Original Article

Dynamic change in the thickness of the masseter muscle between contraction and relaxation is associated with the masticatory function in older adults: a cross-sectional study

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Background: Decreased masticatory function contributes to malnutrition in the elderly. The purpose of our study was to explore whether the masseter muscle is involved in masticatory function in older adults and to help determine if the masticatory function of the elderly can be improved by exercising the masseter muscle.

Methods: Random sampling was adopted in our research, and a total of 413 older adults from 9 nursing homes in China were recruited from March 10 to June 12, 2022. The thickness and echo intensity of their masseter muscles were assessed using ultrasound. Masticatory function was measured using a color-changing chewing gum, and the change of α* before and after chewing (Δα*) was defined as masticatory function. If Δα* <14.2 in males or <10.8 in females was masticatory dysfunction. Their number of molar occlusal supports (MOSN), comorbidity, oral diadochokinesis (ODK), maximum tongue pressure (MTP), and calf circumference (CC) were evaluated. Multiple linear regression analysis was performed to identify the factors independently associated with the masticatory function.

Results: Of the 413 older adults, 179 (43.3%) had masticatory dysfunction. The average thickness of the masseter muscle between contraction and relaxation was 1.3 mm (range, 0.7–2.0 mm). The thickness of the masseter muscle and ODK decreased with age, while the echo intensity of the masseter muscle increased. The results of the multiple linear regression analysis showed that dynamic change in the thickness of the masseter muscle between contraction and relaxation (β=0.085; P=0.049), MTP (β=0.147; P=0.001) and MOSN (β=0.349; P<0.001), brushing teeth ≥2 times/day (β=−0.187; P<0.001), and CC (β=0.135; P=0.002) were independent factors affecting masticatory function.

Conclusions: We found that masticatory dysfunction was prevalent among older adults in nursing homes in Southwest China, and the dynamic change in the thickness of the masseter muscle between contraction and relaxation was positively correlated with masticatory function. This result suggests that we can improve the masticatory function of the elderly by increasing the thickness of the masseter muscle between contraction and relaxation (e.g., by exercising the masseter).

Keywords: Dynamic change; masticatory function; masseter muscle; older people; ultrasonography

Submitted Oct 27, 2022. Accepted for publication Dec 14, 2022.
doi: 10.21037/apm-22-1344
View this article at: https://dx.doi.org/10.21037/apm-22-1344

Introduction

The United Nations General Assembly declared 2021–2030 the decade of Healthy Ageing. In 2019, 1 billion people were aged 60 years and older, and this number will increase to 1.4 billion by 2030 (1). In China, in 2020, 190 million people were aged over 65 years, accounting for 13.5% of the total population (2). Malnutrition is common among older people, and the prevalence of malnutrition is estimated to range from 30 to 50% in nursing homes (3). Malnutrition in older adults is not only associated with increased mortality and morbidity, but is also associated with the development of geriatric syndromes and sarcopenia. Age is an established non-modifiable risk factor for malnutrition. Masticatory dysfunction, which is an aging-associated change, contributes to malnutrition by food choice and dietary intake. Masticatory dysfunction refers to a debilitating condition in which normal masticatory function is compromised by functional factors (e.g., poor masticatory performance) or structural factors (e.g., tooth loss). Studies have reported that the prevalence of masticatory dysfunction in the elderly is 20.3–56.9% (4-6). Masticatory dysfunction can significantly reduce the nutrient intake levels of older people, except for carbohydrate intake (7). A previous study has also shown that masticatory dysfunction is significantly associated with cognitive function and quality of life in older adults (8).

Previous studies have shown that masticatory function is related to nutritional status , the number of teeth, maximum tongue pressure and oral diadochokinesis (9-11). Therefore, measures to improve masticatory function are largely limited to increasing the number of teeth and improving oral hygiene.The masseter muscle is the most important masticatory muscle, which may be a new factor that helps improve masticatory function in older adults. However, previous studies found that the masseter muscle is unrelated to masticatory function (12,13). Therefore, these studies only measured the thickness of the masseter muscle in the relaxed state. In the present study, we measured the dynamic change in the thickness of the masseter muscle between contraction and relaxation, which can reveal the function of the masseter muscles more objectively. For the masseter muscle measurement, we used an ultrasonic apparatus that has been proven to be a valid and reliable measurement of both muscle quantity and quality (14). Compared to computed tomography and magnetic resonance imaging, ultrasound imaging is portable, economical, non-invasive, and does not require ionizing radiation.

