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Dietary intake and its association with sarcopenia in older adults: a cross-sectional analysis

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ABSTRACT

Sarcopenia, a condition characterized by the loss of muscle mass and function, poses a major health challenge among older adults. Identifying nutritional factors and dietary patterns associated with sarcopenia is critical for developing targeted interventions. This study analyzed data from 584 community-dwelling older adults (245 male, 339 female) enrolled in the Yakumo Study to investigate the relationship between dietary factors and sarcopenia. Nutritional intake was assessed using a validated Food Frequency Questionnaire (FFQ), while dietary diversity was evaluated using dietary variety score (DVS). Sarcopenia was diagnosed according to the Asian Working Group for Sarcopenia (AWGS) criteria, based on skeletal muscle mass, hand grip strength, and walking speed. The prevalence of sarcopenia in the study population was 7.4%. Nutritional intake of individual nutrients, such as protein and vitamin D, did not significantly differ between sarcopenic and non-sarcopenic participants. However, the intake rates for total calories, dietary fiber, vitamin B1, vitamin B2, and vitamin C were significantly higher in the sarcopenia group. No significant differences were found in DVS, and no correlations were found between DVS scores and skeletal muscle mass index, grip strength, or walking speed. These results may indicate that factors beyond nutrient intake—such as nutrient absorption, utilization, and metabolic efficiency—play a pivotal role in sarcopenia development.

Keywords: sarcopenia, nutrition, elderly, dietary intake, muscle health

Abbreviation:
DVS: dietary variety score

INTRODUCTION

Sarcopenia has attracted considerable attention due to the rapidly aging population in developed countries. Based on analyses using muscles obtained from autopsies, Lexell et al reported that

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skeletal muscle mass was reduced by ~50% in older individuals compared with young individuals.[1] Generally, the skeletal muscle area and muscle strength of elderly individuals decrease by 25%–30% and 30%–40%, respectively, compared with those in their 20s, and muscle mass decreases by 1%–2% annually after the age of 50 years.[2] The presence of sarcopenia is closely related to staggering, falls, and even frailty in the elderly, leading to the need for nursing care.[3] Therefore, the causes and pathogenesis of sarcopenia should be investigated to develop and introduce interventional strategies associated with these causes and pathogenesis.

As Japan transitions into a superaged society, the burden of social security costs, particularly for elderly care, has become significant.[4] Musculoskeletal disorders, including osteoporotic fractures and sarcopenia, are the leading causes of decreased healthy life expectancy. Sarcopenia is characterized by an age-related decline in muscle mass, strength, and physical function, which are often influenced by aging, malnutrition, and physical inactivity.[5] The global prevalence of sarcopenia varies widely depending on the diagnostic criteria used, the population studied, and assessment methods. A systematic review and meta-analysis reported that the prevalence of sarcopenia is 10%–27% in adults aged ≥60 years, with the highest prevalence observed in Oceania and the lowest in Europe.[5]

Nutritional status plays a crucial role in the development and progression of sarcopenia.[6-8] Muscle mass and function are maintained through adequate protein intake. Older individuals often have insufficient protein intake, which leads to reduced muscle protein synthesis and increased muscle breakdown. In addition to protein, other nutrients, such as vitamins C, D, and E, and omega-3 fatty acids, are important for muscle health.[9] Vitamin D deficiency has been associated with muscle weakness and increased risk of falls, whereas antioxidants, such as vitamins C and E, help reduce oxidative stress and inflammation, which are contributors to muscle degradation.[7]

However, large-scale comparative studies between sarcopenic individuals and healthy controls in terms of nutrient intake and dietary diversity are limited. While extensive research has investigated the role of protein intake and specific micronutrients in sarcopenia,[10-13] there is a lack of studies focusing on dietary diversity, which encompasses the variety of food groups consumed. Dietary diversity has been associated with better overall health outcomes, including enhanced nutrient absorption and bioavailability—factors that are particularly relevant in the context of sarcopenia. Considering the complex interactions between various nutrients, an exclusive focus on individual nutrients may fail to capture the broader benefits of a diverse diet. This highlights the need for further research into the role of dietary diversity in preventing and managing sarcopenia.

