分担研究者

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ORIGINAL ARTICLE

Development of a simple screening test for sarcopenia in older adults

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Aim: To develop a simple screening test to identify older adults at high risk for sarcopenia.

Methods: We studied 1971 functionally independent, community-dwelling adults aged 65 years or older randomly selected from the resident register of Kashiwa city, Chiba, Japan. Data collection was carried out between September and November 2012. Sarcopenia was defined based on low muscle mass measured by bioimpedance analysis and either low muscle strength characterized by handgrip or low physical performance characterized by slow gait speed.

Results: The prevalence of sarcopenia was 14.2% in men and 22.1% in women. After the variable selection procedure, the final model to estimate the probability of sarcopenia included three variables: age, grip strength and calf circumference. The area under the receiver operating characteristic curve, a measure of discrimination, of the final model was 0.939 with 95% confidence interval (CI) of 0.918–0.958 for men, and 0.909 with 95% CI of 0.887–0.931 for women. We created a score chart for each sex based on the final model. When the sum of sensitivity and specificity was maximized, sensitivity, specificity, and positive and negative predictive values for sarcopenia were 84.9%, 88.2%, 54.4%, and 97.2% for men, 75.5%, 92.0%, 72.8%, and 93.0% for women, respectively.

Conclusions: The presence of sarcopenia could be detected using three easily obtainable variables with high accuracy. The screening test we developed could help identify functionally independent older adults with sarcopenia who are good candidates for intervention. **Geriatr Gerontol Int 2014; 14 (Suppl. 1): 93–101.**

Keywords: disability, rehabilitation, sarcopenia, screening, sensitivity and specificity.

Introduction

Sarcopenia is a syndrome characterized by progressive and generalized loss of skeletal mass and strength with aging.[1] A recent realization that sarcopenia is associated with a risk of adverse events, such as physical disability, poor quality of life and death, has provided significant impetus to sarcopenia research.[1] Effective interventions have been vigorously sought and some interventions, such as resistance training in combination with nutritional supplements, appear promising.[2–4] It is also becoming apparent that interventions might be more effective early rather than late in the course when patients develop physical disability or functional dependence.[4,5] The early stage in the course of sarcopenia (i.e. without loss of physical or functional independence) might therefore represent a valuable opportunity to carry out interventions to decelerate the progress of sarcopenia and prevent physical disability.

However, patients with sarcopenia are generally unaware of their sarcopenic state until the gradual decline in muscle function becomes severe enough to be pathological, resulting in physical and functional dependence.[4,6] As patients are unlikely to seek medical

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attention for their sarcopenic state, population screening to detect sarcopenia before the occurrence of physical disability could improve the chance of intervention.

Currently, the recommended criteria for the diagnosis of sarcopenia require the documentation of low muscle mass and either low muscle strength or low physical performance.[1] Muscle mass is commonly assessed by dual energy X-ray absorptiometry (DXA) or bioimpedance analysis (BIA), muscle strength with handgrip strength, and physical performance with Short Physical Performance Battery or usual gait speed.[1,7] Unfortunately, the feasibility of applying the recommended diagnostic algorithm in the setting of population screening is limited by the need for special equipment and training. Hence, a screening test for sarcopenia simple enough to be carried out on a large scale is required.

Using baseline data from the Kashiwa study on functionally independent, community-dwelling older adults, we designed an analysis to develop a simple screening test for sarcopenia and examine its ability to estimate the probability of sarcopenia.

Methods

Participants

The Kashiwa study is a prospective cohort study designed to characterize the biological, psychosocial and functional changes associated with aging in community-dwelling older adults. In 2012, a total of 12 000 community-dwelling, functionally independent (i.e. not requiring nursing care provided by long-term care insurance) adults aged 65 years or older were randomly drawn from the resident register of Kashiwa city, a commuter town for Tokyo in Chiba prefecture, Japan, and asked by mail to participate in the study. A total of 2044 older adults (1013 men, 1031 women) agreed to participate in the study and comprised the inception cohort. The sample reflected the distribution of age in Kashiwa city for each sex.

Baseline examinations were carried out between September and November 2012 at welfare centers and community centers close to the participants' residential area, to obviate their need to drive. A team consisting of physicians, nurses, physical therapists, dentists and nutritionists carried out data collection. To standardize data collection protocol, they were given the data collection manual, attended two sessions for training in the data collection methods and carried out a rehearsal of data collection. A total of 73 participants who did not undergo BIA, usual gait speed or handgrip strength measurements were excluded, leaving an analytic sample of 1971 older adults (977 men, 994 women).

The study was approved by the ethics committee of the Graduate School of Medicine, The University of Tokyo. All participants provided written informed consent.

Sarcopenia classification and measurement of each component of sarcopenia

We followed the recommendation of the European Working Group on Sarcopenia in Older People (EWGSOP) for the definition of sarcopenia.[1] The proposed diagnostic criteria required the presence of low muscle mass plus the presence of either low muscle strength or low physical performance.

Muscle mass measurement

Muscle mass was measured by BIA using an Inbody 430 machine (Biospace, Seoul, Korea).[8] Appendicular skeletal muscle mass (ASM) was derived as the sum of the muscle mass of the four limbs. ASM was then normalized by height in meters squared to yield skeletal muscle mass index (SMI) (kg/m^2).[1] SMI values lower than two standard deviations below the mean values of young male and female reference groups were classified as low muscle mass (SMI <7.0 kg/m^2 in men, <5.8 kg/m^2 in women).[9]

Muscle strength measurement

Muscle strength was assessed by handgrip strength, which was measured using a digital grip strength dynamometer (Takei Scientific Instruments, Niigata, Japan). The measurement was carried out twice using their dominant hand, and the higher of two trials (in kilograms) was used for the present analysis. Handgrip strength values in the lowest quintile were classified as low muscle strength (cut-off values: 30 kg for men, 20 kg for women).

