Oropharyngeal Swallow in Younger and Older Women: Videofluoroscopic Analysis

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Much of the initial research on normal swallowing has been conducted in young men. Recently, there has been increasing interest in determining whether there are differences between the sexes in swallowing function and in the effects of aging on swallowing in both sexes. This investigation examined the swallowing ability of 8 healthy young women between the ages of 21 and 29 and 8 healthy older women between the ages of 80 and 93 during two swallows each of 1 ml and 10 ml liquid boluses. Videofluoroscopic studies of these swallows were reviewed in slow motion and real time to confirm the absence of swallowing disorders. Kinematic analysis of each swallow was completed. Data on range of motion of pharyngeal structures and coordination characteristics of the oropharyngeal swallow were taken from this kinematic analysis. Position of the larynx at rest and length of neck were compared between the two groups. Data from this study were compared with previously published data on younger and older men. Interestingly, the range of motion of the older women was often greater than that of the young women. Only tongue base movement diminished significantly with age in women. Volume effects observed in duration and extent of movement during the 1 ml and 10 ml swallows were similar to those in earlier studies. Older women also exhibited an increased range of motion relative to the old men. This increase may indicate a compensation for aging effects not seen in older men.

KEY WORDS: swallowing, normal aging, videofluoroscopy, gender, kinematic analysis

In the past 10 to 15 years, there has been increasing interest in sex differences in swallowing function and in effects of aging on deglutition in normal men and women (Hiss, Treole, & Stuart, 2001; Logemann et al., 2000; McKee, Johnston, McBride, & Primrose, 1998; Perlman, Schultz, & Van Daele, 1993; Rademaker, Pauloski, Colangelo, & Logemann, 1998; Robbins, Hamilton, Lof, & Kempster, 1992; Sonies, Parent, Morrish, & Baum, 1988). Still, much of the literature that measures normal swallow function has been completed in young men (Kahrilas, Lin, Chen, & Logemann, 1996; Kahrilas & Logemann, 1993; Logemann et al., 1992; Logemann et al., 2000; Ohmae, Logemann, Kaiser, Hanson, & Kahrilas, 1995) or has not compared measures in men and women though data were available in these studies to make these comparisons (Fucile et al., 1998; Nilsson, Ekberg, Olsson, & Hindfelt, 1996; Yokoyama, Mitomi, Tetsuka, Tayama, & Niimi, 2000). Studies of the effects of bolus characteristics, such as bolus volume and viscosity, generally have not compared swallow of young and old men and women.

In a study of temporal measures of oropharyngeal swallow in normal women of various ages (Rademaker et al., 1998), we found an increased duration of the swallow and longer closure and opening of the airway and upper esophageal sphincter respectively with increasing age. Increased duration of the swallow in both older men and women has been reported earlier by several investigators (Robbins et al., 1992; Sonies et al., 1984; Sonies et al., 1988). These studies added significantly to our knowledge of aging and sex differences in swallow but stopped short of examining deglutition in the subjects 80+ years old.

Recently, we completed a comparison of the pharyngeal and laryngeal movements during swallow in young (21–29 years) and old (80+ years) men (Logemann et al., 2000). This study revealed significant changes in hyolaryngeal movement with aging in the men. This present project was designed to determine whether these same changes or others occur as a result of aging in women. Definitions of any differences in aging effects on swallow in normal men and women should help to tailor more effective treatments for the oldest dysphagic persons of each sex.

Method

Subject Recruitment

Normal younger and older women volunteers were recruited between 1991 and 1994 through advertisements for swallowing studies. These individuals had no history of a swallowing problem or of any diseases, illnesses, medications, or surgeries involving the central nervous system, gastrointestinal tract, or head and neck region that might affect swallowing. Eight women between the ages of 21 and 29 and 8 women between the ages of 80 and 93 were included in this study. The young women were provided with pregnancy tests before participation. The study protocol was approved by the Institutional Review Board of Northwestern University. Data on old and young men were taken from Logemann et al. (2000) for comparison with the old and young women. Age ranges and criteria for inclusion of old and young men and women were the same.

Data Collection and Reduction

Collection and reduction of swallowing data followed procedures described in Logemann et al. (2000). Each subject completed 2 swallows each of 1 ml and 10 ml "watery" liquid barium in the lateral view. A penny was taped under the chin of the subjects at midline to serve as a "ruler" to compensate for radiographic magnification during the kinematic analysis. Videofluorographic studies were recorded on 3/4-inch videotape, with timing information encoded onto each frame to facilitate later frame-by-frame analysis and computer kinematic analysis.

Each subject's videofluorographic study was first analyzed in slow motion to define any swallowing disorders—that is, visible swallowing abnormalities in bolus flow or structural movements displayed on each swallow. Timing and etiology of any aspiration and the presence of residue in the oral cavity, on the pharyngeal walls, in the valleculae or in the pyriform sinuses were noted and rated as *none*, *mild*, *moderate*, or *severe*. All videofluoroscopic analysis and ratings were done by 3 raters all identically trained with more than 10 years experience each in the interpretation of videofluoroscopic studies.

