Research

Evaluation of Manometric Measures During Tongue-Hold Swallows

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Purpose: Based on visual inspection, prior research documented increased movement of the posterior pharyngeal wall in healthy volunteers during tongue-hold swallows. This manometric study investigated the immediate effects of the tongue-hold maneuver on pharyngeal peak pressure generation, duration of pressure generation, and pressure slope measurements in healthy volunteers.
Method: Pharyngeal pressures from 40 young, healthy individuals (mean age = 25.8 years, gender equally distributed) were recorded at 3 locations: oropharynx, hypopharynx, and upper esophageal sphincter (UES), during normal control and tongue-hold swallows. Measures of peak amplitude, duration, and slope of pressure generation were subjected to statistical analysis.
Results: Tongue-hold swallows produced lower pharyngeal peak pressure and shorter pharyngeal pressure durations compared to control swallows. Further, tongue-hold swallows produced lower UES relaxation pressures. Between sensors, peak pressure was lower and pressure slopes were steeper in the hypopharynx compared to the oropharynx. Several gender-specific differences were found for pharyngeal peak pressure, pressure duration, and pressure slopes.
Conclusions: Reduced amplitude and duration of pharyngeal peak pressure is likely a result of decreased base of tongue retraction during tongue-hold swallows. Central clinical considerations and future research directions are discussed in this article.

Key Words: deglutition, manometry, biomechanics, tongue-hold maneuver

Rehabilitative swallowing maneuvers and neuromuscular exercises have been evaluated and subsequently implemented in clinical practice to address the specific impairments of clients with dysphagia. Clark (2003) provided a detailed review of neuromuscular treatments used in the rehabilitation of speech and swallowing disorders. One main category of neuromuscular treatments is active exercise. Neuromuscular exercise relies on active recruitment of muscle fibers and has the potential to target therapeutic mechanisms of strength, endurance, and power. Recruitment of muscle fibers during active exercise is dependent on the characteristics of the exercise, including parameters such as force, contraction velocity, and duration of muscle contraction. Specifically, exercises with high levels of resistance target muscle strength. Exercises with low levels of resistance target endurance, if sufficient repetitions are performed. Exercises incorporating the parameter of contraction velocity (i.e., the speed at which a muscle contracts) aim to improve muscle power.

One technique used in swallowing rehabilitation that addresses some of the characteristics of neuromuscular treatments reported by Clark (2003) is the tongue-hold maneuver, sometimes referred to as the "Masako maneuver" (Fujiu & Logemann, 1996; Fujiu, Logemann, & Pauloski, 1995). This maneuver was first introduced by Fujiu and colleagues, and requires protrusion of the tip of the tongue between the incisors, to a maximal but comfortable degree, during swallowing. Based on the theoretical prerequisites stipulated by Clark (2003), the tongue-hold maneuver offers optimal training conditions for some of the pharyngeal constrictors that are heavily involved in base of tongue (BOT) retraction during physiological swallowing. In particular, the BOT is connected with pharyngeal wall structures via the glossopharyngeal portion of the superior pharyngeal constrictor and, indirectly, via the hyoglossus muscle and the hyoid bone, to the middle pharyngeal constrictor (Zemlin, 1998). Anterior movement of the BOT results in an increase in resistance to superior and middle constrictor movement and, during swallowing, provides a training environment that may yield greater muscle strength, endurance, and power. The task-specific design of the tongue-hold swallow may also facilitate the transition of a training effect from exercise to nontraining conditions.

Initial research into the effects of the tongue-hold maneuver in participants with surgical tip of tongue resection due to oral cancer documented increased anterior movement of the posterior pharyngeal wall (PPW) in 7 of 11 participants (Fujiu et al., 1995). Based on visual inspection of liquid and paste swallows during videofluoroscopy, these participants displayed greater than 30% increased anterior movement 3 months after surgery compared with their preoperative baselines. The authors hypothesized that the postsurgical anterior anchoring point of the remaining body of the tongue accounted for this phenomenon. Anterior placement of the body of the tongue resulted in a consequent anterior displacement of the BOT. Increased anterior bulging of the PPW during tongue-hold swallows was thought to be an immediate, compensatory response to reduced BOT retraction. These results have subsequently led to the implementation of the tongue-hold maneuver as a resistance exercise to strengthen PPW muscle contraction.