This study aimed to fill this gap by providing comprehensive data on nutrient intake and dietary diversity in a large cohort of elderly individuals, highlighting the novel aspects of nutrient intake patterns associated with sarcopenia.

METHODS

Study participants and ethical considerations

This study involved volunteers who participated in health checkups conducted in Yakumo, a rural town located in southern Hokkaido, Japan. These health checkups, organized as part of a long-standing community health initiative supported by the local government (the Yakumo Study), included internal examinations as well as optional orthopedic and functional assessments. The program has been running for over 30 years and targets individuals aged 40 years and older, as recommended by the local government to promote health and prevent disease. Participants in this initiative underwent annual evaluations as part of their commitment to maintaining community health. The study was approved by the Committee on Ethics on Human Research of Nagoya

University, and informed consent was obtained from all participants prior to their inclusion in the study. We included all participants who completed evaluations of fasting blood samples and nutritional intake.

Of the 758 participants who received health checkups, 584 (245 male and 339 female) met the inclusion criteria. The Human Research Ethics Committee and Nagoya University Institutional Review Board approved the research protocol (Approval no. 2014-0207), which complied with the guidelines of the responsible governmental agency. All participants provided written informed consent before participation. The study procedures were conducted following the principles of the Declaration of Helsinki (1976, revised 2013).

Grip strength and walking speed measurement

Grip strength was measured using a handgrip dynamometer (Toei Light Co Ltd, Saitama, Japan). The measurement was taken with participants standing, arms by their sides, and instructed to squeeze the dynamometer as hard as possible. Measurements were taken for both hands, and the average value was used for analysis. Moreover, the handgrip dynamometer has been validated for use in elderly populations and provides reliable and accurate measurements of grip strength.

The participants were instructed to walk a 10-m straight path as quickly as possible, and the time taken to complete the distance was measured and recorded as their 10-m walking time. A 2-meter acceleration phase and a 2-meter deceleration phase were provided before and after the measurement to ensure an accurate reading of maximum walking speed.

Sarcopenia diagnosis and muscle mass measurement

Sarcopenia was diagnosed based on the criteria established by the Asian Working Group for Sarcopenia (AWGS). The diagnosis was determined using three indicators: hand grip strength, walking speed, and skeletal muscle mass. Skeletal muscle mass was measured using bioelectrical impedance analysis (BIA) with an Inbody 720 device (Biospace Co, Ltd, Seoul, Republic of Korea). BIA evaluates body composition by analyzing variations in electrical impedance across different biological tissues, including fat, muscle, and bone. The appendicular skeletal muscle mass index (aSMI) was calculated as appendicular skeletal muscle mass (kg) divided by height squared (m^2).

Participants were classified as having sarcopenia if they exhibited reduced skeletal muscle mass (aSMI below the AWGS-defined cutoff values of <7.0 kg/m^2 for male and <5.8 kg/m^2 for female) in combination with either low hand grip strength (<26 kg for male, <18 kg for female) or slow walking speed (<0.8 m/s). This two-step diagnostic approach ensured a comprehensive evaluation of both muscle mass and physical function in identifying sarcopenia.

Biochemical analysis

During the health checkup, fasting blood samples were collected by venipuncture and centrifuged within 1 h from collection. The serum samples were stored at −80 °C until analysis to ensure sample integrity and minimize degradation. Routine biochemical analyses were conducted at the Yakumo Town Hospital laboratory.