A kinematic analysis of the pharyngeal swallow in these subjects was completed on their two 1 ml and two 10 ml liquid swallows. Each video frame (1/30 s intervals) from each of the swallows of liquid was digitized, using an IBM-compatible personal computer equipped with a Data Translation Image Digitizing Board (Data Translation Frame Grabber, model DT 2861) with interactive software (Logemann, Kahrilas, Begelman, & Pauloski, 1989; Pauloski, Logemann, Fox, & Colangelo, 1995). For detailed information on the use of anchor points, reference distances, and head angles for scaling and rotating images, see Logemann et al. (1989, 2000).

In this study, the points, lines, and angles were marked on each digitized video frame as illustrated in Figure 1.

In order to assess reliability of measurement, six randomly selected swallows (10% of all 64 swallows in this study) were completely remarked by the same research assistant and by a second research assistant. Reliability of measurement assessed with Pearson correlation coefficients ranged from .90 to .99 for intrajudge and .89 to .98 for interjudge reliability. Maximum difference between remarkings was 1 mm for interjudge reliability on laryngeal elevation.

Computer software calculated the coordinate values of each point marked on each video frame and stored these for later analysis. Distance-over-time plots of the movement of each selected anatomic point throughout each swallow were then produced. Twenty-six measures were taken from the data points on these plots.

1–4 Duration measures (in s): (1) pharyngeal delay (time from the bolus head reaching the point where the lower edge of the mandible crosses the tongue base until the first laryngeal elevation in the swallow is seen); (2) base of tongue contact at any level to the posterior pharyngeal wall; (3) cricopharyngeal opening; and (4) laryngeal closure.

5–8 Onset of movement measures (in s) in relation to the first frame indicating cricopharyngeal opening: (5) onset of base of tongue posterior movement at the level opposite the anterior-inferior corner of the 2nd cervical vertebra; (6) posterior pharyngeal wall movement anteriorly at the level of the anterior-inferior corner of the 2nd cervical vertebrae; (7) laryngeal closure; (8) bolus arrival at the upper pyriform sinuses.

9–12 Measures of extent of structural movement (in mm) in relation to the first frame indicating cricopharyngeal opening: (9) vertical laryngeal movement; (10) anterior laryngeal movement; (11) vertical hyoid movement; and (12) anterior hyoid movement.

13 Time (in s) from first frame indicating cricopharyngeal opening to level of maximal opening

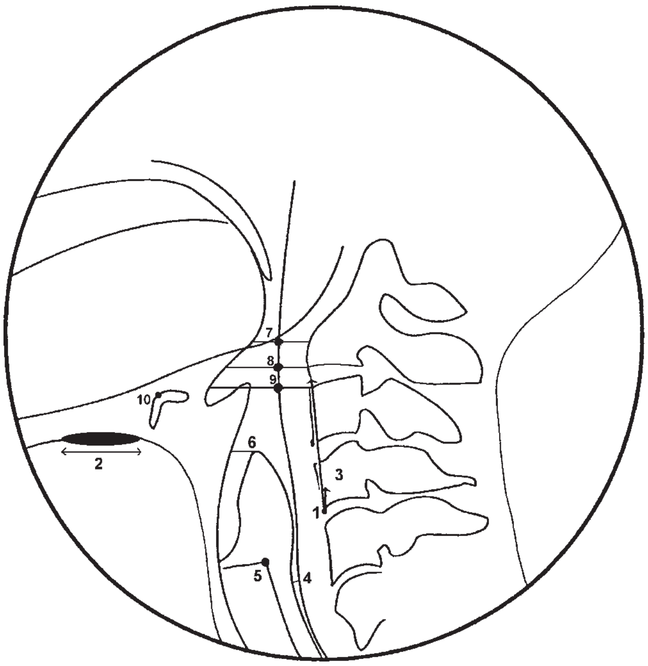
14–26 Maximal extent of structural movement (in mm) including: (14) base of tongue (BOT) movement at the level of mid-C2; (15) anterior movement of the posterior pharyngeal wall (PPW) wall at level of mid C2; (16) base of tongue movement at the level of anterior-inferior corner of C2; (17) anterior movement of the posterior pharyngeal wall at level of inferior C2; (18) anterior-posterior diameter of cricopharyngeal opening; (19) base of tongue movement at level of superior C3; (20) anterior movement of PPW at level of superior C3; (21) posterior movement of the epiglottic base at the level of the superior tip of the arytenoid; (22) anterior movement of the superior tip of the arytenoid cartilage; (23) vertical laryngeal movement; (24) anterior laryngeal movement; (25) anterior hyoid movement; and (26) vertical hyoid movement.

All measures of structural movement (9–12 and 14–26) begin with the videoframe showing first movement and end with the videoframe exhibiting last movement. Laryngeal position was measured at rest in relation to the anterior-inferior corner of the fourth cervical vertebra. The distance between the anterior-superior corner of C2 and the anterior-inferior corner of C4 was measured as a representation of neck length. Measures 14, 15, 19, and 20 were measured only in women.

