 (SPSS Inc. Chicago, IL, USA), with a significance threshold of 0.05.
Results

Demographic data for participants stratified by frailty group are shown in Table 1. There were 89 participants (32.6%) in the non-frailty group, 155 participants (56.8%) in the pre-frailty group, and 29 participants (10.6%) in the frailty group. ANOVA showed that there were significant differences in age, walking speed, and grip strength among the three groups (Table 1). In the chi-square test, there were significant differences in the prevalence of cognitive decline, memory decline, and sarcopenia (Table 1). In addition, the frailty group had significantly lower MMSE (F = 6.78, p = 0.001, Figure 1a) and SPMT (F = 18.5, p < 0.001, Figure 1b) than the non-frailty and pre-frailty groups, and lower SMI (F = 5.17, p = 0.006, Figure 1c) than the non-frailty group.

Eighteen participants (6.6%) had cognitive decline, 20 participants (7.3%) had memory decline, and 23 participants (8.4%) had sarcopenia. In the multivariate logistic regression analysis after adjustment for age, BMI, and medications, by using non-frailty group as the reference, the pre-frailty group was significantly more likely to have sarcopenia (OR: 2.77, 95% CI: 1.05–9.26, p = 0.044), but not cognitive decline or memory decline (Table 2). The frailty group was significantly more likely to have cognitive decline (OR: 5.76, 95% CI: 1.20–27.6, p = 0.029), memory decline (OR: 5.53, 95% CI: 1.64–18.7, p = 0.006), and sarcopenia (OR: 19.1, 95% CI: 3.73–98.0, p < 0.001) (Table 2).

In the logistic regression analysis in which the frailty groups were the dependent variables and cognitive decline and sarcopenia were independent variables, cognitive decline was independently only associated with a frailty score of ≥3 (OR: 3.73, 95% CI: 1.23–11.4, p = 0.020), while sarcopenia was independently associated with both pre-frailty (score ≥ 1; OR: 5.33, 95% CI: 1.88–14.4, p = 0.002), and frailty (OR: 19.1, 95% CI: 3.73–98.0, p < 0.001) groups.
1.22–23.3, p = 0.026) and frailty (score > 3; OR: 13.1, 95% CI: 4.98–34.2, p < 0.001). These associations remained significant after adjustment for age and medications (Table 3).
Discussion

The results of this study showed that frailty (defined as frailty score \( \geq 3 \)) was associated with cognitive decline, memory decline, and sarcopenia, and that pre-frailty (frailty score = 1 or 2) was associated with only sarcopenia. It is a new and interesting finding that there were differences in the association between physical frailty and cognitive decline, memory decline, and sarcopenia according to level of frailty.

In this study, we showed that frailty, but not pre-frailty, was associated with cognitive decline and memory decline. Our results also showed that frailty and pre-frailty were associated with sarcopenia, in contrast to cognitive and memory decline. In Japanese, multicenter, population-based studies, the prevalence of dementia was not high among those aged 65–74 years (less than 10%), but was higher among those aged 75 years and older 24. The prevalence of sarcopenia exhibited the same tendency, with the prevalence rising among those aged 75 years and older 25, 26. Thus, older adults (particularly those 75 and older) are prone to both cognitive impairment and sarcopenia. However, low physical performance, low physical strength, and the decrease of muscle mass, which overlap with both sarcopenia and frailty, can be found from middle age 27-29. Thus, as shown in the results of this study, it is possible that sarcopenia is associated with frailty at an earlier stage than is cognitive impairment, and that sarcopenia is affected more by frailty than is cognitive impairment.