In a more recent investigation, Lazarus and colleagues documented the effects of swallowing maneuvers on pharyngeal biomechanics of 3 participants with reduced BOT-PPW contact pressures subsequent to treatment for head and neck cancer (Lazarus, Logemann, Song, Rademaker, & Kahrilas, 2002). During tongue-hold swallows, increased BOT-PPW contact pressures were measured with concurrent manometry and videofluoroscopy compared with normal saliva swallows. Based on the underlying physical and anatomical substrates of this exercise, this finding is rather unexpected. One would hypothesize that anterior anchoring of the BOT during tongue-hold swallows would result in a decrease in pharyngeal contact pressure. It may be possible that the participants in this study experienced weakness of the tongue. Weakness would limit their ability to protrude the tongue, resulting in the bulk of the tongue retracting during swallowing. If PPW movement is increased during tongue-hold swallows, then greater deglutitive contact pressure would be recorded between the BOT and PPW. Alternatively, these participants may have been used to swallowing with increased effort. This hypothesis is based on the fact that participants were reported to have mild dysphagic symptoms and participated in this study several years after surgery. Consequently, what appears to be an immediate compensatory effect of the tongue-hold maneuver (i.e., increased pharyngeal pressure generation) may in fact also have been an accommodation effect that was accrued by these participants over a longer period of time. A similar supposition was made by the authors to explain the decrease in radiographically observed pharyngeal residue of contrast agent after tongue-hold swallows compared with baseline swallows. Unfortunately, the authors did not report on changes in PPW movement during execution of the tongue-hold maneuver. Although limited by small participant numbers and/or confounding factors, both studies investigating the effects of the tongue-hold in participants with dysphagia suggest that the tongue-hold maneuver may provide immediate compensatory benefits in these participant populations (Fujiu et al., 1995; Lazarus et al., 2002).

Only one study investigated the effects of the tongue-hold maneuver in a healthy participant sample (Fujiu & Logemann, 1996). In an evaluation of 10 healthy male individuals performing the tongue-hold maneuver under videofluoroscopic assessment, Fujiu and Logemann confirmed the findings of their earlier study of participants with oral cancer. Significantly increased anterior bulging of the PPW was observed at the levels of the mid (C2) and inferior (C4) cervical vertebrae when participants positioned the tip of the tongue between their front teeth during swallowing.

Based on the theoretical prerequisites and limited clinical data, the tongue-hold maneuver may have potential to provide an active strengthening exercise for the PPW. However, the available research into the effects of this maneuver in a healthy population has been based solely on PPW movement during lateral videofluoroscopic assessment of the pharynx (Fujiu & Logemann, 1996; Fujiu et al., 1995). The ultimate goal of the tongue-hold exercise is to increase pharyngeal pressure in order to aid pharyngeal bolus transit. However, increased pressure is theoretically unlikely to occur as a result of immediate compensatory increase in PPW movement, because BOT structures are anteriorly anchored. It is possible that, similar to other skeletal muscles, increased contraction (and a subsequent increase in pressure generation) will occur as a cumulative result of regular training. Given the nature of the tongue-hold maneuver, it is thus surprising that in the head and neck cancer population, an immediate compensatory effect was observed (Lazarus et al., 2002). Additional research is required to investigate the short-term effects of this exercise on a variety of biomechanical and neurophysiological measures of healthy swallowing before moving into the assessment of dysphagic individuals with normal anatomy. In other words, it would be of benefit to identify whether increased anterior movement of the PPW yields a physiological corroboration of benefit in the pharynx in the healthy population or individuals with dysphagia secondary to etiologies other than head and neck cancer.

The aim of this study was to investigate the immediate effects of the tongue-hold maneuver on four biomechanical measures of deglutitive pressure generation in healthy individuals: peak pressure and pressure durations in the pharynx and upper esophageal sphincter (UES), slope measures of pressure generation in the oropharynx and hypopharynx, and latency between peak pressure in the oropharynx and the hypopharynx. These outcome measures enable investigation of changes in peak amplitude and temporal pharyngeal pressure patterns during tongue-hold swallowing. Analysis of temporal measures was included to identify changes in pharyngeal contraction velocity as a result of altered pharyngeal biomechanics during tongue-hold swallows.

It is hypothesized that, in the healthy population, there will be no immediate, compensatory increase in pharyngeal pressure generation during execution of the tongue-hold maneuver. In fact, pharyngeal contact pressures will likely be decreased due to anterior anchoring of the BOT and subsequent limitation of BOT posterior movement.

It is further hypothesized that tongue-hold swallows will produce shorter contact pressure durations due to limited BOT approximation with the PPW. This effect will likely be larger in the oropharynx than in the hypopharynx, as BOT retraction contributes more to pharyngeal contact pressure in the proximal pharyngeal region.

Theoretically, the tongue-hold maneuver may influence the speed at which the pharyngeal constrictors contract because each repetition of this exercise is performed in the context of a swallow. It is hypothesized, however, that an immediate effect on pharyngeal contraction speed will not be documented in the current investigation due to insufficient repetitions of the maneuver in this research paradigm.

Analysis of peak-to-peak latency serves to determine whether there is a significant change of latency between maximum pressures in the oropharynx and in the hypopharynx. It is expected that latency may be decreased during tongue-hold swallows as anterior positioning of BOT may prolong the period of time required to reach maximal BOT contact with the PPW.

Method

Research Participants

Forty-two research participants were initially recruited from the public, two of whom withdrew from the study secondary to intolerance of manometric catheter placement. Thus, a total of 40 healthy research participants (20–45 years, gender equally represented) were evaluated at a tertiary research institute. The project was approved by the appropriate Regional Health Ethics Committee. All participants provided written informed consent and completed a brief medical questionnaire prior to data collection. No participant reported a history or current symptoms of swallowing difficulty, or history of neurological or muscular diseases. Research participants reported no drug use that would potentially affect gastrointestinal motility, and all participants expressed full comprehension of the tasks they were asked to perform.

