findings, we discussed our observations and results separately, detailing each KCL domain and linking it to the participants' sociodemographic and lifestyle characteristics.

According to the KCL domains, we observed differences regarding the mean scores in IADL ($P < 0.001$) and physical ($P = 0.047$) domains among the three groups; however, such differences failed to remain statistically significant when we dichotomized them according to the cut-off points to determine frailty. A similar pattern was observed in the nutritional domain; no group showed a significantly different risk level to develop frailty. Although no differences were found in the physical and nutritional domains among the groups, we can discuss the significant difference observed in BMI ($P < 0.001$), especially because BMI is an important indicator of physical and nutritional status, and an increased BMI could be an alarming sign of imminent frailty evaluated by both domains. In the present study, the Brazilian participants were more obese (BMI 28.1 ± 5.39 kg/m^2) than the other groups. Although the KCL considers low bodyweight to be a frailty symptom, epidemiological studies show that both overweight and underweight are negative health outcomes associated with a greater risk for morbidity and mortality.[15]

There are some data showing that the Brazilian environment might pose a risk for developing obesity compared with the Japanese environment; a study verified that the risk for developing central obesity was 2.8-fold higher among Japanese Brazilians living in Brazil.[8] Although that study did not include Brazilian natives, there is evidence supporting concurrent increases in obesity in Brazil.[16]

Furthermore, we found that Brazilian participants were threefold more likely to be frail in terms of oral health (eating domain) than the Japanese group (OR 3.18, 95% CI 1.47–6.85, $P = 0.003$). In this case, the educational level of the participants seems to be related to their poor oral condition; considering the evidence that older adults who received elementary school level education had a significantly larger number of missing teeth and significantly fewer healthy gingival units compared with those who received higher than elementary school level education.[17] Another study showed that not only educational level, but also living arrangement influenced the participants' oral health; concluding that poorly educated and divorced women had fewer remaining teeth than better-educated and married women.[18] In the present study, the most favored group in terms of educational and living arrangement conditions was the Japanese cohort that were also more concerned about dehydration (consuming liquids, especially tea, as one of the Japanese habits), another included aspect in the oral domain.

Regarding the socialization domain, the Brazilian participants also showed a greater risk for becoming frail compared with the Japanese participants (OR 9.15, 95% CI 3.53–23.7, $P < 0.001$). A study showed that a partner relationship, such as marriage, might impact women's health status in numerous ways and could confer health-related benefits, such as providing nurturing conditions and socialization through a spouse,[19] and building a network with the partner's family.[20] Furthermore, a relationship possibly includes access to material resources and other social support.[21] These privations could lead Brazilian women to a poorer condition not only in the seclusion domain, but also in the mood domain, as the study concluded that individuals who lack social connections or report frequent feelings of loneliness tend to suffer higher rates of depression as well.[22]

Although the older Brazilian women showed a higher life satisfaction ($P = 0.002$), they presented a higher risk for being frail in terms of depression (OR 6.63, 95% CI 2.74–16.0, $P < 0.001$) than the Japanese group. Evidence showed that living alone or with other(s) than a partner could lead to depression and anxiety disorders in women.[23]

Finally, the results that we found in the memory domain did not differ from those aforementioned. The Brazilian participants were threefold more likely to be frail compared with the Japanese group (OR 3.87; 95% CI 1.93–7.75, $P < 0.001$). It is widely recognized that low education is one of the conditions that affect cognitive performance, especially phonological verbal fluency, calculation and working memory[24,25] that are required when processing the tasks assessed by the KCL cognitive domain. Another factor that might be related to the lowest scores achieved by Brazilian women in the memory domain is their highest number of medication use (Brazilian participants 2.9 ± 2.1 *vs* Japanese participants 2.1 ± 1.5, $P = 0.028$). Although we did not investigate the drug classes, the cognitive impairment is repeatedly reported to be a side-effect among medications prescribed for the elderly.[26,27]

We discerned that the majority of the differences in the present study were shows between Japanese and Brazilian natives. However, we must emphasize that an improved condition in terms of frailty was observed in the Brazilian Japanese descendants. This result might be linked to their higher educational level that predicts a higher-level financial status and better living conditions, which might in turn reflect a better health education, as they showed the lowest total KCL score ($P < 0.001$), and also the lowest mean KCL score in physical strength ($P = 0.047$), eating ($P = 0.001$) and mood ($P < 0.001$) domains.

We emphasize that the native Brazilian participants might be more vulnerable and frail because of the sociodemographic disadvantages that they are exposed to and their adopted lifestyle. However, such conditions are reversible; and an early detection of the frail aspects

is essential to reverse it in older adults. For this purpose, the KCL was designed to monitor the health conditions and to detect negative health outcomes at the earliest stage, thereby assuring prompt prevention or rehabilitation interventions, being an accurate, cheap, easy and fast diagnostic tool.

The present study had several limitations: (i) the present study was a cross-sectional design, which did not enable us to determine a cause–effect relationship; (ii) the present study was carried out in only one Brazilian and one Japanese region, which did not allow us to extend our findings to the national level; and finally, (iii) we only analyzed older women with heterogeneous characteristics, which complicated our comparisons. We recommend prospective studies to include a greater sample size, with male participants recruited from several regions of Brazil and Japan, and that future studies investigate important aspects that could be related to frailty, such as the financial situation of the participants.

In summary, we found that Brazilian natives were more frail than Japanese natives, but not Brazilian Japanese descendants. In addition to the environment, we believe that the lifestyle and the sociodemographic conditions could reflect the frailty of older Brazilian women in the present study. Hence, we recommend the dissemination of general health education among these older adults, including incentives for regular engagement in physical activity and a well-balanced diet, the principles of oral health safety and social and cognitive approaches to warrant a healthy aging process.

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Disclosure statement

The authors declare no conflict of interest.

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Original Study

Differential Association of Frailty With Cognitive Decline and Sarcopenia in Community-Dwelling Older Adults

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A B S T R A C T

Objectives: Frailty in older adults is a serious problem because of 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 nonfrail, prefrail, 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, whereas cognitive decline was associated only with frailty.

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.[1,2] Using the frailty criteria developed by the Cardiovascular Health Study, 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.[1] In Japanese, the prevalence of frailty in community-dwelling adults aged 65 or older was 11.3%, and it increased with aging.[3] 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.[4] Sarcopenia, defined as progressive loss of skeletal muscle mass, strength, and physical function, is regarded as a key component of physical frailty.[5,6] The Interventions on Frailty Working Group assessed various methods for screening, recruiting, evaluating, and

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retaining frail elderly individuals in clinical trials.[7] 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.[7] 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.[5] Thus, the domains of frailty overlap with the factors related to sarcopenia, and both frailty and sarcopenia mutually result in adverse health outcomes.[5,6]

Of note, some definitions of frailty include cognitive function and dementia.[4,8] Several cross-sectional studies have reported an association between physical frailty and cognitive function.[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)[11] and mild cognitive impairment.[12] It has been indicated that frailty is associated with AD pathology[13] and its biological mechanisms.[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.[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 prefrailty 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. Participants were interviewed and excluded if they met any of the following criteria: severe cardiac, pulmonary, or musculoskeletal disorders; severe neurologic 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.[3] As in that study, we considered the frailty phenotype to be characterized by limitations in the following 5 domains by using frailty criteria developed by the Cardiovascular Health Study[1]: 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: <17 kg). Exhaustion was assessed via self-report by using the Geriatric Depression Scale[16] (ie, 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: prefrailty = 1 or 2, frailty ≥3.[1]

