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Relationship between masticatory function and sarcopenic obesity in community-dwelling older adults aged 75 or older: a cross-sectional study

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Abstract

Objective The relationship between sarcopenic obesity and masticatory function is poorly understood. This study aims to explore this association in community-dwelling individuals aged 75 years or older.

Methods This study analyzed data from 236 community-dwelling adults aged 75 years or older. Masticatory function was assessed using spectrophotometric measurement of gum color differences before and after chewing color-changeable gum (ΔE^*ab). Participants were categorized into tertiles of masticatory function based on their ΔE^*ab values. The tertiles were defined as low, intermediate, and high. Sarcopenic obesity was assessed using the Consensus statement of the Japanese Working Group on Sarcopenic Obesity. Bayesian multinomial logistic regression was employed to examine the relationship between masticatory function and sarcopenic obesity.

Results The prevalence rates for obesity, sarcopenia, and sarcopenic obesity were 15.3%, 24.2%, and 9.7%, respectively. After adjusting for covariates, participants with high masticatory function had a significantly lower posterior estimate of sarcopenic obesity (posterior estimate: −1.83 [95% credible interval: −3.66, −0.22]) and sarcopenia (posterior estimate: −1.97 [95% credible interval: −3.37, −0.72]) compared with participants with low masticatory function. However, no significant associations were observed between masticatory function and obesity.

Conclusions These findings suggest that high masticatory function is associated with a significantly lower prevalence of sarcopenic obesity in older adults.

Keywords Sarcopenic obesity, Sarcopenia, Obesity, Masticatory function

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Introduction

In recent years, sarcopenic obesity has become increasingly prevalent, affecting more than one in ten older adults worldwide [1]. This condition is linked to increased risks of cardiometabolic diseases, cancer, mortality, and reduced quality of life [2, 3]. Furthermore, compared with sarcopenia or obesity, sarcopenic obesity is associated with an increased risk of adverse clinical outcomes, including cardiovascular disease, physical disability, frailty, and mortality [4–6]. Therefore, early detection and management of risk factors for sarcopenic obesity are crucial for extending lifespan and alleviating healthcare burdens.

Sarcopenic obesity is influenced by various risk factors, including age-related changes in body composition, hormonal differences between sexes, inflammation, physical inactivity, and diabetes [7, 8]. Proposed treatment strategies often focus on lifestyle interventions, such as nutrition (e.g., protein supplementation) and exercise.

Recent studies have highlighted a potential link between oral function and sarcopenic obesity [9]. Furthermore, an association between masticatory function and both obesity [10] and sarcopenia [11, 12] has been reported, indicating that this relationship may be influenced by nutritional factors. However, to date, no studies have directly explored the relationship between masticatory function and sarcopenic obesity.

This study addresses this gap by examining the association between masticatory function and sarcopenic obesity in community-dwelling older adults.

Methods

Study design

This cross-sectional study utilized data from the 2018 Tosa Longitudinal Aging Study (TLAS) [13], conducted as part of resident welfare activities in Tosa Town. The study included residents aged 75 years or older, excluding those who were hospitalized or institutionalized. In 2018, 189 of the 1,079 residents aged 75 years or older in Tosa Town were hospitalized or institutionalized. The remaining 890 residents were invited to join the 2018 TLAS and 260 (29.2%) consented to participate. Of these, 24 individuals with incomplete data on (a) grip strength, (b) body composition, (c) gait speed, (d) height, (e) body weight, and (f) masticatory function were excluded from the study. As a result, 236 participants were included in the final analysis (Fig. 1). The 2018 TLAS obtained ethical approval from the Ethics Committee of the Graduate School of Medicine, Kyoto University (approval number: C1292). Written informed consent was obtained from all the participants before the commencement of the study.

