Original Article

Differences and overlap between sarcopenia and physical frailty in older community-dwelling Japanese

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Background and Objectives: Sarcopenia and frailty result in loss of function and independence. Sarcopenia may be a risk factor for frailty; however, risk factors for sarcopenia with frailty, and associated incidence of falls and poor quality of life remain unclear. We investigated the clinical characteristics and relevant factors for sarcopenia with frailty in older community-dwelling Japanese. **Methods and Study Design:** This cross-sectional study included 331 Japanese community-dwelling adults aged ≥60 years. We assessed falls history in the past year, health-related quality of life (HRQOL), including physical component summary (PCS) and mental component summary (MCS), age, total energy intake per ideal body weight (TEI/kg IBW), total protein intake/kg IBW, vitamin D intake, and exercise habits. Sarcopenia was determined using low hand grip strength or slow gait speed and low skeletal muscle mass index. Frailty was determined if ≥3 components, such as unintended weight loss, exhaustion, low muscle strength, slow gait speed, and low physical activity were present. **Results:** The prevalence of sarcopenia with frailty was 3.6%; such participants had a higher risk of recurrent falls and lower PCS and MCS scores than robust participants. Age, TEI/kg IBW, total protein intake/kg IBW, and vitamin D intake were significantly associated with risk of sarcopenia with frailty by multivariate logistic regression analysis. **Conclusions:** This study showed that sarcopenia with frailty was had higher incidences of recurrent fall and poor HRQOL than robust older adults. Aging and poor energy, protein, and vitamin D intake, may be relevant factors for sarcopenia with frailty.

Key Words: frailty, health-related quality of life, incident of falls, older adults, sarcopenia

INTRODUCTION

Sarcopenia is defined as a loss of muscle mass in combination with a loss of muscle strength and/or physical performance.[1,2] Therefore, sarcopenia describes a progressive decline in muscle mass and function associated with aging, physical inactivity, poor nutritional status, and chronic disease, ultimately increasing the risk of adverse outcomes, such as physical disability.[2] The physical frailty phenotype was defined by Fried et al. as "a biologic syndrome of decreased reserve and resistance to stressors, resulting from cumulative declines across multiple physiologic systems, and causing vulnerability to adverse outcomes including falls, disability."[3] Both sarcopenia and frailty are geriatric syndromes resulting in a loss of functionality and independence. Current common definitions for frailty overlap considerably with those for sarcopenia, in relation to both muscle strength and physical function.[2] A previous study reported that sarcopenia may be a risk factor for frailty.[4] However, the previous study did not identify clinical characteristics and risk factors for overlap between sarcopenia and frailty. There is a possibility that older adults with sarcopenia and frailty have a high risk of incident falls and poor health-related quality of life (HRQOL).

The purpose of this study was to evaluate differences in clinical characteristics and relevant factors for sarcopenia and frailty and the overlap of their criteria in older community-dwelling Japanese. Additionally, we attempted to identify potential measures for the diagnosis of sarcopenia with frailty by evaluating total energy, protein, and vitamin D intake.

METHODS

Participants

This study was approved by the Ethics committee of Tokushima University (approval #2281). As per the Helsinki Declaration, we explained the contents of the study and the risk for participants both verbally and in writing. Written informed consent was obtained from the participants enrolled in this study. In this study, we recruited for older adults aged 60- to 85-years-old, at six community center (Kakogawa, Harima, Inami, Kato, Nishiwaki, Yokawa) from Harima community in Hyogo, Japan. A cross-sectional analysis was performed on each set of data obtained from January until December 2017.

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Manuscript received 28 June 2018. Initial review completed 22 August 2018. Revision accepted 02 September 2018.
doi: 10.6133/apjcn.201810/PP.0007

Assessment of body composition, muscle strength, and physical performance

Body weight, body mass index, and skeletal muscle mass were measured with a body composition analyzer (In-Body bioelectrical impedance analyzer, Biospace, Seoul, Republic of Korea) using multi-frequency bioelectrical impedance analysis. Skeletal muscle mass index (SMI) was calculated by dividing the upper- and lower-limb skeletal muscle mass by height squared.[2]