Procedures

Data were collected using a manometric catheter (Medical Measurements Model CT/S3+EMG, 2.1 mm in diameter) with three unidirectional pressure transducers at intervals of 3 cm. Before insertion, the catheter was calibrated at room temperature at 250 mmHG and coated with a gel lubricant to facilitate placement. Participants were seated in a comfortable chair in an upright position, and detailed instructions about how to correctly perform the tongue-hold maneuver were given. Mastery was judged by the primary investigator, a second speech-language pathologist, and the participant. Satisfactory execution was achieved when the participant reported maximal but comfortable tongue protrusion, which was visually observed by the primary investigator and the second speech-language pathologist. Once research participants had demonstrated mastery of this technique, the catheter was placed into the pharynx transnasally. No anesthetic was applied to the nasal mucous membranes during catheter insertion. Participants swallowed the catheter into the proximal esophagus before the catheter was slowly retracted at 1-cm increments. Each sensor measured increased pressure when passing through the high-pressure zone of the UES; therefore, sensor location could be monitored. The catheter was securely fixed to the outside of the nose with two strips of tape in order to minimize sensor movement in either the superior/inferior or lateral planes when the most distal pressure sensor was placed in the superior aspect of the high-pressure zone of the UES. Correct sensor placement was confirmed by observation of the typical M-shaped waveform during swallowing (Castell & Castell, 1993; see Figure 1). The M-shaped waveform represents an initial increase in pressure due to laryngeal elevation and the consequent rise of the high-pressure zone of the UES onto the sensor. This pressure peak is followed by a sudden decrease in pressure caused by UES relaxation. The final increase in pressure is observed due to contraction of the UES before the larynx descends post-swallow (Castell & Castell, 1993).

The tip of the catheter and the sensors were thus placed in the following locations:

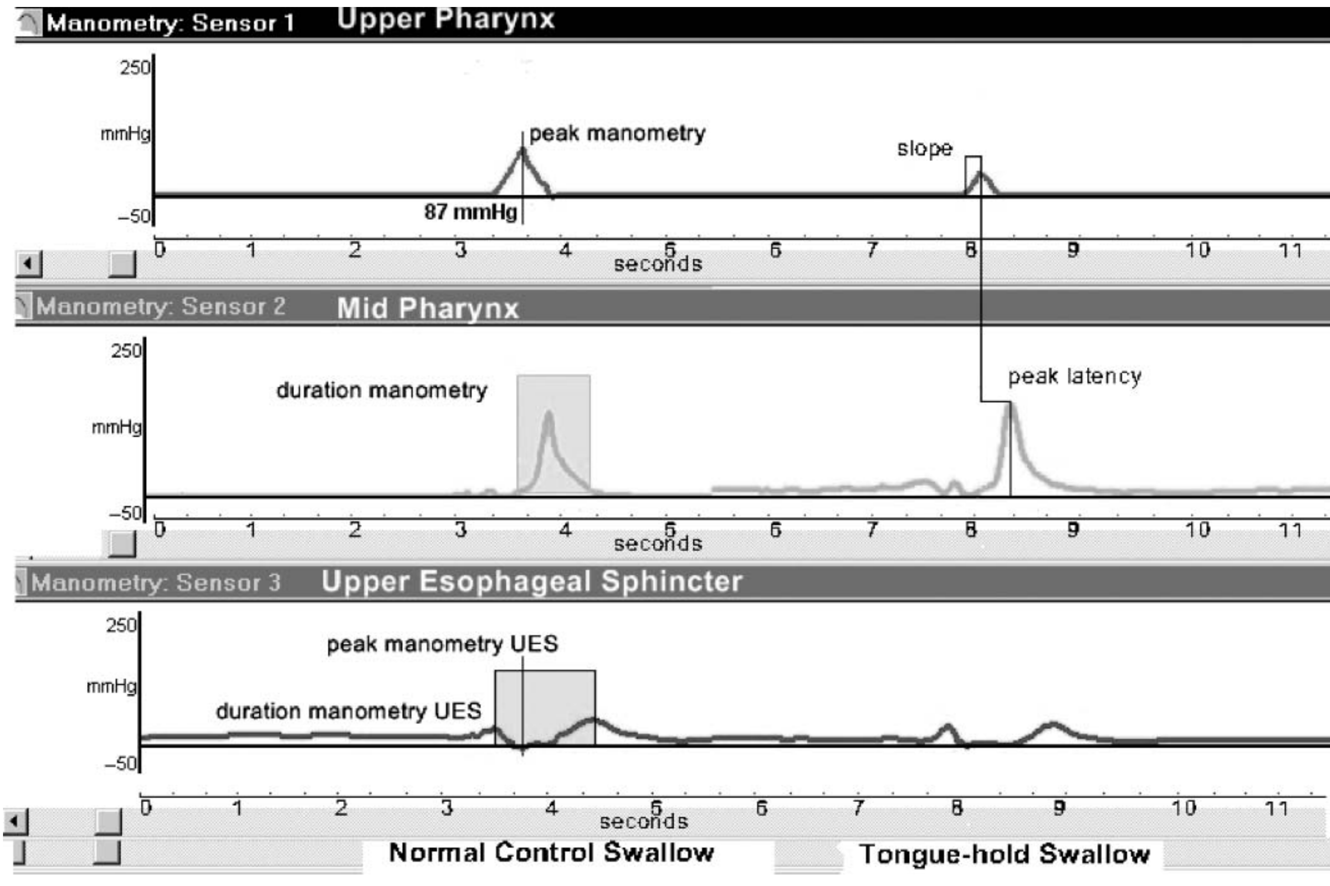
- manometric sensor 1 (most proximal) rested approximately even with the superior aspect of the epiglottis (hereafter referred to as the oropharynx);
- manometric sensor 2 rested approximately at the superior edge of the arytenoid cartilages (hereafter referred to as the hypopharynx);
- manometric sensor 3 (most distal) rested in the proximal aspect of the high-pressure zone of the UES;
- the tip of the catheter was located in the proximal esophagus, approximately 3 cm below the high-pressure zone of the UES.