Physical performance measurement

Physical performance was assessed by usual gait speed. Participants were instructed to walk over an 11-m straight course at their usual speed. Usual gait speed was derived from 5 m divided by the time in seconds spent in the middle 5 m (from the 3-m line to the 8-m line). Good reproducibility of this measurement was reported previously.[10] Usual gait speed values in the lowest quintile were classified as low physical performance (cut-off values: 1.26 m/s for each sex).

Other measurements

Demographic information and medical history of doctor-diagnosed chronic conditions were obtained using a standardized questionnaire. Physical activity was assessed using Global Physical Activity Questionnaire and Metabolic Equivalent minutes per week was computed.[11] Serum albumin was measured at the time of the visit. Anthropometric measurements were obtained with the participants wearing light clothing and no shoes. Height and weight were measured with a fixed stadiometer, and a digital scale and used to compute body mass index (BMI). Upper arm, thigh and calf circumferences were measured to the nearest 0.1 cm directly over the skin using a measuring tape with the participant sitting. Upper arm circumference was measured at the mid-point between the olecranon process and the acromion of the non-dominant arm with the participant's arm bent 90° at the elbow. Calf circumference measurement was made at the maximum circumference of the lower non-dominant leg with the participant's leg bent 90° degrees at the knee. Thigh circumference was measured 15 cm above the upper margin of the patella of the dominant leg.

Statistical analysis

All analyses were stratified by sex. Differences in participant characteristics between those with and without sarcopenia were examined using Student's *t*-test or Wilcoxon rank–sum test. To develop a statistical model to estimate the probability of sarcopenia, candidate variables were selected by experts based on cost, ease of measurement and availability of equipment to measure them. The candidate variables included age, sex, BMI, grip strength, and thigh, calf and upper arm circumferences. Pearson's correlation between each component of sarcopenia and the candidate variables was first computed. We then examined the functional form of the relationships between the variables, and the logit of sarcopenia probability using restricted cubic spline plots and the Wald test for linearity.[12] We considered dichotomization, square and logarithmic transformations if the Wald test for linearity was statistically significant, rejecting the assumption of linearity.[12] A multivariate logistic regression model including all the candidate variables ("full model") was constructed. Variable selection with Bayesian Information Criteria was carried out to make the model parsimonious, and a multivariate logistic regression model including the variables selected ("restricted model") was made.[13] A bootstrapping procedure was used to obtain estimates of internal validity of the model[14] and to derive the final models by correcting the regression coefficients for overoptimism.[15] The final model was presented as a score chart to facilitate clinical application.[15] The score chart was created based on rounded values of the shrunken regression coefficients.

The ability of each model to correctly rank order participants by sarcopenia probability (discrimination ability) was assessed by the area under the receiver operator characteristic (ROC) curve.[16,17] The model fit was verified using the Hosmer–Lemeshow goodness-of-fit test.[18]

There were no missing values of any variable in the entire analytic sample.

All analyses were carried out using SAS version 9.3 (SAS Institute, Cary, NC, USA) and R statistical software version 2.15.2 (R Foundation, Vienna, Austria). Two-sided $P < 0.05$ was considered statistically significant.

Results

There were 32.2% of men and 48.9% of women classified as having low muscle mass, and 14.2% of men and 22.1% of women were classified as having sarcopenia. The participant characteristics by the sarcopenia status in each sex are shown in Table 1. Those with sarcopenia were older and had smaller body size compared with those without sarcopenia in each sex (all $P < 0.001$). Those with sarcopenia were physically less active in each sex. Chronic medical conditions were in general more prevalent in those with sarcopenia, and a statistically significant difference was observed for hypertension in women, stroke in men and osteoporosis in both sexes. Serum albumin was significantly lower in those with sarcopenia in each sex.

Table 2 shows the correlation between each component of sarcopenia and the candidate variables. SMI was correlated with all the variables, with the highest correlation coefficient observed with calf circumference in each sex. Usual gait speed was most highly correlated with age, followed by grip strength and calf circumference in the order of the magnitude of correlation, and this finding was consistent in both sexes.

Visual inspection of the restricted cubic spline plots and the Wald test for linearity suggested that the variables were linearly associated with the logit of sarcopenia probability, except for grip strength in both sexes and upper arm circumference in women (data not shown). However, neither dichotomization nor transformation improved the model fit, and we decided to use linear terms of these variables in the development of statistical models.

Table 3 shows the unadjusted and adjusted associations between sarcopenia and the variables. In bivariate analysis, all the variables were significantly associated with sarcopenia. In multiple logistic regression with all the variables (full model), age was positively, and grip strength and calf circumference were inversely associated with sarcopenia, whereas BMI, thigh circumference and upper arm circumference were not significantly associated. Variable selection resulted in the selection of age, grip strength and calf circumference, and the three selected variables were significantly associated with