Dietary assessment

Dietary information was obtained using a validated food frequency questionnaire (FFQ), which covered the intake of 188 food and beverage items, excluding supplements.[14] Energy and nutrient intake were calculated by multiplying the frequency of consumption, portion size, and energy and nutrient content of each food item, based on fifth revised and expanded Standard Tables of Food Composition in Japan (Council for Science and Technology, Ministry of Education, Culture,

Sports, Science, and Technology). We used the FFQ validated for use in similar populations, providing reliable estimates of dietary intake. The nutrients assessed included protein, fats, carbohydrates, minerals (sodium, potassium, calcium, and iron), vitamins (carotene, vitamins A, D, E, B1, B2, folate, C), and total dietary fiber, which were divided into soluble and insoluble fibers. Fats were categorized into saturated fatty acids, monounsaturated fatty acids (MUFAs), n-6 and n-3 polyunsaturated fatty acids (PUFAs), n-3 highly unsaturated fatty acids ([n-3 HUFAs] including eicosapentaenoic acid [20:5], docosapentaenoic acid [22:5], docosahexaenoic acid [22:6]), and cholesterol. Dietary variety score (DVS)[15] was used to assess dietary variety, which quantified the diversity of food groups consumed by the participants (Table 1). DVS was also calculated to evaluate dietary habits and was the sum of the number of times each respondent answered "eat almost every day" for the 10 food groups (maximum score 10).

Table 1 Dietary variety score (DVS)

Food group
1. Meat
2. Fish and shellfish
3. Eggs
4. Soy products
5. Milk
6. Green and yellow vegetables
7. Seaweed
8. Potatoes
9. Fruits
10. Dishes using oil

Scoring: Consumed almost daily, 1 point; consumed once every two days, 1–2 times weekly, or rarely, 0 points

The nutritional intake rate for each nutrient was calculated by referencing Dietary Reference Intakes for Japanese (2020) published by the Ministry of Health, Labour and Welfare, Japan. This rate was determined by dividing the participants' daily nutrient intake by the recommended daily intake specific to their age and sex categories, as defined in the guidelines. This approach allows for a standardized assessment of nutrient adequacy and facilitates comparison across individuals.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation. Continuous and categorical variables between the L and N groups were compared using the Student's t-test and chi-square test, respectively. These analyses were conducted separately for total adults and older adults. Statistical significance was set at $P < 0.05$. Pearson's correlation analysis was conducted to evaluate the relationships between nutrient intake rates, aSMI, and physical performance indicators such as hand grip strength and walking speed. SPSS Statistics v28.0 software for Mac (IBM Corp, Armonk, NY, USA) was used for all statistical analyses.

RESULTS

The sarcopenia group comprised 43 individuals (7.4%; mean age, 71.1 ± 10.0 years; 32.6% male), whereas the non-sarcopenia group included 541 individuals (92.6%; mean age, 64.1 ± 10.2 years; 42.7% male). The sarcopenia group had significantly lower body mass index (BMI) and body fat percentage than the non-sarcopenia control group ($P < 0.05$). Total protein (TP) and albumin (ALB) levels were not significantly different between the groups (Table 2).

Table 2 Characteristics and nutritional status of participants

	Sarcopenia (n = 43)	**Non-sarcopenia (n = 541)**	***P*-value**
Male/female sex (male, %)	14 (32.6)	231 (42.7)	
Age (years)	71.0 ± 10.0	66.0 ± 10.2	<0.001*
Male aged ≥65 years (%)	13 (92.8)	161 (69.7)	
Female aged ≥65 years (%)	22 (75.9)	149 (48.0)	
BMI (kg/m^2)	20.2 ± 3.4	23.8 ± 3.6	<0.001*
Body fat percentage (%)	25.8 ± 7.1	28.8 ± 7.5	0.007*
WBC (/μL)	5214 ± 1751	5100 ± 1489	0.63
CRP (mg/dL)	0.14 ± 0.31	0.16 ± 0.35	0.72
TP (g/dL)	7.25 ± 0.31	7.34 ± 0.33	0.08
ALB (g/dL)	4.30 ± 0.28	4.35 ± 0.16	0.06

*$P < 0.05$
BMI: body mass index
CRP: C-reactive protein
TP: total protein
ALB: albumin
WBC: white blood cell

Major nutritional intake items showed no significant differences between groups (Table 3): energy intake (1662.0 vs 1594.6 kcal/day in the sarcopenia and non-sarcopenia groups, respectively, $P = 0.245$), protein intake (55.1 vs 52.1 g/day in the sarcopenia and non-sarcopenia groups, respectively, $P = 0.111$), and vitamin D intake (7.2 vs 7.0 μg/day in the sarcopenia and non-sarcopenia groups, respectively, $P = 0.608$).