Thus, this study sought to describe the relationship between the dynamic change in the thickness of the masseter muscle and masticatory function, and changes in the masseter muscle with age. We present the following article in accordance with the STROBE reporting checklist (available at https://apm.amegroups.com/article/view/10.21037/apm-22-1344/rc).

Highlight box

Key findings

- We found that the dynamic change in the thickness of the masseter muscle between contraction and relaxation was positively correlated with masticatory function.

What is known and what is new?

- Previous studies have shown that masticatory function is related to nutritional status , the number of teeth, maximum tongue pressure and oral diadochokinesis.
- This study proved that the masseter muscle is associated with masticatory function in old adults, and this is a new finding.

What is the implication, and what should change now?

- This result suggests that we can improve the masticatory function of the elderly by increasing the thickness of the masseter muscle between contraction and relaxation (e.g., by exercising the masseter).

Methods

Participants and study design

A cross-sectional study with an estimated sample size of 362 individuals was performed from March 10 to June 12, 2022. Five nursing homes in urban areas and four in rural areas in China were selected to ensure that the data were more representative. In addition, we conducted cognitive function screening, and only elderly people with normal cognitive function could participate in the survey to ensure the accuracy of the survey. To be eligible for inclusion in this study, participants had to meet the following inclusion criteria: (I) be an older adult aged ≥65 years; (II) reside in a nursing home for at least 6 months; and (III) have normal cognitive function and the ability to communicate with the interviewers. Participants were excluded from the study if they met any of the following exclusion criteria: (I) had a disease that could affect masseter muscle function, including a cerebrovascular disorder with paralysis, a neuromuscular disease, masseteric hypertrophy, bruxism, or had undergone tumor interventions or mandibular

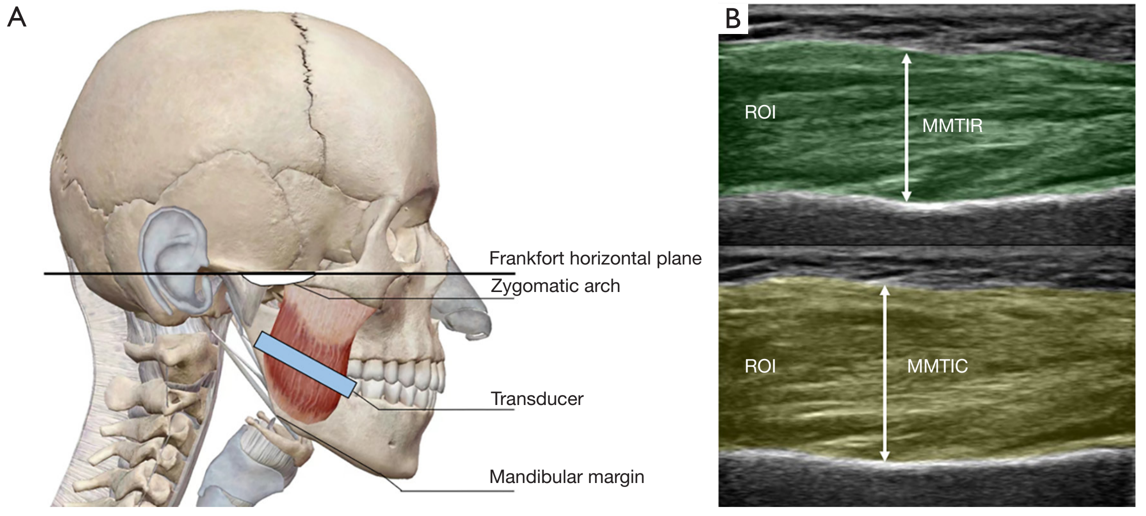

Figure 1 Measurement of the masseter muscle. (A) Each participant was instructed to sit on a chair in a relaxed, upright position with their Frankfort horizontal plane parallel to the floor and the transducer was positioned approximately halfway between the zygomatic arch and the mandibular margin, parallel to the mandibular margin and perpendicular to the skin. (B) The MMTIR and MMTIC are shown by the solid arrows. The region of interest, which was used to analyze the masseter muscle echo intensity, is highlighted in yellow and green, respectively. ROI, the region of interest; MMTIR, masseter muscle thickness in the relaxed state; MMTIC, masseter muscle thickness in the contracted state.

