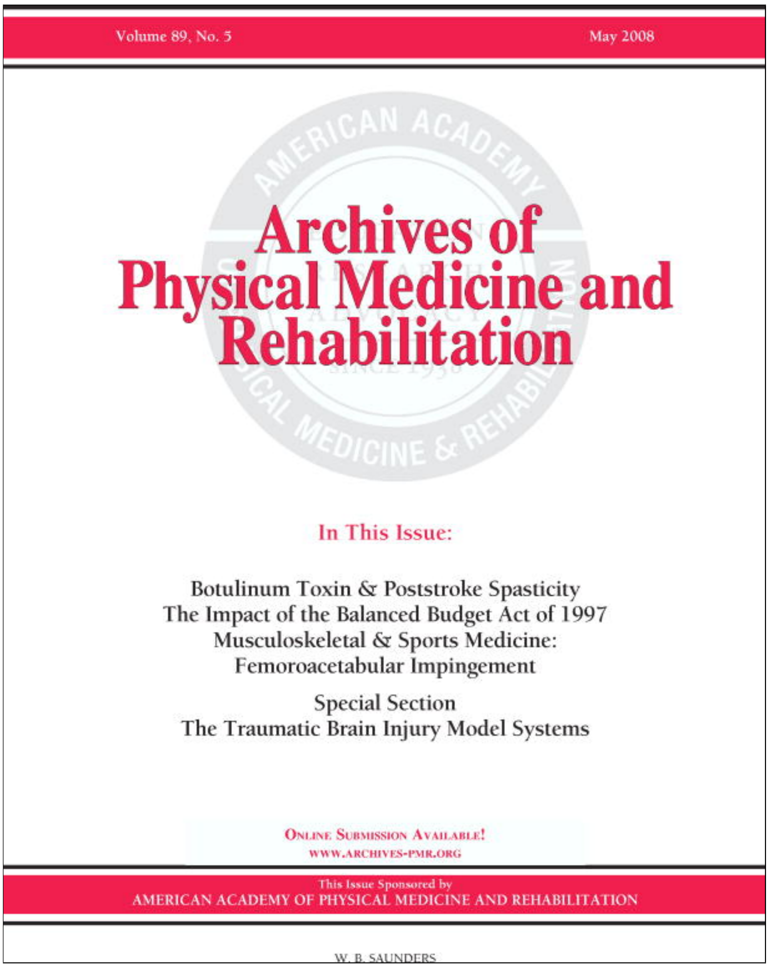
Volume 89, No. 5
May 2008
Archives of Physical Medicine and Rehabilitation
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ORIGINAL ARTICLE

The Effect of Effortful Swallow on Pharyngeal Manometric Measurements During Saliva and Water Swallowing in Healthy Participants

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ABSTRACT. Witte U, Huckabee M-L, Doeltgen SH, Gumbley F, Robb M. The effect of effortful swallow on pharyngeal manometric measurements during saliva and water swallowing in healthy participants. Arch Phys Med Rehabil 2008;89:822-8.

Objective: To evaluate the effect of effortful swallow on pharyngeal manometric pressure measurements during saliva and water swallowing.

Design: Comparative analysis of pharyngeal pressure generation under 2 bolus and 2 task conditions.

Setting: Swallowing rehabilitation research laboratory.

Participants: Healthy participants (N=40), sex equally represented, with a mean age of 25.8 years.

Interventions: Not applicable.

Main Outcome Measures: Manometric peak and nadir amplitude and duration measures at 3 locations in the pharynx.

Results: Significantly higher peak pressures were measured for saliva swallows compared with water swallows under both swallowing conditions at the proximal pharyngeal sensor only (P=.011). No significant differences were observed between the effortful versus noneffortful conditions at the proximal and midpharyngeal sensors; however, upper esophageal sphincter (UES) nadir pressures were significantly lower for effortful than noneffortful swallows (P=.034) with significantly lower pressure measurements in saliva effortful swallows (P=.008) compared with water effortful swallows. Saliva swallows resulted in significantly longer pressure durations than water swallows at the proximal (P=.003) and middle (P=.048) sensors. Pressure-generation duration was significantly longer in effortful versus noneffortful swallows for the middle sensor (P=.036) only.