Statistical Analysis

Statistical comparisons between the younger and older women were made by two-factor repeated measures analysis of variance with factors for age and volume. The two trials for each subject on each bolus volume were kept as distinct repeated measures in the statistical analysis. For variables with a significant interaction between age and volume, comparisons were

Figure 1. Tracing of a lateral view from one videofluoroscopic frame of a swallow study with marked points including (1) a point on the anterior-inferior corner of C4, which served as the anchor point; (2) a line along the length of a penny taped under the subject's chin to serve as the reference distance; (3) the angle of the subject's head tilt from true vertical, measured from the anterior-inferior aspect of C4 to the anterior-inferior corner of C2; (4) a line between the anterior and posterior walls of the cricopharyngeal region approximately 10 mm below the undersurface of the true vocal folds to represent cricopharyngeal opening; (5) a point on the posterior-superior corner of the subglottic air column to represent laryngeal movement; (6) a line from the anterior-superior tip of the arytenoid to the point on the posterior surface of the epiglottic base immediately anterior to the arytenoid to represent laryngeal closure at the vestibule; (7) a line from the anterior surface of C2 midway along the length of that vertebra to a point on the posterior pharyngeal wall and a point on the tongue base at that level to measure posterior tongue base movement and anterior movement of the posterior pharyngeal wall at the level of mid-C2; (8) a line from the anterior-inferior corner of C2 to a point on the posterior pharyngeal wall and a point on the tongue base at that level to measure posterior tongue base movement and anterior movement of the posterior pharyngeal wall at the level of inferior C2; (9) a line from the anterior-superior corner of C3 to a point on the posterior pharyngeal wall and a point on the tongue base at that level to measure posterior tongue base movement and anterior movement of the posterior pharyngeal wall at the level of superior C3; and (10) a point on the most anterior-superior aspect of the hyoid bone to represent hyoid movement.



made separately for each volume or age group. For variables with no interaction between age and volume, comparisons of age groups were made by averaging across the two volumes. To account for neck length, analyses comparing younger women to older women and analyses comparing men to women were adjusted using neck length from C2 to C4 as a covariate. For the volume comparison, no adjustment for neck length was made because these are within-person comparisons. Analysis of variance was used to compare C2 to C4 length between younger and older women and men. Analyses similar to those described above were used to compare men and women separately for the 1 ml and 10 ml bolus. A total of 26 measures were analyzed for women. A total of 22 measures were analyzed for men when men were included in the analysis. Results are initially reported using $p < .05$ as the criterion for statistical significance for each measure. In addition, the results are reported using a Bonferroni adjustment of $p < .002$ (.05/26 = .002) as the criterion for significance. To account for the multivariate nature of the data and intercorrelations among the 22 measures common to women and men, a factor analysis was performed, pooling women and men. Six factors with eigenvalues greater than 1 were identified by varimax rotation. These six factors explained 72% of the total variance in the 22 measures. Individual measures were then qualitatively associated with each factor if the factor loading was greater than .60. Analyses as described above comparing men and women were performed using the six factors as separate dependent variables. Analyses were done using PROC FACTOR and PROC MIXED in SAS (SAS Institute, 1997).

Results

No swallowing disorders were observed in either the young or the old women. No aspiration or penetration was seen. Residue was ranked as none or mild for all subjects in both groups for both bolus volumes. The vertical position of the larynx was not significantly different for young and old women. The distance between the anterior-superior corner of the second cervical (C2) vertebra and the anterior-inferior corner of the fourth cervical (C4) vertebra was 35.9 (1.3) mm in the young women and 30.3 (1.4) mm in the old women. Young women had significantly longer C2 to C4 differences than old women. Data on height indicate that neither older nor younger women were exceptionally tall. Heights ranged from 4'11" to 5'6".

Age Effects

Table 1 presents the effects of age in the 16 women. The analysis covers 64 swallows, two each of 1 ml and 10 ml for each subject. All durations were the same or longer in older women but only significantly so for cricopharyngeal opening.

Onset of movements in relation to first cricopharyngeal opening was not significantly affected by age. Extent of structural movement in relation to first cricopharyngeal opening consistently increased with age but not significantly so. Maximal extent of structural movement was significantly reduced in base of tongue movement at mid C2 in older women and significantly increased in the anterior movement of the arytenoid and vertical laryngeal movement. None of these differences was significant using the Bonferroni criterion of $p < .002$.