However, the intake rates for total calories (85.1% vs 77.5% in the sarcopenia and non-sarcopenia groups, $P < 0.001$), dietary fiber (64.2% vs 59.1% in the sarcopenia and healthy groups, respectively, $P = 0.039$), vitamin B1 (73.3% vs 69.3% in the sarcopenia and non-sarcopenia groups, respectively, $P = 0.031$), vitamin B2 (105.6% vs 97.7% in the sarcopenia and non-sarcopenia groups, $P = 0.039$), and vitamin C (98.3% vs 94.7% in the sarcopenia and healthy groups, respectively, $P = 0.041$) were significantly higher in the sarcopenia group (Table 4).

Table 3 Nutrient intake

	Sarcopenia (n = 43)	**Non-sarcopenia (n = 541)**	***P*-value**
Energy (kcal/day)	1662	1594.6	0.245
Protein (g/day)	55.1	52.1	0.111
Carbohydrates (g/day)	224.9	222.7	0.354
Fat (g/day)	46.7	43.3	0.105
Saturated fatty acids (g/day)	12.2	11.4	0.122
Monounsaturated fatty acids (g/day)	15.6	15.5	0.36
Polyunsaturated fatty acids (g/day)	13.1	12.7	0.495
Cholesterol (mg/day)	245.9	233.8	0.311
n-3 polyunsaturated fatty acids (g/day)	2376.9	2142.5	0.145
n-6 polyunsaturated fatty acids (g/day)	10979.7	10573.3	0.476
n-3 highly unsaturated fatty acids (g/day)	738.4	721.4	0.843
Dietary fiber (g/day)	12.5	10.9	0.102
Soluble dietary fiber (g/day)	2.4	2	0.115
Insoluble dietary fiber (g/day)	7.7	7.7	0.173
Vitamin A (μg/day)	765.6	698.9	0.246
Vitamin D (μg/day)	7.2	7	0.608
Vitamin C (mg/day)	80.1	77.9	0.07
Vitamin E (mg/day)	7.7	7.7	0.26
Vitamin B1 (mg/day)	0.7	0.7	0.619
Vitamin B2 (mg/day)	1.1	1	0.121
Folate (μg/day)	297.2	284.6	0.134
Sodium (mg/day)	1820.8	1853.1	0.514
Potassium (mg/day)	2185.7	2078.3	0.341
Calcium (mg/day)	551.6	531	0.264
Iron (mg/day)	7.4	6.6	0.145
Carotene (μg/day)	2835.3	2717.5	0.146

Subgroup analyses were conducted to investigate potential differences in nutritional intake rates between age groups. Participants were divided into two groups: those aged ≥65 years and <65 years, as well as those aged ≥75 years and <75 years. Even when subgroup analyses were conducted, significant differences between the sarcopenia and non-sarcopenia groups were observed only for the same items identified in the overall analysis.

No significant differences were found in DVS (Figure), and no correlations were found between DVS scores and skeletal muscle mass index, grip strength, or walking speed (Table 5).

