Japanese Journal of Comprehensive Rehabilitation Science (2011)

Original Article

Examination of chew swallow in healthy elderly persons: Does the position of the leading edge of the bolus in the pharynx change with increasing age?

Wataru Fujii, DDS, DMSc,[1,2] Izumi Kondo, MD, DMSc,[3] Mikoto Baba, MD, DMSc,[4] Eiichi Saitoh, MD, DMSc,[5] Seiko Shibata, MD, DMSc,[5] Sumiko Okada, SLP, DMSc,[6] Keiko Onogi, MD, DMSc,[5] Hideki Mizutani, DDS, DMSc[2]

[1]Department of Dental Surgery, Fujita Health University Nanakuri Sanatorium, Tsu, Mie, Japan
[2]Department of Oral and Maxillofacial Surgery, School of Medicine, Fujita Health University, Toyoake, Aichi, Japan
[3]National Center for Geriatrics and Gerontology Hospital, Ohbu, Aichi, Japan
[4]Department of Rehabilitation, Ashikaga Red Cross Hospital, Ashikaga, Tochigi, Japan
[5]Department of Rehabilitation Medicine I, School of Medicine, Fujita Health University, Toyoake, Aichi, Japan
[6]Faculty of Rehabilitation, School of Health Sciences, Fujita Health University, Toyoake, Aichi, Japan

ABSTRACT

Fujii W, Kondo I, Baba M, Saitoh E, Shibata S, Okada S, Onogi K, Mizutani H: Examination of chew swallow in healthy elderly persons: Does the position of the leading edge of the bolus in the pharynx change with increasing age? Jpn J Compr Rehabil Sci 2011; 2: 48−53

Objective: To determine whether aging influences the position of the leading edge of the bolus during chew swallow as identified using videofluorography (VF).

Methods: Subjects comprising 53 healthy individuals (35 men and 18 women; mean age of 54.5 ± 19.3 years and range of 25−89 years), were subdivided into 4 groups: young adults, middle age, sixties, and seventy and over. Subjects underwent lateral VF to evaluate the position of the leading edge of the bolus just prior to the onset of swallowing, with normal chew swallow for solid foods and swallowing on command for liquids.

Results: For solid foods, the position of the leading edge of the bolus during chewing changed with increasing age. Mastication time and the number of chew cycles increased with increasing age and were much higher in women than in men for the seventy and over group.

Conclusion: For solid foods, the position of the leading edge of the bolus during chewing in the pharynx changed with increasing age; this may affect the number of chew cycles and increasing age. Gender may also affect both of these factors, with women tending to show a deeper transition of the bolus into the pharynx.

Key words: aging, deglutition, chewing, Stage II transport

Correspondence: Wataru Fujii, DDS, DMSc
Department of Dental Surgery, Fujita Health University Nanakuri Sanatorium, 424−1 Ohtori, Tsu, Mie 514−1295, Japan
E-mail: wataru@fujita-hu.ac.jp
Accepted: August 24, 2011
Acknowledgments. This study was supported in part by a Health Sciences Research Grant, Comprehensive Research on Aging and Health (H14-Cyoju-019) from the Ministry of Health, Labour and Welfare, Japan.

Introduction

The concept of stage II transport for bolus movement during chewing was recently proposed by Palmer et al. (1,2), suggesting that the bolus is transferred to the oropharynx where it accumulates until the onset of swallowing. Saitoh et al. speculated that chewing reduced the effectiveness of the posterior tongue-palate seal, and as a consequence, the oral contents could easily spill into the pharynx. They also suggested that this mix of foods with different consistencies (both solid and liquid phases) would increase the risk of aspiration (3). In addition, with liquids, part of the bolus might enter the pharynx before the onset of swallowing, particularly in older subjects (4−6). Using videoendoscopy, it has been reported that the bolus remains in the pharynx of healthy individuals before swallowing in 60% of liquid swallows and 76% of solid food swallows (7). If unintentional entry of liquid into the pharynx is affected by age, at the intake of solid foods, older individuals would show bolus entry into the pharynx during the earlier phase of swallowing.

The purpose of this study was to determine whether the position of leading edge of the bolus during chew swallow changes with increasing age.

