A Study of Tongue Thickness in Elderly People in Japan

Authors
Fumiyo Tamura
Takeshi Kikutani
Hiroyasu Furuya
Hiromi Okayama
Noriaki Takahashi

Affiliations
The Nippon Dental University, Tama Oral Rehabilitation Clinic
Division of General Dentistry, The Nippon Dental University, Dental Hospital

Corresponding author:
Fumiyo Tamura, DDS, PhD
Division of Rehabilitation for Speech and Swallowing Disorders
The Nippon Dental University, Tama Oral Rehabilitation Clinic
4-44-19, Higashi-cho, Koganei, Tokyo 184-0011, Japan
Tel: +81-42-316-6211
FAX: +81-42-316-6212
Email: fumita@tky.ndu.ac.jp

Abstract

The tongue is an important organ responsible for eating, swallowing and articulatory functions. We have focused on the tongue and studied the relationships of tongue muscles with swallowing function and systemic conditions (nutritional status).

Ultrasonography was used to non-invasively measure tongue volume, setting the vertical thickness of the tongue as an index of the tongue's volume.

We have conducted three types of studies and obtained the following results:

1. Dysphagia or malnutrition may affect tongue thickness, with subsequent worsening of malnutrition.
2. Decreased tongue thickness in elderly people requiring nursing care is associated with not only their physical state but also declining oral functions.
3. Tongue muscle mass to change in parallel with skeletal muscle mass changes in men.

These results suggested that measurement of tongue thickness using ultrasonography may be beneficial for screening evaluation of nutritional status and motor function in elderly people.

1. Introduction

With the rapid aging of society, Japanese people age 65 and older now account for 26.7% of the total population (percentage of the elderly) according to a survey conducted by the Cabinet Office in 2015. It is forecasted that by 2060, one in 2.5 Japanese will be 65 years of age or older, and that one in 4 will be 75 or older. Therefore, measures to cope with an aging society have already been launched in various fields. In the dental field, an effort to prevent oral sarcopenia and frailty has been initiated following increased attention to sarcopenia and frailty in the elderly. Oral functions can be evaluated employing various methods: among them, we have focused on the tongue as it is an important organ responsible for eating, swallowing and articulatory functions. We have conducted several studies to clarify tongue muscle relationships with swallowing function and systemic conditions (nutritional status). Herein, we present a portion of the results obtained thus far.

2. Measuring system for vertical tongue thickness by ultrasonography

We have been under the clinical impression that patients with poor nutritional status and/or dysphagia have a lower tongue volume. When people are malnourished, skeletal muscles decrease and emaciation proceeds. Since the lingual muscle is a skeletal-type muscle, we speculated that tongue volume might indicate nutritional status, and have explored a way to non-invasively measure tongue volume.

The ultrasonography measurement system we used to measure tongue thickness is utilized mainly for functional analysis of tongue movements in the study of dysphagia[1,2] as a very effective device for visually evaluating the tongue.

A study measuring tongue volume with ultrasonography was reported by Ajaj et al.[3], and another measuring tongue volume with MRI was reported by Humbert et al.[4]. However, it is not possible to use these methods in a study including subjects such as ours.

We have studied tongue thickness using the measuring system with ultrasonography according to Watanabe's method[5]. This system consists of an ultrasonography measurement system and a fixation device to retain a convex probe in an appropriate position[5,6]. The fixation device was employed to obtain accurate images of both the upper and the lower surfaces of the lingual muscles in the frontal section at the points where the perpendicular plane meets the Frankfort horizontal plane, as shown in Figure 1. Measurements were performed in freeze-frame when the tongue was restored to the resting position after swallowing saliva, and the mean values were obtained.

The advantage of this system is that it is non-invasive and convenient, while providing quantification, for measurement.