Measurement of Cognitive Function

Participants' cognitive function was measured by using 2 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 5 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.[18]

Definition of Sarcopenia

We defined sarcopenia by using the diagnostic algorithm recommended by the Asian Working Group for Sarcopenia, which assesses the presence of both low muscle function (low physical performance or low muscle strength) and low muscle mass.[20] A bioelectrical impedance data acquisition system (Inbody 430; Biospace Co, Ltd, Seoul, Korea) was used to perform bioelectrical impedance analysis.[21] 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 2 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/m^2). This index has been used in several epidemiological studies.[22,23] 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/m^2), then they were defined as having sarcopenia.[20]

Statistical Analysis

Prior to the analysis, we classified participants into the following 3 groups according to their frailty score: nonfrailty, prefrailty, and frailty. Differences in the demographic variables, MMSE, SPMT, and

Table 1
Demographic Differences According to Frailty Scores

	Total (n = 273)	Frailty Level			*P* for Trend	Post-hoc
		Nonfrailty (n = 89)	Prefrailty (n = 155)	Frailty (n = 57)		
Age (y)	73.0 ± 5.4	73.1 ± 4.6	72.3 ± 5.6	76.6 ± 5.1	<.001†	a, b
BMI (kg/m^2)	22.5 ± 3.2	22.2 ± 3.0	22.7 ± 3.3	21.9 ± 3.8	.291	–
Medications	2.32 ± 2.24	2.18 ± 2.35	2.23 ± 2.10	3.27 ± 2.55	.072	–
Walking speed (m/s)	1.40 ± 0.20	1.43 ± 0.18	1.41 ± 0.20	1.21 ± 0.20	<.001†	a, b
Grip strength (kg)	22.4 ± 4.0	23.4 ± 3.4	22.6 ± 3.8	18.3 ± 4.1	<.001†	a, b
Cognitive decline (n)	18 (6.56%)	4 (4.49%)	9 (5.81%)	5 (8.77%)	.047*	
Memory decline (n)	20 (7.33%)	6 (6.74%)	4 (2.58%)	10 (17.5%)	<.001†	
Sarcopenia (n)	22 (8.06%)	2 (2.25%)	9 (5.81%)	11 (19.3%)	<.001†	

AWGS, Asian Working Group for Sarcopenia; BMI, body mass index.
Nonfrailty was defined as frailty score of 0, prefrailty 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.
a, significant difference between frailty and nonfrailty ($P < .01$).
b, significant difference between score frailty and prefrailty ($P < .01$).
*$P < .05$.
†$P < .01$.

SMI among the 3 groups were examined by using the analysis of variance. 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 3 groups were evaluated by using the χ^2 test. In addition, multivariate logistic regression analyses, adjusted for age, body mass index, 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, whereas the 3 frailty groups (dummy coded with non-frailty group as the reference group) were independent variables. 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), 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 nonfrailty group, 155 participants (56.8%) in the prefrailty group, and 29 participants (10.6%) in the frailty group. Analysis of variance showed that there were significant differences in age, walking speed, and grip strength among the 3 groups (Table 1). In the χ^2 test, there were

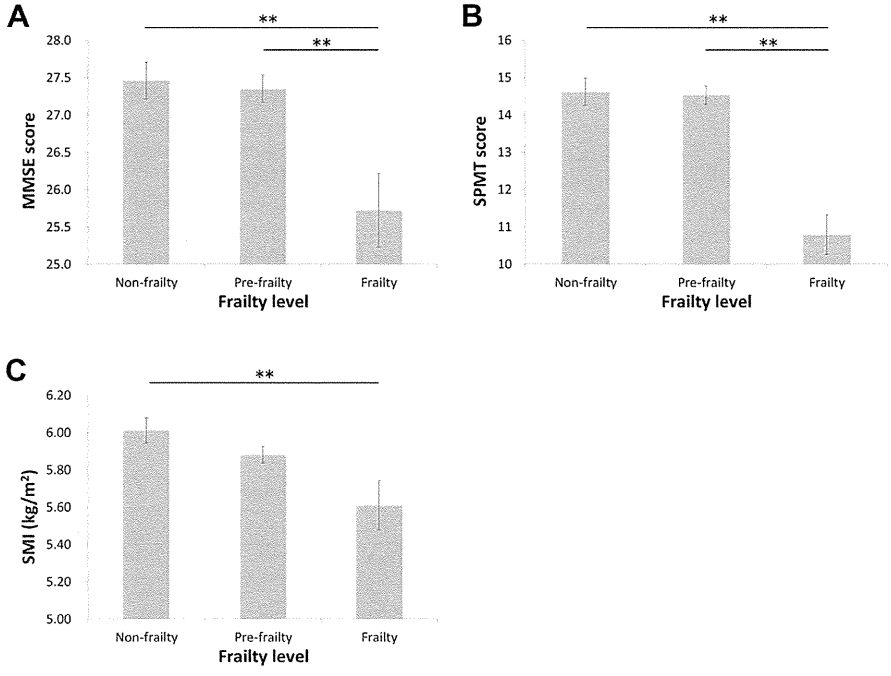

Fig. 1. Comparison of the MMSE, SPMT, and SMI between the groups according to the level of frailty. (A) There were significant differences in the MMSE scores between the 3 groups ($F = 6.78$, $P = .001$). (B) There were significant differences in the SPMT scores between the 3 groups ($F = 18.5$, $P < .001$). (C) There were significant differences in the SMI between the 3 groups ($F = 5.17$, $P = .006$). *$P < .05$, **$P < .01$.

Table 2
Relationship Between the Level of Frailty and Cognitive Decline, Memory Decline, and Sarcopenia

Frailty Level	Cognitive Decline		Memory Decline		Sarcopenia	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Nonfrailty	1 [Reference]	-	1 [Reference]	-	1 [Reference]	-
Prefrailty	1.79 (0.47–6.84)	.394	0.37 (0.10–1.36)	.134	2.77 (1.05–9.26)	.044*
Frailty	5.76 (1.20–27.6)	.029*	5.53 (1.64–18.7)	.006†	19.1 (3.73–98.0)	<.001†

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.
*$P < .05$.
†$P < .01$.

