AJSLP

Research Article

Pharyngeal Pressure Generation During Tongue-Hold Swallows Across Age Groups

Sebastian H. Doeltgen,[a,b,c] Phoebe Macrae,[a,b] and Maggie-Lee Huckabee[a,b]

Purpose: To compare the effects of the tongue-hold swallowing maneuver on pharyngeal pressure generation in healthy young and elderly research volunteers.
Method: Sixty-eight healthy research volunteers (young, *n* = 34, mean age = 26.8 years, *SD* = 5.5; elderly, *n* = 34, mean age = 72.6 years, *SD* = 4.8; sex equally represented) performed 5 noneffortful saliva swallows and 5 tongue-hold swallows each. Amplitude and duration of pharyngeal pressure were investigated during both swallowing conditions with solid-state pharyngeal manometry at the level of the oropharynx, hypopharynx, and upper esophageal sphincter (UES).
Results: At both pharyngeal levels, tongue-hold swallows produced lower peak pressure compared with saliva swallows. During tongue-hold swallows, UES relaxation pressure was increased in the elders, whereas the younger group displayed a trend toward reduced relaxation pressure. Elderly individuals produced pressure longer during control swallows in the oropharynx and hypopharynx than young individuals.
Conclusions: The tongue-hold maneuver affects oropharyngeal and hypopharyngeal pressure in the young and elders in similar ways, whereas effects on UES peak relaxation pressure differ between age groups. Reduced pharyngeal peak pressure and increased UES relaxation pressure underscore the notion that tongue-hold swallows should not be performed when bolus is present. Long-term training effects remain to be investigated.

Key Words: pharyngeal manometry, tongue-hold maneuver, pharyngeal pressure, aging

The tongue-hold maneuver, sometimes also referred to as the Masako maneuver, was first introduced by Fujiu, Logemann, and Pauloski (1995). In a group of patients with surgical resection of the tip of the tongue due to oral cancer, these researchers observed increased anterior movement of the posterior pharyngeal wall (PPW) during swallowing (Fujiu & Logemann, 1996). Greater PPW protraction in these patients, as assessed during videofluoroscopic swallowing study (VFSS), was thought to reflect increased PPW contraction during swallowing to compensate for reduced base of tongue (BOT) retraction. In individuals with dysphagia due to reduced pharyngeal pressure generation, increasing PPW contractile strength may aide pharyngeal bolus transit and airway protection. Therefore, to mimic the anatomical deficit of the oral cancer patient group in anatomically unimpaired individuals, Fujiu and Logemann (1996) devised the tongue-hold maneuver, in which the tip of the tongue is placed anteriorly between the frontal incisors during swallowing. In a cohort of healthy research volunteers, these researchers demonstrated that this maneuver leads to increased PPW protraction during swallowing, as assessed visually by VFSS (Fujiu & Logemann, 1996).

Since its introduction, the tongue-hold maneuver has been implemented as a routine pharyngeal muscle-strengthening exercise in many clinical settings. However, only a small number of studies have investigated the functional effects of this exercise using assessment techniques other than VFSS. Using pharyngeal manometry, Doeltgen, Witte, Gumbley, and Huckabee (2009) identified that pharyngeal pressure generation during tongue-hold swallowing was decreased, rather than increased, compared to noneffortful saliva swallows. This finding was in contrast to what one might expect given reports of increased PPW anterior movement (Fujiu & Logemann, 1996). However, anterior positioning of the tip of the tongue displaces the BOT anteriorly, and it is likely that this anatomical modification resulted in decreased peak pharyngeal pressure due to reduced BOT retraction during tongue-hold swallows. Umeki and colleagues (2009) reported that peak pharyngeal pressure during tongue-hold swallows did not differ from that recorded during noneffortful saliva swallows. This finding suggests that increased PPW anterior movement observed visually during VFSS (Fujiu & Logemann, 1996) may in some individuals have the potential to compensate, at least in part, for decreased BOT retraction. Interestingly, in a preliminary study of three patients with reduced

[a]University of Canterbury, Christchurch, New Zealand
[b]The Van der Veer Institute for Parkinson's and Brain Research, Christchurch, New Zealand
[c]University of Adelaide, Adelaide, Australia

Correspondence to Sebastian H. Doeltgen: sebastian.doeltgen@adelaide.edu.au

Editor: Laura Justice
Associate Editor: Nancy Solomon

Received August 2, 2010
Accepted February 24, 2011
DOI: 10.1044/1058-0360(2011/10-0067)

BOT-PPW contact pressures due to head and neck cancer, BOT-PPW contact pressures were found to be significantly higher during tongue-hold swallows compared with normal saliva swallows (Lazarus, Logemann, Song, Rademaker, & Kahrilas, 2002). It is possible that these mildly dysphagic patients were accustomed to swallowing with increased effort. The increased pressure observed during tongue-hold swallows may have represented behavioral accommodation that was accrued by these patients over time.

