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Original Article

Calf circumference and serum albumin level are the reliable biomarkers for predicting the chewing ability and nutritional status of the elderly people

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Abstract *Background/purpose:* The relationship among chewing ability, food texture selection, and nutritional status in the elderly is well-known. This study tried to find the reliable biomarkers to predict the chewing ability and nutritional status of the elderly people.
Materials and methods: Sixty-eight elderly subjects (mean age, 80.38 ± 7.32 years) were enrolled in this study. Oral examinations assessed the number of total teeth, pair of antagonistic teeth, and type of dentures in participants. Sociodemographic data, dietary habits, and medical history were collected via self-reported questionnaires. Nutritional status was assessed based on the calf circumference and serum albumin level measurements.
Results: The elderly individuals with fewer number of total teeth, fewer pairs of antagonistic teeth, or the removable dentures preferred minced and moist food textures. These preferences were significantly associated with the smaller calf circumference (31.29 ± 4.08 cm, $P < 0.05$) and lower serum albumin levels (3.52 ± 0.63 g/dL, $P < 0.001$) compared to those with better chewing ability. The elderly participants with <20 total teeth, <10 pairs of antagonistic teeth, or the removable dentures showed significantly lower calf circumference and serum albumin levels than those with ≥20 total teeth, ≥10 pairs of antagonistic teeth, or the fixed dentures, respectively (all *P*-values <0.05).

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Conclusion: Optimal chewing ability is crucial for maintaining an adequate nutritional status in the elderly people. The calf circumference and serum albumin level are found to be the reliable biomarkers for predicting the chewing ability and nutritional status of the elderly people.

Introduction

The issue of aging has become a major concern in many developed countries, including Taiwan, where the aging population is projected to reach the "super-aged society" status by 2025. The age-related changes and diseases can lead to poor mastication in the elderly individuals, resulting in nutritional challenges and an increased risk of malnutrition.[1—3] As a result, the World Health Organization (WHO) has established a goal of retaining at least 20 natural teeth at 80 years of age.[4] Poor chewing ability can result in reduced willingness to consume proper foods, leading to a high prevalence of malnutrition.[5—7] Poor oral health, chewing, and occlusion in the elderly can also lead to frailty and malnutrition.[8,9] Therefore, it is important to understand the chewing status and nutritional problems of the elderly individuals and provide them with suitable dietary patterns to prevent malnutrition.

The elderly individuals with more effective dental or chewing function can choose foods of various textures and are more likely to ingest the balanced nutrients. Those with poor chewing ability tend to choose softer foods and may consume fewer meats, fruits, and vegetables, which are associated with sarcopenia.[10,11] Poor dental health can affect the ability to chew and choose unhealthy foods, eventually leading to malnutrition, weakness, and immobility. To address malnutrition and poor chewing ability in the elderly, the European Society for Clinical Nutrition and Metabolism Guidelines recommends providing texture-modified and nutrient-enhanced food to the older adults who are at risk of malnutrition and show signs of poor chewing or swallowing ability.[12]

However, there is still limited information available on the factors that relate to poor chewing ability in the elderly individuals. Therefore, the aim of this study was to identify the critical factors that can predict the chewing ability or the nutritional status of the elderly people and to investigate their association with the selection of suitable food textures and the nutritional status in the elderly individuals. Understanding these factors will enable the development of targeted interventions to improve chewing ability and promote better nutritional outcomes in the elderly population. The findings of this study can potentially contribute to the development of more effective dietary interventions and policies to prevent malnutrition in the elderly, particularly in rapidly aging societies such as Taiwan and other developing or developed countries.

Materials and methods

Participants

A total of 70 participants aged 65 years or older were enrolled in the study, with the exclusion criteria in place to ensure the validity of the results. Specifically, participants with chewing pain during dental treatment, head and neck cancer or digestive system tumors during concurrent chemoradiotherapy or surgical intervention, severe delirium, and moderate to severe dementia (clinical dementia rating, CDR $>$1.0) were excluded from this study. Two participants who had CDR score higher than 1.0 were excluded. Thus, the final participants were 68 elderly subjects. This study was conducted from April to December 2017 at a medical center in the northern Taiwan, and the protocol was approved by the Research Ethical Community of the National Taiwan University Hospital (201703015RINA). The written informed consent was obtained from each participant prior to their enrollment into this study.