Muscle strength and physical performance measurements included grip strength, knee extension strength, gait speed, and the Timed Up and Go test (TUG).[5-7] Grip strength and knee extension strength were measured using handheld dynamometers (T.K.K 5401, Takei Scientific Instruments, Tokyo, Japan; μ-tus F-100, ANIMA, Tokyo, Japan). Knee extension muscle strength was calculated as the knee extension torque divided by current body weight (Nm/kg).[5]

Sarcopenia was defined using the Asian Working Group for Sarcopenia (AWGS) criteria, as follows: low hand grip strength or slow gait speed, and low SMI.[7] Frailty was determined based on criteria defined by Fried et al, with ≥3 of the following components present: unintended weight loss, exhaustion, low muscle strength, slow gait speed, and low physical activity.[3] The definition and cut-off value for sarcopenia and frailty in this study is shown in Supplementary table 1. In this study, participants who were not diagnosed with sarcopenia or frailty were defined as robust. Therefore, the participants were classified into four groups: robust, sarcopenia only, frailty only, and sarcopenia with frailty. Knee extension strength of <1.13 and 1.01 Nm/kg current body weight and slow TUG of >11.0 and 11.0 sec, for men and women respectively, were classified as poor muscle function.[6,8] Previous studies have shown that poor knee extension strength or slow TUG are important risk factors for incident falls.[6-8]

Incident of falls history

An interview assessed the participants' history of falls within a year. An incident fall was defined as one fall, and recurrent falls were defined as two or more falls. The "fall event" was considered a sudden loss of balance causing the contact of any part of the body above the feet with the floor.[9]

Assessment of HRQOL

HRQOL of the surveyed participants was estimated using the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36).[10] The SF-36 is one of the most widely used health-related quality of life measures and is a standardized questionnaire consisting of 36 questions/items measuring physical component summary (PCS) and mental component summary (MCS) in relation to health concepts. Higher scores represent better self-perceived health.

Nutritional survey

A nutritional survey was administered to document the total daily energy intake (TEI) and the total intake of protein, fat, and carbohydrate adjusted by ideal body weight (IBW), g/kg IBW/day, and the total vitamin D intake (μg/day). Nutrient intake was calculated based on the Fifth Revised Edition of the Standard Tables of Food Composition in Japan and the 2015 Japanese Dietary Reference Intakes by using nutrition calculation software (Excel Eiyou version 8.0, Kenpakusha, Tokyo, Japan).[11] The nutritional survey was conducted using a weighing method documenting the five consecutive days prior to the start of the study. In addition, if there were missing responses, individual interviews were conducted with the participant regarding their food intake status. Based on PROT-AGE study recommendations, the TEI and total protein intake required to maintain muscle mass and strength of older adults was suggested to be ≥25 kcal/kg IBW/day and ≥1.00 g/kg IBW/day, respectively.[12]

Assessment of physical activity

Physical activity was estimated using the diagnostic survey method with a short version of the International Physical Activity Questionnaire.[13] The data collected from these questionnaires were used to calculate the weekly energy consumption expressed in kilocalories (kcal/day, or week), and ≥1 days with no-exercise habits per week (%).

Clinical data

History of chronic disease, such as type 2 diabetes, hypertension, and dyslipidemia; systolic blood and diastolic blood pressure; glycated hemoglobin (HbA1c); and certification of long-term care requirement were collected from routine medical checkup records and face-to-face interviews.

Statistical analysis

SPSS Statistics 22 (IBM Japan, Tokyo, Japan) was used for statistical processing. All data were presented as mean ± standard deviation. Intergroup comparisons (step 1: robust, sarcopenia or frailty, step 2: robust, sarcopenia only, frailty only, sarcopenia with frailty) were assessed using an unpaired one-way analysis of variance (continuous variables) or chi-squared test (categorical variables). Comparisons between the groups for PCS and MCS were assessed using an analysis of covariance (ANCOVA), adjusted for age and sex. Uni- and multivariate logistic regression analyses were performed to assess the cross-sectional association of the severity of sarcopenia with frailty, sarcopenia only, and frailty only (input of covariates: age, type 2 diabetes, TEI [categorize variables to increase by 1.0 kcal/kg IBW/day], total protein intake [categorize variables to increase by 0.20 g/kg IBW/day], vitamin D [categorize variables to increase by 1.0 μg /day], and ≥1 days with no-exercise habits per week). Multivariate logistic regression analyses were performed to assess the cross-sectional association of the severity of low knee extension strength, slow TUG, and incident and recurrent falls (input of covariates: step 1; robust, sarcopenia only, step 2; robust, frailty only, step 3; robust, sarcopenia with frailty), adjusted for age and sex. The odds ratio (OR) with 95% confidence interval (CI) was calculated in the logistic regression models using a stepwise procedure. Finally, we used the receiver operating characteristic (ROC) curve and the area under the curve (AUC) to determine the cut-off values of age, TEI/kg IBW,