significant differences in the prevalence of cognitive decline, memory decline, and sarcopenia (Table 1). In addition, the frailty group had significantly lower MMSE ($F = 6.78$, $P = .001$, Figure 1, a) and SPMT ($F = 18.5$, $P < .001$, Figure 1, b) than the nonfrailty and prefrailty groups, and lower SMI ($F = 5.17$, $P = .006$, Figure 1, c) than the nonfrailty 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, body mass index, and medications, by using nonfrailty group as the reference, the prefrailty group was significantly more likely to have sarcopenia (OR: 2.77, 95% CI: 1.05–9.26, $P = .044$) 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, $P = .029$), memory decline (OR: 5.53, 95% CI: 1.64–18.7, $P = .006$), and sarcopenia (OR: 19.1, 95% CI: 3.73–98.0, $P < .001$) (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, $P = .020$), whereas sarcopenia was independently associated with both prefrailty (score ≥1; OR: 5.33, 95% CI: 1.22–23.3, $P = .026$) and frailty (score ≥3; OR: 13.1, 95% CI: 4.98–34.2, $P < .001$). 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 ≥3) was associated with cognitive decline, memory decline, and sarcopenia, and that prefrailty (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 prefrailty, was associated with cognitive decline and memory decline. Our results also showed that frailty and prefrailty 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 4 times more likely to have AD, and 8 times more likely to have cognitive impairment than robust older adults were. Prefrail older adults showed an increased risk for dementia in the aforementioned study, but some estimates were not statistically significant in the fully adjusted models.[30] The results of that study were consistent with our study. Previous studies indicated that frailty is associated with AD pathology[13] and biological mechanisms,[14] 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.[13] On the other hand, it has been indicated that comorbidities caused by cognitive impairment were also associated with frailty in patients with AD or mild cognitive impairment.[31] 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.[5,6] The causal mechanisms underlying sarcopenia can be oxidative stress, dysregulation of inflammatory cytokines and hormones, malnutrition,

Table 3
Independent Relationship Between Each Level of Frailty and Cognitive Decline or Sarcopenia

Domains	Univariate Analysis						Multivariate Analysis					
	Frailty Score						Frailty Score					
	≤1		≤2		≤3		≤1		≤2		≤3	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Cognitive decline	1.76 (0.56–5.51)	.331	1.43 (0.54–3.84)	.473	3.73 (1.23–11.4)	.020*	2.48 (0.68–9.07)	.168	1.63 (0.56–4.72)	.371	4.61 (1.27–16.8)	.020*
Sarcopenia	5.33 (1.22–23.3)	.026*	9.07 (3.22–25.5)	<.001†	13.1 (4.98–34.2)	<.001†	5.47 (1.21–24.6)	.027*	8.75 (3.00–25.5)	<.001†	10.0 (3.40–29.6)	<.001†

The multivariate analyses were adjusted for age and medications.
*$P < .05$.
†$P < .01$.

physical inactivity, and muscle apoptosis, all of which have been hypothesized to contribute to frailty through interactive pathways.[32,33] Recently, the definition of sarcopenia has been the coexistence of low muscle mass and low physical performance,[5,20,34] which are contained in frailty domains. Thus, the association of sarcopenia with even prefrailty seems reasonable. Overlapping intervention strategies (eg, 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.[15] 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 prefrailty. The results indicate that we need to understand the consecutive mechanism as well as the association of prefrailty 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 activities of daily living. 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 prefrailty and frailty. Further studies are required to understand these associations including biological mechanisms.

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Research paper

Ethnic and geographic variations in muscle mass, muscle strength and physical performance measures

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ABSTRACT

Purpose: While a universal definition of sarcopenia is desirable, ethnic diversity affects anthropometric measures, which in turn may affect the parameters used for the definition of sarcopenia. Other than Caucasian Asian differences, there may be diversity within different Asian populations. It is important to examine differences, if any, in the field of sarcopenia research. We compared available data (mean body mass index, muscle mass, grip strength, walking speed and chair stand times) for community living older people from different Asian locations and ethnicity to explore the extent of variation, and compared similar data from a Caucasian population.
Subjects and methods: Recent community studies which contain anthropometric and physical performance variables for men and women in the three age groups (65–74, 75–84, 85+) were identified from participants of the Asian Working Group on Sarcopenia and from other known longitudinal studies in the region. Caucasian values from the UK Hertfordshire Cohort Study were also used for comparison.
Results: There was considerable variation in mean values in body mass index, appendicular skeletal mass index (ASM/ht^2), grip strength, walking speed between different Asian ethnic groups, and also between same ethnic groups living in different geographic locations. Differences in mean values were greater between the Asian groups compared with Caucasians. Comparison of ASM/ht^2 between Asian groups was limited by the use of different instruments.
Conclusion: A universal definition of sarcopenia that depends on absolute measurements may not be applicable to all ethnic groups and different geographic locations.

1. Introduction

In the past two decades, sarcopenia has come to be recognized as an important geriatric syndrome, becoming a major focus of research covering from basic science to clinical management perspectives [1]. A universally accepted definition is thus of great importance, to facilitate the conduct of clinical trials of a preventive or interventional nature. In particular, clinical trials involving pharmaceutical agents would need to fulfil regulatory requirements [2]. There is current consensus worldwide that the working definition has evolved from the original one covering muscle mass only [3] to including measures of muscle strength as well as physical performance measures [4,5]. Three consensus groups have met and essentially arrived at the same conclusions, although there are minor variations. These are the International Working Group on Sarcopenia (IWGS) which has a predominantly North American input [6], the European Working Group on Sarcopenia in Older People (EWSOP) [7], and the Asian Working Group for Sarcopenia (AWGS) [8]. While there is broad consensus on the choice of measurement of each of these parameters (appendicular muscle mass divided by height^2, grip strength and walking speed), the classification of what values are normal so that cut-off values may be determined is unclear, there being variations between studies [6]. Among Caucasians, consensus cut-off values appear to have been accepted. Proposed cut-off values are not necessarily based on population studies, which have been limited. However, since all these measures are likely dependent on body

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size and shape, and to a certain extent lifestyle habits [9–11], it is not surprising that studies among Asian populations yield different values. The AWGS agreed on a consensus regarding the cut-off values appropriate for Asians, based on available published studies [8].

However there is ethnic diversity even within Asia with respect to anthropometry and lifestyle, factors which may affect the parameters used for the definition of sarcopenia. Existing data are sparse; yet a comparison of available age group and sex specific mean values used for sarcopenia definition between different Asian populations may begin to address this question. In this study we compared available data (mean body mass index, muscle mass, grip strength, walking speed and chair stand times) for community living elderly people aged 65–74, 75–84, and 85+ for Chinese in Beijing, Hong Kong, Singapore, Japanese, and Malays and Indians in Singapore, to explore the extent of variation. Similar data from a Caucasian population [12] are listed for comparison.

2. Subjects and methods

Recent community studies which contain anthropometric and physical performance variables for men and women in the three age groups (65–74, 75–84, 85+) were identified from participants of the Asian Working Group on Sarcopenia, consisting of researchers from Taipei, Beijing, Hong Kong, Japan, Malaysia, Thailand, Korea; and from other known longitudinal studies in the region (Singapore Longitudinal Aging Study [SLA]). The SLA consists of predominantly Chinese, but also smaller numbers of Malays and Indians [13]. Participants from each country and the Principal Investigator of the SLA were contacted to see if they can provide data for comparison. Data from Japan, China (mainland), China (Hong Kong), and Singapore (Chinese, Malays and Indians) were available, although not all parameters were available from all cohorts. Caucasian values from the UK Hertfordshire Sarcopenia Study (HSS), a sub-study of the Hertfordshire Cohort Study (HCS) were also used to compare Asian Caucasian differences [12].