Table 1 Characteristics of study participants

	Men Sarcopenia (*n* = 139)	No sarcopenia (*n* = 838)	*P*	Women Sarcopenia (*n* = 220)	No sarcopenia (*n* = 774)	*P*
Age (years)	78.4 ± 5.5	72.2 ± 5.0	<0.001	76.2 ± 5.8	71.8 ± 4.9	<0.001
Height (cm)	160.0 ± 5.6	164.9 ± 5.5	<0.001	148.2 ± 5.6	152.3 ± 5.1	<0.001
Weight (kg)	54.1 ± 7.2	64.3 ± 8.0	<0.001	46.4 ± 5.7	52.9 ± 7.6	<0.001
BMI (kg/m^2)	21.1 ± 2.5	23.6 ± 2.6	<0.001	21.1 ± 2.6	22.8 ± 3.2	<0.001
Grip strength (kg)	27.5 ± 4.3	36.0 ± 5.3	<0.001	18.4 ± 3.2	23.6 ± 3.3	<0.001
Thigh circumference (cm)	38.8 ± 3.5	42.4 ± 3.3	<0.001	38.9 ± 3.4	41.7 ± 4.0	<0.001
Calf circumference (cm)	32.8 ± 2.3	36.3 ± 2.5	<0.001	32.1 ± 2.1	34.5 ± 2.7	<0.001
Upper arm circumference (cm)	25.7 ± 2.5	28.4 ± 2.4	<0.001	25.7 ± 2.3	27.3 ± 2.9	<0.001
SMI (kg/m^2)	6.34 ± 0.48	7.44 ± 0.58	<0.001	5.25 ± 0.41	6.02 ± 0.60	<0.001
Usual gait speed (m/s)	1.28 ± 0.24	1.51 ± 0.24	<0.001	1.26 ± 0.26	1.51 ± 0.23	<0.001
Physical activity (MET-minutes/week)	1813 (720, 3504)	2540 (1200, 4746)	0.008	1341 (33, 3209)	2587 (1092, 4824)	<0.001
Chronic conditions (%)						
Hypertension	51.1	46.5	0.32	45.9	38.1	0.04
Diabetes mellitus	18.0	14.9	0.36	8.2	8.9	0.73
Stroke	12.2	6.4	0.01	5.9	4.4	0.35
Osteoporosis	4.3	1.4	0.02	32.7	16.6	<0.001
Use of medications (%)						
Statins	18.7	17.4	0.71	29.1	30.6	0.66
Antihypertensives	53.2	45.1	0.08	42.7	36.2	0.08
Albumin (g/dL)	4.37 ± 0.26	4.43 ± 0.23	0.005	4.39 0.23	4.43 ± 0.22	0.04

Values are shown as mean ± standard deviation except for physical activity which was not normally distributed and therefore the mean value and inter-quartile range were shown. BMI, body mass index; MET, Metabolic Equivalent; SMI, skeletal muscle mass index.

Table 2 Pearson correlations between components of sarcopenia and six candidate variables

	Age	BMI	Grip strength	Thigh circumference	Calf circumference	Upper arm circumference
Men						
SMI	−0.33***	0.70***	0.49***	0.70***	0.78***	0.69***
Grip strength	−0.46***	0.21***	1	0.27***	0.35***	0.35***
Usual gait speed	−0.35***	0.007	0.29***	0.06	0.13***	0.10**
Women						
SMI	−0.24***	0.69***	0.50***	0.67***	0.75***	0.65***
Grip strength	−0.36***	0.16***	1	0.22***	0.33***	0.21***
Usual gait speed	−0.42***	−0.08**	0.36***	0.01	0.12***	−0.02

*, **, ***Significance at 0.1%, 1%, 5% level, respectively. BMI, body mass index; SMI, skeletal muscle mass index.

sarcopenia in multiple logistic regression (restricted model). These findings were consistent in both sexes. The area under the ROC curve of the full model was 0.940 (95% confidence interval [CI] 0.920–0.959) for men and 0.910 (95% CI 0.888–0.932) for women, showing excellent discriminative ability. The area under the ROC curve of the restricted model (0.939 with 95% CI 0.918–0.958 for men and 0.909 with 95% CI 0.887–0.931 for women) was not significantly different from that of the full model in both sexes ($P = 0.71$ for men, 0.43 for women). Assessment of internal validity showed that discriminative ability of the restricted model is expected to be good in similar populations (area 0.937 for men, 0.907 for women).

The final model was presented as a score chart in each sex (Table 4). The use of the score chart with two hypothetical patients is shown in Table S1. The discriminative ability of the score chart was comparable with those of the full and restricted models in each sex (area 0.935 for men, 0.908 for women; Fig. S1).

Figure 1 shows the estimated probabilities corresponding to the sum scores as calculated with the score chart in Table 4, and the sensitivity and specificity using the sum scores as cut-off values. The sum score that maximized the sum of sensitivity and specificity was 105 for men and 120 for women. The corresponding sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were 84.9%, 88.2%, 54.4% and 97.2%, and 7.19 and 0.17 for men, and 75.5%, 92.0%, 72.8% and 93.0%, and 9.44 and 0.27 for women, respectively.

Sensitivity analysis

Because there are no established reference cut-off values for grip strength and usual gait speed in Japanese older adults, we used the lowest quintiles of the observed distributions to classify low muscle strength and low physical performance. As sensitivity analysis, we used the lowest deciles of grip strength and usual gait speed to capture participants with more severely impaired muscle function (i.e. strength or performance), and defined them as having sarcopenia, with the same cut-off values for muscle mass as in the main analysis. We then examined the model performance with all six variables and with the same set of three variables as selected in the main analysis (age, grip strength and calf circumference). The cut-off value of grip strength was 27 kg for men and 17 kg for women, and that of usual gait speed was 1.16 m/s for men and 1.13 m/s for women. The prevalence of sarcopenia was 9.6% in men and 12.7% in women. Both models performed well (area of the full model: 0.932 for men, 0.919 for women; area for the restricted model; 0.931 for men, 0.918 for women; Figure S2).

Discussion

To estimate the probability of sarcopenia in functionally independent, community-dwelling Japanese older adults, we created multivariate models based on the three selected variables (age, grip strength and calf circumferences), and found excellent discrimination ability of the models: the area under the curve was 0.939 for men and 0.909 for women. We constructed a score chart in each sex so that the approximate probability of sarcopenia could be easily obtained from the values of the three variables, and confirmed that the score charts also had excellent discrimination.