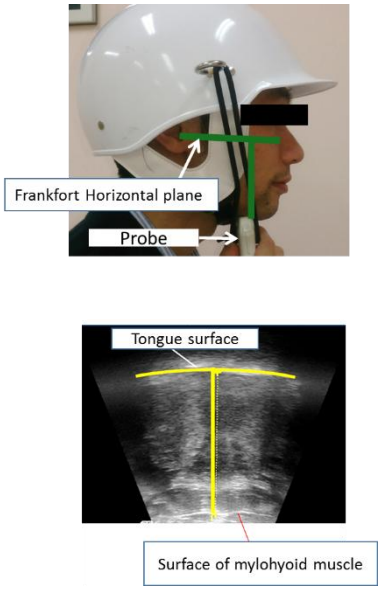

Figure 1. Ultrasonography measurement system and imaging

3. Relationship between tongue muscle mass and nutritional status

Sarcopenia is a decline in skeletal muscle mass and strength, that occurs with aging, due to insufficient intake of protein and calories[7], and it can also be observed in the oral cavity, making it important to examine oral function in affected patients.

In our first study[8], we hypothesized that sarcopenia may compromise oral function, resulting in dysphagia. We studied 104 elderly subjects (32 men and 72 women, mean age: 80.3 ± 7.9 years) who were living in Tokyo, Kyoto and Yamanashi prefectures. All underwent measurement of tongue thickness employing an ultrasonography measurement system (Nemio 17, SSA-550A, Toshiba Medical Systems, Tokyo, Japan). Because the absence of occlusal support affects tongue movements and oral function[9-11], subjects who maintained occlusal support with either natural dentition or dentures were selected. Moreover, we eliminated subjects with either paralysis or atrophy of the tongue, which are caused by certain disorders.

Okada et al.[12] and Chazot et al.[13] suggested that triceps skinfold (TSF) and mid-arm muscle area (AMA) correlate with

nutritional status. TSF represents the fat volume, and AMA, the muscle volume of the upper arm. We evaluated the nutritional status of all subjects by obtaining anthropometric data including TSF, AMA, body weight (BW) and height (HT), as shown in Figure 2.

AMA, which reflects nutritional status, and age were identified as factors influencing tongue thickness by multiple regression analysis. Since there was a significant association between tongue thickness and nutritional status, tongue muscle volume was considered to also be related to nutritional status. Sarcopenia was suggested to develop not only in skeletal muscles but also in the tongue. Accordingly, dysphagia or malnutrition may affect tongue thickness, with subsequent worsening of malnutrition.

Figure 2. Measurement of anthropometric data

Physical measurement of the upper arm using the Adipometer®,and the Insertape®.
Anthropometric data: triceps skinfold and arm muscle area

4. Effects of nursing care on tongue thickness in elderly people

4.1 Factors affecting tongue thickness in elderly people requiring nursing care

Next, in the study by Okayama and colleagues[14], we investigated factors possibly affecting tongue thickness in elderly people requiring nursing care. The subjects consisted of 129 elderly people age 65 years or older (38 men and 91 women, mean age 77.4 ± 8.4 years) living in Tokyo, Kyoto and Yamanashi prefectures. The subjects were divided into two groups: the healthy elderly group (91 subjects; 28 men and 63 women, mean age 73.4 ± 5.1years) and the elderly people requiring nursing care group (38 subjects; 10 men and 28 women, mean age 87.1 ± 6.5 years).

Two tongue muscle indexes were used in this study. Tongue thickness was measured using an ultrasonography measurement system (LOGIQ® BOOK XP, GE Healthcare Japan, Tokyo, Japan). Tongue pressure was evaluated using a tongue pressure measurement device (TPS-350, ALNIC Co., Hiroshima, Japan) at the time when the maximum pressure was generated by the tongue pressed onto the palate, in accordance with the method of Hayashi et al.[15]. The relationships among tongue thickness, tongue pressure, age, sex, level of care needed, body mass index (BMI) and dysphagia were analyzed. Relationships among tongue thickness, tongue pressure and BMI were demonstrated (Table 1).