Alternatively, it is possible that the tongue-hold maneuver has different, more compensatory effects in elderly participants compared to younger volunteers. Indeed, in the studies that did not find increased pharyngeal pressures during the tongue-hold maneuver (Doeltgen et al., 2009; Umeki et al., 2009), young, healthy research volunteers (age 20 to 46 years) were examined, whereas the age of the three patients investigated by Lazarus et al. (2002) was much higher, ranging from 65 to 73 years.

A number of studies have documented that age affects biomechanical aspects of swallowing function in a number of ways. For example, studies using combined manometry and videofluoroscopy have demonstrated that oral (Shaw et al., 1995) as well as oropharyngeal and hypopharyngeal bolus transit times (Yokoyama, Mitomi, Tetsuka, Tayama, & Niimi, 2000) are significantly prolonged in nondysphagic elders. Some authors also report increased pharyngeal pressure generation in the hypopharynx (Shaw et al., 1995), although this finding is not consistent across studies (Yokoyama et al., 2000). Differences in the manometric catheter designs used may have contributed to this discrepancy. Yokoyama and colleagues (2000) observed in a group of asymptomatic elders that upper esophageal sphincter (UES) relaxation during a 10-ml barium swallow was significantly decreased, and this resulted in prolonged bolus passage through the UES. Similarly, Bardan, Kern, Arndorfer, Hofmann, and Shaker (2006) reported an increased pressure gradient at this level of the pharynx in healthy elderly compared to healthy young individuals using video-manometry. In fact, fiberoptic endoscopic evaluation of swallowing (FEES) demonstrated a high incidence of subclinical signs of laryngeal penetration and aspiration in a population of healthy, asymptomatic elderly individuals (Butler, Stuart, & Kemp, 2009).

The documented changes in oropharyngeal swallowing biomechanics may be related, at least in part, to a general loss of muscle mass and strength, a process known as sarcopenia. Sarcopenia is characterized by a reduction of predominantly fast-twitch Type II fibers and is also associated with a decrease in the number of motor units (Brown, Strong, & Snow, 1988; Lexel, Taylor, & Sjostrom, 1988). In regard to swallowing function, Butler et al. (2010) recently demonstrated that healthy elderly individuals who presented with subclinical signs of penetration and aspiration produced lower pharyngeal peak pressures than their age-matched peers who showed no signs of penetration or aspiration. In addition, previous research identified a decline in maximal tongue strength in elders (Robbins, Levine, Wood, Roecker, & Luschei, 1995; Youmans, Youmans, & Stierwalt, 2009), which may have significant impact on oropharyngeal pressure generation. Not surprisingly, training of muscle strength has been a central component of functional dysphagia rehabilitation for many years. In an excellent review of this topic, Burkhead, Sapienza, and Rosenbek (2007) noted that the effects of muscle training in elders differ from those observed in younger individuals, especially in regard to the maintenance of training effects.

Given the marked changes in swallowing biomechanics with increasing age and an age-related decline in muscle strength, it is possible that swallowing maneuvers such as the tongue-hold maneuver affect biomechanical measures of swallowing differentially across age groups. It is therefore vital that the effects of this maneuver are investigated in unimpaired elderly individuals. Investigating age-related differences in swallowing biomechanical function is further warranted due to the increased vulnerability of elderly individuals for conditions that can cause swallowing impairment, such as stroke, neurodegenerative disease, or sarcopenia.

The current study expands on the earlier findings of our group (Doeltgen et al., 2009) by investigating the immediate biomechanical effects of the tongue-hold maneuver in a healthy, elderly participant group. Using the same methods as described previously, the effects of tongue-hold swallowing on peak manometric pressure generation and pressure duration in the oropharynx, hypopharynx, and UES were examined and compared with those observed in a younger participant group. The following research questions were investigated. Does the tongue-hold maneuver significantly affect pressure generation in the pharynx and UES compared with noneffortful saliva swallows in both young and elderly participants? Are changes in pressure generation observed in the pharynx and UES during tongue-hold swallows significantly affected by age and sex?