Conclusions: The results indicate that the effect of effortful swallow on pharyngeal peak pressure measurement is not altered by bolus type (saliva vs water). However, this is not the case for nadir pressure measurements in the UES, which were significantly lower in effortful saliva swallows than in effortful water swallows.

Key Words: Deglutition; Rehabilitation.

SEVERAL SWALLOWING MANEUVERS are applied in the management of patients with swallowing disorders that are targeted toward either compensation for the disorder or restitution of impaired function.[1-9] The effortful swallow was introduced as a compensatory maneuver for patients with a reduced base of tongue retraction presenting with vallecular residue. The instruction for effortful swallow (ie, swallow hard) was intended to improve the base of the tongue to the posterior pharyngeal wall contact, thus resulting in improved bolus passage.[1] A number of studies[10-18] have investigated the effortful swallow in order to elucidate its effect on swallowing biomechanics and its potential for facilitating pharyngeal bolus propulsion. However, conflicting results indicate the necessity to further clarify the effect of this maneuver.

Pouderoux and Kahrilas[10] investigated oral and oropharyngeal pressure and submental surface electromyographic measurements testing various swallowing maneuvers, bolus volumes, and consistencies in 8 healthy participants. They documented higher pharyngeal peak pressures in effortful swallows than in noneffortful swallows. By using manofluoroscopy, Lazarus et al[14] also observed increased pharyngeal pressure associated with effortful swallows as well as prolonged duration of the base of the tongue to the pharyngeal wall contact and slightly reduced pharyngeal residue in 3 head and neck cancer patients. In both studies,[10,14] all swallows were executed with a liquid bolus or a bolus of a higher viscosity, pharyngeal pressure measurements were exclusively collected at the level of the base of the tongue, and only small numbers of participants were included. Hind et al[15] investigated the effect of effortful swallowing in healthy participants by using videofluoroscopy swallow study (VFSS) and oral pressure bulbs during the ingestion of a barium bolus. They documented significantly increased pressure at the oral pressure bulbs, prolonged and increased anterior hyoid excursion, and prolonged laryngeal closure and upper esophageal sphincter (UES) opening.

In a series of 3 studies, Bülow et al[11-13] investigated (among other swallowing maneuvers) the effortful swallow maneuver in healthy participants and in patients with moderate to severe swallowing disorders by using manofluoroscopy. All swallows were executed with a thin or medium barium bolus. A minor decrease of peak pharyngeal pressure measured at the level of the inferior pharyngeal constrictor was found in effortful swallows versus noneffortful swallows in all participants. In the group of healthy participants, the duration of the UES opening and pharyngeal contraction was observed to be slightly longer for the condition of effortful swallow. In the patient group, a reduced duration of pharyngeal contraction and UES relaxation

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Presented to the New Zealand Speech Language Therapists Association, April 9–12, 2006, Christchurch, NZ; the 36th Jahreskongress des Deutschen Bundesverbandes für Logopädie, June 7–9, 2007, Karlsruhe, Germany; and the 27th World Congress of the International Association of Logopedics and Phonatrics, August 5–9, 2007, Copenhagen, Denmark.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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0003-9993/08/8905-00090$34.00/0
doi:10.1016/j.apmr.2007.08.167

and incomplete UES relaxation were observed. In 2 patients, a tendency toward increased pharyngeal residue was noted with effortful swallow. No significant increase of intrabolus pressures or intrabolus pressure durations were found for the effortful swallow at the sensor located at the level of the inferior pharyngeal constrictor.

The results reported by Bülow et al[11-13] on effortful swallow were unexpected. The tendency toward decreased pharyngeal pressure, increased residue (in 2 patients), and an incomplete UES opening in the condition of effortful swallow are contrary to the targeted effect and raise some concerns about the appropriateness of this maneuver for certain pathophysiologic conditions. Certainly, they indicate a necessity for further research on effortful swallow.