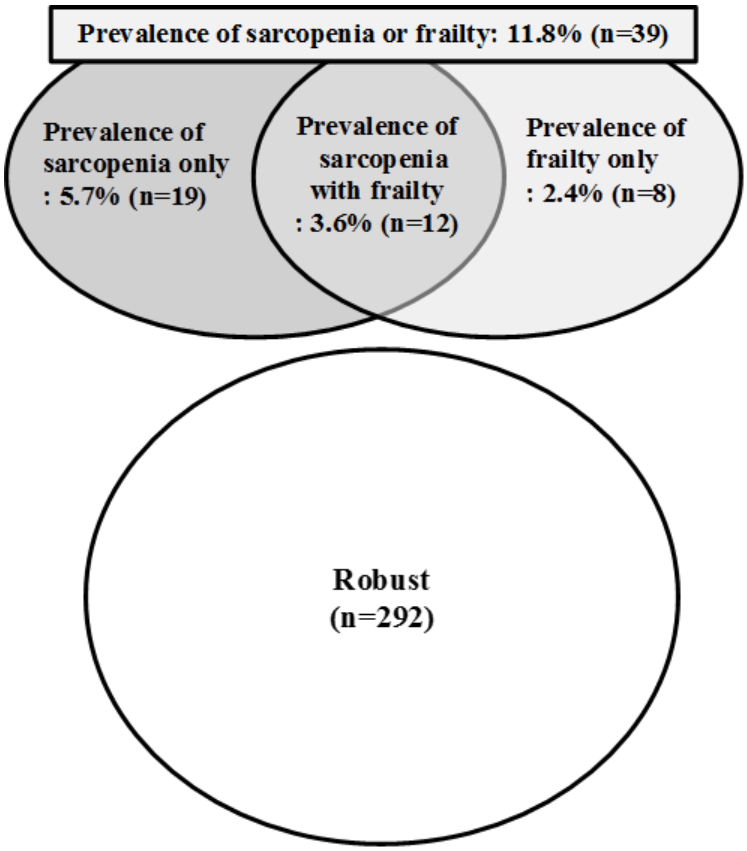

Figure 1. Overlap between sarcopenia with frailty in older community-dwelling Japanese

protein intake/kg IBW, and vitamin D intake for the diagnosis of sarcopenia with frailty. Statistical significance was defined as a $p<0.05$.

RESULTS

Differences in physical characteristics

The overlap between sarcopenia and frailty in older community-dwelling Japanese is shown in Figure 1. In the 331 participants (93 men, 238 women) enrolled in the study, the prevalence of sarcopenia or frailty was 11.8% (n=39). In addition, the prevalence of sarcopenia only, frailty only, and sarcopenia with frailty, 5.7% (n=19), 2.4% (n=8), and 3.6% (n=12), respectively.

The differences in physical characteristics between robust, sarcopenia only, frailty only, and sarcopenia with frailty groups are shown in Table 1 and Supplementary Table 2. Sarcopenia or frailty participants (n=39) were older and had a higher frequency of type 2 diabetes, no exercise habits, incident falls and recurrent falls, low knee extension strength, slow TUG, TEI <25.0 kcal/kg IBW, total protein intake <1.00 g/kg IBW, and lower total vitamin D intake, PMC and MCS than robust subjects. Sarcopenia with frailty participants (n=12) were older and had a higher frequency of type 2 diabetes, no exercise habits, incident falls and recurrent falls, low knee extension strength, slow TUG, TEI <25.0 kcal/kg IBW, total protein intake <1.00 g/kg IBW, and lower PMC and MCS than robust subjects. Further, this group were also older and had a higher frequency of recurrent falls than the sarcopenia only group (n=19). Adjusted for age and sex, sarcopenia with frailty subjects had lower PCS and MCS than robust subjects (PCS; $p<0.05$, MCS: $p<0.001$). Sarcopenia with frailty participants had lower PMC and MCS than robust subjects.