Volume Effects

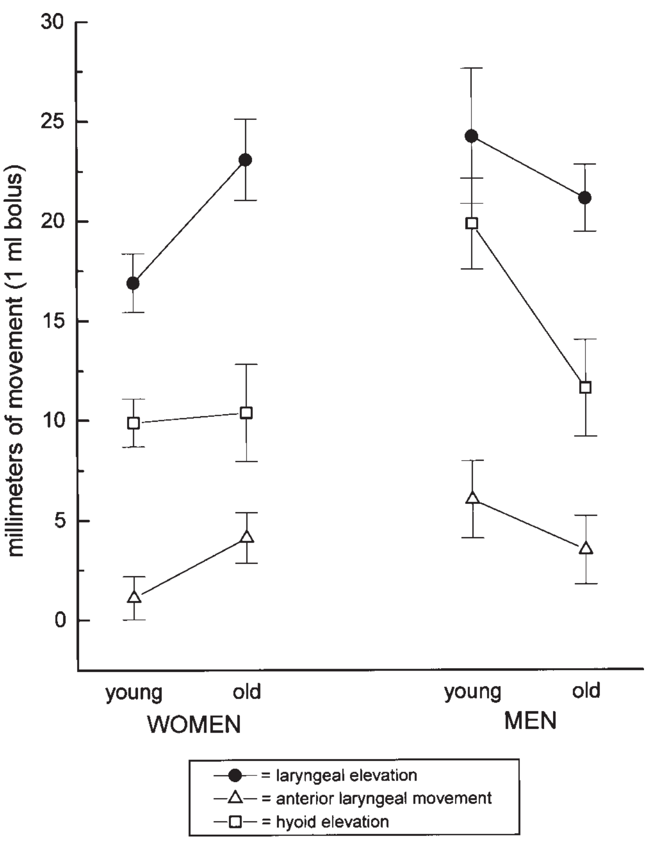
Volume effects are shown in Table 2, which compares the swallow measures at 1 ml and 10 ml volumes for the younger and older women. Durations of laryngeal closure and cricopharyngeal opening were significantly longer on 10 ml volumes. No significant changes were seen in onset of movements in relation to first cricopharyngeal opening or in extent of structural movement in relation to first cricopharyngeal opening. Time to maximum cricopharyngeal opening in relation to first cricopharyngeal opening was significantly longer on 10 ml versus 1 ml boluses. Maximum range of movement increased significantly on 10 ml boluses for posterior pharyngeal wall movement at superior C3, width of cricopharyngeal opening, vertical laryngeal movement, and anterior laryngeal and hyoid movement. Differences related to cricopharyngeal opening and anterior hyoid movement remained significant at $p < .002$.

Differences by Sex

Tables 3 and 4, respectively, compare temporal measures and extent of movement for women and men on 1 ml and 10 ml boluses. The only significant difference seen in durations of swallow measures between women and men occurred on 10 ml boluses (Table 3) for cricopharyngeal opening. Old women exhibited significantly longer cricopharyngeal opening than old men on the 10 ml bolus swallows. Onset of base of tongue and posterior pharyngeal wall ($p < .001$) movements in relation to first cricopharyngeal opening were significantly earlier for men on 1 ml boluses, whereas laryngeal closure began significantly earlier on 1 ml boluses for women. On 10 ml boluses, old women exhibited a significantly longer time to achieve maximal cricopharyngeal opening in relation to first cricopharyngeal opening.

Table 4 indicates that young women exhibited less structural movement than men on 1 ml and 10 ml boluses. Significant results show that young men had greater movement than young women on laryngeal elevation, anterior laryngeal movement, and hyoid elevation ($p < .001$) at first cricopharyngeal opening and maximal laryngeal elevation, hyoid elevation ($p < .001$ at 10 ml), and anterior hyoid movement. For all these measures, no significant differences were seen between old women and old men except for maximum anterior hyoid movement at 10 ml. For these measures, there was a significant age-by-sex interaction (p values for interaction ranged from .004 to .05), indicating that women's motion increased and men's motion decreased with age (Figure 2).

Figure 2. Change in laryngeal elevation, anterior laryngeal movement, and hyoid elevation on 1 ml bolus by age and sex. Error bars present standard errors for each measure.



Factor Analysis

Results of the factor analysis are presented in Tables 5 through 7. Table 5 describes the measures that are associated with each factor, the percent of total variance explained by each factor, and the factor loadings. Separate qualitative constructs may be identified for each factor. Factor 1 represents movement in the anterior posterior plane. Factor 2 represents laryngeal and hyoid elevation. Factor 3 represents timing of tongue base movement and laryngeal closure. Factor 4 represents cricopharyngeal opening. Factor 5 represents a single measure, namely extent of posterior movement of the base of tongue. Factor 6 represents pharyngeal bolus movement. Factor loadings indicate the magnitude and direction of the correlation between the factor and the individual measure. Using the criterion of .60 to associate a measure with a factor, 21 of 22 original measures were uniquely associated with one of the six factors. Of the remaining 16 factors, 5 had eigenvalues between .50 and 1.00, and 11 had eigenvalues less than .50.

Comparisons of factor scores between women and men are presented in Table 6 for the 1 ml bolus and in Table 7 for the 10 ml bolus. The actual values of the factor score means are artificial but may be used to indicate relative magnitude of women versus men. These tables also describe in words how the factors are related to the individual measures. Tables 6 and 7 provide multivariate comparisons of factors between women and men, whereas Tables 3 and 4 provide the associated univariate comparisons of individual measures.

Tables 6 and 7 indicate no significant differences between women and men on Factor 1 scores, which represent anterior movement of the hyoid, larynx, and arytenoids and posterior movement of epiglottic base. Measures associated with Factor 2, vertical movement of the larynx and hyoid, are lower in young women than in young men. There were no differences between older women and older men in these measures. For 1 ml boluses, men showed lower mean values for Factor 3, which indicates earlier onset of base of tongue movement and posterior pharyngeal wall movement relative to first cricopharyngeal opening. These differences were not seen on the 10 ml bolus, and sex differences on these measures were not age-specific. Factor 4 measures of cricopharyngeal opening were significantly higher in older women than in older men on the 10 ml bolus. Factor 5 scores indicated greater posterior base of tongue movement in men than in women, but this factor represents a single measure that was reported in Table 4. There were no significant differences in Factor 6 scores of pharyngeal bolus transport between women and men.