Although our multivariate models had excellent discrimination capacity, the model's sensitivity and specificity at candidate diagnostic thresholds must be assessed to judge the model's clinical usefulness.[18] Higher sensitivity can be achieved at the expense of lower specificity and vice versa. For example, if higher sensitivity was desired; for example, 90%, then the cut-off score would be 101 for men and 104 for women, and the specificity would be lower at 82.2% for men and 70.4% for women. Higher specificity, 90%, could be achieved with the higher cut-off score of 107 for men

Table 3 Unadjusted and adjusted associations between sarcopenia and the variables

Variables	Men						Women					
	Bivariate		Multivariate (full model)		Multivariate (restricted model)		Bivariate		Multivariate (full model)		Multivariate (restricted model)	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Age	1.21 (1.17–1.26)	<0.001	1.07 (1.02, 1.12)	0.008	1.07 (1.02, 1.12)	0.008	1.16 (1.13, 1.20)	<0.001	1.10 (1.05, 1.14)	<0.001	1.09 (1.04, 1.13)	<0.001
BMI	0.68 (0.63–0.74)	<0.001	0.96 (0.78, 1.18)	0.69			0.82 (0.78, 0.87)	<0.001	0.86 (0.74, 1.00)	0.05		
Grip strength	0.71 (0.67, 0.75)	<0.001	0.73 (0.68, 0.78)	<0.001	0.73 (0.68, 0.79)	<.001	0.57 (0.53, 0.62)	<0.001	0.58 (0.53, 0.64)	<0.001	0.59 (0.55, 0.65)	<0.001
Thigh circumference	0.73 (0.69, 0.78)	<0.001	1.05 (0.91, 1.21)	0.53			0.82 (0.78, 0.86)	<0.001	0.94 (0.85, 1.04)	0.24		
Calf circumference	0.57 (0.52, 0.63)	<0.001	0.62 (0.53, 0.73)	<0.001	0.62 (0.56, 0.69)	<.001	0.68 (0.64, 0.74)	<0.001	0.80 (0.69, 0.91)	<0.001	0.71 (0.65, 0.78)	<0.001
Upper arm circumference	0.63 (0.57, 0.68)	<0.001	0.97 (0.82, 1.15)	0.71			0.80 (0.75, 0.85)	<0.001	1.15 (0.98, 1.35)	0.10		

BMI, body mass index; CI, confidence interval; OR, odds ratio.

and 118 for women, resulting in lower sensitivity of 77.7% for men and 76.8% for women (Fig. 1). The trade-off between sensitivity and specificity depends on the cost of incorrect classification of those with sarcopenia relative to the cost of incorrect classification of those without sarcopenia. The cost of incorrect answers would vary according to the clinical or research scenario and personal preferences.[16,17]

Several observations suggested that the selection of three variables (age, grip strength and calf circumference) was not based on chance. First, sarcopenia was classified based on muscle mass, muscle strength and physical performance, all of which were significantly correlated with the three variables. Calf circumference was used to represent muscle mass, considering the highest correlation between SMI and calf circumference among the variables considered. A strong correlation between calf circumference and muscle mass was previously shown in Caucasian older women who were on average more obese than women in the present.[19] Grip strength was used as an indicator of muscle strength. Usual gait speed, a measure of physical performance, was significantly correlated with each of the three variables. Second, sarcopenia was associated with each of the three variables in both bivariate and multivariate analyses in each sex, and *P*-values for these findings were comfortably below 0.01. Third, the models with the three variables had excellent discrimination for sarcopenia based on more stringent cut-off levels for grip strength and usual gait speed.

There have been several prior attempts at estimating the quantity of muscle mass using a variety of variables with varying degrees of accuracy.[20–23] Although these studies were inspired by the desire to facilitate the diagnosis of sarcopenia, recently developed definitions of sarcopenia entail the presence of low muscle function, as well as muscle mass.[1,24] The present study developed statistical models with high accuracy for sarcopenia, which was defined based on muscle mass and muscle function.

This study had several limitations. First, the measurement method of usual gait speed was different from those used by the majority of previous studies.[25] The measurement method used in the present study required the participant to walk 3 m before the measurement started. An attribute of this method is that it is less affected by the gait initiation phase where age-related changes independent of gait speed occur.[26,27] This method has been widely used in Japan,[9,28] and has been shown to be reliable,[10] but because it starts measuring after the gait initiation phase, it tends to yield higher values than those obtained with other measurement methods, such as usual gait speed over a 4- or 6-m course,[25] making direct comparison difficult. Second, the current analysis was carried out on data from Japanese older adults, and our findings therefore might not

Table 4 Score charts for estimated probability of sarcopenia

Variables	Value													
Men														
Age			<66	66	68	70	72	74	76	78	80	82	84	86≦
Score			0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11
Grip strength		<20	20	23	26	29	32	35	38	41	44	47	50≦	
Score		+99	+90	+81	+72	+63	+54	+45	+36	+27	+18	+9	0	
Calf circumference	<26	26	28	30	32	34	36	38	40	42≦				
Score	+81	+72	+63	+54	+45	+36	+27	+18	+9	0				
Estimated individual probability of sarcopenia														
Sum score	70	80	90	95	100	105	110	115	120	125	130	135	140	145
Probability (%)	1	2	5	8	13	19	28	39	51	64	74	83	89	93
Women														
Age			<66	66	68	70	72	74	76	78	80	82	84	86≦
Score			0	+2	+4	+6	+8	+10	+12	+14	+16	+18	+20	+22
Grip strength		<14	14	16	18	20	22	24	26	28	30	32	34≦	
Score		+110	+100	+90	+80	+70	+60	+50	+40	+30	+20	+10	0	
Calf leg circumference			<26	26	28	30	32	34	36	38	40	42≦		
Score			+63	+56	+49	+42	+35	+28	+21	+14	+7	0		
Estimated individual probability of sarcopenia														
Sum score	80	90	95	100	105	110	115	120	125	130	135	140	145	150
Probability (%)	1	3	5	8	12	19	28	39	51	63	74	82	88	93