Table 4 Nutrient intake rates

	Sarcopenia (n = 43)	**Non-sarcopenia (n = 541)**	***P*-value**
Energy (%)	**85.1**	**77.5**	**<0.001***
n-3 polyunsaturated fatty acids (g/day)	117.3	108.4	0.099
n-6 polyunsaturated fatty acids (g/day)	421	375.5	0.074
Dietary Fiber (%)	**64.2**	**59.1**	**0.039***
Vitamin A (%)	152.6	135.1	0.091
Vitamin D (%)	84.4	82.6	0.608
Vitamin C (%)	**98.3**	**94.7**	**0.041***
Vitamin E (%)	117.3	119.5	0.318
Vitamin B1 (%)	**73.3**	**69.3**	**0.031***
Vitamin B2 (%)	**105.6**	**97.7**	**0.039***
Folate (%)	148.6	142.3	0.134
Sodium (%)	303.5	308.9	0.514
Potassium (%)	94.1	94.1	0.233
Calcium (%)	106.6	92.9	0.16
Iron (%)	123.1	112.9	0.141

*$P < 0.05$

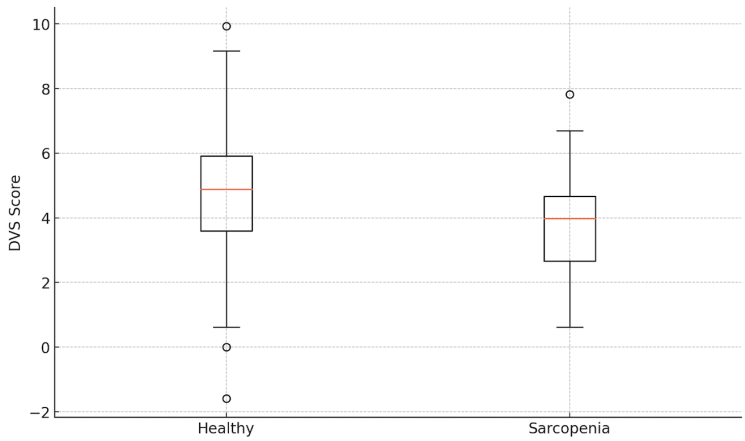

Fig. Dietary variety score (DVS) comparison between healthy and sarcopenic individuals
The box plot displays the DVS scores for healthy (n = 541) and sarcopenic individuals (n = 43). The median DVS score, interquartile range, and outliers are shown for each group. Statistical analysis showed no significant difference in the DVS scores between the two groups ($P = 0.188$).

Table 5 Correlation between DVS and various factors

	Correlation coefficient	**95% confidence interval**	***P*-value**
Skeletal muscle mass index	9.42×10^{-3}	−0.1648	0.823
Grip strength	-2.69×10^{-2}	−0.1647	0.523
Walking speed	-8.54×10^{-3}	−0.174	0.848

DVS: dietary variety score

DISCUSSION

Sarcopenic individuals often exhibit lower BMI and body weight, yet their overall nutrient intake does not significantly differ from that of healthy controls. This aligns with previous studies suggesting that merely meeting basic nutritional requirements may not suffice to prevent sarcopenia. For instance, while the sarcopenia group in this study showed higher intake of total calories, dietary fiber, and certain vitamins (B1, B2, and C), they still developed sarcopenia. This indicates that factors beyond nutrient intake—such as nutrient absorption, utilization, and metabolic efficiency—play a pivotal role in sarcopenia development.

Our findings highlight the complex relationship between dietary intake and sarcopenia. Although absolute nutrient intake (Table 3) did not differ significantly between the sarcopenia and non-sarcopenia groups, nutrient intake rates (Table 4) revealed notable disparities. These results underscore the importance of evaluating dietary adequacy relative to recommended standards, as intake rates provide a more individualized measure of dietary sufficiency.

Adequate protein intake is essential for maintaining muscle mass,[12,16] yet protein consumption was relatively similar between the two groups. This suggests that other nutritional factors, or perhaps the timing and quality of protein intake, may have a critical influence.[12] Additionally, dietary fiber, known for promoting gut health and reducing systemic inflammation, could also impact muscle health.[17] However, evidence linking dietary fiber intake directly to sarcopenia prevention is limited, highlighting a need for further investigation.