ORs of sarcopenia and frailty in older adults

The ORs for sarcopenia with frailty in older adults are shown in Table 2. Age, no exercise habits, type 2 diabetes, TEI/kg IBW, total protein intake/kg IBW, and vitamin D intake were significantly associated with sarcopenia with frailty in a univariate model. After adjustment for all covariates by stepwise regression, the association between age, TEI/kg IBW, total protein intake/kg IBW, and vitamin D intake remained significant (age: OR 1.61, 95% CI 1.23-2.11; TEI/kg IBW: OR 0.68, 95% CI 0.55-0.85; total protein intake/kg IBW: OR 0.19, 95% CI 0.05-0.69; total vitamin D intake: OR 0.41, 95% CI 0.20-0.81).

After adjustment for all covariates by stepwise regression, age, TEI/ kg IBW, and total protein intake/kg IBW were significantly associated with the sarcopenia only group (age: OR 1.17, 95% CI 1.05-1.29; TEI/kg IBW: OR 0.89, 95% CI 0.78-0.99; total protein intake/kg IBW: OR 0.43, 95% CI 0.23-0.79), and no-exercise habits and total protein intake/kg IBW were significantly associated with the frailty only group (no-exercise habits: OR 16.0, 95% CI 2.45-103; total protein intake/kg IBW: OR 0.11, 95% CI 0.02-0.49) (not shown in table or supplementary).

ORs of low muscle function and incidents falls

The ORs for low muscle function and incident falls in sarcopenia only, frailty only, and sarcopenia with frailty in older adults are shown in Table 3. After the adjustment for all covariates by stepwise regression, sarcopenia with frailty participants were significantly associated with low knee extension strength, slow TUG, and incident falls and

Table 1. Differences in physical characteristics between robust, sarcopenia only, frailty only, and sarcopenia with frailty groups

	Overall (n=331)	Robust (n=292)	Sarcopenia or frailty (n=39)	*p* value	Sarcopenia or frailty (n=39)					
					Sarcopenia only (n=19)	*p* value	Frailty only (n=8)	*p* value	Sarcopenia with frailty (n=12)	*p* value
Age (years)	71.5±5.1	70.9±4.8	75.7±5.0	***	74.1±3.6	*	75.3±7.0		78.6±4.3	***, †
With type 2 diabetes (%)	9.7	8.2	20.5	*	15.8		12.5		33.3	*
1 days with no-exercise habits per week (%)	23.3	19.9	48.7	***	31.6		75	**	58.3	**
TEI/kg IBW (kcal/kg IBW/day)	33.3±4.6	33.8±4.3	29.4±3.3	***	30.2±3.3	**	31.2±1.9		27.2±3.2	***
Total protein intake/kg IBW (g/kg IBW/day)	1.25±0.20	1.28±0.19	1.05±0.17	***	1.11±0.15	**	1.00±0.13	***	0.98±0.21	***
TEI <25.0 kcal/kg IBW (%)	4.8	3.8	12.8	*	5.3		0		33.3	**
Total protein intake <1.00 g/kg IBW (%)	6.7	4.1	25.6	***	15.8		12.5		41.7	***
Total vitamin D intake (μg/day)	8.7±1.7	8.8±1.7	7.9±1.4	***	8.3±1.1		7.5±1.8		7.6±1.4	
Low knee extension strength (%)	18.4	15.4	41	**	21.1		37.5		75	***
Slow TUG (%)	5.7	1.3	38.5	***	26.3	***	25	**	66.7	***
Incident falls (%)	14.2	9.6	48.7	***	31.6	**	50	**	75	***
Recurrent falls (%)	4.2	3.1	12.8	*	10.5		0		25	**, ††, ‡‡
PCS (score)	45.3±12.5	46.2±11.9	38.8±14.8	**	41.9±14.8		37.8±13.2		34.4±15.6	**, §
MCS (score)	54.1±8.7	54.8±8.2	48.4±10.5	**	52.0±10.4		46.2±12.1	*, §§	44.6±8.0	***, §§§

IBW: ideal body weight; CBW: current body weight; TEI: total energy intake; TUG: Timed up & Go; PCS: physical component summary; MCS: Mental component summary.
Data are shown as mean value ± standard deviation.
Unpaired one-way ANOVA or $\chi 2$ test: vs robust, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, vs sarcopenia only; $^{\dagger}p<0.05$, $^{\dagger\dagger}p<0.01$, vs frailty only; $^{\ddagger\ddagger}p<0.01$.
Analysis of covariance adjusted for age, female: robust; $^{\S}p<0.05$, $^{\S\S}p<0.01$, $^{\S\S\S}p<0.001$.