A recent study investigated the association of physical frailty and pre-frailty with dementia and cognitive impairment 30. In that study, physically frail older adults were over four times more likely to have AD, and eight times more likely to have cognitive impairment than robust older adults were.
Pre-frail older adults showed an increased risk for dementia in the aforementioned study, but some estimates were not statistically significant in the fully adjusted models. The results of that study were consistent with our study. Previous studies indicated that frailty is associated with AD pathology and biological mechanisms, such as diffuse neuritic plaques, oxidative stress, and inflammation. It is also possible that frailty and AD share common lifestyle risk factors, such as physical inactivity and smoking, that lead to their pathophysiology, which contributes simultaneously to physical frailty and AD. On the other hand, it has been indicated that comorbidities caused by cognitive impairment were also associated with frailty in AD or MCI patients. Thus, it is likely that these associations interact with one another, leaving the causal association between physical frailty and cognitive decline unclear. Further studies are required to understand these associations.

Definitions of frailty and sarcopenia overlap, and sarcopenia is considered one of the core symptoms of physical frailty. The causal mechanisms underlying sarcopenia can be oxidative stress, dysregulation of inflammatory cytokines and hormones, malnutrition, physical inactivity, and muscle apoptosis, all of which have been hypothesized to contribute to frailty through interactive pathways. Recently, the definition of sarcopenia has been the coexistence of low muscle mass and low physical performance, which are contained in frailty domains. Thus, the association of sarcopenia with even pre-frailty seems reasonable. Overlapping intervention strategies (e.g., nutritional supplementation and exercise) may be required to prevent both frailty and sarcopenia.

During recent years, the definition of frailty has been changing. Frailty has been considered to include other aspects, for instance social aspects and comorbidities. In addition to these aspects,
poor cognition needs to be included in the definition of frailty, as shown in previous studies \(^4,^8\) and 

by this study. Furthermore, this study indicated that poor cognition was associated with frailty, and 

that sarcopenia was associated even with pre-frailty. The results indicate that we need to 

understand the consecutive mechanism as well as the association of pre-frailty and frailty with 

cognitive decline, sarcopenia, and other adverse health outcomes. Interventions may need to be 

tailored to the level of frailty to effectively prevent various functional declines. Future studies should 

investigate these intervention strategies.

There were several limitations to this study. First, the cross-sectional design prevented us from 

establishing causal associations between frailty and cognitive decline or sarcopenia. Second, the 

findings in this study should be considered preliminary owing to the relatively small sample size, 

which may introduce some error of inference, reduce the power of analysis, and limit generalization. 

Third, the design of this study was not a population sampling, and participants in this study were 

independent in ADLs. This may lead to an underestimation of the prevalence of frailty, cognitive 

decline, and sarcopenia, as the participants were relatively healthy elderly persons.

In conclusion, our results indicate that there were differences in the association between physical 

frailty and cognitive decline, memory decline, and sarcopenia according to the level of frailty. 

Cognitive decline and memory decline were associated with frailty. Sarcopenia was associated with 

pre-frailty and frailty. Further studies are required to understand these associations including 

biological mechanisms.
Acknowledgements

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Conflict of Interest: The authors declare no conflicts of interest.
References


### Table 1. Demographic differences according to frailty scores

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 273)</th>
<th>Non-frailty (n = 89)</th>
<th>Pre-frailty (n = 155)</th>
<th>Frailty (n = 29)</th>
<th>p for trend</th>
<th>Post-hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>73.0 ± 5.4</td>
<td>73.1 ± 4.6</td>
<td>72.3 ± 5.6</td>
<td>76.6 ± 5.1</td>
<td>&lt;0.001†</td>
<td>a, b</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.5 ± 3.2</td>
<td>22.2 ± 3.0</td>
<td>22.7 ± 3.3</td>
<td>21.9 ± 3.8</td>
<td>0.291 –</td>
<td>–</td>
</tr>
<tr>
<td>Medications</td>
<td>2.32 ± 2.24</td>
<td>2.18 ± 2.35</td>
<td>2.23 ± 2.10</td>
<td>3.27 ± 2.55</td>
<td>0.072 –</td>
<td>–</td>
</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>1.40 ± 0.20</td>
<td>1.43 ± 0.18</td>
<td>1.41 ± 0.20</td>
<td>1.21 ± 0.20</td>
<td>&lt;0.001†</td>
<td>a, b</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>22.4 ± 4.0</td>
<td>23.4 ± 3.4</td>
<td>22.6 ± 3.8</td>
<td>18.3 ± 4.1</td>
<td>&lt;0.001†</td>
<td>a, b</td>
</tr>
<tr>
<td>Cognitive decline (n)</td>
<td>18 (6.56%)</td>
<td>4 (4.49%)</td>
<td>9 (5.81%)</td>
<td>5 (17.2%)</td>
<td>0.047*</td>
<td></td>
</tr>
<tr>
<td>Memory decline (n)</td>
<td>20 (7.33%)</td>
<td>6 (6.74%)</td>
<td>4 (2.58%)</td>
<td>10 (34.5%)</td>
<td>&lt;0.001†</td>
<td></td>
</tr>
<tr>
<td>Sarcopenia (n)</td>
<td>22 (8.06%)</td>
<td>2 (2.25%)</td>
<td>9 (5.81%)</td>
<td>11 (37.9%)</td>
<td>&lt;0.001†</td>
<td></td>
</tr>
</tbody>
</table>

