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Nutrient and food group intakes and skeletal muscle index in the Japanese elderly: a cross-sectional analysis of the NHNS 2017

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Abstract

Objective: To examine nutrient and food intakes according to the levels of skeletal muscle mass index (SMI) in the elderly.
Design: Cross-sectional study.
Setting: Data were derived from the 2017 National Health and Nutrition Survey in Japan. SMI was calculated by dividing appendicular skeletal muscle (or lean) mass (kg) by height squared (m^2). We calculated the multivariable-adjusted means of individuals' dietary intake. Dietary intake of energy, nutrients and food categories was assessed by examining dietary records using a semi-weighed method and compared according to the sex-specific quartiles of SMI.
Participants: Men and women aged ≥60 years.
Results: Among 797 men and 969 women, individuals with a higher SMI consumed more energy and more nutrients than did those with a lower SMI after adjusting for age, lifestyle and physical activity factors. After further adjusting for energy intake, total dietary fibre, vitamin A, vitamin B$_6$, K, Fe and Cu were positively associated with higher SMI in men ($P_{\text{for trend}} < 0{\cdot}05$). For food categories, men with a higher SMI consumed more vegetables and meats, but the associations were attenuated after adjustment for energy and remained significant for vegetable only ($P_{\text{for trend}} = 0{\cdot}018$).
Conclusions: Japanese elderly people with a higher SMI consumed more energy and nutrients and more vegetables than did those with a lower SMI. This finding shows that diet is important in preventing muscle loss among the elderly in an ageing society.

Keywords
Skeletal mass index
Appendicular skeletal muscle mass
Dietary intake
Elderly

A rapidly ageing society is now a global problem, with populations aged ≥60 years projected to account for nearly a quarter or more of all regional populations by 2050, except in Africa[1]. One of the most advanced ageing societies is Japan, with populations aged ≥65 years dramatically increasing from 6·3 % in 1965 to 26·6 % in 2015[1]. Japan is also known for its longevity and high healthy life expectancy; however, there are still disparities between life expectancy and healthy life expectancy (8·4 years for men and 10·1 years for women)[2]. Therefore, new evidence which contributes to the further extension of healthy life expectancy is urgently needed.

Muscle weakness is a major public health issue which inhibits the extension of healthy life expectancy for an ageing society because low muscle mass has been reported to be associated with increased risk of losing physical independence[3,4] or the need for long-term care[5]. According to the European Working Group on Sarcopenia in Older People, sarcopenia can be categorised into 'primary sarcopenia', in which ageing is the only evident cause, and 'secondary sarcopenia', in which one or more other causes of inactivity, disease or malnutrition are evident[6]. Malnutrition, especially energy and/or protein, is caused by multiple factors such as malabsorption, gastrointestinal disorders or anorexia-inducing medications[6]. However, the previous reports for the association between dietary intake and muscle mass among elderly people are mainly from Western countries[7–9], and evidence in Asian countries with different dietary habits and intakes is scarce.

The 2017 National Health and Nutrition Survey of Japan focused on the health and lifestyle status among the elderly

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population[10]. In addition to the routine survey items, the muscle mass among the participants aged ≥60 years was assessed. The current study aimed to investigate nutrient and food intakes according to the skeletal muscle mass among the Japanese elderly using national data from the National Health and Nutrition Survey of Japan.

Methods

We used secondary data approved by the Ministry of Health, Labour and Welfare. The National Health and Nutritional Survey in Japan has been conducted every year by the Ministry of Health, Labour and Welfare to clarify the citizens' physical condition, dietary intake and lifestyle and to obtain basic data for implementing measures that promote public health. It is performed at public health centres in all prefectures across Japan according to the Health Promotion Act (Act No. 103 of 2002)[10,11]. The 2017 survey participants were from households with one or more members as of 1 November 2017, in randomly sampled 300 areas from the zones set for the preceding Comprehensive Survey of Living Conditions in 2017. The following households and household members were excluded from the survey: households whose head were foreigners; households which were provided with delivered/prepared meals three times a day; single-member households such as dormitories where meals are provided; infants aged under 1 year; persons who were on a special diet, such as those who had only liquids or medicines due to illness and individuals who were absent throughout the survey period (e.g. due to travel/business trip, long-term inpatient, hospitalisation and living in a social welfare facility). All surveys were carried out according to the specific survey manual.