Table 2. ORs for sarcopenia with frailty in older adults†

	Sarcopenia with frailty					
	Odds ratio (95 % confidence interval)					
	Univariate		*p* value	Multivariate		*p* value
Age (+1years)	1.35	(1.18-1.54)	<0.001	1.61	(1.23-2.11)	<0.001
No-exercise habits (applicable)	4.98	(1.53-16.2)	0.008			N.S.
With type 2 diabetes (applicable)	5.58	(1.57-19.9)	0.008			N.S.
TEI/kg IBW (+1.0 kcal/kg IBW/day)	0.75	(0.66-0.86)	<0.001	0.68	(0.55-0.85)	0.001
Total protein intake/kg IBW (+0.20 g/kg IBW/day)	0.30	(0.16-0.58)	<0.001	0.19	(0.05-0.69)	0.012
Total vitamin D intake (+1.0μg/day)	0.60	(0.39-0.91)	0.016	0.41	(0.20-0.81)	0.011

†Uni- and multivariate logistic regression analyses.

Table 3. ORs for low muscle function and incident falls in sarcopenia only, frailty only, and sarcopenia with frailty in older adults†

	Incident falls			Recurrent falls		
	Odds ratio (95% confidence interval)			Odds ratio (95% confidence interval)		
	Multivariate		*p* value	Multivariate		*p* value
Robust	Ref			Ref		
Step 1: Sarcopenia only	3.03	(1.01-9.09)	0.049			N.S.
Step 2: Frailty only	9.43	(2.24-39.8)	0.002			N.S.
Step 3: Sarcopenia with frailty	8.54	(1.84-39.7)	0.006	11.8	(2.68-52.0)	0.001
	Low knee extension strength			Slow TUG		
Robust	Ref			Ref		
Step 1: Sarcopenia only			N.S.	22.8	(6.79-76.7)	<0.001
Step 2: Frailty only			N.S.	13.2	(3.79-45.8)	<0.001
Step 3: Sarcopenia with frailty	8.05	(1.85-35.0)	0.005	20.3	(4.54-91.2)	<0.001

†Multivariate logistic regression analyses by age, female.

recurrent falls (low knee extension strength: OR 8.05, 95% CI 1.85-35.0; slow TUG: OR 20.3, 95% CI 4.54-91.2; incident falls: OR 8.54, 95% CI 1.84-39.7; incidents of recurrent falls: OR 11.8, 95% CI 2.68-52.0).

ROC analysis to determine cut-off values of age, TEI, protein, and vitamin D intake for sarcopenia with frailty

ROC analysis revealed the cut-off values of age, TEI, and protein intake for sarcopenia with frailty are shown in Supplementary figure 1. The area under the ROC curve for age, TEI/kg IBW/day, total protein intake/kg IBW/day, and total vitamin D intake/day was 75 years (AUC: 0.87, $p<0.001$), 30.4 kcal/kg IBW/day (AUC: 0.83, $p<0.001$), 1.03 kg/kg IBW/day (AUC: 0.80, $p<0.001$), and 7.3 μg/day (AUC: 0.72, $p<0.001$), respectively.

DISCUSSION

Here, we demonstrated the differences in clinical characteristics and relevant factors for sarcopenia and frailty, and the overlap of their criteria, in older community-dwelling Japanese for the first time. Sarcopenia with frailty participants had a lower HRQOL, and had a higher incident of recurrent falls, TEI <25.0 kcal/kg IBW, and total protein intake <1.00 g/kg IBW than robust participants. In addition, we showed that older age, and poor intake of total energy, protein, and vitamin D was associated with sarcopenia with frailty. Finally, this study is the first to demonstrate the cut-off values for potential age, TEI, and total protein and vitamin D intake indicators for the diagnosis of sarcopenia with frailty.