BMI = body mass index

Non-frailty was defined as frailty score of 0, pre-frailty was score 1 or 2, frailty was score 3 or greater.

Cognitive decline was defined as the cut-off of MMSE score (23/24).

Memory decline was defined as the cut-off of SPMT score (9/10).

Sarcopenia was defined by using the AWGS-recommended diagnostic algorithm.

*: p < 0.05, †: p < 0.01

a, significant difference between frailty and non-frailty (p < 0.01)

b, significant difference between score frailty and pre-frailty (p < 0.01)
Table 2. Relationship between the level of frailty and cognitive decline, memory decline, and sarcopenia

<table>
<thead>
<tr>
<th>Frailty level</th>
<th>Cognitive decline</th>
<th>Memory decline</th>
<th>Sarcopenia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>p</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>Non-frailty</td>
<td>1 [Reference]</td>
<td>-</td>
<td>1 [Reference]</td>
</tr>
<tr>
<td>Pre-frailty</td>
<td>1.79 (0.47–6.84)</td>
<td>0.394</td>
<td>0.37 (0.10–1.36)</td>
</tr>
<tr>
<td>Frailty</td>
<td>5.76 (1.20–27.6)</td>
<td>0.029*</td>
<td>5.53 (1.64–18.7)</td>
</tr>
</tbody>
</table>

The analyses for cognitive decline and memory decline were adjusted for age, BMI, and medications. The analysis for sarcopenia was adjusted for age and medications.

*: p < 0.05, †: p < 0.01
Table 3. Independent relationship between each level of frailty and cognitive decline or sarcopenia

<table>
<thead>
<tr>
<th>Domains</th>
<th>Frailty score</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 1</td>
<td>≤ 2</td>
<td>≤ 3</td>
</tr>
<tr>
<td>Cognitive decline</td>
<td>OR (95% CI)</td>
<td>p</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td></td>
<td>1.76 (0.56–5.51)</td>
<td>0.331</td>
<td>1.43 (0.54–3.84)</td>
</tr>
<tr>
<td>Sarcopenia</td>
<td>OR (95% CI)</td>
<td>p</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td></td>
<td>5.33 (1.22–23.3)</td>
<td>0.026*</td>
<td>9.07 (3.22–25.5)</td>
</tr>
</tbody>
</table>

Note:
The multivariate analyses were adjusted for age and medications.
*: p < 0.05, **: p < 0.01
Figure 1. Comparison of the MMSE, SPMT, and SMI between the groups according to the level of frailty.

(a) There were significant differences in the MMSE scores between the three groups ($F = 6.78$, $p = 0.001$).

(b) There were significant differences in the SPMT scores between the three groups ($F = 18.5$, $p < 0.001$).

(c) There were significant differences in the SMI between the three groups ($F = 5.17$, $p = 0.006$).

*: $p < 0.05$, **: $p < 0.01$