Table 1. Relationships among tongue thickness and evaluated factors

	Tongue thickness	Tongue pressure	BMI
Tongue thickness	1	0.271**	0.320**
Tongue pressure		1	0.413**
BMI			1

Pearson's correlation coefficient

**: $p < 0.01$

BMI= body mass index

One-way analysis of variance (ANOVA) was used to compare differences in tongue thickness between age groups. A significant difference in tongue thickness was observed among age groups (p=0.017). The Bonferroni test also revealed a significant difference in tongue thickness among the age groups, as shown in Figure 3 (age 70-74 group vs the over 80 group: p=0.024).

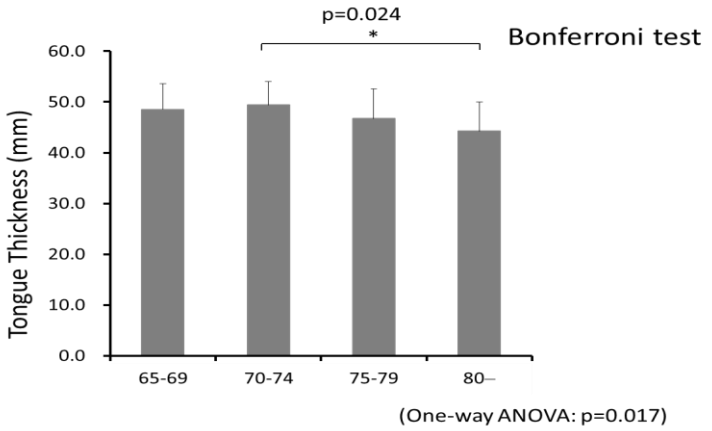

Figure 3. Relationship between tongue thickness and age groups

4.2 Relationship between tongue thickness and the level of care needed

Relationships among tongue thickness, tongue pressure and the factors evaluated were analyzed in 38 elderly people requiring nursing care. One-way ANOVA was used to compare differences in tongue thickness among the groups requiring different levels of care. A significant difference in tongue thickness was observed among groups requiring different levels of care ($p<0.001$). In addition, the Bonferroni test demonstrated significant differences among age groups, as shown in Figure 4 (Healthy elderly people vs Elderly people in need of moderate care: $p=0.033$, Healthy elderly people vs Elderly people in need of high-level care: $p<0.001$, Elderly people in need of moderate care vs Elderly people in need of high-level care: $p=0.035$)

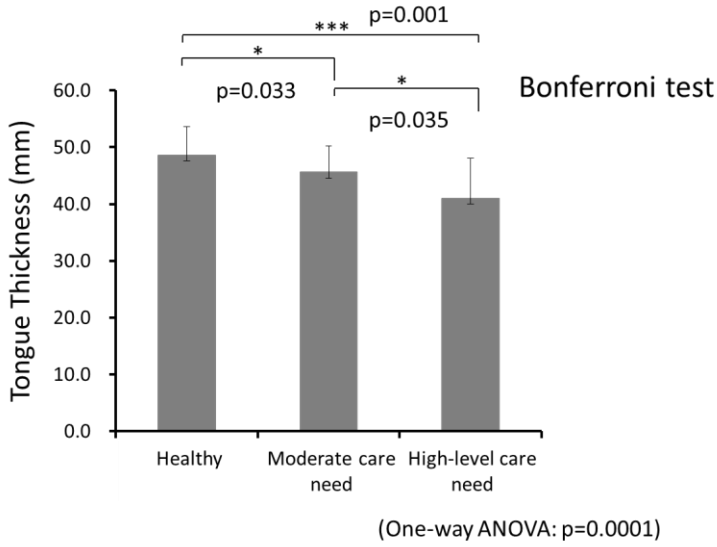

Figure 4. Relationship between tongue thickness and level of care needed

4.3 Factors affecting tongue thickness

In the elderly requiring nursing care, nursing care duration and BMI were found to be predictors, according to multiple regression analysis using the stepwise method, of tongue thickness (nursing care duration: $p<0.05$, BMI: $p<0.05$).