Our study population consisted of individuals aged ≥60 years who completed the dietary survey and the skeletal muscle measurement.

Physical condition assessment

Height and body weight were measured according to the standardised procedure, and BMI was calculated as weight (kg) divided by height squared (m^2).

In 2017, to evaluate the health status of elderly people, the appendicular skeletal muscle (or lean) mass (ASM) measurement was conducted among individuals aged ≥60 years. This was performed using a multi-frequency, bioelectrical impedance apparatus (product code: MC-780 A portable type), which has been evaluated for its validity in estimating ASM[12]. Individuals with an electric medical device such as a pacemaker were excluded from the measurement. For accurate measurement, participants stood barefoot on the metal contacts (after removing dust from their palms and feet) with their arms extended apart from their trunk and their legs spread so that their inner thighs would not touch. We calculated the skeletal muscle mass index (SMI) as the ASM (kg) divided by height squared (m^2)[13] and assigned the sex-specific quartile (Q).

Dietary assessment

The details of the dietary survey protocol are reported elsewhere[14]. Briefly, the survey was carried out on a single day during November 2019 on a usual eating day, except on Sundays, holidays or other special days including ceremonial occasions when dietary patterns might be changed. Participants received instructions for reporting their dietary status for each meal (e.g. home-cooked, eating-out, ready-to-eat, provided or skipped) and their dietary intakes according to the nutritional survey manual. The household member who was in charge of preparing meals for the family recorded the dietary status, as well as the dish name, food name used in each dish, the weight of each food used in the dish, the weight of the food waste and also the proportion of the food eaten by each household member separately for breakfast, lunch, dinner and snacks. Participants were requested to weigh all foods eaten on a food scale. When weighing was not possible, the dieticians in charge of checking the reports applied a standardised weight for each food according to the nutritional survey manual. The nutrient intake of each participant was estimated based on the 2010 Standard Tables for Food Composition in Japan[15], and the proportions of energy were calculated using the energy-conversion values (protein 16·736 kJ/g, fat 37·656 kJ/g; carbohydrate regarded as their residual). Food intake was classified into seventeen food groups: cereals, potatoes/starches, sugars/sweeteners, pulses, nuts/seeds, vegetables, fruits, mushrooms, algae, fish/molluscs/crustaceans, meat, eggs, milk/dairy products, fats/oils, confectionaries, beverages and seasonings/spices.

Lifestyle and physical activity factors

The participant's current occupation was categorised into the following five occupational groups: professional/management (professional or management), office work, sales/service, manual (security, farming, forestry, fishery, transportation or labour service) or unemployed (housework, unemployed or other). Information on lifestyle factors (drinking status, smoking status and sleep duration) was obtained by a self-administered questionnaire. Participants measured their amount of physical activity (number of steps) in a day using a pedometer (product code: Yamasa AS-200) and recorded their total number of steps on the questionnaire. If exercise for the purpose of maintaining and promoting health and physical strength (e.g. sports or personal fitness training) was not prohibited by doctors, then participants also recorded the number of days per week they exercised, their average exercise time (duration) and the period they have been exercising (i.e. less than or more than

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1 year). Habitual exercise was defined as continuing exercise with ≥30 min/d and ≥2 d/week for more than 1 year.