Medical record review

Informed consents were obtained from all participants to access their electronic medical records within the information system. The records were then thoroughly examined to gather information on disease diagnoses and medication utilization.

Anthropometry and serum albumin level measurement

The height of the participants was measured using a height-measuring instrument that was regularly calibrated at a teaching hospital, with a minimum unit of one decimal point. For cases where the instrument was not applicable, the knee length estimation formula described by Cheng et al.[13] was utilized. The calf circumference was measured using a tape measure by a professional dietitian. The serum albumin level measurement was taken from the latest serum albumin level within three months of the electronic medical record. Prior to accessing the medical records, the informed consents were obtained from all participants.

Evaluation of food texture

The National Dysphagia Diet (NDD) was widely recognized food texture classification systems in Taiwan since 2003. As

the participants in this study were enrolled in 2017, the food texture classification was adjusted based on the NDD. The modified classifications of diets comprised three categories: regular diet (RD), soft diet (SD), and minced and moist diet (MMD). RD encompassed all foods allowed and required good chewing capability. SD featured a soft and moist texture and necessitated moderate chewing capability, with food easily cut into a palatable size within a spoon or less than 2.5 cm in length. MMD was characterized by a moist texture and could be crushed with chopsticks or a spoon. The length of the food was less than 0.6 cm, and mild chewing capability was required.

Medication classification

This study utilized the World Health Organization's Anatomical Therapeutic Chemical Classification System/Defined Daily Dose (WHO-ATC/DDD) medication classifications to conduct a review of the participants' medical history. Specifically, chronic prescription drug information was collected from the participants' most recent three months of medical records using the WHO-ATC/DDD codes for drug classification, which encompass 14 categories. Prior to data collection, the informed consent was obtained from all participants for access to their medical records.

Statistical analysis

This study employed IBM SPSS Statistics Version 21 (IBM Corp., Armonk, NY, USA) for statistical analysis. Descriptive statistics were used to analyze the demographic characteristics, chewing capability, nutritional status, health and disease status, and dietary characteristics of the elderly. An independent t-test was used to examine the difference in the values of a specific variable between two groups of elderly people with different chewing abilities. Analysis of variance (ANOVA) was utilized to assess the difference in the values of a specific variable among three groups of the elderly people with different diets (regular, soft, or minced and moist diets). A P-value less than 0.05 was considered statistically significant.

Table 1 Descriptive statistics of health and social demographic data in 68 elderly subjects enrolled in this study.

Descriptive variables	Mean ± SD n (%)	Median
Gender		
Men	27 (39.71)	
Women	41 (60.29)	
Living status		
Lives alone or lives with a foreign caregiver	7 (10.29)	
Lives in the facility	1 (1.47)	
Lives with family	60 (88.24)	
Dental status		
Edentulous without dentures	7 (10.29)	
Removable dentures	27 (39.71)	
Fixed dentures	23 (33.82)	
Nature teeth or dental implants	11 (16.18)	
Medication		
0	14 (20.59)	
1	16 (23.53)	
2	20 (29.41)	
3	7 (10.29)	
4	5 (7.35)	
5 or above	6 (8.82)	
Food texture		
Regular diet	27 (39.71)	
Soft diet	27 (39.71)	
Minced and moist diet	14 (20.59)	
Age (year)	80.38 ± 7.32	79.10
Weight (kg)	55.63 ± 9.61	54.95
Body mass index (BMI, kg/m^2)	22.89 ± 3.50	22.80
Serum albumin level (g/dL)	3.96 ± 0.52	4.10
Calf circumference (cm)	33.54 ± 3.88	34.00
Number of total teeth	20.19 ± 10.81	27.00
Pair of antagonistic teeth	10.43 ± 5.49	14.00

Regular diet: All foods allowed.
Soft diet: The texture of the food was soft and its length was less than 2.5 cm.
Minced and moist diet: The texture of the food was soft and moist. The length was less than 0.6 cm.

Results

Descriptive characteristics of study participants

There were 68 elderly subjects enrolled in this research. Table 1 presents the descriptive characteristics of these 68 subjects. There were 27 men and 41 women and the mean age of the 68 elderly participants was 80.38 ± 7.32 years (range, 67.16—95.33 years). Most of the participants had a normal body weight, with a mean body mass index (BMI) of 22.89 ± 3.50. Moreover, 60 (88.24%) of the 68 subjects resided with their families.