Oral functions, particularly tongue motor function, are highly involved in forming food boluses and forwarding them downward into the pharynx during eating and swallowing. Hence, we considered the proper functioning of the tongue to be indispensable, and have examined factors affecting the tongue muscles of elderly people requiring nursing care, using tongue thickness as the indicator.

The results indicated that there were relationships in all subjects between tongue thickness and sex, level of care needed and BMI. We previously reported lingual pressure to be associated with the level of care needed[16]. However, in this study, the level of care needed was found to be a factor affecting both tongue thickness and pressure as well. Furthermore, tongue thickness was revealed to be related to nursing care duration and BMI in groups of elderly people requiring nursing care. These results indicate that tongue thickness does not decrease with age, while the physical state of the elderly, as indicated by BMI, has a major effect. Since nursing care duration was found to be a factor affecting tongue thickness, it can reasonably be assumed that tongue thickness decreases according to the duration of receiving nursing care, suggesting an impact of

tongue disuse.

The results of this study suggested that the tongue thickness decrease in elderly people requiring nursing care is associated with not only their physical states but also declining oral functions. Sarcopenia, which is defined as loss of muscle mass, strength, and skilled movement associated with aging, may also occur in the oral regions of elderly people requiring nursing care.

5. Effects of tongue muscle mass and strength on whole-body muscle in the community-dwelling elderly

Finally, we introduce the results of the Kashiwa study[17,18] from the report by Furuya and colleagues[19]. The purpose of the study was to clarify how tongue muscle mass and strength are associated with whole-body muscle with normal aging in community dwelling elderly people. We assessed 364 healthy community-dwelling older people (169 men and 195 women, mean age: 75.6 ± 5.8 years, 67-92 years) living in Kashiwa city, Chiba Prefecture, near Tokyo. Their skeletal muscle mass index (SMI), BMI and physical abilities were measured. Tongue pressure was measured using the maximum strength measurement device and tongue thickness was measured by ultrasonography. Skeletal muscle thickness was measured using multi-frequency bioelectrical impedance with eight tactile electrodes (InBody S10, Seoul, Korea)[20]. Appendicular skeletal muscle mass (ASM) was derived as the sum of the muscle masses of the four limbs. ASM was then normalized by height in meters squared to yield the SMI (kg/m_2)[21].

A significant difference between men and women in tongue muscle volume was observed in the 74 or younger age groups, with men showing higher values than women. No significant difference was found in the 75 or older age groups (Figure 5). Tongue thickness decreased with age in men, but not in women

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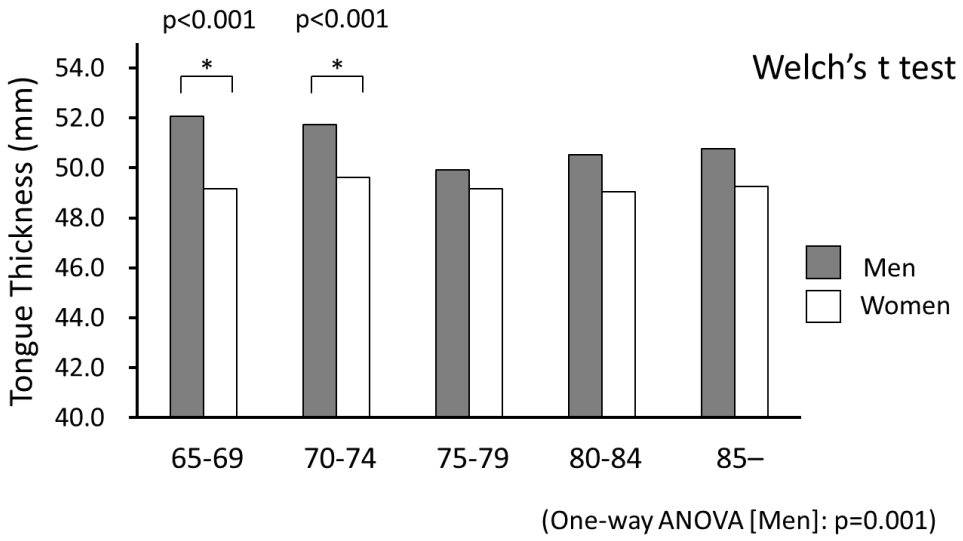

Figure 5. Results of tongue thickness measurement

Welch's test showed a significant difference in tongue thickness among age groups. The Bonferroni test in men confirmed significant differences between the 65-69 vs 85– (p = 0.003) and 70-74 vs 85– (p = 0.004) age groups.