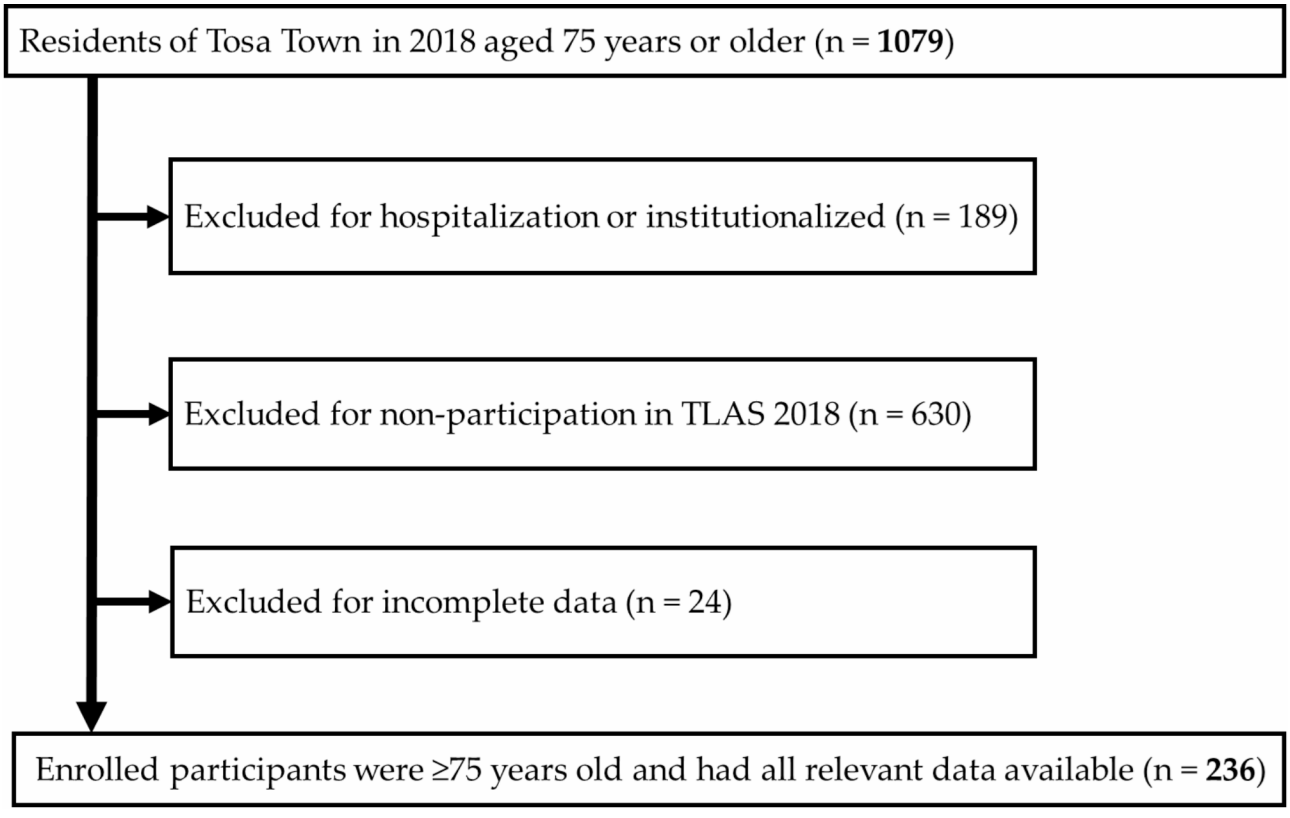

Fig. 1 Flow diagram of participant selection

All procedures were performed in accordance with the principles of the Declaration of Helsinki on experimentation involving human subjects. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for reporting observational studies. Clinical trial number: not applicable.

Assessment of sarcopenia, obesity and sarcopenic obesity

In this study, sarcopenic obesity, sarcopenia, and obesity were defined according to the consensus statement on sarcopenic obesity by Ishii et al. [14] and the criteria of the Asian Working Group for Sarcopenia 2019 (AWGS 2019) [15]. Specifically, sarcopenic obesity was defined as the coexistence of sarcopenia, characterized by low muscle mass along with either low muscle strength or low physical function [14, 15], and obesity, defined as a high body mass index (BMI) and high body fat percentage [14]. Because this study was conducted before the publication of the Ishii et al. statement, the five times sit-to-stand test recommended for evaluating physical function was not used. Instead, gait speed was adopted to evaluate physical function, based on the recommendations of the AWGS 2019 [15].