In older adults, participants with sarcopenia with frailty had higher percentage of recurrent falls than robust participants, and a higher percentage of recurrent falls than the other groups. In addition, the sarcopenia with frailty group had higher percentage of lower limb muscle strength weakness compared to the robust group. However, the sarcopenia only group and frailty only group had no difference in recurrent falls incidents and lower limb muscle strength compared to the robust group. Compared to other groups, both lower limb muscle strength and dynamic balance ability were reduced in the sarcopenia with frailty group and, as a result, the incidences of recurrent falls could be increased in older adults. A previous report showed that sarcopenic subjects, based on the European Working Group on Sarcopenia in Older People criteria, were not significantly associated with recurrent falls.14 However, our present study shows that sarcopenia with frailty participants had a higher percentage of recurrent falls and severe reduction in muscle function in older adults.

In addition, as a result of ANCOVA analysis adjusted by age and sex, physical- and mental-related HRQOL was significantly lower in the sarcopenia with frailty group compared to the robust group. A previous study showed that the reduction in muscle strength and physical performance was related to a decline in physical-related QOL in older adults.[10] The previous study reported that decline of mental-related HRQOL was associated with reduced physical performance, and poor physical-related HRQOL was associated with a decline in mental-related HRQOL.[10] Due to the cross-sectional design in this study,

it is not possible to explain the causal relationship between physical- and mental-related HRQOL in detail, but both of these factors were lower in sarcopenia with frailty participants compared to robust participants. In this study, older adults with sarcopenia with frailty may be at high risk of requiring long-term care, because of the high incidence of falls due to a decline in muscle function, dynamic balance capacity, and physical- and mental-related QOL. Therefore, the diagnosis of sarcopenia, as defined by the AWGS, and physical frailty, as defined by Fried et al., is required at an early stage to prevent the requirement of long-term care in Japanese older adults.

The sarcopenia with frailty group contained older adults than the robust and sarcopenia only groups. Therefore, there is a possibility that aging may increase the sarcopenia with frailty. In addition, older age, low TEI, and low protein intake were associated with common relevant factors for sarcopenia only and sarcopenia with frailty. In particular, in the sarcopenia with frailty group, there was a large proportion of participants that consumed less than reference intakes for TEI and total protein intake to maintain muscle mass and strength, from PROT-AGE study recommendations.[12] Therefore, in this study, poor nutritional status, including suboptimal TEI and total protein intake, was related to the onset of sarcopenia with frailty. In order to prevent sarcopenia with frailty, it is necessary to evaluate dietary intake, by referring to the recommended TEI and protein intake indicated in the PROT-AGE study of older adults.

In this study, the sarcopenia only and frailty only groups did not show significant associations with low total vitamin D intake, but the sarcopenia with frailty group was significantly related to low vitamin D intake. Vitamin D is a fat-soluble vitamin crucial for muscle and bone function, among many other physiological roles. Low serum vitamin D is linked to reduced physical functioning and frailty development, as well as falls and mortality.[4,11] The Asia-Pacific Clinical Practice Guidelines for the Management of Frailty show that lack of vitamin D is common in older adults and in older populations residing in the Asia Pacific region, although not all studies have found a high rate of deficiency.[4] Although it is possible to obtain adequate vitamin D intake via sun exposure alone, this may not occur in older adults because of sun avoidance or disability that limits outdoor exposure. Furthermore, older adults have ~75% reduction in the ability to synthesize vitamin D in the skin. In this study, the sarcopenia with frailty group had low intake of vitamin D, and, because there were no outdoor exercise habits, serum vitamin D value may be low. Therefore, there is a possibility that this contributes to muscle mass and function decline in older adults.

The sarcopenia with frailty group had higher HbA1c levels and prevalence of type 2 diabetes, but differences were not seen when comparing the sarcopenia or frailty only groups to the robust group. The previous study showed that muscle mass and strength declined with chronic hyperglycemic control in older adults.[15-17] In this study, it is possible that a hyperglycemic condition may be associated with muscle dysfunction, and sarcopenia with frailty. On other hand, physical inactivity was higher in the sarcopenia with frailty group than the robust group. By univariate logistic analysis, exercise habits and type 2 diabetes were significantly associated with sarcopenia with frailty, but not associated using multivariate logistic analysis. Aging and poor nutritional status were major relevant factors for sarcopenia with frailty, whilst physical inactivity and type 2 diabetes were minor relevant factors, in Japanese community-dwelling older adults.