Interestingly, our study did not observe significant differences in protein or vitamin D intake between sarcopenic and non-sarcopenic individuals, which contrasts with prior findings. For example, Yokoyama et al reported a protective dietary pattern against sarcopenia in older Japanese adults,[18] while Liberman et al highlighted the benefits of vitamin D and protein supplementation in reducing inflammation.[13] The lack of significant differences in our study may reflect limitations, including a relatively small sample size and differences in dietary assessment methods. Future studies with larger cohorts are needed to validate these associations.

Vitamins and minerals with antioxidant properties, such as vitamins C and E, are crucial for reducing oxidative stress and inflammation, which contribute to muscle degradation.[19] Despite higher intake rates of vitamins C, B1, and B2 in the sarcopenia group, their physiological effectiveness may depend on factors like bioavailability, metabolic pathways, and health conditions. For example, thiamine (B1) and riboflavin (B2) are essential for energy metabolism and redox reactions, and increased intake has been linked to reduced sarcopenia risk in previous studies.[20] However, the physiological implications of these differences require further exploration.

The role of dietary diversity in sarcopenia is shaped by a complex interplay of physical, psychological, and social factors. Physical limitations, such as restricted mobility or frailty, can hinder access to diverse food options, while psychological conditions like depression or cognitive impairment may diminish appetite and reduce dietary variety. Socioeconomic status,

living arrangements, and cultural practices further influence dietary habits, creating a multifaceted relationship between dietary diversity and sarcopenia. Yokoyama et al identified that a diet rich in fish, soybean products, and vegetables was inversely associated with sarcopenia in older Japanese adults, highlighting the influence of cultural dietary patterns.[18] Similarly, Asaoka et al reported that a low DVS was significantly associated with sarcopenia, emphasizing the need to account for these external influences when interpreting the connection between dietary patterns and muscle health.[11]

While DVS did not significantly differ between sarcopenic and non-sarcopenic individuals in this study, the broader benefits of dietary diversity in enhancing nutrient intake and overall health are undeniable. Dietary diversity has been linked to improved nutrient absorption and bioavailability, which are critical for muscle health. The findings suggest that addressing the underlying determinants of dietary habits—such as physical, psychological, and social conditions—could provide valuable insights into prevention strategies. This comprehensive approach is essential to understand the intricate relationship between dietary diversity and sarcopenia, as well as to develop culturally sensitive nutritional interventions.

This study has several limitations that should be acknowledged. First, we assessed physical performance using maximum walking speed, which, while being a sensitive indicator of physical decline, may not fully capture the functional abilities relevant to daily life. Comfortable or usual walking speed has been widely utilized in recent studies, including in the definitions of sarcopenia and frailty. The use of maximum walking speed in our study may limit the comparability of our findings with prior research. Future studies should consider incorporating both maximum and usual walking speeds to provide a more comprehensive evaluation of physical performance. Second, while chronic inflammation is a key factor in the development of sarcopenia, our study was limited to evaluating C-reactive protein and white blood cell count as markers of inflammation. Our analysis found no significant differences in these markers between the sarcopenia and non-sarcopenia groups. However, this limited scope prevents us from fully exploring the role of inflammation in muscle degeneration. Future research should include a broader range of inflammatory markers to provide a more comprehensive understanding of the relationship between chronic inflammation and sarcopenia. Lastly, the sample size, while adequate for initial analyses, may limit the generalizability of our findings. Larger-scale, longitudinal studies are warranted to validate our results and explore causative mechanisms in greater detail.

CONCLUSION

This study contributes to understanding the complex interplay between nutrition and muscle health in sarcopenia. The findings suggest that factors beyond mere nutrient intake, such as nutrient absorption, utilization, and metabolic efficiency, are critical in the development of sarcopenia. Future research incorporating longitudinal designs and precise assessments of dietary intake will be crucial for confirming and further elaborating on these observations.

CONFLICTS OF INTEREST

The authors declare that there are no relevant conflicts of interest.

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