surgeries; and/or (II) had significant symptoms that could affect masticatory function, including temporomandibular disorder, caries, periodontal disease, periodontitis, or severe pain during jaw opening. After excluding participants with missing data, 413 participants were included in this study. Then, we investigated gender, age, height, weight, comorbidity, teeth brushing frequency, tongue pressure, ODK, calf circumference, masseter muscle and masticatory function in the elderly. This study was approved by the Ethics Committee on Biomedical Research of West China Hospital of Sichuan University [No. 2022(303)]. The study protocol was explained to all the participants and written informed consent was obtained. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Ultrasonographic measurements of the masseter muscle

All the ultrasonographic images were recorded by the same investigator who had sufficient training in taking muscle thickness and echo intensity measurements. The masseter muscle was evaluated using an ultrasonic diagnostic apparatus (Lumify, Philips, Holland), and a linear probe with a 4–12 MHz broadband frequency. Each participant was instructed to sit on a chair in a relaxed, upright position with their Frankfort horizontal plane parallel to the floor. To standardize the measurements, the image depth was kept uniform at 35 mm, and the gain was set to 50 for all the muscle thickness and echo-intensity measurements. The probe was pressed perpendicularly and lightly against the skin to prevent muscle deformation. Based on a previous study (15), the probe was positioned approximately halfway between the zygomatic arch and mandibular margin, parallel to the mandibular margin and perpendicular to the skin (*Figure 1A*). The thickness of the masseter muscles on both sides was measured. The thickest part of the masseter muscle on the thicker side in the relaxed state (MMTIR) was recorded (*Figure 1B*). The investigator then held the probe still and instructed the participant to tighten the masseter muscle with maximum force, and the thickness was recorded as the masseter muscle thickness in the contracted state (MMTIC; *Figure 1B*). Both measurements were repeated 3 times, and the mean values were used for the analyses.

The dynamic change in the thickness of the masseter muscle between contraction and relaxation (ΔMMT) was calculated using the following equation: ΔMMT = MMTIC – MMTIR. MMTIR, MMTIC, masseter muscle echo intensity in the relaxed state (MMEIIR) and masseter muscle echo intensity in the contracted state (MMEIIC) were measured using Image J (version 1.53c, National

Institutes of Health, USA). MMEIIR and MMEIIC were measured in the region of interest (ROI), including the maximum muscle without the fascia and bone (*Figure 1B*). The mean echo intensity of the ROI is expressed as a value ranging from 0 (black) to 255 (white). Muscle echo intensity represents the non-contractile tissue in muscles, such as intramuscular fat and fibrous tissue. A higher echo intensity indicates greater intramuscular fat and fibrous tissue. The methods used for measuring the thickness and echo intensity of the masseter muscle had high reliability (intraclass correlation coefficient =0.863–0.952).

Measurement of masticatory function

To examine masticatory function, we used color-changing chewing gum (xylitol; Lotte, Saitama, Japan). Under the procedure, each participant was asked to chew the gum for 60 seconds. The chewed gum was flattened to a thickness of 1.5 mm and measured at the upper, lower, left, and right points using a colorimeter (CR-20; Konica-Minolta, Japan). Masticatory function was defined as the change of α^* before and after chewing ($\Delta\alpha^*$). If $\Delta\alpha^* < 14.2$ in males or <10.8 in females was defined as masticatory dysfunction (16).

Measurements of other parameters

Each participant's number of molar occlusal supports (MOSN), maximum tongue pressure (MTP), and oral diadochokinesis (ODK) were assessed by a dentist. MOSN was determined by counting the number of occluding molar pairs (with values ranging from 0 to 8). Artificial teeth and dental implants were included; however, removable dentures were excluded. Tongue muscle force, represented by MTP, was measured using a tongue pressure measurement device (TPS100, Cybermedic, South Korea). Each participant was asked to compress the balloon onto the palates for approximately 6 s with maximum voluntary effort of the tongue. The mean peak values of the 3 records were defined as the MTP (17). ODK was evaluated using an oral function measurement device (TKK-3351, Kenko-kun, Takei, Japan). ODK was evaluated by determining the articulatory velocity of /ta/. Each participant had to repeat /ta/ as quickly as possible for 5 s, and the number of syllables pronounced per second was recorded as ODK (18).