In response to the research by Bülow,[11-13] Huckabee[16,18] and Hiss[17] and colleagues conducted a series of studies investigating the effect of effortful swallow on pharyngeal pressure generation and pressure duration as well as on submental surface electromyographic measurements in healthy participants. Increased pressures were identified in the 2 proximal sensors (tip of epiglottis and midpharynx)[16,18] and lower nadir of pressure in the third sensor (placed in the UES) for the condition of effortful swallow[16] as well as significantly longer pharyngeal pressure generation and longer UES relaxation.[17]

Unlike prior research[10-15] on effortful swallow in which all swallows were executed with a water or barium bolus, the 3 studies by Huckabee[16,18] and Hiss[17] and colleagues were conducted with saliva swallows. Thus, it is important to evaluate the effect of effortful swallow with saliva and water swallows to determine whether both conditions are equal in their effect on swallowing biomechanics because differences between saliva and water swallows have been documented in earlier studies on noneffortful (normal) swallows.[19-22] Although Perlman et al[19] documented longer pressure duration but no differences in pharyngeal peak pressure amplitudes in noneffortful saliva versus water or paste swallows, Castell et al[20] observed shorter pressure duration but a tendency toward increased pharyngeal pressure in saliva swallows. Also, significantly lower nadirs of pressure in the UES during sphincter relaxation have been reported for saliva swallows[21] as well as longer durations of negative pressure.[22]

Additionally, differences in pressure generation have been documented for men and women. In some studies, longer pharyngeal pressure durations were observed in men versus women.[19,23] Other differences were lower UES resting pressure[23] and shorter UES relaxation intervals in men than in women.[23,24] These findings indicate the necessity to take sex into account when analyzing manometric measurements and to control sex distribution in research projects on swallowing physiology.

To date, no study has investigated the effect of bolus type on effortful swallows by comparing saliva effortful swallows to water effortful swallows. As such, it is not possible to determine whether the results of studies conducted with a water or liquid bolus can be compared with the results of studies with saliva. The aim of this study was to investigate the effect of effortful swallow on pharyngeal manometric measurements during saliva and water swallowing in healthy participants. The following hypotheses were posed: (1) pharyngeal peak pressure and duration of pressure generation will be greater in saliva swallows than water swallows, irrespective of maneuver; (2) UES nadir pressure will be lower and duration of UES relaxation will be longer in saliva swallows than water swallows, irrespective of maneuver; (3) pharyngeal peak pressure and duration of pressure generation will be greater in effortful swallows than in noneffortful swallows, irrespective of bolus type; and (4) UES nadir pressure will be lower and duration of UES relaxation will be longer in effortful swallows than in noneffortful swallows, irrespective of bolus type.

METHODS

Participants

Participants were recruited through written and verbal advertisement. Forty-two young, healthy subjects aged between 20 and 43 years (mean age, 25.8±5.89y) participated in the project after the provision of informed consent. Sex was distributed equally. Exclusion criteria included neurologic disorders (eg, stroke, neurodegenerative disorders), nasal obstruction, heart attack, asthma, chronic obstructive pulmonary disease, swallowing difficulties, head and/or neck injury or surgery, gastroesophageal reflux diseases, paralysis of the diaphragm, and chronic fatigue syndrome. Two participants (1 man, 1 woman) dropped out of the study because of intolerance of catheter placement. Thus, data from 40 sex-matched participants who completed the study were available for analysis. Ethics approval was obtained from the regional health research ethics review board; informed consent was obtained from all participants.

Equipment

Data were collected by using a solid-state manometry catheter (diameter, 2.1mm)[a] with 3 unidirectional pressure sensors, facing posteriorly, with a distance of 2cm between the most proximal and middle pressure sensors and a distance of 3cm between the middle and distal pressure sensors. The catheter was calibrated at room temperature at 250mmHg. All measurements were displayed on a computer monitor[b] during data collection and were digitally recorded for later analysis.

Procedure

The study was conducted at a swallowing rehabilitation research laboratory located in a free-standing brain-research facility. Research participants were seated comfortably in a chair, unable to observe the manometric tracings on the monitor. To facilitate catheter insertion, a lubricant was applied to the tip of the catheter, and the catheter was subsequently passed transnasally. Once the catheter reached the upper pharynx, the participant was asked to ingest a glass of water by using consecutive swallows until the catheter was pulled down approximately 30cm, thus placing the tip of the catheter in the proximal esophagus. The catheter was then repositioned until the most distal manometric sensor registered elevated pressure and displayed the typical M wave at the onset of the swallow, suggesting placement within the proximal aspect of the UES. The proximal manometric sensor (sensor 1) was therefore located in the oropharynx, with the middle sensor (sensor 2) in the midpharynx and the distal sensor (sensor 3) in the UES, as documented in an earlier study on manometry and pharyngeal surface electromyographic measurements by Huckabee.[16] The catheter was secured by taping it to the participant's nose with medical tape to ensure continued correct placement. Throughout data collection, data were evaluated to ensure that placement remained stable by using identification of the M wave to confirm location.