Discussion

This investigation examined age, volume, and sex effects on oropharyngeal swallows of 1 ml and 10 ml liquid in 8 healthy young (age 21–29) and 8 healthy old (age 80–93) women. A few significant differences were observed in terms of age in these women. All durations were prolonged in the older women, though only cricopharyngeal opening significantly so. Laryngeal closure

Table 1. Mean (±*SEM*) swallow measures by age group. Statistics are based on 32 swallows, two 1 ml and two 10 ml, for each of the 8 younger women and 8 older women. Analyses are adjusted for length from C2 to C4 as a covariate.

Measure	Younger		Older		*p* value
Duration (s)					
Pharyngeal delay	–.11	(.02)	.11	(.10)	.06
Base of tongue contact to pharyngeal wall	.40	(.07)	.44	(.10)	.78
Cricopharyngeal opening	.41	(.02)	.48	(.02)	.04*
Laryngeal closure	.58	(.03)	.71	(.07)	.15
Onset (s) in relation to first cricopharyngeal opening					
Base of tongue movement	–.05	(.03)	–.09	(.09)	.73
Posterior pharyngeal wall movement	–.11	(.02)	–.10	(.07)	.95
Laryngeal closure	–.08	(.01)	–.16	(.06)	.26
Bolus reaches pyriform sinuses	–.04	(.01)	–.03	(.02)	.66
Extent (mm) of structural movement in relation to first cricopharyngeal opening					
Vertical laryngeal movement	15.85	(1.43)	20.67	(1.61)	.06
Anterior laryngeal movement	1.22	(1.13)	4.66	(0.99)	.06
Vertical hyoid movement	9.26	(1.25)	10.52	(2.04)	.64
Anterior hyoid movement	4.56	(1.26)	7.18	(0.97)	.15
Time (s) to maximum cricopharyngeal opening in relation to first cricopharyngeal opening	.13	(.01)	.14	(.02)	.73
Maximal extent of structural movement (mm)					
Base of tongue movement posteriorly at mid C2	9.74	(.50)	6.57	(.83)	.01*
Posterior pharyngeal wall movement anteriorly at mid C2	6.38	(1.02)	6.48	(1.02)	.95
Base of tongue movement posteriorly at inferior C2	7.09	(.35)	5.80	(.59)	.10
Posterior pharyngeal wall movement anteriorly at inferior C2	5.21	(.47)	5.74	(.65)	.56
Base of tongue movement posteriorly at superior C3	6.89	(.28)	5.64	(.70)	.14
Posterior laryngeal wall movement anteriorly at superior C3	5.16	(.58)	5.36	(.59)	.83
Anterior-posterior cricopharyngeal opening	5.97	(.59)	6.33	(.60)	.71
Posterior movement of epiglottic base	5.64	(.64)	3.78	(.71)	.10
Anterior movement of arytenoid	2.86	(.51)	5.07	(.67)	.03*
Vertical laryngeal movement	21.83	(1.59)	27.16	(1.50)	.046*
Anterior laryngeal movement	5.13	(1.20)	8.19	(1.04)	.10
Vertical hyoid movement	12.94	(1.14)	15.40	(2.02)	.34
Anterior hyoid movement	10.11	(1.03)	10.32	(.79)	.89

* $p < 0.05$

durations were longer for older women, but not significantly. This corresponds with data from Hiss et al. (2001), who found that women had longer swallowing apnea durations (SAD) than men and that women exhibited an increase in SAD with age whereas men exhibited a decrease in SAD with increasing age. Extent of structural movements was generally increased in the older women, particularly the movements related to opening of the upper esophageal sphincter (i.e., anterior hyoid and laryngeal movement and elevation; Jacob, Kahrilas, Logemann, Shah, & Ha, 1989) though only one (laryngeal elevation) significantly so. Increases in hyolaryngeal movement may be a compensation for the lowered position of the larynx with age in women (Robbins et al., 1992). Only tongue base movement diminished significantly with age in women.

Volume effects observed in duration and extent of movement during the 1 ml and 10 ml swallows in this study are similar to those observed in other investigations of swallow changes as bolus volume increases: increased duration and width of cricopharyngeal opening (Cook et al., 1989; Jacob et al., 1989; Kahrilas & Logemann, 1993) and increased duration of airway entrance closure (Logemann et al., 1992), increased extent of posterior pharyngeal wall movement at superior C3, increased laryngeal elevation and anterior movement of the larynx and hyoid. The increases in laryngeal and hyoid movement probably result in the longer and wider cricopharyngeal opening because the movements of these structures “yank” open the upper esophageal sphincter (cricopharyngeal region; Cook et al., 1989; Jacob et al., 1989).

Table 2. Mean (±*SEM*) swallow measures by bolus size. Statistics are based on 32 swallows, two swallows for 8 younger women and for 8 older women at each of the two bolus volumes.