Partial correlational analysis with age demonstrated tongue pressure to be significantly related only to tongue thickness in men (r =0. 207, p =0.007). However, all items such as SMI (r = 0.227, p =0.001), BMI (r = 0.221, p =0.002), knee extension strength (r = 0.307, p < 0.001), handgrip strength (r = 0.386, p < 0.001), usual gait speed (r = 0.202, p =0.005) and tongue muscle mass (r = 0.159, p =0.027) correlated significantly with tongue pressure in women.

Tongue thickness showed a significant decrease with age in men. On the other hand, no significant reduction in tongue thickness was observed with age in women. Tongue thickness differed significantly between the sexes only in participants younger than 75 years, with no significant difference being observed in those who aged 75 or older. There are reports related to skeletal muscle mass and sex differences. Skeletal muscle mass decreases with aging in both men and women, but the rate of decrease is greater in men[22]. Moreover, the difference in muscle mass between the sexes disappears with aging[23]. Our present study demonstrated tongue muscle mass to change in parallel with skeletal muscle mass changes. According to Baumgartner's study, the sex difference in muscle mass

change, and a decrease in serum free-testosterone, as well as a male hormones with anabolic effects, accelerated the reduction of muscle mass in men[24], suggesting that serum free-testosterone may have a similar effect on tongue muscles. Men have more whole-body skeletal muscle mass and tongue muscle mass than women, such that the decrease in muscle mass due to aging was considered to be more readily apparent in men.

6. Conclusion

Measurement of tongue thickness using ultrasonography may be beneficial for screening evaluation of nutritional status and motor function in elderly people.

7. References

1. Peng CL, Miethke RR, Pong SJ, Lin CT. Investigation of tongue movements during swallowing with M-mode ultrasonography. J Orofac Orthop. 2007; 68(1): 17-25. (article in English and German)
2. Ardakani FE. Evaluation of Swallowing Patterns of the Tongue Using Real-time B-mode Sonography. J Contemp Dent Pract. 2006; 7(3): 67-74.
3. Ajaj W, Goyen M, Herrmann B, Massing S, Goehde S, Lauenstein T, et al. Measuring tongue volumes and visualizing the chewing and swallowing process using real-time TrueFISP imaging--initial clinical experience in healthy volunteers and patients with acromegaly. Eur Radiol. 2005; 15(5): 913-918.
4. Humbert IA, Reeder SB, Porcaro EJ, Kays SA, Brittain JH, Robbins J. Simultaneous estimation of tongue volume and fat fraction using IDEAL-FSE. J Magn Reson Imaging. 2008; 28(2): 504-508.
5. Watanabe S, Ayano R, Ohtsuka Y, Mukai Y, Kanko Y. Ultrasound analysis in coronal section of tongue surface movements during swallowing. JJSDH. 1995; 16(1): 24-37. (article in Japanese)
6. Okayama H, Tamura F, Kikutani T, Kayanaka H, Katagiri H, Nishiwaki K. Effects of a palatal augmentation prosthesis on lingual function in postoperative patients with oral cancer: coronal section analysis by ultrasonography. Odontology. 2008; 96(1): 26-31.
7. Rosenberg H. Summary comments: Epidemiologic and methodologic problems in determining nutritional status of older persons. Proceedings of a conference. Albuquerque, New Mexico, October 19-21, 1988. Am J Clin Nutr. 1989; 50(5 Suppl): 1231-1233.
8. Tamura F, Kikutani T, Tohara T, Yoshida M, Yaegaki K. Tongue thickness relates to nutritional status in the elderly. Dysphagia. 2012; 27(4): 556-561.
9. Kikutani T, Tamura F, Nishiwaki K, Kodama M, Suda M, Fukui T, et al. Oral motor function and masticatory performance in the community-dwelling elderly. Odontology. 2009; 97(1): 38-42.
10. Tamura F, Mizukami M, Ayano R, Mukai Y. Analysis of feeding function and jaw stability in bedridden elderly. Dysphagia. 2002;17(3): 235-241.
11. Tamura F, Suzuki S. Effects of edentulism on lingual functions during swallowing. J Disabil Oral Health.