Data Collection

Each participant performed 4 different swallowing conditions: (1) saliva noneffortful swallow, (2) water noneffortful swallow, (3) saliva effortful swallow, and (4) water effortful swallow. For each condition, 5 trials were completed with a

30-second interval between each swallow. Saliva noneffortful swallow was always the first condition (providing baseline data) so that the completion of effortful type swallows would not inadvertently influence the performance of noneffortful saliva swallows. The 3 remaining conditions were presented in random order to control for practice effect, fatigue, and intercondition variability. For all trials with water, participants were asked to ingest 10mL boluses of tap water served in a medicine cup.

To ensure the consistency of instruction, complete instructions were read to the participants at the beginning of each condition. For the noneffortful swallows, participants were instructed to swallow their saliva as they normally would and for water swallows to swallow the water all at once. For the conditions of effortful swallow, participants were instructed to squeeze hard with all of their muscles as they swallow. This particular instruction for effortful swallow was used because it is similar to the instruction swallow hard, which is the most commonly given instruction for effortful swallow.

Data Analysis

The following data were extracted from the waveform and tabulated for statistical analysis. Peak manometry amplitudes of the proximal and middle sensor were defined as the highest pressure reading during swallowing, reflecting tissue contact pressure. Throughout the article, the terms *peak manometry amplitudes* or *peak pressure* refer to tissue contact pressure. Contact pressure measures tissue contact after the bolus has passed, whereas intrabolus pressure reflects the pressure generated on the bolus by the accumulated effects of pressure at the bolus site, paired with the pressure generated above the bolus and resistance offered by the UES. It is the succeeding contact pressure that is the stripping wave associated with the clearance of bolus residue as stated by Kahrilas et al.[25] Because most of the investigations into effortful swallowing have evaluated contact pressure, this will be the subject of this research. Nadir amplitudes of the distal sensor, located in the UES, were defined as the lowest pressure recording. The duration of pressure generation in the proximal and middle sensor was defined as the time latency between the onset of a pressure increase greater than 2mmHg preceding peak pressure and the offset defined as the point in time when the recorded waveform returned to baseline. In instances in which the pressure increase or return to baseline started or ended with subatmospheric pressure, the time was only measured to the first subatmospheric pressure reading. Duration measurements for the distal sensor located in the UES were defined as the time between the highest pressure reading before the pressure drop during UES relaxation and the highest pressure reading after the pressure drop. Overall swallowing duration was defined as the time from the first observed onset of pressure change at any of the sensors to the offset of pressure at any sensor. An example for the manometric signals is provided in figure 1, indicating peak and nadir amplitude and durational measurements.

Statistical Analysis

For each participant, the values for all conditions were expressed as means of the 5 trials of each condition. General