Statistical analysis

The statistical analyses were based on the data for sex-specific quartiles of SMI. We calculated sex-specific means or proportions of the survey participants' characteristics and compared them using χ^2 test for categorical variables. One-way ANOVA was used for continuous variables. We also calculated multivariable-adjusted means for the analyses of dietary intake of nutrients and foods. The adjusted variables included age (years), drinking status (never, ex-drinker or current drinker of 1–3 d/month, 1–4 or 5–7 d/week), smoking status (never, ex-smoker or current smoker), sleep duration (<6·0, 6·0–6·9, 7·0–7·9 or ≥8·0 h), exercise habit (yes or no), occupation (one of the five categories) and further energy intake. Participants with missing data were categorised as 'missing' and included in all analyses. The multivariable-adjusted means for intake of nutrients and foods in each quartile SMI group were compared with the lowest quartile groups using the Dunnett method[16] and the trend test using linear regression analysis. BMI was not included as a covariate due to the possibility of a correlation between BMI and SMI (correlation coefficient: 0·50 in men and 0·42 in women). We also analysed who had habitual exercise in a restricted population to assess the combined status with exercise and performed a sub-analysis of ASM% (ASM (kg)/body weight (kg)) to assess the relation of weight instead of height with dietary intake. Two-sided P values <0·05 were considered statistically significant. All analyses were performed using SAS version 9.4 (SAS Institute Inc.).

Results

The median SMI of the male and female participants was 7·7 and 6·4 kg/m^2, respectively. The sex-specific characteristics according to the quartiles of SMI in 797 men and 969 women are shown in Table 1. Individuals in the highest quartile of SMI were significantly younger, had a higher BMI, had shorter sleep durations and were more likely to be current drinkers and have work than were individuals with a lower SMI. Over 40 % of individuals within the highest SMI quartile were simultaneously overweight or obese, as defined using a cut-off value of 25 or 30 kg/m^2.

Dietary intake of energy and most nutrients was significantly higher in individuals with a higher SMI than in those with a lower SMI after adjustment for age, drinking, smoking, sleep duration, occupation and exercise habits (online Supplemental Table 1). After further adjusting for energy intake, total dietary fibre intakes were significantly higher in men with higher SMI compared with the men with the lowest SMI (Table 2). Intakes of vitamin A, vitamin B$_6$, K, Fe and Cu were significantly higher in the higher SMI group only among men. Furthermore, when analyses were limited to those who had exercise habits, we observed a significantly positive correlation between mean protein intake and SMI only in men not in women (Q1: 76·0 g, Q2: 81·5 g, Q3: 79·7 g and Q4: 83·1 g with $P_{\text{for trend}} = 0·040$ in men and Q1: 69·6 g, Q2: 71·2 g, Q3: 69·8 g and Q4: 69·7 g with $P_{\text{for trend}} = 0·84$ in women, according to the quartile of sex-specific SMI; data not shown in tables).

We also evaluated dietary intakes as per food group according to the quartiles of SMI after adjusting for age, drinking, smoking, sleep duration, occupation and exercise habits (online Supplemental Table 2). Both sexes with the highest quartile of SMI consumed significantly more vegetable and meats than did those with the lowest quartile of SMI (multivariable-adjusted means: 363 g and 278 g with $P_{\text{for trend}} < 0·001$ in men and 357 g and 302 g with $P_{\text{for trend}} = 0·019$ in women for vegetables; 101 g and 81 g with $P_{\text{for trend}} = 0·08$ in men and 76 g and 59 g with $P_{\text{for trend}} = 0·007$ in women for meats). Men with higher SMI consumed significantly more cereals and fruits. After further adjustment for energy intake, vegetables among men retained statistical significance for a higher SMI (Table 3).

In sub-analysis of ASM% after adjustment of the full model including energy intake, a similarly positive trend to that of SMI was observed for total dietary fibre in both men and women. Further, fat and mineral (K, Ca and Mg) intake was significantly higher, while carbohydrate and Na intake was lower in women with a higher ASM% than in those with lower ASM% (online Supplemental Table 3). For food group, a positive trend for fruit intake was observed in women (online Supplemental Table 4). In the assessment of the potential effect of sex, there was no sex interaction for all nutrients and food groups ($P_{\text{interaction}} > 0·05$) (data not shown in Tables).

Discussion

We observed that Japanese elderly people with a higher SMI had a higher energy intake and consumed more nutrients than did those with a lower SMI after adjustment for age, sleep duration and physical activity factors. Elderly people with a higher SMI consumed more vegetables and meats.