The collection of the other data was completed by 2 trained nurses. Cognitive function was assessed using the Mini-Mental State Examination (MMSE) (19), which comprises 10 items that include tasks on orientation, memory and attention. Scores can range from 0 to 10, with lower values indicating better cognitive performance.

Calf circumference (CC) was measured using a millimeter-graded tape. The participants were instructed to remain in a standing position, with the widest part of both calves being recorded. The best result for either calf was used for the analyses. BMI was calculated using the following equation: BMI (kg/m^2) = body weight/height^2.

Statistical analysis

For the categorical variables, the data are presented as the number (percentage), and Chi-square tests were used to compare the intergroup differences. The normality of the continuous data was confirmed using the Shapiro-Wilk test. For the continuous variables, the data are presented as the mean ± standard deviation (SD), and the differences between the groups were compared using the Mann-Whitney U test or Pearson's correlation coefficient. Spearman's rank correlation coefficient test and Pearson's correlation coefficient test were used to compare each variable for masticatory function among the participants. Variables with $P<0.05$ which is two-sided were added into multiple linear regression analyses to identify the factors independently associated with masticatory function. The data analyses were performed using SPSS version 26.0 (IBM SPSS Inc., USA). P value <0.05 was considered statistically significant.

Results

Participant characteristics according to sex

The characteristics of the participants according to sex are shown in *Table 1*. The study sample comprised 413 older adults, with a mean age of 83.0±7.9 years, of whom 63.0% were female, and with 25.2% brushing teeth less than 2 times/day. Among the participants, 45.0% had more than two comorbidities and 57.4% had ≤2 MOSN, with a mean MMTIR of 13.4±2.5 mm, a mean MMTIC of 14.9±2.6 mm, and an average ΔMMT of 1.3 mm (range, 0.7–2.0). Compared to the female participants, the male participants had significantly higher values for ΔMMT (P=0.001), MMTIR (P=0.008), MMTIC (P<0.008), CC (P<0.001) and a higher incidence of masticatory dysfunction (P=0.009), brushing teeth less than twice a day (P=0.003), less than two comorbidities (P=0.015),, but had lower values for MMEIIR and MMEIIC (both P<0.001). No significant differences in

Table 1 Participant characteristics according to sex

Characteristics	Total (N=413)	Male (N=153)	Female (N=260)	P value
Age (years)	83.0±7.9	82.2±8.5	83.5±7.6	0.134
BMI (kg/m^2)	23.6±3.9	23.9±3.5	23.5±4.2	0.227
Brushes teeth ≥2 times/day, n (%)	104 (25.2)	51 (33.3)	53 (20.4)	0.003
MOSN (≤2), n (%)	237 (57.4)	86 (56.2)	151 (58.1)	0.711
Comorbidity, ≥2 chronic diseases, n (%)	186 (45.0)	57 (37.3)	129 (49.6)	0.015
CC (cm)	33 [31–35]	35 [32–36]	32 [30–34]	<0.001
ODK (syllables/s)	3.2 (2.4–4.0)	3.0 (2.3–3.8)	3.2 (2.4–4.2)	0.171
MTP (kPa)	9.4 (5.4–14.1)	9.3 (6.2–12.9)	9.4 (5.0–14.6)	0.639
MMTIR (mm)	13.4±2.5	13.9±2.4	13.2±2.5	0.008
MMEIIR	69.2 (65.2–72.5)	66.3 (62.6–70.1)	70.4 (67.1–72.9)	<0.001
MMTIC (mm)	14.9±2.6	15.5±2.5	14.6±2.6	<0.001
MMEIIC	67.3 (63.2–70.3)	63.4 (60.1–67.6)	68.5 (65.6–71.2)	<0.001
ΔMMT (mm)	1.3 (0.7–2.0)	1.7 (1.0–2.3)	1.2 (0.6–1.9)	0.001
Masticatory dysfunction	179 (43.3)	79 (51.6)	100 (38.5)	0.009

The data are expressed as number (percentage), median (interquartile range), or mean ± standard deviation. BMI, body mass index; MOSN, molar occlusal supports; CC, Calf circumference; ODK, oral diadochokinesis; MTP, maximum tongue pressure; MMTIR, masseter muscle thickness in the relaxed state; MMEIIR, masseter muscle echo intensity in the relaxed state; MMTIC, masseter muscle thickness in the contracted state; MMEIIC, masseter muscle echo intensity in the contracted state; ΔMMT, dynamic change in thickness of the masseter muscle between contraction and relaxation.

the other variables were observed between the males and females.