Subjects and Methods

This study comprised 53 healthy individuals (35 men and 18 women; mean age of 54.5 ± 19.3 years and range of 25−89 years) without neurological, pharyngeal, or laryngeal disorders that could provoke dysphagia. All subjects were able to eat regular meals. To clarify the effect of aging, subjects were subdivided into the following 4 groups: young adults, 13 individuals (mean age, 28.5 ± 2.5 years; range, 25−39 years; 8 men and 5 women); middle age, 15 individuals (mean age, 47.4 ± 5.1 years; range, 40−59 years; 8 men and 7 women); sixties, 12 individuals (mean age, 64.8 ± 3.1 years; range, 60−69 years; 10 men and 2 women); and seventy and over, 13 individuals (mean age, 79.2 ± 5.9 years; range, 70−89 years; 7 men and 6 women). Written informed consent was obtained from all subjects prior to enrolment. The Medical Ethics Committee of Fujita Health University approved the design of this study.

With regard to use of dentures, the young adult and middle age groups did not include any individuals who used dentures. The group of sixties included only 1 subject with partial dentures. Among the seventy and over group, 5 used complete dentures, 3 subjects used partial and complete dentures, 4 subjects used partial dentures, and 1 subject did not use dentures; all of the subjects who customarily wore dentures used their dentures during this study.

Each subject was seated comfortably in a chair and videofluorography (VF) was performed at 30 frames/s

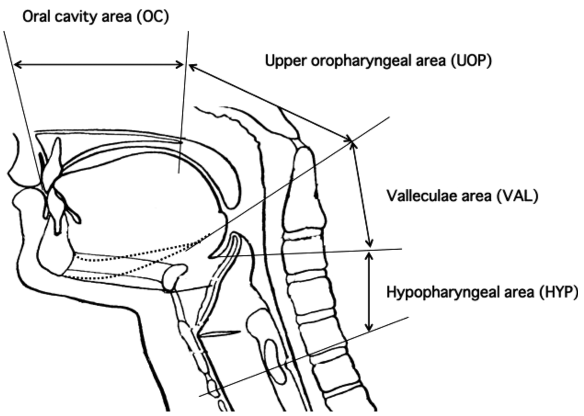

Figure 1. Classification of oropharyngeal areas and position of the leading edge of a bolus were defined as follows in the VF image frame at the start of swallowing.
OC : oral cavity area
UOP : upper oropharynx area
VAL : valleculae area
HYP : hypopharynx area

from a lateral perspective. Each subject consumed the following foods: 50% w/v liquid barium with the command to swallow (COM), corned beef hash with barium (CB), and a shortbread cookie with barium paste (CK). For the liquid barium, 10 mL of liquid barium was placed in the mouth using a syringe, and the subject was instructed to swallow. For CB and CK, 8 g of food was placed in the mouth of each subject, and they were directed to chew it thoroughly; for these tests, the subjects were not instructed how to eat, but permitted to eat the food in the manner they preferred. We assumed that the position of the leading edge of the food in the pharynx before the onset of swallowing would be affected by the processing time of the food in the mouth, which in turn would depend on the degree of chewing before swallowing.

For each kind of food, 2 trials were performed, with a total of 6 trials for each subject. Overall, 311 VF recordings of swallowing at 30 frames/s were recorded and analyzed on a personal computer using video-editing software (iMac DV model and iMovie, Apple). Of these, 7 VF recordings had to be excluded due to technical difficulties with recording. Slow-motion, still-picture, and reverse-replay functions were used to review the VF recordings.

Each type of swallowing was evaluated to detect the position of the leading edge of the bolus just before the initiation of the hyoid movement, mastication time, and the number of chew cycles. We defined the start of swallowing as the initiation of hyoid movement (IHM).

According to the anatomy of the oropharyngeal areas (Fig. 1), the position of the leading edge of the bolus was identified in the VF image frame at IHM, as follows: oral cavity area (OC), upper oropharynx area (UOP; on the lateral view, beyond the border between the hard and soft palates and up to the lower edge of the mandible extend to the posterior), vallecular area (VAL; beyond the lower edge of the mandible and up to the vallecular), and hypopharynx area (HYP; beyond the valleculae and up to the beginning of the esophagus). Mastication time was defined as the duration from the point at which the bolus started to change shape between the upper and lower teeth after being placed in the oral cavity until the end of jaw movement. For each mastication time, the number of chew cycles was also counted.