The Hong Kong cohort was the Mr. and Ms Os dataset collected between 2001–2003 as part of a bone health survey, and consisted of two thousand community-dwelling Chinese men and women aged 65 and older recruited by placing recruitment notices in community centers for older adults and housing estates. Participants were volunteers, and excluded those who were unable to walk independently, had had bilateral hip replacement, and not competent to give informed consent [14].

Appendicular muscle mass was measured by DEXA using a Hologic Delphi W4500 densitometer (Hologic Delphi, auto whole body version 12.4, Hologic Inc, Bedford, Massachusetts, USA). ASM was calculated as the sum of appendicular lean mass minus bone mineral content of arms and legs. ASM index (ASMI) was calculated as ASM divided by height in meters squared (ASM/ht^2). Grip strength was measured using a dynamometer (JAMAR Hand Dynamometer 5030JO, Sammons Preston Inc, Bolingbrook, IL, USA). Two readings were taken from each side, and the average value between right and left was used for analysis. Gait speed was measured using the average time in seconds to complete a walk along a straight-line 6 meters long. A warm up period of < 5 minutes was followed by two walks, and the average time recorded. Chair stand was measured by asking the participant to rise from a chair (seat height 54 cm) with arms folded across the chest, five times as quickly as possible. The time taken was recorded on a stopwatch.

The Japanese cohort consisted of community-dwelling older people living in both rural and urban areas [15]. Exclusion criteria were classification as frail according to the long term care insurance certification in Japan; artificial implants such as cardiac pacemakers or joints which precluded the use of bioimpedance for measurement of muscle mass; severe cognitive impairments; severe cardiac, pulmonary or musculoskeletal disorders; comorbidities associated with greater risk of falls such as Parkinson's disease or stroke. Appendicular muscle mass was measured using bioimpedance [Inbody 720, Biospace Co. Ltd, Seoul, South Korea]. Participants stood on two metallic electrodes and held metallic grip electrodes. Grip strength was measured using a hand held dynamometer with the arm by the side of the body. Participants were instructed to squeeze as hard as they can use the dominant hand. The better of two performances was used. Walking speed was measured as the best time taken to walk 15 metres at a comfortable pace. The time required to reach the 10 m point (marked in the course) was recorded using a stopwatch. For the chair stand, participants were asked to stand up and sit down five times as quickly as possible, and the time taken from the initial sitting position to the final standing position at the end of the fifth stand was recorded. The better performance of two trials was taken.

The China (mainland) cohorts consist of volunteers ≥ 65 years, being part of a nation-wide survey of the health status of older people carried out from 2010–2013 in different regions of China. Some parameters were only available from the Beijing urban and rural cohorts, which consisted of retired teachers, workers and farmers [unpublished data]. Appendicular muscle mass was not available from this cohort. Grip strength was measured using a hand dynamometer (WCS-II, Beijing), with the highest of two readings for each hand being chosen; walking speed was measured over 6 m.

The Singapore data were from the Singapore Longitudinal Ageing Study [13], which consists of whole population samples from several contiguous small areas in the South East and South West Region of Singapore, covering Singapore citizens and permanent residents who were aged 55 years and above, not physically or mentally incapacitated, able to provide informed consent, participate in face-to-face interviews and carry out physical performance tests. The response rate was 75%. Muscle strength was assessed as knee extension strength. This was measured isometrically in the dominant leg, with the angles of the hip and knee at 90 degrees with the participant seated, using Lord's strap and strain gauge assembly component of the Physiological Profile Assessment (PPA). The best of three trials was recorded in kg [16]. The 6-meter fast gait speed test used the average of two measurements of the participants walking across a distance of 6 m as fast as possible [17]. Single timed chair rise was measured as the time in seconds taken for the participant to complete 5 stands from a seated position on a hard back chair with arms folded [18].

For the Hertfordshire cohort, only data for men were available. Body composition was assessed by anthropometry in all participants and validated using DEXA (Hologic Discovery, software version 12.5) in a sub-set; the walking speed measured as the customary paced walk over 3-m; chair rise time as the time to move from a seated position to fully standing five times unaided, and grip strength measured using a Jamar dynamometer with the maximum value attained from three attempts in both the right and left hands derived as the best grip strength (Promedics, Blackburn, UK) [19].

For each parameter, the mean (SD) values and the lowest 20th percentile values with the exception of chair stand time were listed according to the three age groups for men and women separately. Linear trend ANOVA test was used to examine changes with age within each cohort, and Student's unpaired t-test to examine between cohort differences by age and gender, using HK Chinese as a reference group.

Table 1a
Descriptive statistics and comparison by populations on body mass index (BMI).

Ethnic groups	Male							Female						
	n	65–74	*n*	75–84	*n*	≥85	*P*-value[c]	*n*	65–74	*n*	75–84	*n*	≥85	*P*-value[c]
Mean (±SD), *lowest 20th percentile*														
Chinese (Hong Kong)[d]	1295	23.62 (±3.06), *21.25*	543	23.08 (±3.23), *20.2*	42	21.98 (±3.02), *18.91*	<0.001	1292	24.19 (±3.42), *21.37*	583	23.53 (±3.44), *20.68*	57	22.5 (±3.71), *18.71*	<0.001
Chinese (Beijing)[d]	1759	24.1[e] (±3.1), *21.5*	1581	24[f] (±3.2), *21.2*	347	23.7[g] (±3.2), *21*	0.002	1950	24.3 (±3.5), *21.5*	1193	23.8 (±3.6), *20.8*	177	23.1 (±3.6), *20*	<0.001
Chinese (Singapore)[d]	353	23.6 (±3.55), *20.6*	148	23 (±3.68), *19.8*	165	22.9 (±3.76), *19.5*	0.043	541	24.2 (±3.99), *20.9*	178	23.8 (±4), *20.4*	204	23.6 (±3.98), *20.3*	0.062
Japanese[d]	266	23.2[e] (±3.2), *20.7*	254	23.1 (±2.5), *21*	48	21.9 (±3.6), *19.3*	<0.001	650	23[h] (±3.4), *20.3*	594	22.7[i] (±3.11), *20.3*	70	22 (±2.3), *20.5*	<0.001
Malays and Indians (Singapore)[d]	41	25[e] (±3.57), *21.3*	27	23.2 (±2.38), *21*	29	23.2 (±2.4), *20.5*	0.016	67	28[h] (±4.25), *24.9*	14	24.9 (±5.17), *18.7*	15	25[j] (±4.99), *18.9*	0.009
UK – HSS[a,d]	81	27.1[e] (±3.8), *24.0*	24	27.6[f] (±2.6), *26.1*	[b]			[b]		[b]		[b]		

Lower 20th percentile values are shown in italics.

[a] Hertfordshire Sarcopenia Study (HSS) cohort is only comprised of male participants, and is classified into 2 age groups: 68.3 years–74.9 years and 75.0 years–77.4 years, respectively.

[b] Figures not available.

[c] ANOVA test for linear trend was used to examine any significant difference by age group.

[d] Independent 2-sample *t*-test (2-tailed) was used to examine age-specific difference in mean values, with Chinese (Hong Kong) as reference. Only significant difference (*P*-value < 0.05) is reported.

[e] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 0.48, $P < 0.001$), Japanese (mean difference −0.42, $P = 0.042$), Malays and Indians (Singapore) (mean difference 1.38, $P = 0.005$), and UK Caucasian (mean difference 3.68, $P < 0.001$).