Orientation of the pressure sensors toward the PPW was confirmed by ongoing observation of unidirectional markers on the catheter throughout data collection. Research participants were asked to relax, sit quietly, and breathe normally for approximately 10 min before commencement of data collection to acclimate to catheter placement.

Task Conditions

Research participants were instructed to perform a series of two swallowing tasks: five control saliva swallows and five experimental swallows using the tongue-hold maneuver. Control saliva swallows were performed first by all participants in order to avoid a carry-over effect from tongue-hold swallows, which tend to recruit greater volitional effort. Participants were instructed to perform both tasks at a rate of approximately one every 30 s. For control saliva swallows, participants were instructed: “On my command ‘swallow,’ please swallow as you normally would.” For the tongue-hold maneuver, participants were instructed: “I would like you to place your tongue between your front teeth, maximally but comfortably. On my command ‘swallow,’ please swallow your saliva.” The instructions for the tongue-hold maneuver are consistent with those provided to research participants in the original study of this technique (Fujiu & Logemann, 1996).

FIGURE 1. Representative example of manometric pressure waveforms of control and tongue-hold swallows. Markers identify the measures derived for off-line statistical analysis.



Data Recording

Data were recorded using the digital swallowing workstation (Kay Elemetrics Model 7200) at a sampling rate of 250 Hz. The pharyngeal manometry data were displayed to the researcher but not the participant during data collection. The recorded data were reviewed offline, and measures of pressure duration, peak amplitude, and slope for each swallowing event and at each sensor were collected from the data files for statistical analysis.

Biomechanical Measures

The following manometric measurements were derived from the original data set by the principal investigator upon visual inspection: peak amplitude, pressure duration, slope of pressure generation, and peak latency between oropharynx and hypopharynx. Figure 1 illustrates the key measures that were derived for offline analysis in a representative example of the acquired data.

The following definitions were used as guidelines for identification:

Peak pressure: oropharynx and hypopharynx. Peak manometric measure was defined as the manometric value at the apex of the waveform during execution of a pharyngeal swallow.

Pressure duration: oropharynx and hypopharynx. Duration of swallow-related manometric pressure was defined as the time between onset and offset of swallowing-related pressure changes. Onset was defined as the point in time when the manometric waveform exceeded baseline measures with a pressure rise greater than 2 mmHg per sample. Offset was defined as the point in time when the recorded waveform returned to baseline.

Peak relaxation: UES. Peak relaxation was defined as the lowest measurement recorded throughout the duration of UES relaxation.

Duration of relaxation: UES. Duration of UES relaxation was defined as the period of time between the two high-pressure peaks of the typical M-wave.

Peak-to-peak latency between oropharynx and hypopharynx. Peak latency was defined as the time between peak pressure in the oropharynx and peak pressure in the hypopharynx.

Slope. Slope measures were calculated by the swallowing workstation (Kay Elemetrics Model 7200) by dividing changes in pressure (mmHg) over time (seconds). Onset of pressure in the respective sensor marked the beginning of the slope; peak pressure marked the endpoint of the slope.

Data Analysis and Preparation

For each research participant, a full set of five trials for each of the two tasks (control vs. maneuver) was available. Intraclass correlation coefficients (ICC) were used to establish inter- and intrarater reliability. For a random 20% of research participants, all measures were reanalyzed by the primary researcher at least 1 week after initial analysis. For interrater analysis, a second speech-language pathologist, who was familiar with the research methods and design, was trained in the analysis of manometric data in two 1-hr sessions. Training was supervised by the primary investigator and involved analysis of 2 participants not included in the reliability analysis. During subsequent, independent interrater analysis of all swallows of a random 20% of research participants, the speech-language pathologist was allowed to use the definitions described above. The rater was not blind to condition.