Protein and vitamin D have been extensively studied as important nutrients contributing to higher muscle mass in the elderly. It has been reported that dietary intake of protein (i.e. not supplement intake) double the RDA was associated with increased lean mass in comparison with intakes equivalent to the RDA[8]. Higher intake of dietary protein may be effective in preventing loss of lean mass compared with lower intake[9]. In two recent meta-analyses on protein supplementation, one found no positive effect

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Table 1 Characteristics of the subjects by the quartiles of the skeletal muscle mass index (SMI)*

	Men									Women								
	Q1		Q2		Q3		Q4			Q1		Q2		Q3		Q4		
	%		%		%		%		P_{for} difference	%		%		%		%		P_{for} difference
Number		199		199		200		199			242		242		243		242	
SMI (kg/m^2)																		
Median		6·6		7·4		8·0		8·7			5·8		6·3		6·6		7·1	
IQR		6·4–6·9		7·3–7·6		7·9–8·1		8·5–9·1			5·6–6·0		6·2–6·4		6·5–6·7		6·9–7·3	
Age (years)																		
Mean		77·1		73·2		70·2		67·5	<0·001		76·3		72·4		70·5		68·5	<0·001
SE		0·5		0·5		0·4		0·4			0·5		0·4		0·4		0·4	
60–64	2·0		9·0		20·0		39·7		<0·001	5·4		14·5		23·0		30·2		<0·001
65–69	13·1		24·1		28·5		27·1			12·0		22·7		23·0		31·4		
70–74	19·6		23·6		27·0		20·1			27·3		25·6		23·9		22·7		
75–79	28·6		22·6		16·0		10·1			21·5		20·7		21·4		11·2		
≥80	36·7		20·6		8·5		3·0			33·9		16·5		8·6		4·5		
BMI (kg/m^2)																		
Mean		21·9		23·4		24·1		25·7	<0·001		21·3		22·5		23·5		25·2	<0·001
SE		0·2		0·2		0·2		0·2			0·2		0·2		0·2		0·2	
<18·5	13·6		0·5		0·0		0·5		<0·001	20·2		7·9		2·9		1·7		<0·001
18·5–24·9	75·4		74·4		70·0		42·7			70·2		70·7		65·4		51·2		
25·0–29·9	10·6		24·6		28·0		47·2			8·7		19·8		29·2		36·4		
≥30	0·5		0·5		2·0		9·5			0·8		1·7		2·5		10·7		
ASM (kg)																		
Mean		16·8		19·8		21·9		25·1	<0·001		12·4		14·1		15·4		17·1	<0·001
SE		0·1		0·1		0·1		0·2			0·1		0·1		0·1		0·1	
ASM/weight (%)																		
Mean		30·2		32·0		33·6		34·8	<0·001		27·6		28·4		28·6		29·0	<0·001
SE		0·3		0·2		0·2		0·3			0·3		0·3		0·2		0·3	
Current drinker	65·3		73·9		80·5		80·9		<0·001	26·3		43·3		44·0		48·8		<0·001
Current smoker	20·1		17·1		20·5		20·6		0·79	3·8		5·0		6·6		2·1		0·09
Sleep duration (h)																		
<5·9	21·6		22·1		24·5		29·6		<0·001	30·2		38·0		38·7		43·0		<0·001
6·0–6·9	27·6		33·2		34·0		36·7			31·4		29·3		35·8		35·1		
7·0–7·9	27·1		29·6		31·0		29·1			21·9		26·4		18·5		17·4		
≥8·0	23·6		15·1		10·5		4·5			15·7		5·4		7·0		4·5		
Occupation																		
Professional management	3·5		6·5		12·0		16·6		<0·001	2·5		5·8		4·9		6·2		<0·001
Office work	1·5		1·0		6·5		3·0			1·7		2·5		2·5		6·2		
Sales/Service	6·5		7·0		7·0		6·5			6·6		9·1		13·6		12·8		
Manual	10·6		17·1		28·0		29·1			3·3		9·1		7·4		10·3		
Unemployed	77·9		68·3		46·5		44·7			86·0		73·6		71·6		64·5		
No. of steps																		
Mean		4628		5910		6889		6674	<0·001		4252		5405		5341		5938	<0·001
SE		252		280		319		274			210		230		220		219	
Habitual exercise	35·7		43·7		45·0		47·2		0·10	33·5		36·4		37·4		38·8		0·65

IQR, interquartile range; ASM, appendicular skeletal muscle mass.
*In total, 0·8 % of women had missing data for smoking, drinking and sleep duration in Q1 and Q2.