Skeletal muscle mass and body fat percentage were measured using bioelectrical impedance analysis with an InBody S10 body composition analyzer (Biospace, Seoul, Korea) while participants were seated. Grip strength was recorded from separate measurements of the right and left hand using a dynamometer (TKK5401; Takei Scientific Instruments Co., Ltd., Niigata, Japan), and the highest value was recorded. Gait speed was measured over a 4-meter course while the participants walked at their usual pace. Low muscle mass was defined as the muscle mass of the limbs relative to BMI, with a threshold of <0.512 kg/BMI for females and <0.789 kg/BMI for males; low muscle strength was defined as a grip strength of <18 kg in females and <28 kg in males; and low physical function was defined as a gait speed of <1.0 m/s; high BMI was defined as a BMI of ≥25 kg/m^2; high body fat percentage was defined as a body fat percentage of ≥30% in females and ≥20% in males [14–16].

Assessment of masticatory function

The masticatory function was evaluated by trained examiners using a masticatory function evaluation gum (XYLITOL, 70 × 20 × 1 mm, 3.0 g; Lotte, Saitama, Japan). The participants chewed gum for 2 min to simulate normal food chewing [17]. A CR-13 color reader (Konica Minolta Holdings, Inc., Tokyo, Japan) was used to measure the color change of the chewed gum according to a standardized protocol [18, 19]. The color difference (ΔE^*ab) before and after chewing was calculated using the International Commission on Illumination laboratory color space using the following formula: $\Delta E^*ab = \sqrt{\{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}}$. The initial L^*, a^*, and b^* values were 72.8, 12.1, and 34.0, respectively. Although no established cutoff exists for ΔE^*ab, this study categorized participants into tertiles of masticatory function based on their ΔE^*ab values (range 17.4–64.1). The tertiles were defined as low (≤51.0), intermediate (51.0–56.2), and high (>56.3).

Covariates

Trained dentists assessed participants' oral health status, including the number of present teeth and denture use. Nutritional status was assessed using the 11-item Food Diversity Score Kyoto (FDSK-11), an index evaluating food diversity based on the frequency of consumption across eleven major food groups (cereals, potatoes, legumes, meat, fish, shellfish, eggs, dairy products, vegetables, seaweed, nuts, and fruits) [20]. Each food group was scored as 1 if consumed more than once a week and 0 if consumed less frequently, yielding a total score ranging from 0 to 11, with higher scores indicating greater dietary diversity. Additional covariates, such as age, sex, hypertension, diabetes, dyslipidemia, heart disease, stroke, physical activity, smoking history, alcohol consumption, mild cognitive impairment (MCI), and dementia, were assessed using questionnaires. Diagnoses of MCI and dementia were confirmed by a neurologist [21].

Statistical analysis

The participant characteristics according to sarcopenia and obesity status were analyzed using descriptive statistics. Bayesian multinomial logistic regression analysis was employed to assess the association between masticatory function and sarcopenic obesity, using the group without sarcopenia and obesity as the reference group. Bayesian models are particularly suited for studies with small sample sizes [22, 23]. Based on previous studies [7, 8], the regression analysis included three models. Model 1 was unadjusted. Model 2 was adjusted for age and sex. Model 3 included Model 2 as well as additional factors such as FDSK-11, number of teeth present, denture use, physical activity, and diabetes [7, 8]. Variables were considered significant if the posterior 95% credible intervals (CrI) excluded zero, with the posterior median serving as the summary statistic for all regression analyses. Model performance was evaluated using the deviance information criterion (DIC), with lower DIC values indicating a better balance between model fit and complexity. All analyses were conducted using Stata software (version 18.0, StataCorp, College Station, USA).

Results

Characteristics of participants according to sarcopenia, obesity, and sarcopenic obesity status

Table 1 shows the characteristics of the participants based on sarcopenia and obesity status. The median age

Table 1 Characteristics of participants according to sarcopenia, obesity, and sarcopenic obesity status