For pressure peak and pressure duration measures, data analysis was paired into two groups. Physiologically and anatomically, the sensors in the oropharynx and in the hypopharynx represent pharyngeal contact pressures between anterior oral and supraglottic structures and PPW, and would therefore be expected to be affected in a similar way. In contrast, the sensor resting in the high-pressure zone of the UES represents the pull and traction forces resulting from opening of the sphincter. Based on these conceptual considerations, data recorded in the oropharynx and hypopharynx were analyzed as independent variables in the same repeated measures analyses of variance (ANOVAs), while data recorded from the superior esophageal sphincter were analyzed in separate repeated measures ANOVAs.

Preliminary statistical analysis revealed no significant effect of trial on any of the data sets; therefore, data were averaged across all five trials for each participant and each condition for the final analysis. No trials were deleted.

Results

Inter- and Intrarater Reliability

Intrarater reliability was high for manometric peak amplitudes and manometric pressure duration with ICC single measures of .934 (mean difference score = 3.09 mmHg, SD = 23.36) and .884 (mean difference score = 0.07 s, SD = 0.18), respectively.

Evaluation of interrater reliability showed a similar pattern with high reliability for manometric peak measurements of .981 (mean difference score = 0.033 mmHg, SD = 12.21), while durational measures showed a somewhat lower, but acceptable, ICC of .821 (mean difference score = 0.08 s, SD = 0.22) for manometric pressure duration.

Oropharynx and Hypopharynx

Peak amplitudes. To investigate potential differences in peak pressures across tasks, sensors, and gender groups, a mixed-design repeated measures ANOVA was conducted with two within-subjects factors (task and sensor) and one between-subjects factor (gender). This analysis revealed a significant effect of task, $F(1, 19) = 12.264$, $p = .002$. As a group, research participants produced higher pressure during control swallows compared to tongue-hold swallows. Further, there was a significant Task × Gender interaction, $F(1, 19) = 5.133$, $p = .035$. Post hoc paired-samples t tests comparing Task × Gender interactions revealed a significant difference between tongue-hold swallows and control swallows in the male participants of this study, $t(39) = 3.857$, $p < .001$. Specifically, males produced greater pressure during control swallows compared to tongue-hold swallows. See Table 1 for pharyngeal manometric peak pressure.

Pressure durations. To investigate potential differences in pressure durations across tasks, sensors, and gender groups, a mixed-design repeated measures ANOVA was conducted with two within-subjects factors (task and sensor) and one between-subjects factor (gender). This analysis revealed a significant effect of task, $F(1,19) = 8.925$, $p = .008$. Specifically, control swallows created longer pressure durations than tongue-hold swallows. There was also a significant effect of sensor, $F(1, 19) = 5.958$, $p = .025$. Pressure durations were longer in the oropharynx compared to pressure durations in the hypopharynx. Further, there was a Sensor × Gender interaction, $F(1,19) = 10.2$, $p = .005$. Post hoc paired-samples t tests revealed significantly longer pressure durations in the female population of this study, in the oropharynx, compared to the male participants, $t(39) = –3.005$, $p = .005$. This pattern was reversed in the hypopharynx, where males produced longer pressure durations than females, $t(39) = 2.543$, $p = .015$. Males produced longer pressure durations

TABLE 1. Pharyngeal manometric peak pressures (in mmHg) and standard deviations of males and females during control and tongue-hold swallows, and effect sizes of task comparisons within genders.

	Normal control swallows				Tongue-hold swallows					
	Male		Female		Male		Female		Effect size[a]	
Sensor	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Male	Female
Oropharynx	126.59	51.53	97.24	27.23	99.00	40.32	103.93	32.62	.60	–.22
Hypopharynx	109.30	39.74	125.40	60.80	90.60	26.42	105.94	44.23	.55	.37
Upper esophageal sphincter	–8.50	5.68	–9.32	5.94	–10.04	5.51	–11.26	5.91	.28	.33

[a]Cohen's *d*.

in the oropharynx compared to pressure durations of the female participants in the hypopharynx, $t(39) = 2.894$, $p = .006$. Further, females produced longer pressure durations in the oropharynx than in the hypopharynx, $t(39) = 8.179$, $p < .001$. See Table 2 for durational pressure patterns.

Upper Esophageal Sphincter

Peak relaxation. To investigate the effects of task and gender on peak relaxation pressure in the UES, a mixed-design repeated measures ANOVA was conducted with one within-subjects factor (task) and one between-subjects factor (gender). This analysis revealed a significant effect of task, $F(1, 19) = 7.149$, $p = .015$. Across genders, UES relaxation pressure was lower during tongue-hold swallows compared to control swallows. There was no significant effect of gender, $F(1, 19) = 0.444$, $p = .513$, or Task × Gender, $F(1, 19) = 0.047$, $p = .831$.

Relaxation durations. To investigate the effects of task and gender on UES relaxation duration, a mixed-design repeated measures ANOVA was conducted with one within-subjects factor (task) and one between-subjects factor (gender). This analysis revealed no significant effect of task, $F(1, 19) = 1.159$, $p = .259$, gender, $F(1, 19) = 4.175$, $p = .055$, or Task × Gender, $F(1, 19) = 0.127$, $p = .725$.