Method

Participants

A total of 68 neurologically unimpaired research volunteers (34 young adults, age = 18–40 years, mean age = 26.8, *SD* = 5.5; 34 elderly individuals, age = 60–84 years, mean age = 72.6, *SD* = 4.8) participated in this study. Each age group included an equal number of men and women. This project was approved by the relevant regional health ethics committee, and all participants provided written informed consent before participation. Participants had no documented history of neurological or muscular disease and reported no difficulty swallowing. Participants reported no drug use that could affect neurological function and expressed full understanding of the research procedures.

Procedure

Participants were instructed to place their tongue "maximally, but comfortably" between the incisors and to swallow with the tongue in this position. Throughout data collection, participants were generally encouraged to protrude their tongue as far as possible, while still being able to swallow comfortably, although specific feedback was not provided. There was no formal assessment of the absolute degree of tongue protrusion. Participants were allowed to practice the maneuver before data collection, and all participants were able to perform the maneuver after only a few trials.

Upon mastery of the maneuver, a manometric catheter (Medical Measurements Model CT/S3+EMG, 2.1 mm in diameter), which had been calibrated at room temperature to 250 mmHG, was placed transnasally, with the participant sitting in a comfortable, upright position. The catheter housed three unidirectional pressure transducers, with an inter-transducer distance of 3 cm. A small amount of lubricant was applied to the catheter to assist insertion; however, no anesthetic was applied to the mucous membranes of the nose. Correct catheter placement was ensured using a pull-through method to identify transducer position relative to the high-pressure zone of the UES. Each sensor showed increased pressure when passing through the UES, which enabled monitoring of sensor position. The catheter was taped securely to the nose with medical tape when the lowest sensor (UES sensor) measured increased pressure at rest, and it displayed a typical M-shaped waveform during saliva swallowing (Castell & Castell, 1993). The pressure sensors of the catheter were therefore placed in the oropharynx (Sensor 1, most proximal), the hypopharynx (Sensor 2), and the high-pressure zone of the UES (Sensor 3, most distal; see Figure 3 in Doeltgen et al., 2007). The tip of the catheter rested in the proximal esophagus, approximately 3 cm below the UES. The unidirectional pressure sensors were oriented toward the PPW, as confirmed by continuous observation of unidirectional markers on the catheter. After catheter placement, participants were allowed an accommodation period of approximately 5 min before commencement of data collection.

Swallowing Conditions

Participants completed five trials of two swallowing conditions each: (a) noneffortful saliva swallows and (b) tongue-hold swallows. As the tongue-hold swallows were likely to require a larger volitional effort, control saliva swallows were performed first to avoid carryover effects. Participants performed one swallow approximately every 30 s. For the saliva swallows, participants were instructed as follows: "On my command, swallow your saliva as you normally would." The instructions for the tongue-hold maneuver were consistent with those provided by Fujiu and Logemann (1996) in the original study and were as follows: "I would like you to place your tongue between your front teeth, maximally, but comfortably. On my command, swallow your saliva." On very few occasions, participants reported difficulty initiating a tongue-hold swallow. If this occurred, that trial was repeated.

Biomechanical Assessment

The digital swallowing workstation (Kay Elemetrics Model 7200) was used to record data at a sampling rate of 250 Hz. Data were recorded for offline analysis, and measures of peak pressure and pressure duration were identified for each swallow and each sensor for statistical analysis. In the oropharynx and hypopharynx (Sensors 1 and 2), peak pressure was defined as the manometric value at the apex of the waveform during swallowing, whereas peak relaxation in the UES (Sensor 3) was defined as the lowest measurement between the high-pressure peaks of the typical M-wave. Pressure duration was defined as the time between the first rise of manometric pressure (greater than 2 mmHg) from baseline and the return of pressure to baseline levels postswallow. UES relaxation duration was defined as the period between the two high-pressure peaks of the typical M-wave. Total swallow duration was defined as the time between the first onset of swallowing-related pressure generation and the last offset of pressure generation at any sensor (see Figure 1 in Doeltgen et al., 2009).