Variable	Control (*N* = 120, 50.8%)	Obesity (*N* = 36, 15.3%)	Sarcopenia (*N* = 57, 24.2%)	Sarcopenic obesity (*N* = 23, 9.7%)
Age (years), median [IQR]	81.0 [78.0; 84.0]	80.5 [78.0; 84.0]	84.0 [81.0; 88.0]	83.0 [78.0; 86.0]
Sex, n (%)				
Female	78 (65.0)	21 (58.3)	32 (56.1)	12 (52.2)
Male	42 (35.0)	15 (41.7)	25 (43.9)	11 (47.8)
Group (ΔE^*ab), n (%)				
Low masticatory function	31 (25.8)	9 (25.0)	27 (47.4)	12 (52.2)
Intermediate masticatory function	39 (32.5)	14 (38.9)	19 (33.3)	7 (30.4)
High masticatory function	50 (41.7)	13 (36.1)	11 (19.3)	4 (17.4)
FDSK-11, median [IQR]	11.0 [11.0; 11.0]	11.0 [10.0; 11.0]	11.0 [10.0; 11.0]	11.0 [10.0; 11.0]
Limb skeletal muscle mass (kg), mean (SD)	15.1 (3.5)	17.6 (4.3)	11.9 (3.1)	15.6 (3.8)
Handgrip strength (kg), mean (SD)	24.9 (7.0)	27.2 (8.5)	19.5 (6.4)	21.1 (7.3)
Gait speed (m/s), mean (SD)	1.2 (0.3)	1.1 (0.3)	0.9 (0.3)	0.9 (0.3)
BMI (kg/m^2), mean (SD)	21.6 (2.1)	27.3 (2.2)	22.2 (2.4)	27.7 (2.4)
Body fat percentage, mean (SD)	22.8 (6.5)	32.5 (5.5)	26.3 (5.9)	35.5 (5.6)
Number of present teeth, median [IQR]	15.5 [4.0; 23.0]	15.0 [0.0; 25.5]	9.0 [0.0; 19.0]	13.0 [0.0; 23.0]
Denture use, n (%)	88 (75.2)	21 (60.0)	43 (78.2)	17 (77.3)
Hypertension, n (%)	79 (65.8)	29 (80.6)	33 (57.9)	18 (78.3)
Diabetes, n (%)	15 (12.5)	6 (16.7)	9 (15.8)	3 (13.0)
Dyslipidemia, n (%)	15 (12.5)	4 (11.1)	5 (8.8)	2 (8.7)
Heart disease, n (%)	10 (8.3)	5 (13.9)	6 (10.5)	2 (8.7)
Stroke, n (%)	7 (5.8)	1 (2.8)	5 (8.8)	2 (8.7)
MCI, n (%)	7 (6.7)	1 (3.2)	10 (21.7)	1 (5.9)
Dementia, n (%)	3 (2.9)	0 (0.0)	3 (6.5)	0 (0.0)
Low physical activity, n (%)	23 (20.0)	13 (38.2)	11 (20.0)	5 (22.7)
Smoking history, n (%)	29 (24.8)	6 (16.7)	18 (31.6)	3 (13.6)
Alcohol consumption habits, n (%)	22 (19.1)	7 (20.0)	6 (11.1)	4 (18.2)

Abbreviations: FDSK-11, 11-item Food Diversity Score Kyoto; BMI, body mass index; MCI, mild cognitive impairment

was 82 years (interquartile range 78.0; 85.0), with 143 females (60.6%) and 93 males (39.4%). The prevalence rates for obesity, sarcopenia, and sarcopenic obesity were 15.3%, 24.2%, and 9.7%, respectively.

Association between masticatory function and sarcopenic obesity

Table 2 summarizes the results of Bayesian multinomial logistic regression analysis examining the association between sarcopenic obesity and masticatory function. In the unadjusted model (Model 1), compared with participants with low masticatory function, those with high masticatory function had a significantly lower posterior estimate of sarcopenic obesity (posterior estimate: −1.64 [95% CrI: −3.09, −0.46], DIC = 568.137). In the adjusted model, the association remained significant after accounting for age and sex (Model 2: posterior estimate: −1.74 [95% CrI: −3.21, −0.45], DIC = 562.177), as well as physical activity, diabetes, number of present teeth, and denture use (Model 3: posterior estimate: −1.83 [95% CrI: −3.66, −0.22], DIC = 502.966). Additionally, a significant association was observed between masticatory function and sarcopenia (Model 3: posterior estimate: −1.97 [95% CrI: −3.37, −0.72], DIC = 502.966). However, no significant association was observed between masticatory function and obesity (Model 3: posterior estimate: −0.95 [95% CrI: −2.45, 0.56], DIC = 502.966). Model 3 showed a lower DIC value and a better balance between model fit and complexity than Models 1 and 2 (Model 3: DIC = 502.966 vs. Model 1: DIC = 568.137 and Model 2: DIC = 562.177).