To determine whether the position of leading edge of the bolus changed with age, we compared distributions of the bolus position using χ^2 analysis and calculated the value of post-hoc cell contribution. The results of the post-hoc cell analysis were presented with numerical values (no unit), and the order of the results were estimated by the degree of those values. For comparisons of mastication time and number of chew cycles for CB and CK, one-way analysis of variance and the Tukey-Kramer honestly significant difference test were used. The logistic regression analysis was performed using gender, mastication time, number of chew cycles, and use of dentures as the independent variables and the position of the leading edge of the bolus as the dependent variable to confirm the relationship between these factors. Statistical procedures were performed with Statview version5 (SAS; USA).

Results

1. Position of the leading edge of the bolus

Prior to the onset of swallowing, we observed significant differences in the position of the leading edge of the bolus (Table 1) across the age groups for swallowing COM ($\chi^2 = 32.822$, $p < 0.001$) and CB ($\chi^2 =21.184$, $p=0.0119$). The post-hoc cell contributions to COM were 3.938 for OC in the young adult group and 2.613 for VAL and 1.952 for HYP in the seventy and over group. Conversely, the post-hoc cell

Table 1. Leading edge position of bolus just before the initiation of hyoid movement

Young adults	COM		CB		CK	
	N	PHCC	N	PHCC	N	PHCC
N	25		26		26	
OC	12	3.938	4	1.741	1	0.011
UOP	9	0.365	8	0.074	5	−0.249
VAL	4	−0.751	14	−0.553	17	1.310
HYP	0	−3.339	0	−1.162	3	−1.360

Middle age	COM		CB		CK	
	N	PHCC	N	PHCC	N	PHCC
N	30		30		30	
OC	3	−1.678	1	−1.032	0	−1.290
UOP	12	0.967	14	2.322	10	1.972
VAL	4	−1.274	15	−1.115	14	−0.991
HYP	11	1.711	0	−1.281	6	−0.152

Sixties	COM		CB		CK	
	N	PHCC	N	PHCC	N	PHCC
N	24		24		24	
OC	5	0.182	2	0.166	3	2.532
UOP	9	0.708	5	−1.135	5	−0.016
VAL	4	−0.527	17	1.395	12	−0.480
HYP	5	−0.439	0	−1.103	4	−0.587

Seventy and over	COM		CB		CK	
	N	PHCC	N	PHCC	N	PHCC
N	25		26		25	
OC	1	−2.337	1	−0.822	0	−1.140
UOP	4	−2.078	5	−1.401	2	−1.823
VAL	10	2.613	16	0.363	14	0.197
HYP	10	1.952	4	3.576	9	2.118

	COM	CB	CK
P of chi square	0.0001	0.0119	0.0645

OC : Oral cavity area, UOP : Upper oropharyngeal area
VAL : Valleculae area, HYP : Hypopharyngeal area
COM : 10 ml of barium (50% w/v) for command swallow
CB : 8 g of corned beef hash with barium
CK : 8 g of short bread cookie with barium
N : number of trials
PHCC : Post-hoc cell contribution rate

contribution for HYP was –3.389 in the young adult group. These results suggested that in terms of command to swallow with liquid, subjects in the young adult group were able to retain the bolus in their mouths, making the position of leading edge of bolus in the pharynx higher than those in the seventy and over group. In terms of the post-hoc cell contribution of CB, maximum values in each age group were 1.741 for OC in the young adult group, 2.332 for UOP in the middle age group, 1.395 for VAL in the sixties group, and 3.567 for HYP in the seventy and over group. These results suggest that the position of the leading edge of the bolus prior to the onset of swallowing gradually transitioned to a deeper position with advancing age. However, the position of the leading edge of the bolus across the 4 age groups was not significantly different with CK (χ^2=16.117, p= 0.0645). For the post-hoc cell contribution of subjects in the middle age group and the sixties group, all the values were distributed between –1.7 and 1.8, and none of them were as big as the values. No remarkable differences were observed in the young adult group and in the seventy and over group.