Measure	1 ml		10 ml		*p* value
Duration (s)					
Pharyngeal delay	.05	(.07)	–.05	(.04)	.10
Base of tongue contact to pharyngeal wall	.40	(.05)	.44	(.08)	.63
Cricopharyngeal opening	.36	(.02)	.53	(.02)	<.001*
Laryngeal closure	.56	(.04)	.73	(.07)	.04*
Onset (s) in relation to first cricopharyngeal opening					
Base of tongue movement	–.07	(.04)	–.07	(.07)	.99
Posterior pharyngeal wall movement	–.08	(.02)	–.13	(.06)	.40
Laryngeal closure	–.10	(.03)	–.14	(.05)	.54
Bolus reaches pyriform sinuses	–.03	(.01)	–.03	(.02)	.79
Extent (mm) of structural movement in relation to first cricopharyngeal opening					
Vertical laryngeal movement	19.48	(1.13)	17.03	(1.24)	.08
Anterior laryngeal movement	2.66	(.83)	3.23	(.68)	.47
Vertical hyoid movement	10.02	(1.38)	9.77	(1.75)	.91
Anterior hyoid movement	5.68	(1.03)	6.06	(.87)	.74
Time (s) to maximum cricopharyngeal opening in relation to first cricopharyngeal opening	.10	(.02)	.17	(.01)	.002*
Maximal extent of structural movement (mm)					
Base of tongue movement posteriorly at mid C2	8.46	(.55)	7.85	(.72)	.45
Posterior pharyngeal wall movement anteriorly at mid C2	5.86	(.70)	7.01	(.79)	.18
Base of tongue movement posteriorly at inferior C2	6.57	(.42)	6.32	(.44)	.66
Posterior pharyngeal wall movement anteriorly at inferior C2	5.07	(.38)	5.88	(.47)	.10
Base of tongue movement posteriorly at superior C3	6.58	(.46)	5.96	(.39)	.17
Posterior pharyngeal wall movement anteriorly at superior C3	4.52	(.46)	5.99	(.45)	.006*
Anterior-posterior cricopharyngeal opening	3.93	(.41)	8.38	(.42)	<.001*
Posterior movement of epiglottic base	4.79	(.59)	4.63	(.52)	.79
Anterior movement of arytenoids	3.80	(.43)	4.14	(.43)	.42
Vertical laryngeal movement	23.51	(1.09)	25.48	(1.19)	.04*
Anterior laryngeal movement	5.34	(.90)	7.98	(.81)	.01*
Vertical hyoid movement	13.10	(1.31)	15.24	(1.09)	.08
Anterior hyoid movement	8.81	(.80)	11.63	(.58)	<.001*

* $p < 0.05$

Comparisons of the swallow measures in the young and old men and women resulted in some interesting sex differences in the older groups. As the men aged, the movements of larynx and hyoid generally were reduced, whereas women's movements increased or were relatively stable between the two age groups, as reflected in Figure 2. These data indicate that women in this study maintain muscular reserve better than men. Muscular reserve is the difference between extent of movement needed to accomplish a desired functional result (e.g., UES opening) and the actual extent of movement used (Kenney, 1985). Under normal circumstances, reduced maximal movement would be interpreted as greater efficiency in accomplishing a task, but reserve is most critical when the subject becomes ill and weak (Buchner & Wagner, 1992; Johnson, 1993; Kenney, 1985; Troncale, 1996). With adequate reserve, the mechanism can still swallow safely despite some reduction in maximum movement. With reduced reserve, the necessary movements of swallow are reduced in range, and efficiency and safety of swallow are impaired. Although these results may be confirmed by the statistics provided for vertical laryngeal and hyoid movement in Table 4, the Factor 2 summary measure in Table 7 focuses these results. There was no significant difference in the mean Factor 2 scores between young women and old women (–.52 vs –.27, p = 0.57) but there was between young and old men (.94 vs –.18, p = 0.02). Cricopharyngeal measures (onset, duration) related to Factor 4 were also reduced in older men, compared with older women. Changes in muscular reserve observed in the hyolaryngeal movement with age in men (Logemann et al., 2000)

Table 3. Mean (±*SEM*) for temporal swallow measures by sex for the 1 ml and 10 ml liquid boluses. Analyses are adjusted for neck length for C2 to C4 as a covariate.

Measure	Volume		Women		Men		*p* value
Duration (s)							
Pharyngeal delay	1 ml		.06	(.08)	–.03	(.07)	.46
	10 ml		–.05	(.04)	.07	(.03)	.68
Base of tongue contact to pharyngeal wall	1 ml		.39	(.04)	.40	(.03)	.87
	10 ml		.43	(.09)	.32	(.04)	.21
Cricopharyngeal opening	1 ml		.36	(.02)	.35	(.03)	.69
	10 ml	Young	.49	(.02)	.52	(.03)	.25
		Old	.57	(.03)	.50	(.03)	.049*
Laryngeal closure	1 ml		.54	(.04)	.53	(.03)	.84
	10 ml		.72	(.08)	.57	(.04)	.11
Onset (s) in relation to first cricopharyngeal opening							
Base of tongue movement	1 ml		–.07	(.02)	–.28	(.07)	.004*
	10 ml		–.05	(.07)	–.07	(.06)	.83
Posterior pharyngeal wall movement	1 ml		–.08	(.02)	–.27	(.03)	<.001*
	10 ml		–.12	(.06)	–.09	(.04)	.65
Laryngeal closure	1 ml		–.09	(.02)	–.03	(.01)	.03*
	10 ml		–.13	(.07)	.02	(.02)	.06
Bolus reaches pyriform sinuses	1 ml		–.03	(.01)	–.002	(.02)	.23
	10 ml		–.03	(.01)	.00	(.01)	.18
Time (s) to maximum cricopharyngeal opening	1 ml		.10	(.01)	.12	(.01)	.20
in relation to first cricopharyngeal opening	10 ml	Young	.15	(.02)	.18	(.03)	.41
		Old	.19	(.02)	.13	(.02)	.05*