Association between covariates and sarcopenic obesity

Table 2 presents the results of the Bayesian multinomial logistic regression analysis examining the association between sarcopenic obesity and covariates. A positive association was observed between age and sarcopenia (Model 3: posterior estimate: 0.13 [95% CrI: 0.06, 0.19], DIC = 502.966). Additionally, a negative association was suggested between denture use and obesity (Model 3: posterior estimate: −1.77 [95% CrI: −3.13, −0.35], DIC = 502.966).

Discussion

This cross-sectional study suggested that older adults with high masticatory function had a significantly lower prevalence of sarcopenic obesity and sarcopenia compared with participants with low masticatory function.

Table 2 Association between masticatory function and sarcopenic obesity

Variable	Posterior estimate (95% CrI) [d]			DIC
	Obesity	Sarcopenia	Sarcopenic obesity	
Model 1[a]				568.137
Group (ΔE*ab)				
Low masticatory function	Reference	Reference	Reference	
Intermediate masticatory function	0.23 (−0.76, 1.22)	−0.60 (−1.35, 0.16)	−0.79 (−1.89, 0.28)	
High masticatory function	−0.10 (−1.07, 0.90)	−1.40 (−2.29, −0.59)	−1.64 (−3.09, −0.46)	
Model 2[b]				562.177
Group (ΔE*ab)				
Low masticatory function	Reference	Reference	Reference	
Intermediate masticatory function	0.21 (−0.75, 1.24)	−0.40 (−1.24, 0.40)	−0.72 (−1.90, 0.33)	
High masticatory function	−0.22 (−1.26, 0.84)	−1.19 (−2.15, −0.30)	−1.74 (−3.21, −0.45)	
Age (per one increase)	−0.01 (−0.10, 0.08)	0.12 (0.05, 0.20)	0.05 (−0.04, 0.15)	
Sex: male	0.37 (−0.44, 1.18)	0.75 (0.01, 1.51)	0.95 (−0.05, 1.93)	
Model 3[c]				502.966
Group (ΔE*ab)				
Low masticatory function	Reference	Reference	Reference	
Intermediate masticatory function	−0.22 (−1.46, 0.99)	−0.67 (−1.62, 0.21)	−0.98 (−2.26, 0.16)	
High masticatory function	−0.95 (−2.45, 0.56)	−1.97 (−3.37, −0.72)	−1.83 (−3.66, −0.22)	
Age (per one increase)	−0.01 (−0.09, 0.07)	0.13 (0.06, 0.19)	0.04 (−0.04, 0.12)	
Sex: male	0.08 (−0.91, 1.05)	0.70 (−0.18, 1.58)	0.75 (−0.36, 1.81)	
FDSK-11	0.15 (−0.46, 0.70)	−0.24 (−0.79, 0.25)	0.10 (−0.67, 0.88)	
Number of present teeth (per one increase)	−0.01 (−0.08, 0.06)	0.03 (−0.02, 0.09)	0.02 (−0.06, 0.09)	
Denture use	−1.77 (−3.13, −0.35)	−0.25 (−1.50, 0.94)	−0.16 (−1.70, 1.45)	
Low physical activity	0.87 (−0.12, 1.84)	0.01 (−1.00, 0.86)	0.36 (−0.85, 1.43)	
Diabetes	0.02 (−1.73, 1.46)	0.60 (−0.54, 1.68)	0.48 (−1.33, 1.89)	

The group without sarcopenia, obesity, and sarcopenic obesity as the reference group.

Abbreviations: CrI, credible interval; DIC, deviance information criterion; FDSK-11, 11-item Food Diversity Score Kyoto.

[a]Unadjusted model.

[b]Model adjusted for age, sex.

[c]Model adjusted for age, sex, number of present teeth, denture use, low physical activity, diabetes.

[d]Variables were considered statistically significant when 95% CrI did not include 0.

However, no significant association was observed between masticatory function and obesity.