We calculated the cut-off values of age, TEI, total protein, and vitamin D intake to predict sarcopenia with frailty in this study. The AUC of age, TEI/kg IBW, and total protein intake/kg IBW indicators were high accuracy values of 0.80 and above. As a result, TEI and protein intake were equivalent to the recommended amount suggested by the PROT-AGE study, which recommended a TEI of at least 30 kcal/kg IBW/day and a total protein intake of at least of 1.0 g/kg IBW/day to prevent sarcopenia with frailty. On other hand, the AUC of vitamin D intake indicators were moderate accuracy values (AUC: 0.72). Taken together, these findings suggest that measuring intake of vitamin D in an elderly Japanese population may be potentially important for evaluating sarcopenia with frailty.

This study has several limitations. First, it is impossible to infer causality because of the cross-sectional design. Moreover, the sarcopenia and frailty have the slow gait speed as the common component of sarcopenia and frailty. Therefore, the causal relationship between sarcopenia and frailty was unclear in this study. Second, information on psychological or social-related frailty (such as depression, cognitive function, living alone, economy, etc.) decline that could affect both sarcopenia and physical frailty was unclear.[4,18] Third, we could not evaluate biomarkers of malnutrition, such as serum albumin or 25-hydroxy vitamin D.[19] Fourth, participant treatment history for conditions, such as diabetes and hypertension, was unavailable. Finally, the sample size of participants was small, as there was only a limited number of participants with sarcopenia and/or frailty in this study. However, a previous study reported that overlap of sarcopenia with frailty were low rate of 1.9% in community-dwelling older adults.[20] In the study, the prevalence of sarcopenia with frailty was 3.6%. The overlap rate of Sarcopenia with frailty may be very small in older community-dwelling.

Conclusion

In conclusion, this study showed that sarcopenia with frailty had higher incidences of recurrent fall, and lower physical- and mental-related HRQOL than robust older adults. In addition, we showed that older age, and poor intake of total energy, protein, and vitamin D was associated with sarcopenia with frailty. As hypothesis, age-related physiological changes and lifestyle factors, such as diets, may be relevant factors for severe sarcopenia and frailty in older community-dwelling Japanese. Finally, this study is the first to demonstrate potential age, TEI, total protein, and vitamin D intake indicators for the diagnosis of sarcopenia with frailty. Longitudinal studies are needed to determine more accurate cut-off values for each indicator for the diagnosis of sarcopenia.

ACKNOWLEDGEMENTS

We thank the participants in our study.

AUTHOR DISCLOSURES
The all authors declare that they have no competing interests. No funding was received for this study.

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Supplementary table 1. Definition and cutoff value for sarcopenia and frailty in this study

1. Sarcopenia was defined by Asian Working Group for Sarcopenia (AWGS) criteria: low hand grip strength, slow gait speed, and low SMI.	
Low SMI	Male: <7.0 kg/m^2, Female: <5.7 kg/m^2
Low grip strength	Male: <26.0 kg, Female: <18.0 kg
Slow gait speed	Male, Female: < 0.80m/sec
2. Frailty was defined by Cardiovascular Health Study criteria: weight loss, exhausion, low grip strength, slow gait speed, low physical activity ≥3 criteria present	
Weight loss	-Male, female: unintentional weight loss of at least 5% of previous year's body weight. -One year before the start of this study, the rate of change with the measured body weight was calculated.
Exhaustion	Using the CES–D Depression Scale, the following two statements were read: (a) "I felt that everything I did was an effort" and (b) "I could not get going." The question was then asked, "How often in the last week did you feel this way?" 0=rarely or none of the time (<1 day), 1=some or a little of the time (1–2 days), 2=a moderate amount of the time (3–4 days), or 3=most of the time. Subjects who answered "2" or "3" to either of these questions were categorized as frail by the exhaustion criterion.
Low grip strength	-Male: BMI ≤24.0, ≤29.0kg, BMI ≤24.1-26.0, ≤0.0 kg, BMI ≤26.1-28.0, ≤30.0 kg, BMI >28.0, ≤32.0 kg -Female: BMI ≤23.0, ≤17.0 kg, BMI ≤23.1-26.0, ≤17.3 kg, BMI ≤26.1-29.0, ≤18.0 kg, BMI >29.0, ≤21.0 kg
Slow gait speed	-Cutoff for time to walk 5 m in this study -Male: Height ≤173 cm, 0.65 m/sec, Height >173 cm, 0.76 m/sec -Female: Height ≤159 cm, 0.65 m/sec, Height >159 cm, 0.65 m/sec
Low physical activity	-Male: energy consumption of 3 Mets or more <383 kcal/week -Female: energy consumption of 3 Mets or more <270 kcal/week