Latency Between Peak Pressures in the Oropharynx and Hypopharynx

To investigate the effect of task, sensor, and gender on the latency between peak pressures in the oropharynx and hypopharynx, a mixed-design repeated measures ANOVA was conducted with two within-subjects factors (task and sensor) and one between-subjects factor (gender). This analysis revealed no significant effect of task, $F(1, 19) = 3.619$, $p = .072$, gender, $F(1, 19) = 0.408$, $p = .53$, or Task × Gender, $F(1, 19) = 2.5$, $p = .13$. See Table 3 for latency and slope measures.

Slope Measures in the Oropharynx and Hypopharynx

To investigate the effect of task, sensor, and gender on pressure slopes, a mixed-design repeated measures ANOVA was conducted with two within-subject factors (task and sensor) and one between-subject factors (gender). This analysis revealed a significant effect of sensor, $F(1, 19) = 4.379$, $p = .05$. Across tasks and genders, pressure slopes were steeper in the hypopharynx compared to the oropharynx. Further, there was a significant Task × Gender interaction, $F(1, 19) = 5.261$, $p = .033$. Post hoc paired-samples t tests revealed that males produced steeper pressure slopes during control swallows compared to tongue-hold swallows, $t(39) = 2.091$, $p = .043$. Additionally, females produced steeper pressure slopes during tongue-hold swallows compared to males, $t(1, 39) = –8.69$, $p = .39$. Finally, there was a significant main effect for the Sensor × Gender interaction, $F(1, 19) = 6.469$, $p = .02$. A post hoc paired-samples t test indicated that females produced steeper pressure slopes in the hypopharynx compared to the oropharynx, $t(39) = –3.33$, $p = .002$, and compared to pressure slopes of males in the oropharynx, $t(39) = –2.861$, and hypopharynx, $t(39) = –3.565$, $p = .001$.

Summary of Statistically Significant Results Across Both Gender Groups

To summarize, (a) in the oropharynx and hypopharynx, greater pharyngeal peak pressure was measured during control swallows compared to tongue-hold swallows; (b) in the oropharynx and hypopharynx, longer pharyngeal pressure duration was measured during control swallows compared to tongue-hold swallows, and longer pressure duration was detected in the oropharynx compared to the hypopharynx; (c) lower UES relaxation pressure was generated during tongue-hold swallows compared to control swallows; and (d) steeper pressure slopes were evident in the hypopharynx compared to the oropharynx.

Discussion

This study expands on the existing literature by investigating the immediate effects of the tongue-hold maneuver on amplitude, duration, temporal patterns, and pressure slope characteristics of deglutitive manometric pressure generation. While prior research indicated increased anterior movement of the PPW in healthy volunteers (Fujiu & Logemann, 1996; Fujiu et al., 1995; Lazarus et al., 2002), the data of the current study support our hypothesis that there is no immediate, compensatory increase in pharyngeal pressure generation during this maneuver. Central considerations for the clinical application of this maneuver are discussed below.

TABLE 2. Pharyngeal manometric pressure durations (in seconds) and standard deviations of males and females during control and tongue-hold swallows, and effect sizes of task comparisons within genders.

	Normal control swallows				Tongue-hold swallows					
	Male		Female		Male		Female		Effect size[a]	
Sensor	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Male	Female
Oropharynx	0.50	0.11	0.57	0.09	0.46	0.14	0.53	0.09	.31	.44
Hypopharynx	0.53	0.25	0.42	0.12	0.49	0.21	0.37	0.10	.17	.45
Upper esophageal sphincter	1.18	0.25	0.99	0.22	1.12	0.33	0.96	0.25	.20	.13

[a]Cohen's *d*.

TABLE 3. Slope measures of manometric peak pressure (in mmHg/second) in the oropharynx and hypopharynx, latency (in seconds) of peak pressure between the oropharynx and hypopharynx, standard deviations of males and females during control and tongue-hold swallows, and effect sizes of task comparisons within genders.

	Normal control swallows				Tongue-hold swallows					
	Male		Female		Male		Female		Effect size[a]	
Sensor	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Male	Female
Oropharynx	548.92	383.96	376.58	143.68	434.18	232.18	478.11	272.18	.36	−.46
Hypopharynx	446.18	154.99	690.44	499.1	397.77	194.74	688.48	388.4	.28	.005
Peak-to-peak latency	0.22	0.08	0.19	0.09	0.23	0.05	0.22	0.09	−.15	−.33

[a]Cohen's *d*.

Oropharynx and Hypopharynx—Peak Manometric Pressure

The reduced pressure measured in the oropharynx is likely to result from the anterior anchoring of the tip of the tongue during tongue-hold swallows. Anterior positioning of the tip of the tongue causes the entire tongue to move forward, inhibiting BOT retraction during swallowing. Decreased posterior movement of BOT consequently results in decreased generation of contact pressure with the PPW. In this context, it should be noted that one of the limitations of pharyngeal manometry is the inability to directly monitor sensor position during a swallow. Due to the restriction of BOT retraction, there may have been greater variability of sensor movement during the tongue-hold maneuver than during control swallows. While Fujiu and Logemann (1996) radiographically documented increased anterior bulging of the PPW in healthy volunteers, the manometric data of the current study suggest that increased anterior movement of the PPW does not have an immediate, compensatory effect on pharyngeal pressure generation in normal controls. However, it is entirely possible that regular execution of a tongue-hold treatment regimen could result in a cumulative strengthening effect. Ultimately, this may overcome the initially reduced pressure generation by actively strengthening the PPW musculature. It remains to be investigated which frequency and intensity of exercise prove most effective and which population will benefit most from this exercise.