[f] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 0.92, $P < 0.001$), and UK Caucasian (mean difference 4.12, $P < 0.001$).

[g] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 1.72, $P = 0.001$).

[h] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −1.19, $P < 0.001$), and Malays and Indians (Singapore) (mean difference 3.81, $P < 0.001$).

[i] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.83, $P < 0.001$).

[j] Significantly different from Chinese (Hong Kong) – Malays and Indians (Singapore) (mean difference 2.5, $P = 0.035$).

Table 1b
Descriptive statistics and comparison by populations on appendicular skeletal mass index (ASM)/height^2 (kg/m^2).

Ethnic groups	Male							Female						
	n	65–74	*n*	75–84	*n*	≥85	*P*-value[c]	*n*	65–74	*n*	75–84	*n*	≥85	*P*-value[c]
Mean (±SD), *lowest 20th percentile*														
Chinese (Hong Kong)	1295	7.3 (±0.8), *6.66*	543	7.01 (±0.82), *6.31*	42	6.64 (±0.79), *5.93*	<0.001	1292	6.13 (±0.74), *5.51*	583	5.94 (±0.68), *5.35*	57	5.89 (±0.77), *5.3*	<0.001
Chinese (Beijing)[d]	[b]		[b]		[b]			[b]		[b]		[b]		
Chinese (Singapore)[d]	[b]		[b]		[b]			[b]		[b]		[b]		
Japanese[d]	266	6.99[e] (±1.1), *6.22*	254	6.73[f] (±1.08), *5.57*	48	6.28 (±1.71), *4.93*	<0.001	650	5.57[g] (±1.03), *4.6*	594	5.17[h] (±1.01), *4.12*	70	4.64[i] (±0.86), *3.77*	<0.001
Malays and Indians (Singapore)[d]	[b]		[b]		[b]			[b]		[b]		[b]		
UK – HSS[a,d]	81	7.99[e] (±0.91), *7.30*	24	7.89[f] (±0.74), *7.18*	[b]			[b]		[b]		[b]		

Lower 20th percentile values are shown in italics.
[a] Hertfordshire Sarcopenia Study (HSS) cohort is only comprised of male participants, and is classified into 2 age groups: 68.3 years–74.9 years and 75.0 years–77.4 years, respectively.
[b] Figures not available.
[c] ANOVA test for linear trend was used to examine any significant difference by age group.
[d] Independent 2-sample *t*-test (2-tailed) was used to examine age-specific difference in mean values, with Chinese (Hong Kong) as reference. Only significant difference (*P*-value < 0.05) is reported.
[e] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.31, $P<0.001$), and UK Caucasian (mean difference 0.7, $P<0.001$).
[f] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.28, $P<0.001$), and UK Caucasian (mean difference 0.89, $P<0.001$).
[g] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.56, $P<0.001$).
[h] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.77, $P<0.001$).
[i] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −1.25, $P<0.001$).

Table 1c
Descriptive statistics and comparison by populations on appendicular skeletal mass index (ASM)/weight.

Ethnic groups	Male							Female						
	n	65–74	*n*	75–84	*n*	≥85	*P*-value[c]	*n*	65–74	*n*	75–84	*n*	≥85	*P*-value[c]
Mean (±SD), *lowest 20th percentile*														
Chinese (Hong Kong)[d]	1295	0.31 (±0.02), *0.29*	543	0.31 (±0.03), *0.28*	42	0.3 (±0.03), *0.28*	<0.001	1292	0.25 (±0.02), *0.24*	583	0.26 (±0.03), *0.23*	57	0.27 (±0.03), *0.24*	<0.001
Chinese (Beijing)[d]	[b]		[b]		[b]			[b]		[b]		[b]		
Chinese (Singapore)[d]	[b]		[b]		[b]			[b]		[b]		[b]		
Japanese[d]	266	0.3[e] (±0.04), *0.27*	254	0.29[f] (±0.05), *0.24*	48	0.28[g] (±0.05), *0.23*	<0.001	650	0.24[h] (±0.04), *0.19*	594	0.22[i] (±0.04), *0.18*	70	0.21[j] (±0.04), *0.17*	<0.001
Malays and Indians (Singapore)[d]	[b]		[b]		[b]			[b]		[b]		[b]		
UK – HSS[a,d]	81	0.30[e] (±0.03), *0.28*	24	0.29[f] (±0.02), *0.26*	[b]			[b]		[b]		[b]		

Lower 20th percentile values are shown in italics.
[a] Hertfordshire Sarcopenia Study (HSS) cohort is only comprised of male participants, and is classified into 2 age groups: 68.3 years–74.9 years and 75.0 years–77.4 years, respectively.
[b] Figures not available.
[c] ANOVA test for linear trend was used to examine any significant difference by age group.
[d] Independent 2-sample *t*-test (2-tailed) was used to examine age-specific difference in mean values, with Chinese (Hong Kong) as reference. Only significant difference (*P*-value < 0.05) is reported.
[e] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.01, $P < 0.001$), and UK Caucasian (mean difference −0.02, $P < 0.001$).
[f] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.02, $P < 0.001$), and UK Caucasian (mean difference −0.02, $P < 0.001$).
[g] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.05, $P < 0.001$).
[h] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.01, $P < 0.001$).
[i] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.04, $P < 0.001$).
[j] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −0.06, $P < 0.001$).

Table 1d
Descriptive statistics and comparison by populations on average grip strength (kg).

Ethnic groups	Male							Female						
	n	65–74	*n*	75–84	*n*	≥85	*P*-value[e]	*n*	65–74	*n*	75–84	*n*	≥85	*P*-value[e]
Mean (±SD), *lowest 20th percentile*														
Chinese (Hong Kong)[f]	1295	32.7 (±6.05), *27.5*	543	28.64 (±6.21), *24*	42	25.06 (±6.74), *19.3*	<0.001	1292	21.09 (±4.18), *17.5*	583	18.77 (±3.78), *15.5*	57	17.86 (±3.73), *14.5*	<0.001
Chinese (Beijing)[f]	85	34 (±8.6), *27.2*	77	30.6[h] (±7.5), *23*	10	27.4 (±5.6), *20*	<0.001	197	22.1[j] (±5.3), *17.5*	96	20.9[k] (±6.1), *15.5*	3	16.2 (±3.3), [c]	<0.001
Chinese (Singapore)[a,f]	353	20.6[g] (±6.75), *14*	148	17.8[h] (±6.53), *12.6*	165	17.8[i] (±6.47), *12.7*	<0.001	541	14.2[j] (±4.31), *10.7*	178	12[k] (±3.74), *9*	204	12[l] (±3.66), *9*	<0.001
Japanese[f]	266	35[g] (±6.1), *31*	254	29.6[h] (±6.4), *25*	48	22.9 (±5.7), *18*	<0.001	650	23.1[j] (±5.1), *19*	594	19.8[k] (±4.4), *16*	70	17.3 (±4.2), *15*	<0.001
Malays and Indians (Singapore)[a,f]	41	18[g] (±5.73), *13.5*	27	15.6[h] (±7.04), *10.1*	29	15.7[i] (±6.82), *10.3*	0.155	67	13.4[j] (±5.05), *9.1*	14	10.6[k] (±3.7), *8*	15	10.7[l] (±3.58), *8*	0.023
UK – HSS[b,f]	81	40.4[g] (±8.2), *34.0*	24	33.0[h] (±6.5), *28.0*	[d]			[d]		[d]		[d]		

Lower 20th percentile values are shown in italics.