Values for each variable are given with such intervals that the scores show small steps, and scores for intermediate values can be estimated by linear interpolation. The exact formula to calculate the scores are as follows: score in men, 0.62 × (age – 64) – 3.09 × (grip strength – 50) – 4.64 × (calf circumference – 42); score in women, 0.80 × (age – 64) – 5.09 × (grip strength – 34) – 3.28 × (calf circumference – 42). The corresponding probabilities of sarcopenia are calculated with the following formulae: probability in men, $1 / [1 + e^{-(\text{sum score} / 10-11.9)}]$; probability in women, $1 / [1 + e^{-(\text{sum score} / 10-12.5)}]$.

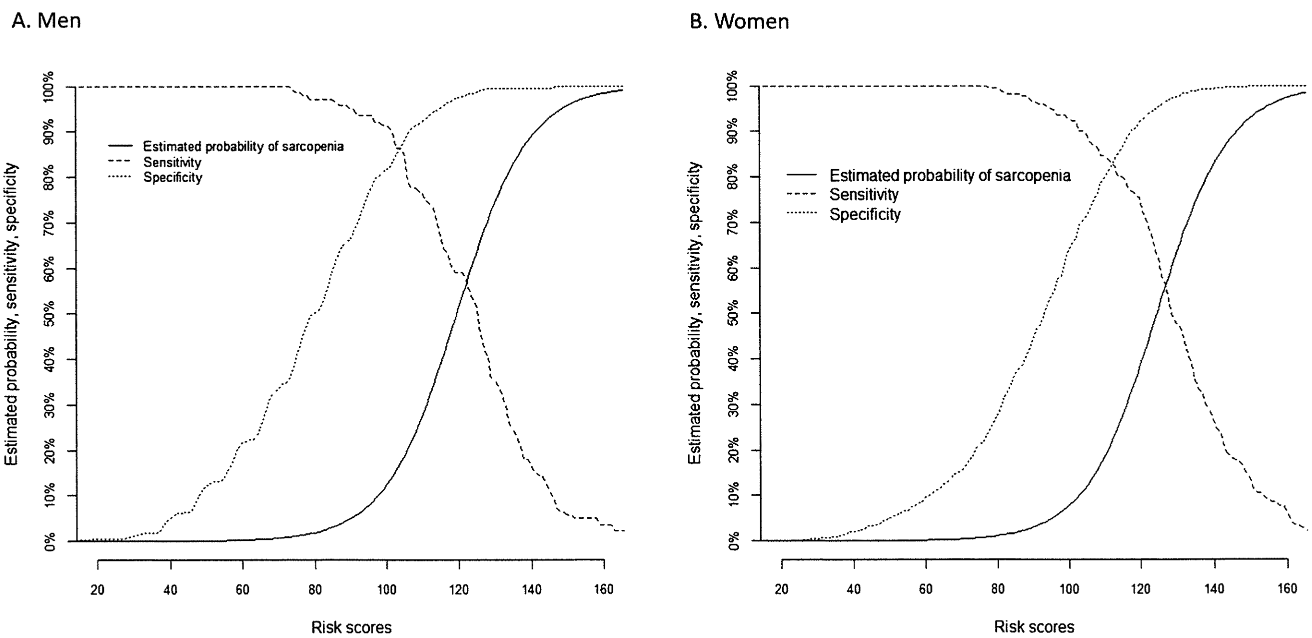

Figure 1 Estimated probabilities, sensitivity and specificity corresponding to sum scores. The sum scores and corresponding estimated probabilities are read from Table 3.

be applicable to populations of other race/ethnicity or in other countries. Similarly, caution should be exercised in projecting beyond the range of our data. For example, the obese were underrepresented in our data, and the performance of our models was not assessed for the obese. However, the present findings suggest that three variables, namely age, grip strength and calf circumference, should be considered for inclusion in the development of sarcopenia screening in other populations. Third, although the internal validity was good (i.e. the models would perform well in a similar population), assessment of external validity is still warranted to determine whether the results can be extended to other Japanese populations. Finally, we could not exclude the possibility of the healthy volunteer effect (i.e. volunteers for clinical studies tend to be healthier than the general population). Although participants were randomly selected from the resident register, participation was voluntary and the response rate was approximately 17%. However, the sensitivity analysis showed that the models' ability to estimate the probability of sarcopenia remained excellent when participants with more severely impaired muscle function were categorized as having sarcopenia.

In conclusion, we showed that the presence of sarcopenia in older adults could be detected with high accuracy using three easily obtainable variables. Importantly, we derived the models from a functionally independent, community-dwelling population. Functionally independent older adults with sarcopenia are good candidates for interventions to prevent further physical limitations, given their potential for regaining muscle mass and restoration of muscle function. The score charts we developed can be used as an effective screening tool and help identify functionally independent older adults with sarcopenia.

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Disclosure statement

The authors declare no conflict of interest.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1 Receiver operating characteristic curves of models estimating the probability of sarcopenia.
Figure S2 Receiver operating characteristic curves of models estimating the probability of sarcopenia based on different cut-off values for grip strength and usual gait speed.
Table S1 Application of Score Chart in two hypothetical patients.