Data Analysis

A repeated measures analysis of variance (ANOVA) revealed no significant main effect of trial, $F(4, 268) = 1.18$, $p = .32$. Therefore, single trial data were averaged for each condition and participant. All subsequent statistical analyses were performed on these averaged data. In agreement with previous research (Doeltgen et al., 2009), peak pressure and pressure duration data were analyzed in two groups: Sensor 1 and 2 (oropharynx and hypopharynx) and, separately, Sensor 3 (UES). Grouping data in this manner was based on the conceptual consideration that the pharyngeal sensors represented pharyngeal contact pressures, whereas the measures detected by Sensor 3 (UES) represented pull and traction forces resulting from sphincter opening. Therefore, pressure data (peak and duration) recorded in the oropharynx and hypopharynx were analyzed in mixed-design, repeated measures ANOVAs, with the independent, within-participant variables of task (control swallows and tongue-hold swallows) and sensor (oropharynx and hypopharynx). Pressure data recorded in the UES were analyzed in a separate mixed-design, repeated measures ANOVA using the independent variable of task. Age and sex were treated as between-participant factors. All analyses were performed using SPSS Version 17.0. On the condition of significant main effects, post hoc paired-samples *t* tests were performed.

Results

Oropharynx and Hypopharynx

Peak amplitudes. There was a significant effect of task, $F(1, 64) = 6.31$, $p = .015$, with tongue-hold swallows producing significantly lower pressure across the pharyngeal recording sites than noneffortful control swallows (see Table 1). In addition, there were significant interactions between task, age, and sex, $F(1, 64) = 11.05$, $p = .001$, and task, age, sex, and sensor, $F(1, 64) = 4.09$, $p = .047$. Post hoc paired-samples *t* tests comparing task differences within each age and sex group, at each pharyngeal sensor, revealed that oropharyngeal pressure was significantly lower during tongue-hold swallows in young men, $F(1, 16) = 4.52$, $p = .049$, with a similar trend observed in elderly women, $F(1, 16) = 4.41$, $p = .052$. In contrast, elderly men and young women demonstrated little differences between tasks. Similarly, hypopharyngeal pressure was lower during tongue-hold swallows compared to control swallows in young men, $F(1, 16) = 5.24$, $p = .036$, although, descriptively, trends in the same direction were also observed in elderly and young women (see Table 1).

Pressure duration. Overall, pharyngeal pressure duration did not differ between maneuver and control swallows. However, there was a significant interaction between sensor and

TABLE 1. Peak manometric pressures (in mmHg) at the level of the oropharynx, hypopharynx, and upper esophageal sphincter (UES) during control saliva swallows and tongue-hold swallows.

		Control saliva swallows				Tongue-hold swallows			
		Male		Female		Male		Female	
Sensor	Age group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Oropharynx	Young	133.8	72.6	96.4	28.4	100.9	42.3	104.4	35.5
Hypopharynx		102.0	23.3	116.6	42.3	91.7	28.2	108.2	46.6
UES		–8.6	6.2	–10.3	5.5	–10.4	5.7	–11.4	5.4
Oropharynx	Elderly	121.1	51.1	117.9	54.6	125.7	42.6	94.1	34.7
Hypopharynx		100.7	55.4	105.6	48.8	106.6	46.4	99.4	40.1
UES		–6.8	4.0	–8.9	4.2	–5.1	4.7	–7.3	5.3

Note. Group means and standard deviations of 17 individuals in each age and gender group are displayed.

age, $F(1, 64) = 4.6$, $p = .035$, and sensor and sex, $F(1, 64) = 12.58$, $p = .001$. Post hoc paired-samples *t* tests revealed that in the oropharynx, elderly participants produced overall longer pressure during control swallows compared to younger participants, $t(33) = 2.32$, $p = .026$. A similar observation was made in the hypopharynx, where elderly participants produced pressure for longer during both control, $t(33) = 2.35$, $p = .025$, and tongue-hold swallows, $t(33) = 3.54$, $p = .001$ (see Table 2).

During control swallows, men produced overall shorter pressure durations in the hypopharynx than women, $t(33) = 2.25$, $p = .031$, whereas during tongue-hold swallows, men produced shorter pressure durations in the oropharynx, $t(33) = 2.03$, $p = .05$ (see Table 2).

UES

Peak amplitudes. There was a significant Task × Age interaction, $F(1, 64) = 7.31$, $p = .009$, with elderly participants demonstrating greater UES pressure during tongue-hold swallows compared to control swallows, $F(1, 33) = 5.13$, $p = .03$, whereas there was no significant difference between tasks in the younger participant group, $F(1, 33) = 2.80$, $p = .104$ (see Table 1).