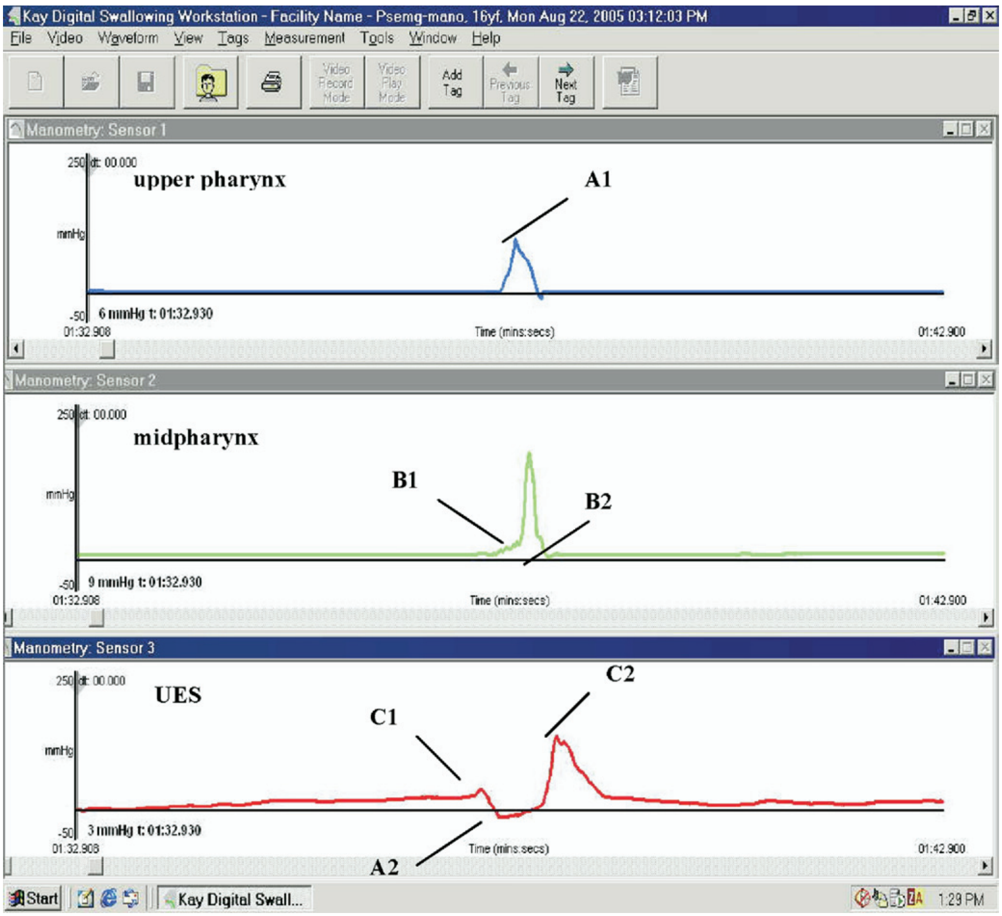

Fig 1. Peak and nadir amplitudes and durational measurements. (A1) Peak amplitude in sensor 1, measuring the highest pressure. (A2) Nadir of pressure in sensor 3, measuring the lowest pressure. (B1, B2) The timepoints that determine pressure generation duration in sensor 2. (C1, C2) The timepoint which determine UES relaxation duration as well as total swallowing duration.

Table 1: Peak Amplitude and Nadir of Pressure Across the Sensors and Swallowing Conditions

Condition	Sensor 1	Sensor 2	Sensor 3
Noneffortful saliva			
Group	111.91±43.31	108.34±33.26	−8.91±5.74
Men	126.59±51.53	102.08±21.60	−8.50±5.67
Women	97.24±27.23	114.61±41.49	−9.32±5.93
Noneffortful water			
Group	93.41±32.71	89.82±26.91	−6.33±5.29
Men	97.62±34.04	84.28±22.05	−8.51±4.44
Women	89.21±31.62	95.37±30.68	−4.15±5.25
Effortful saliva			
Group	121.02±48.80	113.77±43.49	−13.58±8.28
Men	129.81±55.00	104.74±31.23	−15.55±9.66
Women	112.23±41.24	122.81±52.31	−11.61±6.28
Effortful water			
Group	110.19±43.57	109.88±49.66	−6.68±5.89
Men	108.14±44.74	99.68±29.25	−8.56±6.41
Women	112.25±43.53	120.08±63.14	−4.80±4.76

NOTE. Values are mean mmHg ± SD.

linear model repeated-measures analysis of variance (ANOVA) was used to evaluate the effect of bolus type (saliva vs water) and swallow type (effortful vs noneffortful) on both amplitude and duration, with sex selected as a covariate. An α level of P less than .05 was accepted as significant for all analyses. In the few instances in which data were missing (single durational measurements in 3 different trials), an average was calculated from the remaining 4 durational measurements within the same condition. Twenty percent of the dataset was randomly selected and extracted again for the analysis of inter- and intrarater reliability. Inter- and intrarater reliability was calculated by using the intraclass correlation coefficient (ICC).