* $p < 0.05$

were not observed in the women in this investigation. Studies of changes in muscular reserve resulting from age have not examined possible sex differences. The results of this present study indicate that older healthy men have greater risk than older women of developing dysphagia when they become weak from illness because of their lost reserve. Data from our studies of aspiration show a preponderance of men with this consequence, even after accounting for sex differences in etiologic incidence (Smith, Logemann, Colangelo, Rademaker, & Pauloski, 1999).

There are some indications from laryngeal function studies involving speech or voicing that women may be better able to compensate for changes resulting from aging. Both Sapienza and Dutka (1996) and Hoit and Hixon (1992) hypothesized that the healthy older women may be capable of making behavioral adjustments to counteract the effects of aging on laryngeal structures. In a study of swallowing in normal older and younger men and women, Robbins et al. (1992) found a longer duration of upper esophageal sphincter (UES) opening for women than for men and longer pharyngeal response durations with the manometric tube in place than without it in women. These latter measures may be indicators of greater flexibility in the oropharyngeal mechanism of women so that women can develop more successful behavioral adjustments to compensate for aging than men can. The differences in oropharyngeal swallow in the women and men observed in this study emphasize the need to control for sex and age in the design of studies of normal swallow physiology and to examine the comparative impact of disease and trauma on swallowing in women and men at all ages, but particularly in those over age 60. More research is needed to further define and examine the nature of any differences in the way men and women swallow under various conditions, including volume, viscosity, texture, and taste changes.

Table 4. Mean (±*SEM*) for distance of movement measures by sex for the 1 ml and 10 ml liquid boluses. Analyses are adjusted for neck length of C2 to C4 as a covariate.

Measure	Volume		Women		Men		*p* value
Extent (mm) of structural movement in relation to first cricopharyngeal opening							
Vertical laryngeal movement	1 ml	Young	16.89	(1.46)	24.22	(3.38)	.04*
		Old	23.07	(2.03)	21.77	(1.68)	.64
	10 ml	Young	15.18	(2.42)	23.52	(2.74)	.003*
		Old	19.60	(2.67)	17.63	(2.58)	.49
Anterior laryngeal movement	1 ml	Young	1.10	(1.08)	6.02	(1.93)	.008*
		Old	4.12	(1.27)	3.49	(1.72)	.77
	10 ml		3.24	(.92)	2.33	(.79)	.46
Vertical hyoid movement	1 ml	Young	9.88	(1.21)	19.83	(2.29)	<.001*
		Old	10.37	(2.44)	11.59	(2.44)	.65
	10 ml		9.63	(1.55)	16.12	(1.67)	.003*
Anterior hyoid movement	1 ml		5.74	(1.09)	7.03	(1.15)	.47
	10 ml		6.27	(.89)	5.12	(.79)	.35
Maximal extent of structural movement (mm)							
Base of tongue movement posteriorly at inferior C2	1 ml		6.48	(.41)	8.87	(.88)	.02*
	10 ml		6.27	(.48)	8.83	(.65)	.001*
Posterior pharyngeal wall movement anteriorly at inferior C2	1 ml		5.13	(.44)	5.84	(.58)	.33
	10 ml		6.19	(.56)	6.64	(.55)	.46
Anterior-posterior width of cricopharyngeal opening	1 ml		4.00	(.38)	6.15	(.50)	<.001*
	10 ml	Young	7.90	(.77)	12.05	(.63)	<.001*
		Old	8.76	(.74)	9.26	(.55)	.60
Posterior movement of epiglottic base	1 ml		4.91	(.90)	5.71	(.84)	.61
	10 ml		4.37	(.50)	6.80	(.88)	.03*
Anterior movement of arytenoids	1 ml		3.80	(.53)	4.29	(.49)	.51
	10 ml		4.33	(.46)	3.96	(.59)	.59
Vertical laryngeal movement	1 ml		24.00	(1.11)	27.20	(2.46)	.22
	10 ml	Young	23.81	(2.21)	35.16	(3.41)	.006*
		Old	27.98	(2.31)	24.88	(2.10)	.33
Anterior laryngeal movement	1 ml		5.32	(.76)	6.82	(1.59)	.34
	10 ml		7.95	(1.09)	7.56	(1.06)	.81
Vertical hyoid movement	1 ml	Young	11.95	(1.41)	22.43	(2.87)	.004*
		Old	14.60	(2.59)	13.51	(1.87)	.67
	10 ml	Young	14.56	(1.46)	27.15	(1.73)	<.001*
		Old	15.86	(2.32)	15.85	(2.51)	.99
Anterior hyoid movement	1 ml		8.78	(.87)	11.26	(1.72)	.25
	10 ml	Young	11.80	(1.58)	5.30	(2.50)	.08
		Old	11.65	(.99)	8.24	(.90)	.02*

* $p < 0.05$

Table 5. Definition and interpretation of factors used in multivariate analysis, percent of total variance explained, and factor loadings.