Relaxation duration. There were no differences in UES relaxation duration between the duration of tongue-hold swallows ($M = 1.08$ s, $SD = 0.35$) and control swallows ($M = 1.08$ s, $SD = 0.23$), $F(1, 64) = 0.4$, $p = .948$, and no significant Task × Age interaction, $F(1, 64) = 1.16$, $p = .286$, Task × Sex interaction, $F(1, 64) = 1.89$, $p = .174$, or Task × Age × Sex interaction, $F(1, 64) = 0.34$, $p = .56$ (see Table 2).

Total Swallow Duration

There were no differences in total swallow duration between tongue-hold swallows ($M = 1.11$ s, $SD = 0.33$) and control swallows ($M = 1.12$ s, $SD = 0.25$), $F(1, 64) = 0.16$, $p = .695$, and no significant Task × Age interaction, $F(1, 64) = 0.56$, $p = .457$, Task × Sex interaction, $F(1, 64) = 1.63$, $p = .207$, or Task × Age × Sex interaction, $F(1, 64) = 0.07$, $p = .79$ (see Table 2).

Discussion

In a group of young and elderly healthy research participants, this study investigated age-related differences associated with the tongue-hold swallowing maneuver, a rehabilitative exercise commonly recommended for strengthening of the PPW during swallowing. Tongue-hold swallows generated overall lower pressure in the oropharynx and hypopharynx across both age groups. A significant Task × Age interaction in the UES demonstrated that changes in UES pressure during

TABLE 2. Manometric pressure durations (in seconds) at the level of the oropharynx, hypopharynx, and UES during control saliva swallows and tongue-hold swallows.

		Control saliva swallows				Tongue-hold swallows			
		Male		Female		Male		Female	
Sensor	Age group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Oropharynx	Young	0.49	0.11	0.56	0.1	0.46	0.15	0.61	0.32
Hypopharynx		0.56	0.33	0.4	0.1	0.49	0.22	0.36	0.1
UES		1.2	0.25	0.93	0.14	1.13	0.34	0.92	0.2
Total swallow duration		1.25	0.2	0.94	0.15	1.18	0.32	0.93	0.3
Oropharynx	Elderly	0.58	0.15	0.58	0.1	0.57	0.17	0.62	0.12
Hypopharynx		0.67	0.3	0.58	0.17	0.64	0.31	0.59	0.21
UES		1.1	0.24	1.12	0.21	1.07	0.37	1.23	0.4
Total swallow duration		1.15	0.3	1.14	0.21	1.12	0.38	1.2	0.35

Note. Group means and standard deviations of 17 individuals in each age and gender group are displayed.

tongue-hold swallows varied between young and elderly individuals.

Oropharynx and Hypopharynx

In line with previous research (Doeltgen et al., 2009), peak pressure amplitudes in the oropharynx and hypopharynx were lower during tongue-hold swallows compared with noneffortful control swallows. This was likely due to the protruded positioning of the tongue during tongue-hold swallows, which would reasonably limit BOT retraction and would thus decrease BOT-to-PPW contact pressure during swallowing. The observed decrease in pharyngeal pressure generation is an immediate effect of this maneuver, which can potentially be overcome with repeated tongue-hold exercise. The concept of protruding the tip of the tongue during swallowing is to exert resistance to contraction of the pharyngeal constrictors, which insert anteriorly to the hyoid bone and tongue. Therefore, a period of tongue-hold training may strengthen the pharyngeal constrictors, even if the initial decrease in pharyngeal pressure during tongue-hold swallowing is not completely compensated for by increased PPW contraction. Patients with decreased pharyngeal pressure may, therefore, benefit from a carryover effect of increased PPW strength during deglutitive swallowing that is not "artificially impaired" by tongue protrusion. Optimal frequency and intensity of training remain to be identified. In addition, it remains to be investigated whether a tongue-hold training program can prevent swallowing difficulties in healthy elderly individuals by exercising muscle strength otherwise lost to sarcopenia.