Table 2 Energy and nutrient intakes according to the quartile of the skeletal muscle mass index (SMI)§

	Men									Women								
SMI (kg/m^2)	Q1		Q2		Q3		Q4		$P_{\text{for trend}}$	Q1		Q2		Q3		Q4		$P_{\text{for trend}}$
Median	6·6		7·4		8·0		8·7			5·8		6·3		6·6		7·1		
Interquartile range	6·4–6·9		7·3–7·6		7·9–8·1		8·5–9·1			5·6–6·0		6·2–6·4		6·5–6·7		6·9–7·3		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Energy (kcal)‖	2011	39	2086	36	2249‡	36	2281‡	38	<0·001	1657	30	1777*	28	1829‡	28	1814†	29	<0·001
Protein (g)	77·6	1·2	80·6	1·1	78·9	1·1	79·5	1·2	0·32	67·9	0·9	69·5	0·8	68·6	0·8	68·7	0·9	0·59
Protein (% of energy)	14·6	0·2	14·9	0·2	14·7	0·2	14·8	0·2	0·61	15·3	0·2	15·8	0·2	15·6	0·2	15·7	0·2	0·43
Fat (g)	61·7	1·3	61·5	1·2	62·3	1·2	61·4	1·2	0·95	54·2	1·0	53·1	0·9	54·2	0·9	54·4	0·9	0·73
Fat (% of energy)	25·3	0·5	25·6	0·5	25·6	0·5	25·2	0·5	0·90	27·1	0·5	26·8	0·4	26·9	0·4	27·4	0·5	0·76
Carbohydrate (g)	287·7	3·5	289·3	3·2	289·5	3·2	290·0	3·4	0·97	245·6	2·5	245·5	2·3	245·5	2·3	245·7	2·4	1·00
Carbohydrate (% of energy)	60·1	0·6	59·5	0·6	59·7	0·6	60·0	0·6	0·84	57·6	0·5	57·4	0·5	57·6	0·5	56·9	0·5	0·79
Total dietary fibre, g	16·2	0·5	18·2†	0·4	17·7	0·4	18·1*	0·4	0·009	16·8	0·4	16·6	0·4	17·4	0·4	17·9	0·4	0·07
Soluble (g)	3·8	0·1	4·2†	0·1	4·0	0·1	4·2*	0·1	0·013	4·0	0·1	3·8	0·1	3·9	0·1	4·1	0·1	0·27
Insoluble (g)	11·8	0·3	13·3†	0·3	13·0*	0·3	13·3*	0·3	0·004	12·3	0·3	12·1	0·3	12·7	0·3	13·0	0·3	0·14
Vitamin A (μg)	545	69	511	62	755	63	576	67	0·035	554	51	646	48	541	48	614	50	0·37
Vitamin D (μg)	9·0	0·7	8·7	0·6	9·4	0·6	9·0	0·7	0·90	8·5	0·5	9·4	0·5	8·1	0·5	7·6	0·5	0·10
Vitamin E (mg)	7·3	0·2	7·8	0·2	7·4	0·2	7·6	0·2	0·45	7·1	0·2	7·0	0·2	7·2	0·2	7·6	0·2	0·24