Upper Esophageal Sphincter—Peak Relaxation

UES relaxation pressures were significantly lower during tongue-hold swallows compared to control swallows. Two considerations may provide plausible explanations for this phenomenon: One is that anterior positioning of the tongue and BOT structures may exert an anterior pull onto the hyoid, which is related to UES opening due to its membranous and muscular connection to the larynx (Jacob, Kahrilas, Logemann, Shah, & Ha, 1989; McConnel, 1988; Miller, 1982); the other possibility is that the increased overall effort employed during tongue-hold swallows may facilitate UES opening through overall greater pharyngeal and floor-of-mouth muscle contraction. Earlier research has investigated the effect of effort on UES opening behavior during the effortful swallowing task (Hiss & Huckabee, 2005; Huckabee, Butler, Barclay, & Jitt, 2005). In a sample of 22 healthy volunteers, this group reported decreased manometric pressures at the level of the UES during effortful swallows compared to control swallows (Huckabee et al., 2005). Interestingly, this group documented in a related study that effortful swallows resulted in prolonged UES opening (Hiss & Huckabee, 2005). The current study into the effects of the tongue-hold maneuver did not find an influence on UES opening duration.

Similar to the effortful swallow, the tongue-hold maneuver is designed to strengthen pharyngeal musculature. Based on prior research into the effects of increased effort during swallowing on anterior hyoid movement (Bulow, Olsson, & Ekberg, 1999), one may speculate about possible side effects of both maneuvers. Increasing the strength of PPW contraction forces means increasing the posteriorly oriented forces that act upon the hyoid bone, therefore potentially limiting anterior hyoid excursion. Bulow et al. (1999) offered data that suggested potential inhibitory effects on hyoid movement during effortful swallowing. In their study of 8 healthy volunteers, this group documented decreased hyolaryngeal elevation during effortful swallows compared to control swallows. In clients with both decreased anterior hyoid movement and poor pharyngeal motility, the application of the tongue-hold maneuver alone may therefore be contraindicated. Disproportionately increasing the strength of the larger pharyngeal constrictors with repetitive, isolated training may consequently further limit anterior hyoid movement. Future research is warranted to investigate the direct biomechanical effects of the tongue-hold maneuver on UES relaxation and opening duration as well as anterior hyoid movement.

Oropharynx and Hypopharynx—Durational Pressure Measures

When the temporal data were analyzed across the oropharynx and the hypopharynx, research participants produced shorter pressure durations during tongue-hold swallows compared to control swallows. This reduction in pressure duration is plausible, as limited BOT posterior movement would reduce BOT approximation with the PPW, thus generating shorter contact pressure. This finding is in agreement with the pharyngeal peak pressure data of this study, which documents decreased peak contact pressure during tongue-hold swallows. Overall, tongue-hold swallows created decreased pharyngeal contact pressure in both amplitude and duration compared to control swallows.

When analyzed across tasks (control swallows and tongue-hold swallows), pressure durations were overall significantly longer in the oropharynx compared to the hypopharynx. Additional post hoc analysis of the significant gender-by-sensor analysis revealed that females produced significantly shorter hypopharyngeal pressure durations compared to their pressure durations in the oropharynx and compared to pressure durations of males in both the oropharynx and the hypopharynx. We speculate that the short hypopharyngeal pressure durations of females affected the overall mean of pressure durations and are thus responsible for the significant main effect of sensor.

Analysis of peak-to-peak latency of maximum pressures in the oropharynx and hypopharynx revealed no significant effect of task. Contrary to our hypothesis, this finding suggests that tongue position does not influence the relative pressure generation patterns in the pharynx. Although the duration of pressure generation at a single site within the pharynx may be adaptable, the temporal relationship across sensors appears unaffected.

Oropharynx and Hypopharynx—Pressure Generation Pattern

For the analysis of the pattern of pressure generation in the oropharynx and hypopharynx, the analysis of pressure slopes served to determine whether the tongue-hold maneuver has an effect on pharyngeal contraction velocity, or the speed at which pressure is generated in the pharynx. Pressure slopes were calculated by dividing changes in pressure (mmHg) over time (seconds).

Generally, pressure slopes were steeper in the hypopharynx compared to the oropharynx across both genders and tasks. These data are in agreement with both the peak pressure data and the pressure duration data documented in this study. While peak pressure measurements are the same between the oropharynx and the hypopharynx, pressure durations were shorter in the hypopharynx. This means that the same amount of pressure was produced in a shorter period of time in the hypopharynx compared to the oropharynx. It is therefore not surprising that pressure slopes are steeper in the hypopharynx. As reflected in the nonsignificant main effect of task, the tongue-hold maneuver does not seem to have a specific, immediate effect on pharyngeal contraction speed.