2. Mastication time and number of chew cycles

Mastication time and the number of chew cycles increased with age (Fig. 2) for swallowing both CB and CK and were also significantly higher in the sixties group and the seventy and over group than in the young adult and middle age groups. The mean number of chew cycles for CB was significantly higher in women (26.2 ± 20.80) than in men (17.2 ± 10.25; p < 0.05), as was the mean number of chew cycles for CK (38.3 ± 21.27 in women vs. 28.9 ± 13.75 in men, p < 0.05). Figure 3 shows the relationship between the number of chew cycles and age for swallowing CK. Overall, the results showed that the number of chew cycles increased with age and was particularly higher for women and for the seventy and over group.

3. Logistic regression analysis

We repeated these analyses and modified the division of samples for each of the independent factors such as age, mastication time, and the number of chew cycles. However, we were unable to identify any significant relationships aside from the gender differences for the differences in swallowing CK. This may be because of our small sample size. When swallowing CK, women tended to show earlier

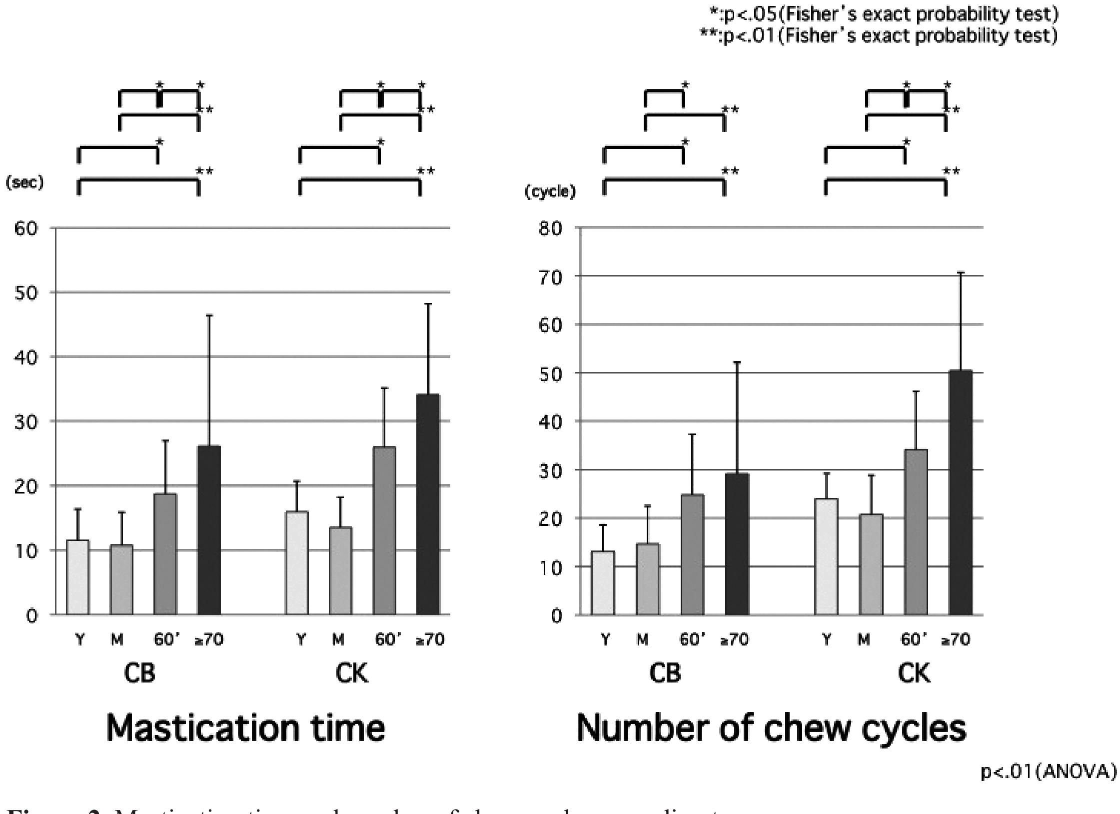

Figure 2. Mastication time and number of chew cycles according to age group.
CB : corned beef hash with barium
CK : shortbread cookie with barium paste
Y : young adults group
M : middle age group
60' : sixties group
≧70 : seventy and over group