The present study further demonstrates that the effects of this maneuver at the level of the oropharynx and hypopharynx, in toto, do not differ between age groups. Interestingly, however, there were significant interactions between task, age, and sex, as well as task, age, sex, and sensor, suggesting subtle differences in the effects of the maneuver in specific subgroups of participants and at different pharyngeal levels. These differences may be related to varying degrees of tongue protrusion across the different subgroups investigated. For example, it is possible that young men displayed overall the greatest capability, or effort, to protrude the tongue maximally, therefore exaggerating the postural changes in oropharyngeal anatomy imposed by the tongue-hold maneuver. This may have led to greater effects on pharyngeal pressure generation than in the other participant subgroups, who displayed similar effects, albeit of lower magnitude. In addition, young men, overall, have a larger oropharyngeal anatomy compared to the other participant subgroups, in particular women, who have smaller upper airways compared to men (Brooks & Strohl, 1992). The distance between the PPW and BOT of men would, therefore, be larger, and a further increase in PPW-to-BOT distance during tongue-hold swallowing may be challenging to overcome.

UES

The results of the current study support the findings of our previous study of young individuals (Doeltgen et al., 2009) that demonstrated lower UES relaxation pressures during tongue-hold swallowing in this age group. Interestingly, the significant Task × Age interaction indicates that the effects of the tongue-hold maneuver on UES relaxation pressure differ between age groups. In line with our previous study, young individuals tended to produce lower UES relaxation pressure during tongue-hold swallows compared to control swallows, although this difference did not reach statistical significance. In contrast, elderly individuals produced significantly higher UES relaxation pressures during tongue-hold swallows, suggesting reduced opening of the UES compared to control swallows. This may appear as a contraindication for the tongue-hold maneuver, as bolus flow may be reduced at this level of the pharynx. However, as noted previously (Doeltgen et al., 2009; Fujiu & Logemann, 1996), the tongue-hold maneuver is recommended as a PPW strengthening exercise only and should not be performed when bolus is present, particularly because reduced oropharyngeal and hypopharyngeal pressures during tongue-hold swallows may impair airway protection.

The reasons for the age-dependent differences of effects of the tongue-hold maneuver on UES peak relaxation pressure are unclear. Anterior and superior hyolaryngeal elevation is crucial for UES opening during swallowing. It may be that tongue protrusion in the elderly participants impaired UES opening due to reduced or less coordinated superior-anterior elevation of the hyolaryngeal complex during tongue-hold swallows. Altered hyolaryngeal movement patterns (Daniels et al., 2004) and age-related changes in overall oropharyngeal coordination (for review, see Gleeson, 1999) have previously been observed in elderly individuals. These age-dependent effects may be exaggerated during tongue-hold swallowing, which requires a significant amount of concentration and coordination for proper placement of the tongue during concomitant swallowing. It remains to be investigated whether performance of the tongue-hold exercise affects measures of swallowing coordination in elderly individuals, as for example assessed by VFSS, and whether repeated tongue-hold training has positive carryover effects on UES opening in nonmaneuver control swallows.

Durational Pressure Measures

Although the data of the present study demonstrate that, overall, durational pressure measures did not differ between tongue-hold and control swallows, elderly individuals were found to generate pharyngeal pressure for a longer period of time during control saliva swallows in both the oropharynx and the hypopharynx compared to their younger counterparts. This finding is in agreement with previous reports (McKee, Johnston, McBride, & Primrose, 1998; van Herwaarden et al., 2003; Yokoyama et al., 2000). Yokoyama et al. (2000) suggested that prolonged pressure duration may compensate for decreased production of saliva, as well as degeneration of mucosal tissue (Heeneman & Brown, 1986) in elders. In addition, a decline in the overall strength of the oropharyngeal musculature with increasing age (e.g., Robbins et al., 1995; Youmans et al., 2009) may explain the increased pharyngeal pressure durations observed in the elders. An age-related decrease of tongue and pharyngeal constrictor muscle strength would result in generally reduced contractile power. Therefore, these muscles would take longer to reach peak contraction, which would result in overall longer pressure durations. Furthermore, van Herwaarden et al. (2003) demonstrated that the onset of UES relaxation is delayed in elderly individuals, possibly leading to a compensatory increase in pharyngeal pressure duration to overcome impaired UES compliance. Further research is warranted to investigate (a) whether a prolonged period of tongue-hold training has facilitatory carryover effects on peak pharyngeal pressure generation during (non-tongue-hold) saliva and bolus swallows and (b) whether a training-induced increase in pharyngeal peak pressure is associated with shorter pressure durations (compared to pretraining baselines) in elders.