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■ プロシーディング 13

シニア世代の就労を介した身体活動量の増加と体組成への改善効果

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要 約

身体活動量の低下は虚弱のリスクを高めるが，退職後のシニアは身体活動量が低下しがちになり体組成のバランス悪化が危惧される．そこで再度の就労につくことで身体活動量がどのように変化し，その結果が心身にどのような影響があるかを調べた．

調査方法は定年退職した60歳以上のシニア16名に健康調査スタッフとして就労についてもらい，就労の前後で身体活動量・体組成・血管内皮機能の測定をした．また就労終了後に生活の質や健康についてのお気持ちの変化についてアンケートを実施した．

結果として3METs以上の活動時間は就労前21.5[13,33]分/日（中央値[IQR]）が就労後29.2[21,40]分/日となり，有意に増加した（p=0.020）．歩数は就労前5592[4568,7374]歩/日が，就労後は7223[4885,9750]歩/日となり有意に増加した（p=0.017）．四肢SMIは10.30[9.0,10.9] kg/m^2から10.33[9.0,10.8] kg/m^2と変化は見られなかった．体脂肪量は16.3[13,21]kgから13.6[13,20]kgへと就労前後で有意に減少した（p=0.004）．Flow Mediated Dilation値は就労前5.4[3,6]%であったが，就労後には5.7[4,6]%と若干改善した．アンケートでは生活の質や健康意識の改善がうかがわれる結果が得られた．

以上のように短期間であっても就労によって身体活動量が有意に増加し，その結果，体脂肪量が有意に減少した．また就労によって健康に対する意識が変わることで，就労が終了してからも身体活動量の増加が維持されたと考えられる．季節変動による血管内皮機能の低下が憂慮されたが，結果は変動が少なく血管内皮機能が維持される可能性があることが分かった．

以上より，シニア世代に対する就労は生きがいを感じると同時に，身体活動量の増加による体組成の改善にも寄与すると考えられる．

Key words　高齢者，虚弱，身体活動量，体組成，メタボリックシンドローム

1 諸 言

厚生労働省は「健康づくりのための身体活動基準2013」[1)]において身体活動量を増やすことがシニアの生活機能低下（ロコモティブシンドローム）のリスク低減につながるとし，身体活動量の低下は虚弱の危険因子としている．また同時にメンタルヘルスや生活の質についても言及している．

そこで本研究では身体活動量の低下に伴い身体能力の低下だけでなく，体組成のバランス悪化が危惧される退職後のシニアを対象とし，再度の就労につくことで身体活動量がどのように変化し，その結果が体組成・血管内皮機能の改善に寄与するかを調べた．さらに就労で体を動かし，口腔・栄養・運動・社会・心理に注目した健康調査のスタッフとしてかかわることで，健康に対する意識にどのような影響があるかをアンケートで調べた．

2 方 法

千葉県柏市在住の定年退職した60歳以上のシニアのうち，研究に同意した16名（平均年齢66.9±4.0歳，男：女=11:5）を対象とした．就労内容は同市内の大規模健康調査スタッフ（9月～11月）として，来場者の誘導や会場設営などであった．会場設営は各人の体力や健康状態に応じて机や椅子を運び，中強度以上の身体活動量が想定される．来場者の誘導業務は会場内を小刻みに移動し，シニア世代には適度な身体活動量となるよう配慮した．8月から9月上旬にかけて就労前検査を，11月下旬から12月にかけて就労後検査を実施した．検査内容は体組成測定と血管内皮機能の検査であり就労の前後での変化を解析

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した．また身体活動量の測定期間は就労開始日と終了日を基準として2回測定している．（後述）

本研究は東京大学の倫理審査委員会の承認を得て対象者全員の同意書を作成して実施した．

1. 身体活動量の測定

身体活動量の測定には日立製の身体活動量計を使用した．この身体活動量計はKen Kawamoto らによって[2]睡眠の解析にも用いられている．身体活動量計内には3軸の加速度センサが内蔵され，そのデータからMetabolic equivalents（以下METs）と歩数を算出した．

対象者は就労開始日を挟んだ前後の2週間と，終了日の前後2週間，計2回身体活動量計を装着し測定した．装着中対象者には記録をつけてもらい，就労についた日を特定した．2回の身体活動量測定のうち就労についた日を「就労日」として，就労開始時の身体活動量測定のうち「就労日」を除いた日を「就労前」として集計した．同様に就労終了時の身体活動量測定のうち就労日を除いた日付を「就労後」として集計した．

METsの集計方法は青柳幸利らの[3]METsと歩数の解析方法を参考とし，3METs以上の活動時間を「中強度活動時間」として集計した．

2. 体組成測定

従来体組成の測定にはDual-energy X-ray absorptiometry（二重エネルギーX線吸収測定法：以下DEXA）による骨密度の測定より副次的に得られるデータが利用されてきた．しかし近年は非侵襲で測定が簡便なBioelectrical Impedance Analysis（生体電気インピーダンス法：以下BIA法）が主流となっている．C Verdichらは[4]介入による食事制限での減量評価にBIAとDEXAを使用し各装置の測定結果を比較している．

本研究ではBIA法による体組成計（バイオスペース社製InBody430）を使用し測定した．測定項目はBody Mass Index（以下BMI）に加え，体脂肪量と四肢骨格筋量Skeletal Muscle Mass Index（以下四肢SMI）を算出した．

3. 血管内皮機能の測定

血管内皮機能の測定にはUNEX製FMD装置を使い，血流依存性血管拡張反応検査にてFlow Mediated Dilation（以下FMD値）を測定した．Maruhashi Tらは[5]本検査によるFMD値を心血管のリスクファクターとなりうるとしている．FMD値の測定は超音波画像より上腕の動脈径を測定する．その後前腕を5分間駆血し解放後に拡張した上腕の動脈径を測定する．駆血前の動脈径に対する駆血解放後の動脈径の拡張率をFMD値として%で表す．