Vitamin K (μg)	265	14	291	12	255	13	280	13	0·16	279	12	252	11	252	11	284	12	0·08
Vitamin B_1 (mg)	0·98	0·03	1·03	0·02	0·97	0·03	0·97	0·03	0·34	0·82	0·02	0·87	0·02	0·88	0·02	0·88	0·02	0·13
Vitamin B_2 (mg)	1·31	0·04	1·34	0·03	1·36	0·03	1·35	0·04	0·80	1·27	0·03	1·23	0·03	1·24	0·03	1·27	0·03	0·68
Niacin (mg)	16·4	0·5	17·7	0·4	17·3	0·4	17·4	0·5	0·21	14·4	0·3	14·5	0·3	15·0	0·3	14·7	0·3	0·63
Vitamin B_6 (mg)	1·29	0·03	1·42†	0·03	1·36	0·03	1·37	0·03	0·007	1·21	0·02	1·19	0·02	1·21	0·02	1·21	0·02	0·95
Vitamin B_{12} (μg)	6·0	0·5	6·7	0·5	7·9*	0·5	7·3	0·5	0·08	6·7	0·4	6·7	0·4	6·2	0·4	5·9	0·4	0·49
Folate (μg)	323·0	11·4	346·9	10·4	366·0*	10·5	355·7	11·1	0·07	337·0	9·5	337·0	8·9	335·9	8·9	355·9	9·3	0·36
Pantothenic acid (mg)	6·15	0·12	6·45	0·10	6·33	0·11	6·48	0·11	0·17	5·68	0·09	5·66	0·09	5·62	0·09	5·70	0·09	0·92
Vitamin C (mg)	113	7	132	6	127	6	139*	6	0·06	134	6	127	5	138	5	143	5	0·16
Na (mg)	4325	109	4565	99	4306	100	4535	106	0·14	3723	87	3802	82	3821	82	3968	85	0·28
Salt equivalents (g)	11·0	0·3	11·6	0·3	10·9	0·3	11·5	0·3	0·14	9·5	0·2	9·7	0·2	9·7	0·2	10·1	0·2	0·28
K (mg)	2554	60	2847‡	54	2762*	55	2735	58	0·003	2583	49	2539	46	2634	46	2655	47	0·30
Ca (mg)	582	19	604	17	588	17	575	18	0·64	594	17	563	16	594	16	586	17	0·50
Mg (mg)	281	6	301*	5	293	5	293	6	0·08	266	5	263	4	268	4	270	5	0·70
P (mg)	1124	19	1167	17	1120	17	1133	18	0·20	1012	15	1019	14	1026	14	1020	15	0·93
Fe (mg)	8·4	0·2	9·1*	0·2	8·9	0·2	9·2*	0·2	0·049	8·6	0·2	8·3	0·2	8·2	0·2	8·5	0·2	0·38
Zn (mg)	8·9	0·2	9·2	0·1	8·8	0·1	9·1	0·1	0·31	7·7	0·1	7·6	0·1	7·8	0·1	7·8	0·1	0·44
Cu (mg)	1·28	0·02	1·37*	0·02	1·29	0·02	1·30	0·02	0·011	1·18	0·02	1·17	0·02	1·16	0·02	1·19	0·02	0·75