RESULTS

Inter- and Intrarater Reliability

Intrarater reliability proved to be significant for all measurements, with an ICC of .987 for peak and nadir manometry amplitudes and .997 for the duration of pressure generation measured at the 3 sensors. For total duration (overall pressure duration during swallowing, r=.992), the ICC was also significant for all measurements collected for interrater reliability, ranging from .997 for peak and nadir manometry amplitudes to .876 for pressure generation at each sensor and .705 for total pressure duration.

Peak and Nadir Manometry Amplitudes

Mean peak and nadir amplitudes and standard deviations (SDs) for all sensors across sex and for each sex separately are displayed in table 1. Effortful swallows resulted in significantly lower nadirs of pressure than noneffortful swallows ($F_{1,38}$=4.821, P=.034) at sensor 3, which was located in the UES. For the other sensors, no significant maneuver effect was observed. For the comparison of saliva versus water swallows, significantly higher peak amplitudes were measured for saliva swallows at sensor 1 ($F_{1,38}$=7.219, P=.011). Statistical analysis revealed a maneuver by bolus interaction at sensor 3, with significantly lower pressure in saliva effortful swallows compared with water effortful swallows ($F_{1,38}$=7.757, P=.008). For peak and nadir amplitudes, no other interactions were found to be significant. Repeated-measures ANOVA output for mean peak and nadir amplitudes across sensors, swallowing condition, and sex is displayed in table 2.

The Duration of Pressure Generation

Descriptive statistics for the duration of pressure generation are tabulated in table 3.

Effortful swallow resulted in a significantly longer pressure generation duration than noneffortful swallow at sensor 2 ($F_{1,38}$=4.714, P=.036). A longer pressure generation duration was also observed for saliva swallows in comparison to water swallows at sensor 1 ($F_{1,38}$=10.211, P=.003) and sensor 2 ($F_{1,38}$=4.177, P=.048).

Statistical analysis revealed some sex effects for durational measurements. At sensor 2, women presented with a significantly longer pressure generation duration than men for the condition of effortful swallow, whereas men presented with a significantly longer pressure generation duration for the condition of noneffortful swallow at the same sensor ($F_{1,38}$=9.855,

Table 2: Repeated-Measures ANOVA Output for Mean Peak and Nadir Amplitudes Across Sensors, Swallowing Conditions, and Sex

Interactions	Sensor 1 ($F_{1,38}/P$)	Sensor 2 ($F_{1,38}/P$)	Sensor 3 ($F_{1,38}/P$)
Maneuvers	0.202/.655	0.011/.916	4.821/.034*
Saliva vs water	7.219/.011*	1.159/.288	0.151/.699
Maneuvers by bolus type	0.097/.757	0.118/.733	7.757/.008*
Maneuvers by sex	2.681/.110	0.609/.440	1.645/.207
Bolus type by sex	3.770/.060	0.004/.949	2.414/.129
Maneuvers by bolus type by sex	0.003/.955	0.052/.821	3.647/.064

*P<.05.

Table 3: Swallowing Duration Across Sensors and Across Swallowing Conditions and Total Duration Across Conditions

Condition	Sensor 1	Sensor 2	Sensor 3	Total Duration
Noneffortful saliva				
Group	0.53±0.10	0.47±0.19	1.08±0.24	1.11±0.24
Men	0.49±0.11	0.52±0.25	1.17±0.24	1.22±0.21
Women	0.56±0.09	0.42±0.11	0.99±0.22	0.99±0.22
Noneffortful water				
Group	0.41±0.14	0.34±0.18	1.08±0.21	1.10±0.22
Men	0.36±0.12	0.39±0.24	1.12±0.22	1.16±0.23
Women	0.47±0.13	0.28±0.08	1.05±0.21	1.05±0.21
Effortful saliva				
Group	0.64±0.16	0.50±0.21	1.12±0.26	1.15±0.23
Men	0.59±0.18	0.49±0.24	1.14±0.27	1.18±0.23
Women	0.69±0.13	0.52±0.18	1.10±0.25	1.13±0.23
Effortful water				
Group	0.52±0.17	0.41±0.18	1.14±0.22	1.16±0.22
Men	0.46±0.13	0.40±0.20	1.15±0.22	1.19±0.19
Women	0.59±0.18	0.41±0.15	1.12±0.22	1.14±0.20

NOTE. Values are mean seconds ± SD.