To date, research exploring the relationship between sarcopenic obesity and oral health remains limited. To the best of our knowledge, only one previous study investigated the association between sarcopenic obesity and oral function [9]. The study demonstrated an association between oral function, assessed using a screening index (8 categories: voice, lips, mucous membranes, tongue, gums, teeth, dentures, saliva production, and swallowing function), and sarcopenic obesity in patients with stroke undergoing rehabilitation. These findings are consistent with the results of this study. Regarding the relationship between sarcopenia and masticatory function, Murakami et al. classified masticatory function as good or poor and found a significant association between sarcopenia and masticatory function [12]. Similarly, Abe et al. evaluated masticatory function as a continuous variable and found a significant association with possible sarcopenia [24]. Consistent with these findings, this study also suggested a significant association between sarcopenia and masticatory function when masticatory function was categorized into tertiles. However, previous studies did not evaluate the association between masticatory function and sarcopenic obesity [9, 12, 24]. To our knowledge, this study is the first epidemiological study to examine the association between masticatory function and sarcopenic obesity.

The results of this study did not show a significant association between masticatory function and obesity, which contrasts with the systematic review by Tada et al. [10]. A possible explanation for this discrepancy may be differences in the definition of obesity. Previous studies have defined obesity using only BMI [10], whereas in this study, obesity was defined using both BMI and body fat percentage.

Nutritional factors may play a critical role in the mechanism explaining the association between masticatory function and sarcopenic obesity. Previous studies have demonstrated a strong connection between masticatory function and nutritional factors, with individuals experiencing reduced masticatory function often reporting

limited food selection and decreased nutritional intake [25, 26]. Furthermore, our 5-year cohort study [27] found that older adults with insufficient dentition had significantly lower intakes of protein, calcium, and antioxidant vitamins than those with adequate dentition. Several studies have identified calorie, protein, and antioxidant intake as key factors in mitigating the risk of sarcopenic obesity [28–30]. A meta-analysis by Kim et al. revealed that older adults who followed an energy-restricted, high-protein diet (intake ≥1.0 g/kg/day) maintained muscle mass more effectively while achieving a greater reduction in fat mass [31]. These findings suggest that high masticatory function may contribute to maintaining muscle mass through high protein intake.

Changes in body composition and muscle quality (muscle mass and strength) may be another potential mechanism explaining the relationship between masticatory function and sarcopenic obesity. Some studies have reported an association between masticatory function and handgrip strength [32] and physical function [33]. Moreover, reduction in muscle mass has been shown to lead to decreased muscle strength, which results in muscle atrophy and impaired function [34]. In addition, obesity causes skeletal muscle inflammation [35, 36], which may affect muscle quality (muscle mass and strength) and masticatory function. Taken together, these studies suggest that the relationship between masticatory function and sarcopenic obesity may result from a decline in muscle strength due to a reduction in muscle mass.

This study has some limitations. First, the number of participants represented only 26.52% of older adults aged 75 years or older in Tosa Town, which limits the external validity of the results. Second, the participants were local residents who voluntarily joined the local health program. Therefore, it is likely that these individuals were more health conscious than those who did not participate, which could introduce selection bias. Third, as this was a cross-sectional study, we could not determine a causal relationship between sarcopenic obesity and masticatory function. Fourth, because the study used a dataset from a local health program, it was not feasible to calculate the sample size prior to the survey. Consequently, the sample size was insufficient, potentially limiting the statistical power to detect associations between masticatory function, sarcopenia, and obesity. Finally, we were unable to examine detailed nutritional data, such as calorie intake. Although this study evaluated food intake diversity as a nutritional factor, more specific nutritional information could not be examined.

Despite these limitations, the public health significance of this study lies in its suggestion that masticatory function may play a protective role against sarcopenic obesity in older adults. Maintaining and improving masticatory function not only contributes to improving quality of life by preventing a decline in the function of the entire musculoskeletal system but may also help reduce medical costs.

Conclusion

In conclusion, this cross-sectional study found that high masticatory function in older adults was associated with a significantly lower prevalence of sarcopenic obesity.

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Author contributions

HS and TA designed the study. SK, YK, MI, CM, TW, RS, YI, MF, KO, and KM collected the data. HS and TA analyzed and interpreted the data. HS performed the statistical analysis. TA and RH underwent supervision. HS and TA drafted the paper. TA takes responsibility for the fact that this study has been reported honestly, accurately, and transparently; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained. All authors reviewed, provided feedback to, and confirmed the final version of the manuscript.