Limitations

In light of the demanding nature of the tongue-hold maneuver, we decided not to counterbalance swallowing tasks but to have all participants perform the noneffortful saliva swallows first. This was done to avoid carryover effects from tongue-hold swallows that require more effort. It may be argued that the absence of counterbalancing may have limited the experimental control of confounding factors such as fatigue from the saliva-swallowing task that was performed first or adaptation to the pharyngeal catheter. Future studies may consider randomizing swallowing tasks while providing a sufficiently long rest period between the different tasks under investigation. In addition, employing an imaging procedure would have provided additional important information about the immediate biomechanical effects of the tongue-hold maneuver. Specifically, such data would allow exploring potential correlations between PPW movement and pharyngeal pressure generation.

Clinical Implications and Future Research Directions

The findings of the present study confirm previous recommendations that tongue-hold swallows should not be performed when a bolus is present (Doeltgen et al., 2009; Fujiu & Logemann, 1996). The anterior positioning of the BOT and reduced peak pharyngeal pressure generation during tongue-hold swallows may leave the laryngeal vestibule less protected and may impair bolus propulsion through the pharynx during swallowing. The risk for penetration or aspiration may be significantly increased in individuals who already have swallowing difficulties.

Future research is warranted to investigate the longer-term effects of the tongue-hold maneuver in both healthy individuals and patients with swallowing impairment. Future studies may employ a combination of pharyngeal manometry and imaging techniques, such as videomanometry or a combination of manometry and FEES, in order to correlate changes in PPW anterior movement previously observed during VFSS (Fujiu & Logemann, 1996) with changes in pharyngeal pressure generation. In addition, formal assessment of the degree of tongue protrusion during tongue-hold swallows, such as measurement of the distance between the tip of the tongue and the upper incisors, may provide some insight into varying degrees of effectiveness of this maneuver. It is noteworthy, however, that even if tongue protrusion was "standardized" by instructing subjects to protrude their tongue a certain distance from the lips or to a certain anatomical landmark of the tongue, interindividual differences in oropharyngeal anatomy would likely introduce between-participant variability with regard to the relative degree of tongue protrusion or the relative degree of perceived effort. Rating scales of self-perceived effort during tongue-hold swallows may also provide important information about the clinical applicability of this maneuver in various patient populations. Given that anterior positioning of the tip of the tongue opposes the posteriorly oriented contraction forces of not only the PPW but also intrinsic tongue muscle fibers, the potential of the tongue-hold maneuver as a tongue-strengthening exercise remains to be investigated.

Conclusion

In summary, the present study demonstrates that the tongue-hold maneuver affects peak pressure and pressure duration in the oropharynx and hypopharynx in young and elderly individuals in similar ways, with some subtle age- and sex-dependent differences evident between the subgroups of individuals examined. At the level of the UES, the effects of the tongue-hold maneuver differ greatly between age groups, with elderly participants displaying increased relaxation pressures and young participants displaying a trend toward decreased relaxation pressures during tongue-hold swallows. Future research is warranted to examine whether both young and elderly individuals may benefit from a longer-term tongue-hold training regimen. The finding of decreased pharyngeal pressures and increased UES relaxation pressure in the elders underscores the previous recommendation that tongue-hold swallows should be performed only during saliva swallowing and not when bolus is present.

Acknowledgments

We wish to thank Pariya Behnami and Freya Gumbley for their valuable contribution to participant recruitment and data collection.

References

Bardan, E., Kern, M., Arndorfer, R. C., Hofmann, C., & Shaker, R. (2006). Effect of aging on bolus kinematics during the pharyngeal phase of swallowing. *American Journal of Physiology. Gastrointestinal and Liver Physiology, 290,* 458–465.

Brooks, L. J., & Strohl, K. P. (1992). Size and mechanical properties of the pharynx in healthy men and women. *American Review of Respiratory Diseases, 146,* 1394–1397.

Brown, W., Strong, M., & Snow, R. (1988). Methods for estimating numbers of motor units in biceps-brachialis muscles and losses of motor units with aging. *Muscle and Nerve, 11,* 423–432.

Burkhead, L. M., Sapienza, C. M., & Rosenbek, J. C. (2007). Strength-training exercise in dysphagia rehabilitation: Principles, procedures, and directions for future research. *Dysphagia, 22,* 251–265.

Butler, S. G., Stuart, A., & Kemp, S. (2009). Flexible endoscopic evaluation of swallowing in healthy young and older adults. *Annals of Otolaryngology, Rhinology & Laryngology, 118,* 190–198.