[a] Lower limb strength was used in Singapore data, measured by average knee extension (kg).

[b] Hertfordshire Sarcopenia Study (HSS) cohort is only comprised of male participants, and is classified into 2 age groups: 68.3 years–74.9 years and 75.0 years–77.4 years, respectively.

[c] Corresponding statistics not available.

[d] Figures not available.

[e] ANOVA test for linear trend was used to examine any significant difference by age group.

[f] Independent 2-sample *t*-test (2-tailed) was used to examine age-specific difference in mean values, with Chinese (Hong Kong) as reference. Only significant difference (*P*-value < 0.05) is reported.

[g] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference −12.1, $P < 0.001$), Japanese (mean difference 2.3, $P < 0.001$), Malays and Indians (Singapore) (mean difference −14.7, $P < 0.001$), and UK Caucasian (mean difference 7.9, $P < 0.001$).

[h] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 1.96, $P = 0.011$), Chinese (Singapore) (mean difference −10.84, $P < 0.001$), Japanese (mean difference 0.96, $P = 0.044$), Malays and Indians (Singapore) (mean difference −13.04, $P < 0.001$), and UK Caucasian (mean difference 5.56, $P < 0.001$).

[i] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference −7.26, $P < 0.001$), and Malays and Indians (Singapore) (mean difference −9.36, $P < 0.001$).

[j] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 1.01, $P = 0.002$), Chinese (Singapore) (mean difference −6.89, $P < 0.001$), Japanese (mean difference 2.01, $P < 0.001$), and Malays and Indians (Singapore) (mean difference −7.69, $P < 0.001$).

[k] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 2.13, $P < 0.001$), Chinese (Singapore) (mean difference −6.77, $P < 0.001$), Japanese (mean difference 1.03, $P < 0.001$), and Malays and Indians (Singapore) (mean difference −8.17, $P < 0.001$).

[l] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference −5.86, $P < 0.001$), and Malays and Indians (Singapore) (mean difference −7.16, $P = 0.035$).

Table 1e
Descriptive statistics and comparison by populations on walking speed using best time (m/s).

Ethnic groups	Male							Female						
	n	65–74	*n*	75–84	*n*	≥85	*P*-value[c]	*n*	65–74	*n*	75–84	*n*	≥85	*P*-value[c]
Mean (±SD), *lowest 20th percentile*														
Chinese (Hong Kong)	1295	1.12 (±0.22), *0.94*	543	1 (±0.22), *0.81*	42	0.87 (±0.17), *0.73*	<0.001	1292	1 (±0.2), *0.84*	583	0.88 (±0.22), *0.71*	57	0.81 (±0.22), *0.58*	<0.001
Chinese (Beijing)[d]	862	1.092[e] (±0.334), *0.853*	533	1.007 (±0.335), *0.711*	45	0.781 (±0.288), *0.534*	<0.001	1026	0.997 (±0.307), *0.736*	498	0.936[i] (±0.335), *0.647*	43	0.753 (±0.254), *0.516*	<0.001
Chinese (Singapore)[d]	353	1.4[e] (±0.37), *1.11*	148	1.3[f] (±0.37), *0.97*	165	1.2[g] (±0.38), *0.94*	<0.001	541	1.3[h] (±0.32), *1*	178	1.1[i] (±0.32), *0.78*	204	1[j] (±0.33), *0.74*	<0.001
Japanese[d]	266	1.38[e] (±0.24), *1.22*	254	1.23[f] (±0.25), *1*	48	1.06[g] (±0.26), *0.83*	<0.001	650	1.37[h] (±0.25), *1.22*	594	1.21[i] (±0.25), *1*	70	1.03[j] (±0.25), *0.8*	<0.001
Malays and Indians (Singapore)[d]	41	1.4[e] (±0.36), *0.99*	27	1.1[f] (±0.39), *0.71*	29	1.1[g] (±0.39), *0.7*	0.002	67	1.1[h] (±0.27), *0.82*	14	0.9 (±0.36), *0.62*	15	0.9 (±0.35), *0.64*	0.008
UK – HSS[a,d]	81	1.11 (±0.19), *0.95*	24	1.09[f] (±0.22), *0.86*	[b]			[b]		[b]		[b]		

Lower 20th percentile values are shown in italics.
[a] Hertfordshire Sarcopenia Study (HSS) cohort is only comprised of male participants, and is classified into 2 age groups: 68.3 years–74.9 years and 75.0 years–77.4 years, respectively. Two values were missing.
[b] Figures not available.
[c] ANOVA test for linear trend was used to examine any significant difference by age group.
[d] Independent 2-sample *t*-test (2-tailed) was used to examine age-specific difference in mean values, with Chinese (Hong Kong) as reference. Only significant difference (*P*-value < 0.05) is reported.
[e] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 0.028, $P = 0.019$), Chinese (Singapore) (mean difference 0.28, $P < 0.001$), Japanese (mean difference 0.26, $P < 0.001$), and Malays and Indians (Singapore) (mean difference 0.28, $P < 0.001$).
[f] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference 0.3, $P < 0.001$), Japanese (mean difference 0.23, $P < 0.001$), Malays and Indians (Singapore) (mean difference 0.1, $P = 0.028$), and UK Caucasian (mean difference 0.1, $P = 0.014$).
[g] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference 0.33, $P < 0.001$), Japanese (mean difference 0.19, $P < 0.001$), and Malays and Indians (Singapore) (mean difference 0.23, $P < 0.001$).
[h] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference 0.3, $P < 0.001$), and Japanese (mean difference 0.37, $P < 0.001$), and Malays and Indians (Singapore) (mean difference 0.1, $P < 0.001$).
[i] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference 0.056, $P = 0.001$), Chinese (Singapore) (mean difference 0.22, $P < 0.001$), and Japanese (mean difference 0.33, $P < 0.001$).
[j] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference 0.19, $P < 0.001$), and Japanese (mean difference 0.22, $P < 0.001$).

Table 1f
Descriptive statistics and comparison by populations on time to complete 5 stands (second).