P=.003). A maneuver by sex interaction was also observed for the total duration of swallowing ($F_{1,38}$=5.823, P=.021). The total duration was significantly longer in men than in women for effortful and noneffortful swallowing. At sensor 3, no interaction resulted in significant changes. The output of repeated-measures ANOVA for durational measurements is displayed in table 4.

DISCUSSION

Our study is the first to investigate the effect of effortful swallow on pharyngeal and UES biomechanics for both saliva and water swallows. By investigating effortful swallow with saliva and water, the study was able to determine whether effortful swallow has similar effects on manometric measurements in both conditions.

We sought to evaluate 4 hypotheses. Our findings of significantly higher pharyngeal pressure at sensor 1 only and longer pressure duration at both pharyngeal sensors in saliva versus water swallows partially confirm hypothesis 1. However, the UES pressure nadir and UES relaxation times did not differ significantly between saliva and water swallows, thus failing to support our second hypothesis. For effortful swallows, the amplitude of pharyngeal pressure generation did not differ significantly from noneffortful swallows; however, the duration of pharyngeal pressure at sensor 2 was longer in effortful swallows than in noneffortful swallows, irrespective of bolus type. Therefore, the third hypothesis can only be partially accepted. Furthermore, the UES nadir of pressure was significantly lower for effortful swallows than for noneffortful swallows, but no significant changes were detected for the UES relaxation time. The first part of hypothesis 4 is verified by the findings; however, the second part of hypothesis 4 cannot be confirmed.

The pressure increase in saliva swallows in the present study was observed at the proximal sensor. Because the base of the tongue was identified as the main driving force in bolus propulsion,[22,25] it is plausible to assume the base of the tongue is the main contributor for increased pharyngeal pressure in saliva swallows. The finding of longer pharyngeal pressure duration in saliva swallows than in water swallows is supported by Perlman et al.[19] The increased effort in saliva swallows may be reflected not only by higher peak amplitudes but also by longer sustained pressure durations. A second possibility is that the pressure duration needs to be sustained longer in saliva swallows because saliva does not flow as fast as a water bolus. No maneuver by bolus-type interaction was evident for pharyngeal peak pressure measurements and durational pressure measurements at sensors 1 and 2. Thus, it can be concluded that the effortful swallowing maneuver has the same effect on pharyngeal peak pressure and pressure duration whether conducted with saliva or with water. However, this conclusion cannot be drawn for UES pressure measurements because saliva effortful swallow resulted in significantly lower nadir of pressure in the UES than bolus effortful swallow.

The finding of an insignificant increase of pharyngeal peak pressure in effortful swallows conflicts with the results of prior research, and some of the differences in the findings were unexpected. The likely reason for the differences relates to methodologic differences between studies. For example, in studies by Huckabee et al,[16,18] surface electromyographic

Table 4: Repeated-Measures ANOVA Output for Mean Durations Across Sensors, Swallowing Conditions and Sex, and Mean Total Durations Across Swallowing Conditions and Sex

Interactions	Sensor 1 ($F_{1,38}$/P)	Sensor 2 ($F_{1,38}$/P)	Sensor 3 ($F_{1,38}$/P)	Total Duration ($F_{1,38}$/P)
Maneuvers	2.847/.100	4.741/.036*	1.185/.283	2.438/.127
Saliva vs water	10.211/.003*	4.177/.048*	1.123/.296	1.178/.285
Maneuvers by bolus type	0.026/.872	0.364/.550	1.434/.239	1.760/.193
Maneuvers by sex	0.567/.456	9.855/.003*	3.119/.085	5.823/.021*
Bolus type by sex	1.128/.295	0.118/.733	1.472/.232	1.456/.235
Maneuvers by bolus type by sex	0.066/.799	0.040/.842	1.329/.256	1.723/.197

*P<.05.

biofeedback was used to teach effortful swallow, whereas the present study did not use such feedback. As a result, the participants in prior studies may have mastered the effortful swallow more effectively, thus showing higher pharyngeal peak pressures. In addition, the instructions given for producing an effortful swallow were not consistent across studies. Furthermore, the anatomic location for the measurement of pharyngeal pressure generation was not held constant across studies. For example, Bülow et al[11,12] measured pharyngeal pressure exclusively at the level of the inferior constrictor. Thus, increased pressure generation at the level of the base of the tongue would not have been detected. Differences in findings on pressure generation may also result from the fact that some studies investigated effortful swallowing in patients with dysphagia,[12-14] whereas other studies investigated effortful swallow in healthy participants,[10,11,15-18] as was the case in our study.