Gender Differences

The primary purpose of this study was to investigate the immediate effects of the tongue-hold maneuver on pharyngeal pressure generation in a relatively large sample of young, healthy research participants. Interestingly, our statistical analyses helped identify a number of significant, gender-specific differences on some of the biomechanical data evaluated in this study that will require further, focused evaluation. We can only speculate that differences in execution of the tongue-hold maneuver may account for the finding that, unlike males, females did not show significantly reduced pressure measures in the oropharynx during the tongue-hold task. In fact, their peak pressures tended to be slightly increased. It may be speculated that females displayed overall less tongue protrusion than males and therefore retained a larger bulk of the tongue to retract. However, standard instructions were given to both groups, and no differences in execution were perceived by the two trained observers. Nevertheless, differential execution of this maneuver may have clinical implications. Based on the biomechanical effects of this exercise, it may be speculated that different degrees of tongue protrusion would influence the level of resistance to the PPW, ultimately translating to varying degrees of training efficacy of this maneuver.

Possibly, differences in pharyngeal anatomy between males and females also account for the fact that females did not show a significant reduction in oropharyngeal peak pressure during tongue-hold swallows. It has previously been reported that males have a larger upper airway area than females (Brooks & Strohl, 1992; Martin, Mathur, Marshall, & Douglas, 1997). Because of these anatomical differences, males may have to cover a bigger span between PPW and BOT to achieve peak contact pressures. This influence of gender-specific differences on oropharyngeal pressure generation may be exaggerated during tongue-hold swallows. Further investigation of both visual and biomechanical measures is required to clarify this issue.

We speculate that potential differences in overall muscle strength may account for the gender-specific differences documented in the temporal data of this study. Previous research has documented larger isometric tongue pressures in males compared to females using the Iowa Oral Performance Instrument (Crow & Ship, 1996; Youmans & Stierwalt, 2006). One possible explanation for this difference was offered by Youmans and Stierwalt (2006), who hypothesized that this result may reflect overall greater strength of other muscles of the male body. In the hypopharynx, where tongue strength does not contribute as substantially to pressure generation as in the oropharynx, females displayed significantly shorter pressure durations and steeper pressure slopes than males.

The above considerations are speculative and are intended to provide some general explanations for the differences between genders documented in this study. Future research is warranted to systematically investigate these gender differences with a number of biomechanical and physiological measurements.

Clinical Implications and Future Research Directions

The results of this study have implications for the clinical use of the tongue-hold maneuver. As outlined, there is evidence in prior literature that PPW movement may be increased during execution of this maneuver. Based on the data of the current study, the ultimately desired training effect of this maneuver does not occur immediately. However, a beneficial effect, characterized by increased pharyngeal constrictor strength and ultimately increased pharyngeal pressure generation, may arise after regular training. Increased pharyngeal constrictor strength, however, may have negative implications for hyoid anterior movement. Consequently, the tongue-hold maneuver may potentially be contra-indicated for individuals with generally decreased anterior hyoid movement. In these instances, it may be beneficial to provide the tongue-hold maneuver alongside the head-lift exercise, a strengthening exercise for the submental muscles that cause the hyoid to move anteriorly during swallowing (Shaker et al., 1997). If the speculation is true that males and females perform the tongue-hold maneuver differentially, although this was not visually noticeable in this study, then careful investigation and encouragement for proper execution of this exercise may be mandatory for the success of this treatment. All of these issues require further investigation.

As described by Fujiu and Logemann (1996), anterior placement of the tongue may leave the laryngeal vestibule in a less protected position during swallowing and may thus increase the risk of aspiration. In favor of this, the manometric data of this study suggest that oropharyngeal contact pressure is decreased and may indeed impair bolus propulsion through the pharynx, thus posing an increased risk of aspiration to individuals who already have swallowing difficulties. Further research is warranted to investigate the specific effects of the tongue-hold maneuver on pharyngeal bolus propulsion and aspiration risk.

Anterior placement of the BOT poses increased resistance to the posteriorly oriented contraction forces of the PPW during tongue-hold swallows. It may be considered that anterior positioning of the BOT also opposes the trajectory of the extrinsic tongue muscles that are also involved in tongue retraction. Electromyographic studies may provide further insight into this hypothesis. If future studies document increased extrinsic tongue activity, then this exercise may be suitable to strengthen not only PPW structures but also extrinsic tongue muscle fibers. Training these muscles may be beneficial to individuals with reduced BOT retraction.

In addition, further research is necessary to investigate whether the tongue-hold maneuver affects lateral movement of the pharyngeal constrictors. It is also of interest to investigate changes in myoelectric activity of the PPW, which may be expected to increase during tongue-hold swallows. Finally, investigation of neurophysiological changes, such as cortical activation and neurotransmission, may one day provide important information about the effects of the tongue-hold maneuver on the neurophysiology underlying swallowing.

It is evident that future research studies are needed to investigate the potential benefits of this tongue-hold exercise on a variety of oral and pharyngeal biomechanics and the underlying swallowing neurophysiology.

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