Ethnic groups	Male							Female						
	n	65–74	*n*	75–84	*n*	≥85	*P*-value[d]	*n*	65–74	*n*	75–84	*n*	≥85	*P*-value[d]
Mean (±SD)														
Chinese (Hong Kong)	1293	12.18 (±3.66)	536	13.31 (±3.81)	41	15 (±5.7)	<0.001	1271	12.79 (±4.3)	574	14.69 (±6.33)	56	13.63 (±3.61)	0.003
Chinese (Beijing)[e]	55	11.2 (±3.5)	26	11.1[g] (±2.8)	1	17[b]	<0.001	95	10.3[i] (±3.7)	40	14.2 (±12.8)	1	12.7[b]	0.135
Chinese (Singapore)[e]	353	10.7[f] (±3.16)	148	12.7 (±5.21),	165	12.9[h] (±5.35)	<0.001	541	11.4[i] (±3.65)	178	13.1[j] (±4.79)	204	14 (±9.03)	<0.001
Japanese[e]	216	8[f] (±1.9)	160	8.5[g] (±2)	12	8[h] (±1.9)	1	422	7.9[i] (±2.5)	270	8.5[j] (±2.6)	6	6.87[k] (±1.4)	<0.001
Malays and Indians (Singapore)[a,e]	41	11.5 (±3.29)	27	14.6 (±6.39)	29	14.5 (±6.22)	0.023	67	14.1[i] (±6.24)	14	17 (±7.65)	15	16.5[k] (±7.62)	0.154
UK – HSS[a,e]	81	17.1[f] (±4.3)	24	17.6[g] (±4.0)	[c]			[c]		[c]		[c]		

[a] Hertfordshire Sarcopenia Study (HSS) cohort is only comprised of male participants, and is classified into 2 age groups: 68.3 years–74.9 years and 75.0 years–77.4 years, respectively. Three values were missing.
[b] Corresponding statistics not available.
[c] Figures not available.
[d] ANOVA test for linear trend was used to examine any significant difference by age group.
[e] Independent 2-sample *t*-test (2-tailed) was used to examine age-specific difference in mean values, with Chinese (Hong Kong) as reference. Only significant difference (*P*-value < 0.05) is reported.
[f] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference −1.48, $P < 0.001$), Japanese (mean difference −4.18, $P < 0.001$), and UK Caucasian (mean difference 4.92, $P < 0.001$).
[g] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference −2.21, $P = 0.004$), Japanese (mean difference −4.81, $P < 0.001$), and UK Caucasian (mean difference 4.09, $P < 0.001$).
[h] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference −2.1, $P = 0.028$), and Japanese (mean difference −7, $P < 0.001$).
[i] Significantly different from Chinese (Hong Kong) – Chinese (Beijing) (mean difference −2.49, $P < 0.001$), Chinese (Singapore) (mean difference −1.39, $P < 0.001$), Japanese (mean difference −4.89, $P < 0.001$), and Malays and Indians (Singapore) (mean difference 1.31, $P = 0.018$).
[j] Significantly different from Chinese (Hong Kong) – Chinese (Singapore) (mean difference −1.59, $P = 0.002$), and Japanese (mean difference −6.19, $P < 0.001$).
[k] Significantly different from Chinese (Hong Kong) – Japanese (mean difference −6.76, $P < 0.001$), and Malays and Indians (Singapore) (mean difference 2.87, $P = 0.04$).

3. Results

The mean body mass index (BMI) for men aged 65–74 and the 20th percentile value for all Asian cohorts were similar. However with increasing age, these values appeared to decline to different degrees among the cohorts, with the Beijing Chinese, Singapore Chinese, Malays and Indians having the least decline, whilst Hong Kong Chinese and Japanese showed a more marked decline in the age 85+ group (Table 1a).

For women, more variations were observed in mean and lowest 20th percentile values for all age groups, with a declining trend with age, the lowest values for the 85+ age group occurring in the Hong Kong Chinese, Malays and Indians. The trend for Singapore Chinese was marginally non-significant. The mean values for UK Caucasian older people were higher than all the Asian values.

Appendicular mass index also showed a declining trend with age in Chinese and Japanese men and women, all values being slightly lower among the Japanese (Table 1b). Mean Caucasian values were higher than all Asian values. However if muscle mass was expressed as a percentage of weight, then Chinese and Japanese values were very similar, and also similar to Caucasian values (Table 1c), although a significant age-related decline was still observed.

For all age and ethnic groups, muscle strength was higher among men compared with women, and showed a decline with age. Excluding the Singapore cohort data, there were variations between Chinese and Japanese, as well as Chinese in different locations (Table 1d). All Asian values were lower than Caucasians. Similarly, walking speed differed between the cohorts, irrespective of ethnicity; Singaporean and Japanese cohorts had faster walking speeds than Chinese in Hong Kong and Beijing (Table 1e). All cohorts showed age-related decline, but the decline in mean values varied between cohorts. Overall walking speed values for Asians and Caucasians were similar. With respect to time for the chair stand, the best performance was observed in the Japanese cohort, while the Hong Kong Chinese and Malays and Indians showed the greatest decline in performance with age (Table 1f). No significant decline with age was observed among Beijing Chinese, Singapore Indian and Malaysian women. Performance for Caucasians was the poorest.

4. Discussion

This descriptive comparison of parameters used for the definition of sarcopenia shows considerable variations within Asian populations that do not fall into any particular pattern according to ethnicity (body size and shape presumably being underlying factors for ethnic difference), or geographic location. Furthermore, while many parameters show age-related decline, some cohorts exhibit greater decline than others, the extent again not following any pattern according to ethnicity or geographic location. These findings would be compatible with within Asian variations being explained by different body size and shape; lifestyle habits (nutrition and pattern of physical activity); cultural traditions such as sleeping and sitting on the floor or low lying furniture among Japanese, etc.; and differing prevalence of frailty with ageing populations. A further complication is that in considering cut-off values for ASM, a value less than 2SD from young adult mean values may be employed, and young adult mean values may also be influenced by lifestyle or early life course factors, such that lower young adult mean values may give rise to lower prevalence of sarcopenia in older adults if muscle mass is considered, as has been pointed out by Lau et al. [10].

The diversity of mean values, approach to diagnosis, and methods used in measurement is highlighted further in a group of papers on research on sarcopenia in Asia published recently as a supplement in *Geriatrics and Gerontology International* (2014, volume 14, supplement 1).

Nevertheless, Asian values for BMI, ASM/height^2, and grip strength were much lower compared with those for Caucasian populations reported in the UK HCS study. Similarly, the mean (SD) BMI for older Italians aged 60–69 was 27.0(3) for men and 26.6(3.8) for women, and for those aged 70–80, 27.1(3.4) for men and 25.6(3.7) for women [20]. The values for ASM/height^2 for the Italian cohort aged 60–69 were also higher, being 8.6(0.9) for men and 6.7(0.9) for women; and for age group 70–80, 8.5(0.9) for men and 6.4(0.8) for women. However, Asian values for walking speed are very similar to those for Caucasians: 0.9(0.1) for men and 0.9(0.2) for women in the UK cohort. On the other hand, physical performance measure as assessed using chair stand was the worst among Caucasian older people. It is uncertain whether the longer chair stand times may be related to the higher BMI for Caucasian older people or just reflect protocol differences between the studies. A point of note is that ASM/ht^2 significantly decline with age in both men and women after age 65 to the same extent, suggesting that achievement of a higher peak muscle mass may attenuate the impact of age-related muscle loss.

The implications for searching for a universal definition of sarcopenia that involves absolute measurements is that possibly one cut-off value for walking speed may be applicable to all ethnic groups and different geographic locations, while different cut-off values for muscle mass, strength and other physical performance measures may be needed. Cut-off values have been proposed recently by the AWGS consensus opinion [8]. The AWGS also recommends a cut-off value for walking speed of 0.8 m/sec. However the cut-off values for muscle mass and grip strength are lower: height-adjusted ASM being 7.0 kg/m^2 for men and 5.4 kg/m^2 for women using DEXA, and 7.0 kg/m^2 for men and 5.7 kg/m^2 for women using BIA; and for grip strength the cut-off values are 26 kg for men and 18 kg for women. The findings also raise the question of the use of ASM/weight being a more universally applicable measurement of muscle mass.