Regarding the dental status of the 68 subjects, 7 (10.29%) were edentulous and did not wear dentures, 27 (39.71%) used removable partial or complete dentures, 23 (33.82) had fixed prostheses, and 11 (16.18%) had nature teeth or dental implants. For medication usage of the 68 subjects, 14 (20.59) had none of medication, 48 (70.59%) had 1-4 kinds of medication, and only 6 (8.82%) had more than 5 kinds of medications. Regarding the dietary preferences, 27 (39.71%) had the regular diet, 27 liked the soft diet, and 14 (20.59%) preferred the minced and moist diet.

For the relevant body and health measurements, the mean body weight was 55.63 ± 9.61 kg, the mean serum albumin level was 3.96 ± 0.52 g/dL, the mean calf circumference was 33.54 ± 3.88 cm. For the dental status, the mean number of total teeth present was 20.19 ± 10.81 teeth, and the mean pair of antagonistic teeth was 10.43 ± 5.49 pairs (Table 1).

Correlation between mastication and food texture

The relationship between mastication ability and food texture selection in the elderly individuals is presented in Table 2. It was observed that the elderly individuals exhibited diverse chewing abilities, which were influenced

Table 2 Comparison of the number of total teeth, pair of antagonistic teeth, calf circumference value, serum albumin level, and body mass index (BMI) between any two of the three groups of the elderly subjects with regular diet (RD), soft diet (SD), or minced and moist diet (MMD).

Variable	(1) RD	(2) SD	(3) MMD	P-value
	n = 27	n = 27	n = 14	
Number of total teeth	27.70 ± 0.70	14.52 ± 12.74	11.13 ± 9.35	(1) (2) <0.001[b]
18.96 ± 11.43 (mean ± SD)				(1) (3) <0.001[b]
Medium	28	18	15	(2) (3) <0.400
Pair of antagonistic teeth	13.78 ± 0.70	10.56 ± 5.22	4.56 ± 5.79	(1) (2) 0.029[a]
10.6 ± 5.4 pairs (mean ± SD)				(1) (3) <0.001[b]
				(2) (3) <0.001[b]
Calf circumference	35.01 ± 3.15	33.43 ± 3.84	31.29 ± 4.08	(1) (2) 0.297
33.54 ± 3.88 cm (mean ± SD)				(1) (3) 0.006[a]
				(2) (3) 0.175
Serum albumin level (g/dL)	4.26 ± 0.24	3.85 ± 0.42	3.52 ± 0.63	(1) (2) 0.002[a]
3.96 ± 0.52 (mean ± SD)				(1) (3) 0.000[b]
				(2) (3) 0.320
Body mass index (BMI)	23.62 ± 3.52	22.43 ± 3.77	22.39 ± 3.03	(1) (2) 0.480
				(1) (3) 0.542
				(2) (3) 0.999

Regular diet: All foods allowed.
Soft diet: The texture of the food was soft and its length was less than 2.5 cm.
Minced and moist diet: The texture of the food was soft and moist. The length was less than 0.6 cm.
[a] There is a significant difference of the variable between the two groups. ($P < 0.05$).
[b] There is a significant difference of the variable between the two groups. ($P < 0.001$).

by their dental condition and subsequently impacted their choice of food texture. Those with better chewing abilities (more number of total teeth or more pairs of antagonistic teeth) tended to select a regular diet, while the elderly individuals with fewer number of total teeth or fewer pairs of antagonistic teeth usually preferred a minced and moist diet.

The elderly subjects with the minced and moist diet had significantly lower calf circumference ($P = 0.006$) and lower serum albumin levels ($P < 0.001$) than those with the regular diet. Notably, there was no significant difference in the BMI among the three elderly subject groups with the regular, soft, or minced and moist diet (Table 2).

Correlation between the chewing ability and the calf circumference or the serum albumin level

The correlation between the mastication ability and the calf circumference or the serum albumin levels is presented in Table 3. The results showed that the elderly participants with <20 total teeth, <10 pairs of antagonistic teeth, or the removable dentures showed significantly lower calf circumference and lower serum albumin levels than those with ≥20 total teeth, ≥10 pairs of antagonistic teeth, or the fixed dentures, respectively (all *P*-values <0.05) (Table 3).

Discussion

The present study shed light on the association among chewing ability, food texture selection, and nutritional status in the elderly individuals. Our findings revealed that the elderly individuals with the lower number of total teeth, lower pairs of antagonistic teeth, absence of dentures, or removable dentures were more likely to have the smaller calf circumference and the poorer nutritional status. These results aligned with those reported by Özsürekci et al.,[14] which highlighted the impact of poor chewing

Table 3 Comparison of calf circumference or serum albumin level between two groups of subjects with different chewing abilities.