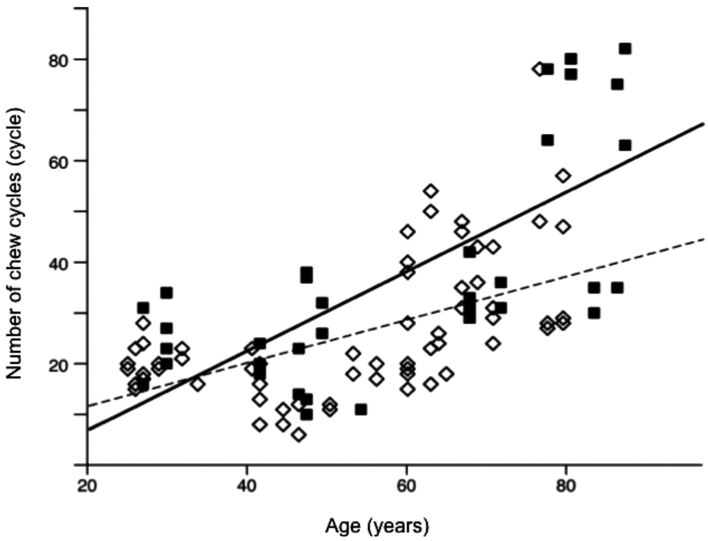

Figure 3. Relationship between number of chew cycles and age for CK.
Open diamond: number of chew cycles for male subjects.
Closed square: number of chew cycles for female subjects.
Bold line: Regression line for female subjects.
Dotted line: Regression line for male subjects.

Table 2. The result of logistic regression analysis for the CK

	χ^2	p	R	Exp	95% lower	95% upper
Gender	13.452	0.0002	0.335	9.684	2.878	32.590
Denture use	0.211	0.6460	0.000	1.573	0.228	10.879
Mastication time *1	0.070	0.7910	0.000	1.393	0.120	16.204
Chew cycle *2	0.041	0.8399	0.000	0.836	0.147	4.762

*1 Mastication time: stratified at 10 second
*2 Chew cycles: stratified at 30 cycle

transition of the bolus into the pharynx than men (Table 2). We did not identify any significant differences for swallowing CB.

Discussion

Feldman et al. reported that tooth loss significantly increased the duration of mastication until swallowing and the size of particles that the subject was willing to swallow (8). From the results of present study, it was confirmed that the mastication time and the number of chew cycles increased with age for solid foods. As there was a possibility that the number of samples was small, from the results of logistic regression analysis we were unable to determine whether mastication time and the number of chew cycles significantly affected to the degree of bolus transition into the pharynx. As for the other factors, although we were unable to identify any determinant factors for CB, the results of the logistic regression analysis for CK showed a significant relationship for gender, with women tending to show an earlier transition of the bolus into the pharynx than men. In a study of oropharyngeal swallowing in different ages, Robbins et al. observed that women showed a longer duration of upper esophageal sphincter opening (5). They suggested that this finding was related to the smaller size of the female head and neck anatomy. From our results for swallowing CK, the number of chew cycles was markedly higher in women seventy and over group. Entry of the bolus into the pharynx during chewing might be affected by the number of chew cycles and age, both of which may be linked to gender.

It has been reported that sensory discrimination in the oral cavity and pharynx progressively diminishes with age, and the threshold for the onset of pharyngeal swallowing also increases with age. Aviv et al. suggested that this decreased sensory discrimination was caused by the age-related loss of superior laryngeal nerve innervation (9). Shaker et al. indicated that threshold for the onset of pharyngeal swallowing and the pharyngoglottal closure reflex increases in the elderly (10,11). In the present study, even for solid food, the position of the leading edge of the bolus changed with increasing age. The tendency for the bolus head to easily reach the pharynx beyond the epiglottis before the initiation of swallowing in the elderly could also be a result of decreased sensitivity and increased reflex threshold in the pharyngeal area. In the elderly, this decreased sensitivity and increased reflex threshold may cause the bolus to easily reach the pharynx beyond the epiglottis before the onset of swallowing.