While cut-off values may be used for epidemiological comparisons of sarcopenia prevalence, the most important aspect is the relationship with incident lower extremity physical limitation. It could be argued that the definition should be based on outcomes from longitudinal studies, as had been proposed by Woo et al. with respect to ASM/height^2 [9]. Along similar lines, a new parameter has been proposed recently by the Foundation of the National Institutes of Health to define sarcopenia: the skeletal muscle function deficit which seeks to relate muscle mass, strength and function cut points to mobility limitation [21]. Exact values used may not be as important for intervention studies, since change in outcomes are being measured, so that the criteria would only be used for recruitment of participants for these trials.

It may be that walking speed alone may be used as a single indicator in future, which would be applicable to all population groups.

There are limitations in this descriptive study, since the characteristics of cohorts may be slightly different, although they are matched by gender and age groups. For example, the Japanese cohort excluded those with stroke, while the Hong Kong cohort did not. However, for the latter cohort the numbers with stroke were small, so that the mean values were not affected after participants with history of stroke were excluded. Furthermore, different instruments and protocols were used for measurement: the Japanese cohort used BIA while the Hong Kong Chinese cohort used DEXA. The grip strength instruments were different between cohorts, although this may improve in the future as a standardized approach to measurement has now been developed [22]. No standardizations were made. Only available data were used, and

these were few. Nevertheless, this descriptive comparison is of interest in highlighting ethnic and cultural variations for some, but not all the parameters used in the definition of sarcopenia, such that for research and clinical care, appropriate classification should be used. Moreover, future studies may explore the underlying basis for variations in these parameters, and the utility of using a single parameter (walking speed) as a universal method for identification of sarcopenia in relating the syndrome to future adverse outcomes.

Disclosure of interest

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

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SYSTEMATIC REVIEWS

Prevalence of and interventions for sarcopenia in ageing adults: a systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS)

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Abstract

Objective: to examine the clinical evidence reporting the prevalence of sarcopenia and the effect of nutrition and exercise interventions from studies using the consensus definition of sarcopenia proposed by the European Working Group on Sarcopenia in Older People (EWGSOP).
Methods: PubMed and Dialog databases were searched (January 2000–October 2013) using pre-defined search terms. Prevalence studies and intervention studies investigating muscle mass plus strength or function outcome measures using the EWGSOP definition of sarcopenia, in well-defined populations of adults aged ≥50 years were selected.
Results: prevalence of sarcopenia was, with regional and age-related variations, 1–29% in community-dwelling populations, 14–33% in long-term care populations and 10% in the only acute hospital-care population examined. Moderate quality evidence suggests that exercise interventions improve muscle strength and physical performance. The results of nutrition interventions are

equivocal due to the low number of studies and heterogeneous study design. Essential amino acid (EAA) supplements, including ~2.5 g of leucine, and β-hydroxy β-methylbutyric acid (HMB) supplements, show some effects in improving muscle mass and function parameters. Protein supplements have not shown consistent benefits on muscle mass and function.
Conclusion: prevalence of sarcopenia is substantial in most geriatric settings. Well-designed, standardised studies evaluating exercise or nutrition interventions are needed before treatment guidelines can be developed. Physicians should screen for sarcopenia in both community and geriatric settings, with diagnosis based on muscle mass and function. Supervised resistance exercise is recommended for individuals with sarcopenia. EAA (with leucine) and HMB may improve muscle outcomes.

Keywords: *exercise intervention, nutrition intervention, prevalence, age-related, sarcopenia, older people*

Introduction

Although exercise and nutrition interventions have proved efficacy to treat different conditions in various populations of adults and older people, the effects in those with sarcopenia have received less attention. Sarcopenia has been defined as the loss of skeletal muscle mass and strength that occurs with advancing age [1]. However, until recently, there has been no widely accepted definition of sarcopenia that was suitable for use in research and clinical practice.

A practical clinical definition of, and consensus diagnostic criteria for, age-related sarcopenia was developed in 2009–10 and reported by the European Working Group on Sarcopenia in Older People (EWGSOP) [2]. The EWGSOP provided a working definition of sarcopenia as 'a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death' [2]. They proposed that sarcopenia is diagnosed using the criteria of low muscle mass and low muscle function (either low strength and/or low physical performance) [2]. A similar approach was taken in 2009 by the International Working Group on Sarcopenia (IWGS), who provided a consensus definition of sarcopenia as 'age-associated loss of skeletal muscle mass and function'. This group proposed that sarcopenia is diagnosed based on a low whole-body or appendicular fat-free mass in combination with poor physical functioning [3].

To date, most prevalence and intervention studies have used varied definitions of sarcopenia that are not current (e.g. based only on decreased muscle mass) and the results may therefore be misleading and difficult to interpret. However, with the implementation of new operational definitions of sarcopenia, it may be possible to define the natural course of the condition and determine which treatments are effective. In 2013, representatives of the EWGSOP, IWGS and international experts from Asia and America came together to form the International Sarcopenia Initiative (ISI) with the intention of developing a systematic review of some aspects of sarcopenia. Specifically, the aims of this systematic review were to (i) assess the prevalence of sarcopenia using definitions that include both muscle mass and muscle function, as proposed by the EWGSOP and the IWGS; and (ii) to review interventions with nutrition and exercise that used both muscle mass and muscle function as outcomes.

Methods

Search strategy

PubMed and Dialog databases were searched from January 2000 to May 2013 using the pre-defined search terms sarcopenia and muscle mass: additional pre-defined search terms were applied (see Supplementary data available in *Age and Ageing* online, Appendix S1) for each of the three areas of interest: prevalence of sarcopenia, nutrition interventions for sarcopenia and exercise interventions for sarcopenia (Figure 1). An additional short search of PubMed and Dialog databases using the terms 'sarcopenia', 'elderly', 'intervention', 'prevalence' and 'treatment' was conducted to cover articles published in the period May–October 2013 (Figure 1). The reference lists of systematic review articles and meta-analyses were scanned for any additional references missed from the PubMed and Dialog searches. The expert group was also asked to identify and provide any additional papers; they deemed to have been missed in the formal literature searches.

Eligibility criteria

Across all three categories, only studies that enrolled participants aged 50 years and older within well-defined populations (such as those in community-dwelling, hospital and nursing home/geriatric settings) were included. Prevalence studies were included if sarcopenia had been assessed according to the EWGSOP definition of sarcopenia, i.e. based on muscle mass *and* muscle strength *or* physical performance [2]. They were excluded if they only used muscle mass to define sarcopenia. Nutrition and exercise intervention studies were included if the outcome measures reported for the interventions included muscle mass and at least one measure of muscle strength or physical performance, even when the population studied was not defined as sarcopenic. If these outcomes were not clearly stated within the study methodology, the study was excluded. Other criteria used to exclude studies in each of the three categories are provided in Supplementary data available in *Age and Ageing* online, Appendix S2.

Observational studies were included in the prevalence category, but for the exercise and nutrition intervention categories, only randomised controlled trials were selected. The ISI group