2004; 5(2): 83-87.

12. Okada K, Enoki H, Izawa S, Iguchi A, Kuzuya M. Association between masticatory performance and anthropometric measurements and nutritional status in the elderly. Geriatr Gerontol Int. 2010; 10(1): 56-63.
13. Chazot C, Laurent G, Charra B, Blanc C, VoVan C, Jean G, et al. Malnutrition in long-term haemodialysis survivors. Nephrol Dial Transplant. 2001; 16(1): 61-69.
14. Okayama H, Tamura F, Tohara T, Kikutani T. A Study on the Tongue Thickness of the Elderly with Care Needs. JJSDH, 2010; 31(4): 723-729. (article in Japanese)
15. Hayashi R, Tsuga K, Hosokawa R, Yoshida M, Sato Y, Akagawa Y. A novel handy probe for tongue pressure measurement. Int J Prosthodont. 2002;15(4): 385-388.
16. Tamura F, Kikutani T, Nishiwaki K, Enomoto R, Inaba S, Yoneyama T. Relation between the level of care needed and frailty for labial functions. Nihon Ronen Igakkai Zasshi. 2006; 43(3): 398-402. (article in Japanese).
17. Ishii S, Tanaka T, Akishita M, Ouchi Y, Tuji T, Iijima K; Kashiwa study investigators. Metabolic syndrome, sarcopenia and role of sex and age: cross-sectional analysis of Kashiwa cohort study. PLoS One. 2014 Nov 2014;8; 9(11): e112718.
18. Kuroda A, Tanaka T, Hirano H, Ohara Y, Kikutani T, Furuya H, et al. Eating Alone as Social Disengagement is Strongly Associated With Depressive Symptoms in Japanese Community-Dwelling Older Adults. J Am Med Dir Assoc. 2015; 16(7): 578-585.
19. Furuya H, Tamura F, Yoshida M, Hirano H, Iijima K, Kikutani T. Tongue Muscle Mass and Strength Relate to Whole-Body Muscle in the Community-Dwelling Elderly. J Jpn Assoc Oral Rehabil. 2016; 29(1): 1-9. (article in Japanese)
20. Shafer KJ, Siders WA, Johnson LK, Lukaski HC. Validity of segmental multiple-frequency bioelectrical impedance analysis to estimate body composition of adults across a range of body mass indexes. Nutrition. 2009; 25(1): 25-32.
21. Kim M, Kim H: Accuracy of segmental multi-frequency bioelectrical impedance analysis for assessing whole-body and appendicular fat mass and lean soft tissue mass in frail women aged 75 years and older. Eur J Clin Nutr. 2013; 67(4): 395-400.
22. Gallagher D, Visser M, De Meersman RE, Sepúlveda D, Baumgartner RN, Pierson RN, et al. Appendicular skeletal muscle mass: effects of age,

gender, and ethnicity. J Appl Physiol (1985). 1997; 83(1): 229-239.

23. Janssen I, Heymsfield SB, Wang ZM, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J Appl Physiol (1985). 2000; 89(1): 81-88.
24. Baumgartner RN, Waters DL, Gallagher D, Morley JE, Garry PJ. Predictors of skeletal muscle mass in elderly men and women. Mech Ageing Dev. 1999; 107(2): 123-136.

Figure legends

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Physical measurement of the upper arm using the Adipometer® (Left), and the Insertape® (Right).

Anthropometric data: triceps skinfold and arm muscle area

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