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Data availability

The datasets analyzed in the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The TLAS was approved by the Kyoto University Graduate School and the Faculty of Medicine Ethics Committee (approval number: C1292). All participants gave written informed consent before enrollment in the study. No separate ethics approval was required for this secondary analysis. All procedures were performed according to the Declaration of Helsinki on experimentation involving human subjects.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Gao Q, Mei F, Shang Y, Hu K, Chen F, Zhao L, et al. Global prevalence of sarcopenic obesity in older adults: A systematic review and meta-analysis. Clin Nutr. 2021;40:4633–41.
2. Wei S, Nguyen TT, Zhang Y, Ryu D, Gariani K. Sarcopenic obesity: epidemiology, pathophysiology, cardiovascular disease, mortality, and management. Front Endocrinol. 2023;14:1185221.
3. Cho Y, Shin S-Y, Shin M-J. Sarcopenic obesity is associated with lower indicators of psychological health and quality of life in Koreans. Nutr Res. 2015;35:384–92.
4. Atkins JL, Wannamathee SG. Sarcopenic obesity in ageing: cardiovascular outcomes and mortality. Br J Nutr. 2020;124:1102–13.
5. Wannamethee SG, Atkins JL. Muscle loss and obesity: the health implications of sarcopenia and sarcopenic obesity. Proc Nutr Soc. 2015;74:405–12.