Comparison of MMTIC, MMTIR, ΔMMT, MMEIIC, MMEIIR, and ODK among the different age groups

We divide the age of the elderly every 10 years old. As *Table 2* shows, MMTIR (P<0.001), MMTIC (P<0.001), and ODK (P<0.001) decreased significantly with age, while MMEIIC and MMEIIR (both P<0.001) increased significantly. However, no significant differences were noted in ΔMMT among the different age groups.

Multiple linear regression analysis for masticatory function

Multiple linear regression analysis for masticatory function is showed in *Table 3*. No multicollinearity was observed between the independent variables in both multiple regression analyses. Both models revealed significant differences in ΔMMT and masticatory function. After adjustments, ΔMMT (β=0.085; P=0.049), MTP (β=0.147; P=0.001), MOSN (β=0.349; P<0.001), Brushing of teeth (β=−0.187; P<0.001) and CC (β=0.135; P=0.002) were independently and significantly associated with masticatory function. However, no such significant associations were observed for the other variables.

Discussion

The present study showed that masticatory dysfunction was prevalent in older adults in nursing homes in Southwest China. Additionally, we found that the thickness of the masseter muscle decreased with age, while that of the intramuscular adipose tissue increased. More importantly, we found that the dynamic change in the thickness of the masseter muscle between contraction and relaxation is associated with masticatory function.

We also showed that the thickness of the masseter muscle both in the relaxed and contracted state decreases with age. This is consistent with the finding that the muscle mass of the quadriceps decreases with age (20). It has been reported that, the body composition changes after 50 years old, with a 1–2% loss of muscle mass per year with aging (21). In older adults, both the total number of muscle fibers

Table 2 Comparison of MMTIC, MMTIR, ΔMMT, MMEIIC, MMEIIR, and ODK among different age groups

Variables	65–74 years (N=69)	75–84 years (N=149)	≥85 years (N=195)	P for trend
MMTIR (mm)	16.0±2.5	14.8±2.4	14.6±2.6	<0.001
MMTIC (mm)	14.5±2.4	13.4±2.3	13.1±2.5	<0.001
ΔMMT (mm)	1.4 (0.8–2.2)	1.3 (0.6–1.9)	1.4 (0.8–2.1)	0.386
MMEIIR	66.8 (63.2–69.7)	69.8 (66.6–73.0)	70.4 (65.7–72.4)	<0.001
MMEIIC	63.4 (59.7–67.8)	67.6 (64.3–70.3)	67.9 (63.2–70.7)	<0.001
ODK (syllables/s)	3.8 (2.8–4.5)	3.2 (2.4–4.0)	2.8 (2.1–3.6)	<0.001

The data are presented as the median (interquartile range) or mean ± standard deviation. MMTIC, masseter muscle thickness in the contracted state; MMTIR, masseter muscle thickness in the relaxed state; ΔMMT, dynamic change in thickness of the masseter muscle between contraction and relaxation; MMEIIC, masseter muscle echo intensity in the contracted state; MMEIIR, masseter muscle echo intensity in the relaxed state; ODK, oral diadochokinesis.

Table 3 Multiple linear regression analysis for masticatory function

Variables	Model I			Model II		
	β	P	Adjusted R^2	β	P	Adjusted R^2
ΔMMT (mm)	0.092	0.03	0.264	0.085	0.049	0.264
MTP (kPa)	0.151	0.001	–	0.147	0.001	–
MOSN	0.339	<0.001	–	0.349	<0.001	–
Brushing of teeth	–0.187	<0.001	–	–0.187	<0.001	–
CC (cm)	–0.144	0.001	–	0.135	0.002	–

β, standardized partial regression coefficient. Model I: Not adjusted; Model II: Adjusted for age and sex. ΔMMT, dynamic change in thickness of the masseter muscle between contraction and relaxation; MTP, maximum tongue pressure; MOSN, molar occlusal supports; CC, calf circumference.

and muscle fiber size decrease with age, and the loss of muscle fibers has been reported to be associated with the age-related loss of motor units, loss of mitochondria, and excitation-contraction uncoupling (22).