§The values are presented as mean values with standard errors adjusted for age, drinking, smoking, sleep duration, exercise habit, occupation and energy intake (except for energy itself).
‖To convert kcal to kJ, multiply it by 4·184.
The reference for comparison for statistical significance was the lowest quartile (*<0·05; †<0·01; ‡<0·001).

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Table 3 Intakes of food group according to the quartile of the skeletal muscle mass index (SMI)§

	Men									Women								
SMI (kg/m^2)	Q1		Q2		Q3		Q4		$P_{for\ trend}$	Q1		Q2		Q3		Q4		$P_{for\ trend}$
Median	6·6		7·4		8·0		8·7			5·8		6·3		6·6		7·1		
Interquartile range	6·4–6·9		7·3–7·6		7·9–8·1		8·5–9·1			5·6–6·0		6·2–6·4		6·5–6·7		6·9–7·3		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE		Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Cereals (g)	477·6	11·1	460·3	10·1	466·7	10·2	477·0	10·8	0·55	350·1	7·9	354·3	7·4	351·2	7·5	339·8	7·8	0·57
Potatoes and starches (g)	57·2	6·1	69·2	5·5	59·1	5·6	59·0	5·9	0·40	60·1	4·7	55·6	4·4	56·4	4·4	56·2	4·6	0·91
Sugars and sweeteners (g)	7·8	0·8	8·3	0·7	8·5	0·7	8·3	0·7	0·92	7·9	0·6	7·4	0·5	8·1	0·5	7·8	0·6	0·81
Pulses (g)	80·8	6·8	95·1	6·2	78·1	6·2	73·2	6·6	0·09	77·9	5·8	84·0	5·5	68·6	5·5	82·6	5·7	0·18
Nuts and seeds (g)	4·2	1·0	3·2	0·9	4·1	0·9	4·3	1·0	0·82	4·1	0·7	3·1	0·7	3·9	0·7	4·6	0·7	0·46
Vegetables (g)	294·1	14·0	348·9†	12·7	334·9	12·8	348·6*	13·6	0·018	316·9	11·8	316·5	11·1	323·5	11·1	351·1	11·5	0·12
Fruits (g)	127·7	11·7	159·6	10·7	164·6	10·8	157·0	11·4	0·11	168·1	9·5	161·0	8·9	173·9	8·9	166·8	9·3	0·79
Mushrooms (g)	16·5	2·4	20·1	2·2	20·4	2·2	22·4	2·4	0·44	16·8	2·1	22·1	1·9	21·2	1·9	17·6	2·0	0·14
Algae (g)	13·8	2·1	13·6	1·9	15·2	1·9	12·6	2·0	0·81	12·1	1·6	11·8	1·5	14·0	1·5	14·9	1·6	0·46
Fish, molluscs and crustaceans (g)	84·0	5·9	93·5	5·4	86·6	5·4	90·8	5·7	0·62	75·7	4·5	82·4	4·2	77·5	4·2	71·3	4·4	0·33
Meats (g)	88·9	5·5	93·3	5·0	95·3	5·1	93·7	5·4	0·87	63·2	3·9	71·0	3·7	74·5	3·7	73·7	3·8	0·17
Eggs (g)	41·1	2·9	41·6	2·7	37·4	2·7	46·3	2·8	0·14	38·2	2·3	37·3	2·1	32·5	2·1	39·0	2·2	0·14
Milk and dairy products (g)	134·9	11·6	132·7	10·5	143·9	10·7	132·8	11·3	0·86	146·9	9·1	136·3	8·5	153·3	8·6	133·0	8·9	0·32
Fats and oils (g)	11·1	0·7	11·3	0·7	11·7	0·7	10·6	0·7	0·70	9·7	0·6	9·4	0·5	9·4	0·5	9·5	0·6	0·99
Confectioneries (g)	26·8	3·3	17·8	3·0	26·0	3·0	23·5	3·2	0·14	27·7	2·9	30·6	2·7	27·5	2·7	28·4	2·8	0·84
Beverages (g)	769·6	34·2	796·5	31·1	845·8	31·5	798·2	33·3	0·43	699·8	28·0	652·1	26·3	676·8	26·3	667·5	27·3	0·66
Seasonings and spices (g)	91·4	7·3	95·3	6·7	99·4	6·7	122·0*	7·1	0·020	76·9	5·7	90·7	5·4	85·9	5·4	85·8	5·6	0·37

§The values are presented as mean values with standard errors adjusted for age, drinking, smoking, sleep duration, exercise habit, occupation and energy intake.
The reference for comparison for statistical significance was the lowest quartile (*<0·05; †<0·01).

of protein supplementation on lean mass without concomitant exercise[17], while the other showed that protein supplementation with resistant exercise has positive effects on lean mass compared with exercise intervention alone[18]. Regarding vitamin D, many studies among elderly people have shown that vitamin D status is positively associated with muscle strength[19] and physical performance[20–23]. A meta-analysis of cross-sectional and cohort studies has indicated that vitamin D deficiency is associated with muscle weakness[24]. A meta-analysis of randomised controlled trials also showed a positive effect of vitamin D supplementation (with or without Ca supplementation) on muscle strength, but not on muscle mass and muscle power[25]. Furthermore, a randomised controlled trial of protein, amino acids and vitamin D supplementation along with physical activity resulted in an increase in fat-free mass and skeletal muscle mass[26].