Factor	Factor loading
1: Movement in the anterior posterior plane (explains 24% of variance)	
Extent (mm) of structural movement in relation to first cricopharyngeal opening	
Anterior laryngeal movement	.64
Anterior hyoid movement	.73
Maximal extent of structural movement (mm)	
Posterior movement of epiglottic base	–.66
Anterior movement of arytenoids	.76
Anterior laryngeal movement	.72
Anterior hyoid movement	.82
2: Movement in the vertical plane (explains 17% of variance)	
Extent (mm) of structural movement in relation to first cricopharyngeal opening	
Vertical laryngeal movement	.79
Vertical hyoid movement	.90
Maximal extent of structural movement (mm)	
Vertical laryngeal movement	.80
Vertical hyoid movement	.89
3: Laryngeal closure and tongue base to pharyngeal wall contact (explains 12% of variance)	
Duration (s)	
Base of tongue contact to pharyngeal wall	–.84
Timing characteristics of laryngeal closure	–.65
Onset (s) in relation to first cricopharyngeal opening	
Base of tongue movement	.82
Posterior pharyngeal wall movement	.85
Laryngeal closure	.68
4: Cricopharyngeal opening (explains 8% of variance)	
Duration of cricopharyngeal opening (s)	.89
Time (s) to maximum cricopharyngeal opening in relation to first cricopharyngeal opening	.75
Maximal anterior-posterior diameter of cricopharyngeal opening (mm)	.75
5: Maximal extent of base of tongue movement posteriorly (mm) at inferior C2 (explains 6% of variance)	.86
6: Pharyngeal bolus movement (explains 5% of variance)	
Pharyngeal delay time (s)	–.65
Onset (s) of bolus reaching pyriform sinuses in relation to first cricopharyngeal opening	.80

Table 6. Mean (±*SEM*) factor scores by sex for the 1 ml liquid bolus. For each factor, statistics are based on 32 swallows, two swallows for each of the 16 women and 16 men. Analyses are adjusted for neck length of C2 to C4.

Factor	Significance of lower scores		Women	Men	*p* value
1	Indicates less anterior movement of the hyoid, larynx, and arytenoids and less posterior movement of epiglottic base		–.21 (.21)	–.01 (.28)	.57
2	Indicates less vertical movement of the larynx and hyoid	Young	–.47 (.14)	.76 (.41)	.004*
		Old	–.11 (.35)	–.15 (.26)	.90
3	Indicates longer duration of base of tongue (BOT) to posterior pharyngeal wall (PPW) contact, longer duration of laryngeal closure, and earlier onset of BOT and PPW movement and laryngeal closure relative to first cricopharyngeal opening (CPO)		.16 (.09)	–.38 (.14)	.003*
4	Indicates earlier onset, shorter duration, and smaller anterior-posterior diameter of CPO		–.69 (.12)	–.71 (.14)	.88
5	Indicates less posterior BOT movement		–.53 (.14)	.56 (.33)	.003*
6	Indicates a longer pharyngeal delay time and earlier onset of the bolus reaching the pyriform sinuses relative to first CPO		–.23 (.20)	.05 (.26)	.42

* $p < 0.05$

Table 7. Mean (±*SEM*) factor scores by sex for the 10 ml liquid bolus. For each factor, statistics are based on 32 swallows, two swallows for each of the 16 women and 16 men. Analyses are adjusted for neck length of C2 to C4.

Factor	Significance of lower scores		Women	Men	*p* value
1	Indicates less anterior movement of the hyoid, larynx, and arytenoids and less posterior movement of epiglottic base		.31 (.18)	–.09 (.26)	.13
2	Indicates less vertical movement of the larynx and hyoid	Young	–.52 (.23)	.94 (.36)	<.001*
		Old	–.27 (.34)	–.18 (.31)	.82
3	Indicates longer duration of base of tongue (BOT) to posterior pharyngeal wall (PPW) contact, longer duration of laryngeal closure, and earlier onset of BOT and PPW movement and laryngeal closure relative to first cricopharyngeal opening (CPO)		–.04 (.35)	.26 (.16)	.45
4	Indicates earlier onset, shorter duration, and smaller anterior-posterior diameter of CPO	Young	.40 (.28)	.86 (.26)	.11
		Old	1.14 (.31)	.40 (.19)	.04*
5	Indicates less posterior BOT movement		–.54 (.15)	.51 (.22)	<.001*
6	Indicates a longer pharyngeal delay time and earlier onset of the bolus reaching the pyriform sinuses relative to first CPO		.05 (.20)	.13 (.15)	.77

* $p < 0.05$

Acknowledgments

This research was supported by NIH/NCI P01 CA40007 and NINDS R01 DC00646.

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Received July 24, 2001

Accepted January 30, 2002

DOI: 10.1044/1092-4388(2002/034)

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