4. 健康に対する意識調査

就労が終了したのちアンケート形式で生きがいや生活の質・生活範囲，食，睡眠，人間関係，活動意欲についてお聞きするとともに，自由記入形式で健康面・虚弱予防活動の意識変化について回答を得た．

有意差検定はIBM SPSS Statistics21を使いWilcoxonの符号付順位検定を用いた．有意水準は5%未満とした．

3 結 果

測定結果をまとめ（表1）に示す．

□表1 就労前後での検査結果

			就労前		就労中		就労後		就労前後の有意差
			中央値	IQR	中央値	IQR	中央値	IQR	
身体活動量	中強度活動時間	分/日	21.5	13, 33	24.2	9, 44	29.2	21, 40	p=0.020
	歩数	歩/日	5592	4568, 7374	6599	4749, 8382	7223	4885, 9750	p=0.017
体組成	BMI	kg/m^2	24.2	23, 26	NA	NA	23.9	23, 26	p=0.004
	四肢骨格筋指数	kg/m^2	10.30	9.0, 10.9	NA	NA	10.33	9.0, 10.8	p=0.642
	体脂肪量	kg	16.3	13, 21	NA	NA	13.6	13, 20	p=0.004
血管内皮機能	FMD 値	%	5.4	3, 6	NA	NA	5.7	4, 6	p=0.277
身体活動量減少群	体脂肪量	kg	13.4	13, 19	NA	NA	13.4	12, 19	p=0.686
身体活動量増加群	体脂肪量	kg	18.2	15, 21	NA	NA	17.5	13, 20	p=0.004

※NA は “not available” を示す

1. 身体活動量

身体活動量計から算出された中強度活動時間・歩数ともに就労前-就労中-就労後と増加した. 特に就労前と就労後は中強度活動時間・歩数ともに有意差を持って増加している.

2. 体組成

四肢SMIは就労前後での変化は見られなかった. しかし, 体脂肪量は就労前後で有意に減少した. さらに就労前に比べ就労中の身体活動量が増加した群（11名）と減少した群（5名）に分けると, 身体活動量増加群での体脂肪率は有意に減少したが身体活動量減少群では有意差が見られなかった.

対象者に就労開始前でBMI18以下はいなかったが, BMIが就労後は有意に低下していた. なかでも就労前BMI25以上であった6名のうち4名にBMI低下が認められた.

3. 血管内皮機能

FMD値は就労後わずかな上昇がみられた.

4. 健康に対する意識

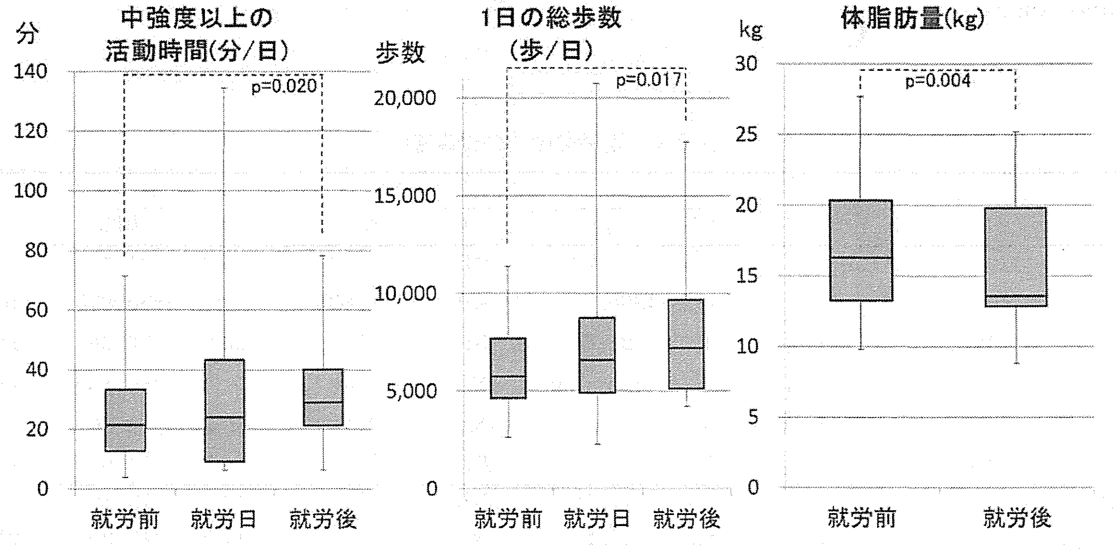
メンタルヘルスや生活の質の向上についての設問については9割以上が意識の向上を感じ, 自由記入では「健康に対する意識改善」「人とのつながり」「運動習慣の見直し」「生活の上での気持ちの向上」に関する記述が目立った.

4 考察

退職後も何らかの社会参加の機会を望むシニアは多い. 本研究の就労はそのようなシニアのニーズにマッチし, 自然な形での身体活動量の増加に寄与できたと考える.

就労前と就労中の身体活動量の推移を見たときに, 就労中身体活動量が増加する群と低下する群があることが分かった. 就労後の聞き取りによると増加群では普段体を動かす機会が少なく, 就労が身体活動量を増加させるきっかけとなったことがうかがわれる. またこの群はもともと体脂肪量が高めであり, 体脂肪量減少の効果も高かった. 対して低下群では日常的にウォーキング・農作業・スポーツをしており, 日常活動より身体活動量の低い就労についたため身体活動量の低下につながった. この群はもともと体脂肪量が低くさらなる減少の効果は見られない. つまり体組成の改善も就労の効果として見据えるのであれば, 各人の日頃の身体活動量を加味して就労内容を決定する必要がる.