Consistent with the results of a previous study (23), we found that the intramuscular adipose tissue in the masseter muscle increases with age. In a 5-year longitudinal study of older adults aged 70–79 years, intermuscular adipose tissue was observed to increase by nearly 30% in the mid-thigh for women and nearly 50% in men (24). This may be attributed to the muscle fat that is embedded within and between muscle fibers in the form of intra- and extra-myocellular adipocytes (droplets of triglycerides), which results in the increased storage of lipid droplets with muscle age (25). Additionally, ODK decreased with age in this study, which indicates that the flexibility of the tongue and lip in the elderly decreases with age.

This study confirmed that ΔMMT is associated with masticatory function. However, consistent with the findings of previous studies (12,13), we found that the thickness of the masseter muscle in the relaxed state is not associated with masticatory function. This may be because the correlation between muscle strength and size in the relaxed state is not uniform (26). Older muscle contains fewer and smaller muscle fibers, and the fat infiltration of the skeletal muscle increases and the level of muscle fibrosis increases in older muscle (22). Thus, increased intramuscular adipose tissue and muscle fibrosis have been reported to be related to decreased muscle strength (27). As a result, older adults may experience increased muscle thickness but decreased muscle strength due to the increase of intramuscular adipose tissue and muscle fibrosis. Thus, ΔMMT may represent the function of the masseter muscle in older people more accurately than the thickness of the masseter muscle in the relaxed state.

Consistent with the results of a previous study (13), the present study also showed that MTP is associated with masticatory function. This may be because the tongue plays an important role in capturing and transferring food to the teeth, mixing food with saliva in the process of mastication.

Consistent with the findings of previous research (28), the number of functional teeth, MOSN, and brushing of teeth were related to masticatory function. This may be because incisors and canines are in charge of cutting and shredding food, while molars help grind food. Thus, the teeth play an important role in maintaining normal masticatory function and brushing teeth > twice per day can prevent the loss of teeth.

The masticatory dysfunction, which is an aging-associated change, is an important risk factor for malnutrition. Studies have identified some factors associated with masticatory function, but the correlation between the masseter muscle and masticatory function remains controversial (9-11). This study confirmed that the thickness of the masseter muscle in relaxation is not related to masticatory function, but the dynamic change in the thickness of the masseter muscle between contraction and relaxation is associated with masticatory function. Thus, our findings suggest that in treating elderly patients with masticatory dysfunction, we should not only seek to maintain the number of functional teeth, MOSN, tongue pressure, and oral hygiene, but should also implement masseter muscle interventions, such as masseter muscle exercises. A recent study revealed that older adults showed a significant improvement in masseter muscle thickness at rest and during contraction after performing isometric exercises on the masseter muscle for 4 weeks (29).

The present study had some limitations. First, a cross-sectional design was used, and longitudinal studies need to be conducted to determine the causal relationship between the masseter muscle and masticatory function. Second, this study was limited in terms of the sample size, and additional studies with larger sample sizes need to be conducted to confirm the results of this study. However, the objective and detailed data on the masseter muscle acquired using an ultrasound technique are valuable.

Conclusions

We found that masticatory dysfunction was prevalent among older adults in nursing homes in Southwest China. The ΔMMT, MTP, MOSN, CC, and the brushing of teeth were significantly associated with masticatory function. Thus, the masticatory function of older adults can be improved by increasing the thickness of the masseter muscle between contraction and relaxation. This study also found that the thickness of the masseter muscle and the flexibility of the tongue and lip decreased, but the intramuscular adipose tissue of the masseter muscle increases with age. Thus, awareness campaigns and interventions are required to improve the masticatory function of older adults in nursing homes in Southwest China.

Acknowledgments

The authors would like to thank all the participants, health professionals, and researchers who were involved in the data collection and analyses.
Funding: None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://apm.amegroups.com/article/view/10.21037/apm-22-1344/rc

Data Sharing Statement: Available at https://apm.amegroups.com/article/view/10.21037/apm-22-1344/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://apm.amegroups.com/article/view/10.21037/apm-22-1344/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Ethics Committee on Biomedical Research of West China Hospital of Sichuan University [No. 2022(303)]. The study protocol was explained to all the participants and written informed consent was obtained.

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(English Language Editor: L. Huleatt)

Cite this article as: Liu X, Zhang X, Feng Q. Dynamic change in the thickness of the masseter muscle between contraction and relaxation is associated with the masticatory function in older adults: a cross-sectional study. Ann Palliat Med 2022;11(12):3755-3763. doi: 10.21037/apm-22-1344