Butler, S. G., Stuart, A., Wilhelm, E., Rees, C., Williamson, J., & Kritchevsky, S. (2010). The effects of aspiration status, liquid type, and bolus volume on pharyngeal peak pressure in healthy older adults. *Dysphagia*. Advance online publication. doi:10.1007/s00455-010-9290-4.

Castell, J. A., & Castell, D. O. (1993). Modern solid state computerized manometry of the pharyngealesophageal segment. *Dysphagia, 8,* 270–275.

Daniels, S. K., Corey, D. M., Hadskey, L. D., Legendre, C., Priestly, D. H., Rosenbek, J. C., & Foundas, A. L. (2004). Mechanism of sequential swallowing during straw drinking in healthy young and older adults. *Journal of Speech, Language, and Hearing Research, 47,* 33–45.

Doeltgen, S. H., Hofmayer, A., Gumbley, F., Witte, U., Moran, C., Carroll, G., & Huckabee, M. L. (2007). Clinical measurement of pharyngeal surface electromyography: Exploratory research. *Neurorehabilitation and Neural Repair, 21,* 250–262.

Doeltgen, S. H., Witte, U., Gumbley, F., & Huckabee, M.-L. (2009). Evaluation of manometric measures during tongue-hold swallows. *American Journal of Speech-Language Pathology, 18,* 65–73.

Fujiu, M., & Logemann, J. A. (1996). Effect of a tongue-holding maneuver on posterior pharyngeal wall movement during deglutition. *American Journal of Speech-Language Pathology, 5*(1), 23–30.

Fujiu, M., Logemann, J. A., & Pauloski, B. (1995). Increased postoperative posterior pharyngeal wall movement in patients with anterior oral cancer: Preliminary findings and possible implications for treatment. *American Journal of Speech-Language Pathology, 4*(2), 24–30.

Gleeson, D. C. L. (1999). Oropharyngeal swallowing and aging: A review. *Journal of Communication Disorders, 32,* 373–396.

Heeneman, H., & Brown, D. H. (1986). Senescent changes in and about the oral cavity and pharynx. *Journal of Otolaryngology, 15*(4), 214–216.

Lazarus, C., Logemann, J. A., Song, C. W., Rademaker, A. W., & Kahrilas, P. J. (2002). Effects of voluntary maneuvers on tongue base function for swallowing. *Folia Phoniatrica et Logopaedica, 54,* 171–176.

Lexell, J., Taylor, C. C., & Sjostrom, M. (1988). What is the cause of the ageing atrophy? Total number, size and proportion of different fiber types studied in whole vastus lateralis muscle from 15- to 83-year-old men. *Journal of the Neurological Sciences, 84,* 275–294.

McKee, G. J., Johnston, B. T., McBride, G. B., & Primrose, W. J. (1998). Does age or sex affect pharyngeal swallowing? *Clinical Otolaryngology, 23,* 100–106.

Robbins, J., Levine, R., Wood, J., Roecker, E. B., & Luschei, E. (1995). Age effects on lingual pressure generation as a risk factor for dysphagia. *Journal of Gerontology, 50A,* M257–M262.

Shaw, D. W., Cook, I. J., Gabb, M., Holloway, R. H., Simula, M. E., Panagopoulos, V., & Dent, J. (1995). Influence of normal aging on oral-pharyngeal and upper esophageal sphincter function during swallowing. *American Journal of Physiology. Gastrointestinal and Liver Physiology, 268,* G389–G396.

Umeki, H., Takasaki, K., Enatsu, K., Tanaka, F., Kumagami, H., & Takahashi, H. (2009). Effects of a tongue-hold maneuver during swallowing evaluated by high-resolution manometry. *Otolaryngology—Head and Neck Surgery, 141,* 119–122.

van Herwaarden, M. A., Katz, P. O., Gideon, R. M., Barrett, J., Castell, J. A., Achem, S., & Castell, D. O. (2003). Are manometric parameters of the upper esophageal sphincter and pharynx affected by age and gender? *Dysphagia, 18,* 211–217.

Yokoyama, M., Mitomi, N., Tetsuka, K., Tayama, N., & Niimi, S. (2000). Role of laryngeal movement and effect of aging on swallowing pressure in the pharynx and upper esophageal sphincter. *Laryngoscope, 110,* 434–439.

Youmans, S. R., Youmans, G. L., & Stierwalt, J. A. G. (2009). Differences in tongue strength across age and gender: Is there a diminished strength reserve? *Dysphagia, 24,* 57–65.