For effortful swallows, pharyngeal pressure duration increased significantly at sensor 2. For saliva swallows, it was suggested that increased effort may not only effect pressure generation but also the duration of pressure generation. Thus, longer pressure generation could also be regarded as an event related to more effort during swallowing. Certainly, the longer duration of pressure generation is desirable in a maneuver designed to facilitate pharyngeal bolus propulsion. If bolus propulsion is impaired because of weak pharyngeal wall contraction or reduced base of tongue retraction, longer sustained pressure generation may compensate for the reduced force in pressure generation. Thus, the documented increase in pharyngeal pressure duration in effortful swallows can be interpreted as a targeted feature of this maneuver. The finding of significantly longer pharyngeal pressure generation in effortful swallows is supported by the findings of Hiss and Huckabee.[17] Bülow et al[11] also found slightly longer pressure durations for effortful swallows in their study with healthy participants.

In contrast to the results on pharyngeal peak amplitudes, UES nadirs of pressure were significantly lower in effortful swallows. The research by Jacob et al[26] may serve as an explanation for greater subatmospheric pressures in the UES during effortful swallows. The researchers pointed out that the magnitude of hyoid excursion is inversely correlated to negative pressure in the UES during swallowing. Thus, it can be speculated that greater subatmospheric pressure in the UES during effortful swallows can be related to increased hyoid excursion, which, in turn, may result from increased effort during the effortful swallow maneuver. Considering that subatmospheric pressure is regarded as a hypopharyngeal suction pump and necessary for adequate bolus transport,[22,27,28] greater subatmospheric pressure is certainly an advantageous effect in a maneuver applied to improve bolus passage. The finding of greater subatmospheric pressure in effortful swallows is in agreement to the findings by Huckabee.[16]

Differences in durational measurements were identified between men and women. For sensor 2, men presented with longer pressure duration in noneffortful swallows, whereas women presented with longer pressure duration for effortful swallows. For total duration, generally longer pressure duration was observed in men. The finding of longer pharyngeal pressure duration in noneffortful swallows in men is supported by the findings by Perlman et al,[19] who speculated that longer pressure durations in men are caused by a greater intraluminal diameter of the pharynx resulting in longer times necessary to reach pharyngeal wall contact. However, the reversed patterns in effortful swallows and the results for total duration are difficult to explain. The findings on differences between sex support the necessity to control for sex effects in research on swallowing physiology. However, no consistent pattern was detected.

Study Limitations

In the present study, data were collected exclusively in healthy, young participants. An extension of this research is needed to investigate the effect of effortful swallow on healthy elderly participants and, more importantly, on patients with reduced base of tongue retraction or pharyngeal constrictor weakness. A limitation of our study is the lack of visualizuation of catheter placement. During swallowing, the UES elevates substantially, which could result in an altered position of the catheter in relation to the UES and potentially result in some variance of measurement. Although the placement of the catheter at the upper borders of the cricopharyngeus allowed for shifting associated with hyolaryngeal excursion, the use of concurrent VFSS and manometry would be feasible to avoid this limitation and to evaluate the effect of effortful swallows on swallowing biomechanics more comprehensively.

CONCLUSIONS

The results indicate that the effect of effortful swallow on pharyngeal pressure measurement is not altered by bolus type (saliva vs water). However, this is not the case for nadir pressure measurements in the UES. Thus, it can be stated that it is possible to compare the results of past (and future) research on the effect of effortful swallow on pharyngeal pressure generation and pressure duration measured in the oro- and midpharynx. In contrast, this conclusion cannot be drawn for UES nadir pressure measurements.

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Suppliers

a. Model CT/S3+emg; Medical Measurements Inc, 56 Linden St, Hackensack, NJ 07601.
b. Digital Swallowing Workstation; Kay Elemetrics Corp, 2 Bridgewater Ln, Lincoln Park, NJ 07035-1488.