Chewing ability	Calf circumference (cm)	*P*-value	Serum albumin level (g/dL)	*P*-value
Number of total teeth ≥20 (n = 52)	34.36 ± 3.75	0.014[a]	4.10 ± 0.45	0.002[a]
Number of total teeth <20 (n = 16)	31.79 ± 3.74		3.69 ± 0.57	
Pair of antagonistic teeth ≥10 (n = 50)	34.13 ± 3.71	0.036[a]	4.05 ± 0.51	0.023[a]
Pair of antagonistic teeth <10 (n = 18)	31.90 ± 3.97		3.72 ± 0.50	
Fixed dentures (n = 23)	34.40 ± 3.88	0.034[a]	4.11 ± 0.41	0.022[a]
Removable dentures (n = 27)	32.68 ± 3.74		3.82 ± 0.59	

[a] A significant difference was observed between two groups of subjects with different numbers of total teeth, pairs of antagonistic teeth, or dentures. ($P < 0.05$).

ability on gastrocnemius muscle thickness in males. Correspondingly, Zhang et al.[15] shared the similar results that frailty decreased with an increased number of teeth, and the older adults with 1 to 20 teeth had a lower likelihood of frailty than those with edentulism.[15] In a parallel study conducted by Abe et al.[16] revealed that the remaining number of teeth and higher level of masticatory function were negatively associated with the possible sarcopenia.[16]

Furthermore, our study also found that the chewing ability might influence the food preferences. The elderly individuals with compromised chewing abilities, including those with fewer number of total natural teeth, fewer pairs of antagonistic teeth, or wearing the removable dentures, tended to choose the soft and minced food textures as the previous report of the elderly's food avoidance.[17] Interestingly, the elderly participants who selected modified food textures displayed poorer nutritional status, characterized by the smaller calf circumference and the lower serum albumin levels. The results of our study raised the detailed evidence to support the research conducted by Watson S. et al., indicating that impaired dental status exerts a discernible impact on food selection and the consumption of important nutrients.[18] The consumption of extensively modified food textures may contribute to a reduced calf circumference and lower serum albumin levels. According to the Asian Working Group for Sarcopenia in 2019,[19] the average calf circumference in Asia is approximately 33—34 cm (below 34 cm in men and below 33 cm in women).[19] Our study found that the mean calf circumference (31.29 ± 4.08 cm) of 14 elderly subjects with the minced and moist diet was smaller than that (35.01 ± 3.15 cm) of 27 elderly subjects with the regular diet, indicating that a significantly smaller calf circumference can be used to predict the type of diet consumed by the elderly individuals. This may also suggest a higher prevalence of low muscle mass among the elderly individuals with fewer than 20 total natural teeth, fewer than 10 pairs of antagonistic teeth, or those wearing the removable dentures. In addition, poor chewing ability appeared to be associated with the lower serum albumin levels. Taken together, these findings suggest that the elderly individuals with poor chewing ability or those who consume texture-modified foods should focus on nutrient-dense diets, particularly diets with high protein content, to prevent the sarcopenia and hypoalbuminemia.

Consistent with the results of a study by Iinuma and Kikutani,[20,21] we found that the elderly individuals with good chewing ability tend to have a diverse food selection and a better nutritional status. Their research demonstrated a higher prevalence of malnutrition among the elderly individuals with inadequate occlusion. Therefore, maintaining good oral health is crucial for preserving the chewing function in the individuals during the aging process. Healthcare providers must prioritize dietary modifications and offer high-nutrient-density diets to the elderly subjects with poor chewing function to further prevent malnutrition and frailty in the high-risk population group.

Optimal chewing ability, achieved through the presence of more than 20 natural teeth, at least 10 pairs of antagonistic teeth, or the restoration of missing teeth with fixed dentures, is associated with a reduced risk of malnutrition and a lower prevalence of sarcopenia. Thus, for the elderly individuals with poor chewing ability, caregivers should provide the nutrient-dense diets and regularly assess their health status to prevent geriatric sarcopenia and muscle depletion. The results of this study also found that the calf circumference and serum albumin level are the reliable biomarkers for predicting the chewing ability and nutritional status of the elderly people.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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