6. Yang M, Hu M, Zhang Y, Jia S, Sun X, Zhao W, et al. Sarcopenic obesity is associated with frailty among community-dwelling older adults: findings from the WCHAT study. BMC Geriatr. 2022;22:863.
7. Batsis JA, Villareal DT. Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies. Nat Rev Endocrinol. 2018;14:513–37.
8. Wang M, Tan Y, Shi Y, Wang X, Liao Z, Wei P. Diabetes and sarcopenic obesity: pathogenesis, diagnosis, and treatments. Front Endocrinol. 2020;11:568.
9. Shiraishi A, Yoshimura Y, Wakabayashi H, Nagano F, Matsumoto A, Shimazu S, et al. Impaired oral status is associated with sarcopenic obesity in post-stroke patients. Gerodontology. 2024. https://doi.org/10.1111/ger.12756.
10. Tada A, Miura H. Association of mastication and factors affecting masticatory function with obesity in adults: a systematic review. BMC Oral Health. 2018;18:76.
11. Tanaka T, Takahashi K, Hirano H, Kikutani T, Watanabe Y, Ohara Y, et al. Oral frailty as a risk factor for physical frailty and mortality in Community-Dwelling elderly. J Gerontol Biol Sci Med Sci. 2018;73:1661–7.
12. Murakami M, Hirano H, Watanabe Y, Sakai K, Kim H, Katakura A. Relationship between chewing ability and sarcopenia in Japanese community-dwelling older adults. Geriatr Gerontol Int. 2015;15:1007–12.
13. Sakamoto R, Okumiya K, Ishine M, Wada T, Fujisawa M, Imai H, et al. Predictors of difficulty in carrying out basic activities of daily living among the old-old: A 2-year community-based cohort study. Geriatr Gerontol Int. 2016;16:214–22.
14. Ishii K, Ogawa W, Kimura Y, Kusakabe T, Miyazaki R, Sanada K, et al. Diagnosis of sarcopenic obesity in Japan: consensus statement of the Japanese working group on sarcopenic obesity. Geriatr Gerontol Int. 2024;24:997–1000.
15. Chen L-K, Woo J, Assantachai P, Auyeung T-W, Chou M-Y, Iijima K, et al. Asian working group for sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc. 2020;21:300–e3072.
16. Studenski SA, Peters KW, Alley DE, Cawthon PM, McLean RR, Harris TB et al. The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. J Gerontol A Biol Sci Med Sci. 2014;69:547–58.
17. Kimura Y, Ogawa H, Yoshihara A, Yamaga T, Takiguchi T, Wada T, et al. Evaluation of chewing ability and its relationship with activities of daily living, depression, cognitive status and food intake in the community-dwelling elderly. Geriatr Gerontol Int. 2013;13:718–25.
18. Komagamine Y, Kanazawa M, Minakuchi S, Uchida T, Sasaki Y. Association between masticatory performance using a colour-changeable chewing gum and jaw movement. J Oral Rehabil. 2011;38:555–63.
19. Yamazaki T, Yamori M, Asai K, Nakano-Araki I, Yamaguchi A, Takahashi K, et al. Mastication and risk for diabetes in a Japanese population: a cross-sectional study. PLoS ONE. 2013;8:e64113.
20. Kimura Y, Wada T, Ishine M, Ishimoto Y, Kasahara Y, Konno A, et al. Food diversity is closely associated with activities of daily living, depression, and quality of life in community-dwelling elderly people. J Am Geriatr Soc. 2009;57:922–4.
21. Iwasaki M, Kimura Y, Ogawa H, Yamaga T, Ansai T, Wada T, et al. Periodontitis, periodontal inflammation, and mild cognitive impairment: A 5-year cohort study. J Periodontal Res. 2019;54:233–40.
22. Azzolina D, Berchialla P, Bressan S, Da Dalt L, Gregori D, Baldi I. A bayesian sample size Estimation procedure based on a B-splines semiparametric elicitation method. Int J Environ Res Public Health. 2022;19:14245.
23. Hampson LV, Whitehead J, Eleftheriou D, Brogan P. Bayesian methods for the design and interpretation of clinical trials in very rare diseases. Stat Med. 2014;33:4186–201.
24. Abe T, Tominaga K, Ando Y, Toyama Y, Takeda M, Yamasaki M, et al. Number of teeth and masticatory function are associated with sarcopenia and diabetes mellitus status among community-dwelling older adults: A Shimane CoHRE study. PLoS ONE. 2021;16:e0252625.
25. Kwon SH, Park HR, Lee YM, Kwon SY, Kim OS, Kim HY, et al. Difference in food and nutrient intakes in Korean elderly people according to chewing difficulty: using data from the Korea National health and nutrition examination survey 2013. Nutr Res Pract. 2017;11:139–46. 6th.
26. Mann T, Heuberger R, Wong H. The association between chewing and swallowing difficulties and nutritional status in older adults. Aust Dent J. 2013;58:200–6.
27. Iwasaki M, Yoshihara A, Ogawa H, Sato M, Muramatsu K, Watanabe R, et al. Longitudinal association of dentition status with dietary intake in Japanese adults aged 75 to 80 years. J Oral Rehabil. 2016;43:737–44.
28. Abiri B, Hosseinpanah F, Seifi Z, Amini S, Valizadeh M. The implication of nutrition on the prevention and improvement of Age-Related sarcopenic obesity: A systematic review. J Nutr Health Aging. 2023;27:842–52.
29. Yoo S, Kim D-Y, Lim H. Sarcopenia in relation to nutrition and lifestyle factors among middle-aged and older Korean adults with obesity. Eur J Nutr. 2020;59:3451–60.
30. Jung UJ. Sarcopenic obesity: involvement of oxidative stress and beneficial role of antioxidant flavonoids. Antioxid (Basel). 2023;12.
31. Kim JE, O'Connor LE, Sands LP, Slebodnik MB, Campbell WW. Effects of dietary protein intake on body composition changes after weight loss in older adults: a systematic review and meta-analysis. Nutr Rev. 2016;74:210–24.
32. Moriya S. Analysis of moment structures for assessing relationships among perceived chewing ability, dentition status, muscular strength, and balance in community-dwelling older adults. Gerodontology. 2012;27:1.
33. Takata Y, Ansai T, Awano S, Hamasaki T, Yoshitake Y, Kimura Y, et al. Relationship of physical fitness to chewing in an 80-year-old population. Oral Dis. 2004;10:44–9.
34. Xue Q-L, Bandeen-Roche K, Varadhan R, Zhou J, Fried LP. Initial manifestations of frailty criteria and the development of frailty phenotype in the women's health and aging study II. J Gerontol Biol Sci Med Sci. 2008;63:984–90.
35. Wu H, Ballantyne CM. Skeletal muscle inflammation and insulin resistance in obesity. J Clin Invest. 2017;127:43–54.
36. Kalinkovich A, Livshits G. Sarcopenic obesity or obese sarcopenia: A cross talk between age-associated adipose tissue and skeletal muscle inflammation as a main mechanism of the pathogenesis. Ageing Res Rev. 2017;35:200–21.

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