就労前に比べて就労後は全体として有意に身体活動量が増加しており（図1), 就労は一過性の介入手段にとどま



❏ 図1 就労による身体活動量と歩数・体脂肪の変化

らず就労が終了してからもその効果の継続が期待できる．一時的な外部からの介入による変化ならば，介入終了とともにその効果の減少が考えられる．しかし強制的な身体活動量の増加ではなくシニアの自発的な社会活動によるものならば，その効果の持続と長期的な就労を介することで永続的な効果が期待される．

体脂肪量の有意な減少は特に過体重傾向であった対象者に改善が見られた．この改善はSMIの減少が見られないことからも，筋肉減弱を伴わない理想的な変化である．Ryu Mらは[6)]身体活動量とサルコペニアの関係を報告しているが，本研究からも身体活動量の増加が体組成の改善に寄与し，メタボリックシンドロームや潜在的な病気へのリスク低減が期待される．

また就労による身体活動量の増加は体組成の変化をもたらすだけではなく，アンケート結果から健康に対する意識の向上にも効果があることがうかがわれ，生活の質向上のきっかけとなりうることが分かった．同時にこの意識の向上が就労終了後も身体活動量が減少せず増加している一因となっているのではないかと思われる．

季節変動による血管内皮機能の低下が憂慮されたが，結果はほとんど変動がなかった．これはほぼ正常値である値が維持された可能性がある．

このようにシニアは退職後再度の就労につくことで，低下しがちな身体活動量を増加させることができる．その結果シニアが陥りがちな虚弱の防止となりうる体組成の改善につながることが分かった．

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Beneficial effects of active working during second life on physical activity and body composition in the elderly

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Retirement of elderly causes a decline in physical activity. It may be attributed to physical, mental and social frailty. We examined whether active working during second life beneficially affect physical activity and body composition in the elderly.

In this study, the participants worked as research staff of large-scale prospective cohort study, so called Dealing with community-dwelling older adults. The participants were over 60 years old, 11male and 5 female. The examinations, including physical activity, body composition and flow-mediated dilation (FMD), were performed before and just after the work of research staff.

Physical activity time of 3METs or more showed 21.5[13,33]min/day (Median [IQR]) before the work, and 29.2[21, 40] min/day just after the work. This increased difference was statistically significant (p=0.020). In addition step count showed 5592[4568, 7374]step/day before the work, 7223[4885, 9750]step/day just after the work. Its difference was also significantly increased (p=0.017). Notably, body fat mass showed 16.3[13, 21]kg before the work, and 13.6[13, 20]kg just after the work. This reduction was statistically significant (p=0.004). The significant improvement of FMD was not observed.

In summary, our observations might suggest that working during second life improves the body composition, especially body fat mass, via an increase in physical activity. This contribution to society with the sense of purpose may play a beneficial role in physical and mental healthcare in the elderly.

Key words physical activity, body composition, elderly, frailty, second life

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Association of decreased sympathetic nervous activity with mortality of older adults in long-term care

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Aim: To investigate the relationship between physical function, mortality and autonomic nervous activity measured by heart rate variability of elderly in long-term care.

Methods: Cross-sectional and longitudinal studies were carried out at hospitals and health service facilities for the elderly in Nagano prefecture, Japan, from July 2007 to March 2011. A total of 105 long-term care older adults and 17 control older adults with independent physical function were included. The Functional Independence Measure (FIM) and Barthel Index were determined as indices of physical function. Twenty-four-hour Holter monitoring was carried out. From RR intervals in electrocardiograms, heart rate and standard deviations of all NN intervals in all 5-min segments of the entire recording, power spectral density, low frequency, high frequency and low frequency/high frequency (LF/HF) were calculated.

Results: FIM score and Barthel Index were 46 ± 26 and 30 ± 31, respectively, in long-term care elderly. FIM and Barthel index were significantly correlated with heart rate and the standard deviations of all NN intervals after adjustment for age, sex, cardiovascular risk factors and FIM. Furthermore, LF/HF was significantly decreased in long-term care elderly compared with control elderly after adjustment for covariates. In addition, decrease in LF/HF was an independent risk factor for mortality.

Conclusion: Low LF/HF activity was observed in long-term care elderly and was related to an increase of overall mortality. **Geriatr Gerontol Int 2014; 14: 159–166.**

Keywords: heart rate variability, long-term care, mortality, motor activity, sympathetic nervous system.

Introduction

The number of older adults who require long-term care (LTC) has been increasing in Japan, and it was reported that there were 4.67 million older adults in LTC in 2008.[1] One of the characteristics of older adults in long-term care is physical and cognitive dysfunction. Physical dysfunction, including slow gait, low handgrip strength, low physical activity, weight loss and exhaustion, are reported to be associated with increased overall mortality.[2] In Japan, LTC elderly is defined as those who require assistance with walking, moving, and washing their face, body and mouth, representing functional disability and high mortality.[3] Thus, it is important to maintain or increase physical function in LTC elderly.

The underlying causes of physical dysfunction in Japanese LTC elderly include cerebrovascular disease, dementia, fractures, falls, weakness as a result of aging, and arthritis.[3] Recent studies have shown that these diseases with physical dysfunction are associated with low sympathetic nervous system activity.[4–7]

Skin sympathetic reactivity (SSR) reflects sympathetic nervous system activity. Muslumanoglu *et al.* showed that low SSR was associated with greater severity of paralysis, and depression of sympathetic reflex activity was associated with moderate or severely limited motor function in the chronic phase of ischemic cerebrovascular disease in elderly patients.[5] In addition, low plasma norepinephrine and low iodine-131-meta-iodobenzylguanidine (^{123}I-MIBG) uptake were observed in patients with Lewy body dementia compared with normal healthy subjects.[6,7] RR intervals in the electrocardiogram are utilized to evaluate heart rate variability

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