Shaker et al. indicated that elderly persons have also been noted to show a lack of coordination between deglutition and respiration (12). In addition, an autopsy study by Mortelitti et al. reporting a significant age-related loss of myelinated nerves in the superior laryngeal nerve (13). The superior laryngeal nerve plays a crucial role in sensation in the larynx. Kikuchi et al. also showed that 71% of elderly persons diagnosed with community-acquired pneumonia were later shown to have silent aspiration; only 10% of healthy age-matched subjects show this same diagnosis (14). The combination of premature transition of the bolus into the pharynx and decreased sensitivity of the larynx might be contributing factors to silent aspiration of food during chewing in the elderly.

Conclusion

Mastication time and number of chew cycles increase with age for solid foods. Entry of the bolus during chewing in the pharynx; this may affect the number of chew cycles and increasing age. Gender may also affect both of these factors, For solid foods, the position of the leading edge of the bolus changed with increasing age, showing a tendency for the head of the bolus to easily reach the pharynx beyond the epiglottis before the initiation of swallowing in elderly persons. This tendency may result from a decreased sensitivity and increased reflex threshold in the pharyngeal area. This premature transition of the bolus into the pharynx and decreased sensitivity of the larynx may cause silent aspiration of food during chewing in elderly persons.

References

1. Palmer JB, Rudin NJ, Lara G, Crompton AS. Cooditation of mastication and swallowing. Dysphagia 1992; 7: 187−200.
2. Hiemae KM, Palmer JB. Food transport and bolus formation during complete feeding sequences on foods of different initial consistency. Dysphagia 1999; 14: 31−42.
3. Saitoh E, Shibata S, Matsuo K, Baba M, Fujii W, Palmer JB. Chewing and food consistency: Effects on bolus transport and swallow initiation. Dysphagia 2007; 22: 100−7.
4. Linden P, Tippett D Johnston J, Siebens A, French J. Bolus position at swallow onset in normal adults preliminary observations. Dysphagia 1989; 4: 146−50.
5. Robbins J, Hamilton JW, Lof GL, Kempster GR. Oropharyngeal swallowing in normal adults of different ages. Gastroenterology 1992; 103: 823−9.
6. Tracy JF, Logeman JA, Kahrilas PJ, Jacob P, Kobara M, Krugler C. Preliminary observation on the effects of age on oropharyngeal deglutition. Dysphagia 1989; 4: 90−4.
7. Dua KS, Ren J, Bardan E, Xie P, Shaker R. Coordination of deglutitive glottal function and pharyngeal bolus transit during normal eating. Gastroenterology 1997; 112: 73−83.
8. Feldman RS, Kapur KK, Alman JE, Chauncey HH. Aging and mastication: changes in performance and in the swallowing threshold with natural dentition. J Am Geriatrics Soc 1980; 28: 97−103.
9. Aviv JE, Martin JH, Jones ME, Wee TA, Diamond B, Keen MS, et al. Age-related changes in pharyngeal and supraglottic sensation. Ann Otol Rhinol Laryngol 1994; 103: 749−52.
10. Shaker R, Ren J, Zamir Z, Sarna A, Liu J, Sui Z. Effect of aging, position, and temprature on the threshold volume triggering pharyngeal swallow. Gastroenterology 1994; 107: 396−402.
11. Shaker R, Ren J, Bardan E, Easterling C, Dua K, Xie P, et al. Pharyngoglottal closure reflex: Characterization in healthy young, elderly and dysphagic patients with predeglutitive aspiration. Gastroenterology 1994; 107: 396−402.
12. Shaker R, Li R, Ren J, Townsend WF, Dodds WJ, Martin BJ, et al. Coordination of deglutition and phases of respiration: Effect of aging, tachypnea, bolus volume, and chronic obstructive pulmonary disease. Am J Physiol 1992; 263: G750−G755.
13. Mortelliti AJ, Malmgren LT, Gacek RR. Ultrastructural changes with age in the human superior laryngeal nerve. Arch Otolaryngol Head Neck Surg 1990; 116: 1062−9.
14. Kikuchi R, Watabe N, Konno T, Mishina N, Sekizawa K, Sasaki H. High incidence of silent aspiration in elderly patients with community-acquired pneumonia. Am J Respir Crit Care Med 1994; 150: 251−3.