The combined effects of several nutrients on lean body mass have also been reported, which support our results that showed significant difference in intakes of some vitamins and minerals. In a case–control study of older adults, those without sarcopenia consumed a varied diet of more protein, vitamin D, vitamin B_{12}, P, Mg and Se compared with those with sarcopenia, with similar energy intakes[27]. Another study examining the effects of a varied diet in elderly people assessed the consumption frequency of ten food items and found that more varied diet led to both a higher lean body mass and appendicular lean mass[28]. In our study, elderly people with a higher SMI consumed more vegetables and meats, although the relationship was attenuated after further adjustment for energy intake. These results agree with several previous studies on vegetables[29] and meats[30,31]. Consumption of meats could be important food group for prevention of loss of muscle mass[30];however, meats intake in Japanese elderly people aged ≥60 years is nearly half of that observed in young people aged 20–29 years (68·3 *v.* 123·7 g)[32]. Although elderly people may not prefer to eat meat because of declining appetite or difficulties in chewing, dietary advice to select a balanced diet with vegetable and meat may be important for nutritional adequacy.

The findings of the present study, such as the positive effect of protein intake combined with exercise, were consistent with those of previous studies. However, it was in contrast in terms of the effects of vitamin D intake. Our results regarding protein intake could be supported by a previous study which showed that dietary protein can acutely stimulate muscle protein synthesis[33]. The most reasonable explanation for vitamin D might be that its sufficiency was achieved through skin absorption from UV rays, instead of from dietary intake. However, we could not estimate the exposure of sunlight in the current study because of limited information regarding the residence and occupation of the participants. There are two major effects of vitamin D on muscle mass: directly via activation of the vitamin D receptor muscle cell and indirectly via Ca and phosphate metabolism[34] which optimise muscle strength and performance[35]. A randomised study reported that vitamin D supplementation increased concentrations of intramyonuclear vitamin D receptors and muscle fibre size in vitamin D-deficient older women[36]. However, the effects of vitamin D supplementation on muscle mass may be negligible among Japanese people due to the possibility of regular exposure to UV rays outdoors. Rather than incorporating a specific nutrient into the Japanese dietary pattern, a typical dietary intake of meats and vegetables adequately leads to intake of the necessary nutrients for a well-balanced diet among elderly people. This may help prevent decreases in muscle mass.

The main strength of the present study was that we used national survey data collected from a large free-living population, which was representative of the elderly Japanese population. In addition, dietary assessment data were of high quality and were evaluated through extensive checking of the dietary records. However, this study also had several limitations. First, the 2017 National Health and Nutrition Survey did not included measurements of skeletal mass strength which are used for assessing sarcopenia as recommended by the European Working Group on Sarcopenia in Older People in 2010[6]. The European Working Group on Sarcopenia in Older People2 recently published sarcopenia cut-off points on the revised European consensus of definition and diagnosis[37], but we did not evaluate the current results by applying these cut-offs because of the evidence in the population that are physically different from Japanese population. Regardless of that, our study showed a significant effect of diet components in determining if survey participants had a high or low skeletal muscle mass. A second limitation is that we could not show the ideal or unideal range of SMI because ASM was only measured among elderly people aged ≥60 years who were physically capable to visit the site of physical examination in each area. Third, dietary intake data obtained from a single day may not reflect habitual intake. Lastly, although this likelihood was decreased by the multivariable adjustment for potential confounding variables, we cannot eliminate the impact of residual confounding or unmeasured variables such as intakes from supplement and drug use, serum nutrient levels and disease conditions.

In conclusion, we observed that elderly people with a higher SMI consumed more energy and nutrients in their diets than did those with a lower SMI. The balanced diet was found to be more beneficial than higher intakes of a specific nutrient. With respect to food group, they consumed more meats and vegetables. Dietary components in these foods might be related to differences in muscle mass according to the quartiles of SMI in both men and women. Although

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we could not examine the causal association because of the cross-sectional study design, sufficient well-balanced dietary intake of energy and nutrients might be associated with the prevention of loss of muscle mass. These results provide evidence for the development of a healthy eating guideline in an ageing society.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980020000415

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