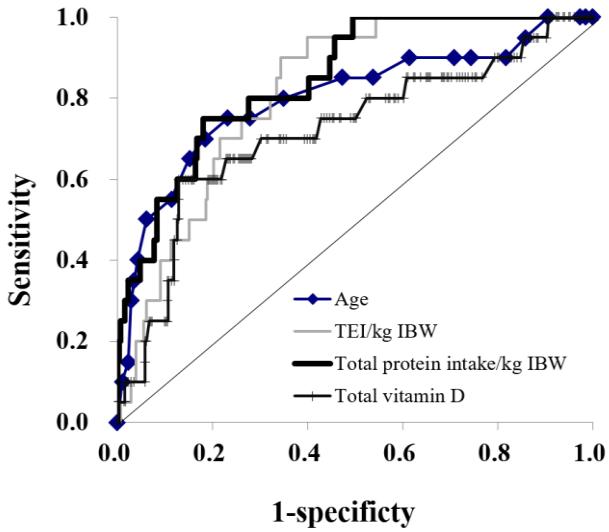
Supplementary table 2. Differences in physical characteristics between robust, sarcopenia only, frailty only, and sarcopenia with frailty groups

	Overall (n=331)	Robust (n=292)	Sarcopenia or frailty (n=39)	*p* value	Sarcopenia or frailty (n=39)					
					Sarcopenia only (n=19)	*p* value	Frailty only (n=8)	*p* value	Sarcopenia with frailty (n=12)	*p* value
Female (%)	71.9	72.3	69.2		73.7		50		75	
BMI (kg/m^2)	22.5±2.9	22.8±2.7	19.8±2.5	***	19.4±2.1	***	22.5±3.0	†	18.7±1.5	***, ‡
SBP (mmHg)	121±11	122±11	113±11	***	109±7	***	122±10	†	115±15	
DBP (mmHg)	74±8	75±7	69±8	***	67±7	***	74±6		69±10	*
Hypertension (%)	24.8	26	15.4		10.5		12.5		25	
Dyslipidemia (%)	15.1	16.8	2.6	*	0		12.5		0	
HbA1c (%)	5.7±0.4	5.6±0.3	5.8±0.4	**	5.7±0.3		5.6±0.4		6.1±0.3	***, ‡
Total carbohydrate intake/kg IBW (g/kg/day)	4.62±0.82	4.68±0.82	4.16±0.64	***	4.31±0.70		4.40±0.36		3.74±0.53	***
Total fat intake/kg IBW (g/kg/day)	1.09±0.20	1.11±0.20	0.95±0.11	***	0.95±0.12	**	1.02±0.07		0.91±0.12	**
Knee extension strength (Nm/kg CBW)	1.48±0.50	1.51±0.49	1.27±0.55	**	1.55±0.62		1.11±0.35		0.92±0.24	***, ††
TUG (sec)	9.39±0.83	9.24±0.73	10.46±0.81	***	10.23±0.83	***	10.15±0.78	**	11.03±0.45	***, †, ‡

BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure.

Data are shown as mean value ± standard deviation.

Unpaired one way ANOVA or χ2 test: vs roubust, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, vs sarcopeia only; $^{\dagger}p<0.05$, $^{\dagger\dagger}p<0.01$, vs frailty only; $^{\ddagger}p<0.05$, $^{\ddagger\ddagger}p<0.01$.



Supplementary figure 1. Receiver operating characteristic analysis revealed the cut-off values of age, TEI and protein intake for sarcopenia with frailty