Influence of Effortful Swallow on Pharyngeal Pressure
– Evaluation Using a High-resolution Manometry.

Kenji Takasaki, M. D.[1)], Hiroshi Umeki, M.D.[1)], Minoru Hara, M. D.[1)],
Hidetaka Kumagami, M. D.[1)] Haruo Takahashi, M. D.[1)]

1) Department of Otolaryngology - Head and Neck Surgery,
Nagasaki University Graduate School of Biomedical Sciences

Address:
Department of Otolaryngology - Head and Neck Surgery,
Nagasaki University Graduate School of Biomedical Sciences
1-7-1, Sakamoto, Nagasaki 852-8501, Japan

Correspondence / Reprint requests:
Kenji Takasaki, M. D.
Department of Otolaryngology, Head and Neck Surgery,
Nagasaki University Graduate School of Biomedical Sciences
1-7-1, Sakamoto, Nagasaki 852-8501, Japan
Phone: +81-95-819-7349, Fax: +81-95-819-7352
E-mail: ktakasa@nagasaki-u.ac.jp

Abstract

Objectives: To evaluate the effect of the effortful swallow on pharyngeal pressure while swallowing saliva and water using a novel high resolution manometry (HRM) system.

Study Design: Case series with planned data collection.

Setting: Nagasaki University Hospital.

Subjects and Methods: Eighteen asymptomatic Japanese adult volunteers were studied. A solid-state HRM assembly with 36 circumferential sensors spaced 1 cm apart was positioned from the velopharynx to the upper esophagus to record pressures while swallowing. The maximum values of the pressure while swallowing saliva (dry swallowing) and 5ml of water were measured at velopharynx, meso- hypopharynx, and at the upper esophageal sphincter (UES) with and without effortful swallows.

Results: The maximum values of dry swallowing pressures (mmHg) at the velopharynx, meso-hypopharynx and UES were significantly higher with effortful swallow (155.7±59.7, 256.7±78.7 and 276.5±87.5, mean ± standard deviation) than without it (115.3±60.8, 172.9±57.0 and195.8±61.3). Those of water swallowing pressures were also statistically higher with effortful swallow (169.3±69.1, 236.6±77.2, and 267.3±79.1) than without it (119.2±59.7, 189.5±70.7, and 221.3±72.7).

Conclusion: The present results provide quantitative evidence of effortful swallow as well as physiological information. It also will hopefully be an aid to future clinical and investigative studies.

Key words: effortful swallow, high-resolution manometry, pharynx, swallowing pressure, upper esophageal sphincter,

Introduction

Several swallowing maneuvers targeted toward either compensation for the disorder or restitution of impaired function are applied in the management of swallowing disorders [1]. Among those maneuvers, effortful swallow is a behavioral technique that is used in the rehabilitation of individuals who have swallowing impairment, or dysphagia. By instructing the patient to ‘‘squeeze hard with all your muscles as you swallow,’’ the effortful swallow is designed to increase contact between the tongue base and posterior pharyngeal wall while swallowing [2]. Although several studies have investigated the effortful swallow in order to elucidate its effect on swallowing biomechanics and its potential for facilitating pharyngeal bolus propulsion, the results from these studies were conflicting. Using a conventional manometry, some studies demonstrated that the pharyngeal pressure increased with effortful swallowing [3-5], while the other documented only a minor decrease of peak pharyngeal pressure measured at the level of the inferior pharyngeal constrictor, found in the effortful swallow versus the non-effortful swallow in all the participants [6].

Characteristics of pharyngeal swallowing have been quite difficult to study using a conventional manometry. That is because the movement of the soft palate and the elevation of the larynx while swallowing causes a spike-like movement along the velopharynx and upper esophagus. Also, it is extremely difficult to detect the exact pressure of a specific point by analyzing the values with only a few sensors widely spaced about 2 cm or more apart. Advances in computer technology enabled the large volume of data acquired by novel high-resolution manometry (HRM) to be presented in real time not only as conventional “line plots,” but also as “spatiotemporal plots” (sometimes referred to as a “contour” or “topographic” plots). These display the direction and force of esophageal pressure activity. Esophageal HRM is now utilized for both research and clinical practice [7]. We already reported the feasibility of the novel HRM system for evaluating pharyngeal swallowing along the velopharynx and upper esophagus of normal Japanese adults, and demonstrated that HRM can overcome those disadvantages of conventional manometric methods [8, 9]. The purpose of this study was to quantify the effects of effortful swallow on the pharyngeal pressure in healthy subjects using the HRM system, and to suggest the feasibility of the effortful swallow maneuver as a rehabilitative procedure for dysphagic patients.

Methods

Subjects

We studied 18 healthy Japanese male volunteers without a history of dysphagia, gastrointestinal symptoms, upper gastrointestinal tract surgery, or significant medical condition. Their ages ranged from 23 to 28 years. The study protocol was approved by the Institutional Review Board Committee of Nagasaki University Hospital, and written informed consent was obtained from each participant.

Measurement Using High Resolution Manometry

The protocol using the HRM system (ManoScan, Sierra Scientific Instruments Inc., Los Angeles, CA) was described in our previous report in detail [8]. In brief, after a local anesthesia in the nasal cavity, the catheter was inserted and fixed by taping at the nostril with the patient in a natural supine position.

Examinees were asked to perform 4 different swallowing conditions: 1) non-effortful dry (saliva) swallow, 2) non-effortful swallow of 5 ml of ice water, 3) effortful dry swallow, and 4) effortful swallow of 5 ml of ice water. For each condition, three trials were completed with a 30-second interval between each swallow, and the mean values were adopted. We used ice water (0 °C) in order to keep the conditions of thermal stimulation to the pharynx constant among examinees during the examination.

Manometric data were initially analyzed using ManoView™ analysis software (Sierra Scientific Instruments Inc., Los Angeles, CA, Figure 1). Parameters measured in this study were the maximum value of the swallowing pressures at velopharynx, meso-hypopharynx, and upper esophageal sphincter (UES) regions. The definition of the swallowing pressures at velopharynx, meso-hypopharynx and UES regions was described in our previous report in detail. In brief, the sites showing the velopharyngeal and meso-hypopharyngeal swallowing pressures were easily identified by vocalizing, "kakkakaka"[8].

To evaluate the effect of swallow type (noneffortful versus effortful) and bolus type (saliva versus 5ml ice water), statistical analysis was made using Wilcoxon signed-ranks test, and p-values below 0.05 were regarded as significant.

Results

On the color-graphic presentation of HRM system, the red color is deeper and wider with effortful swallow than without the effortful swallow while swallowing, indicating that the swallowing pressure increases and lasts longer with effortful swallow. The blue color in the UES region indicates that the UES relaxes with swallowing (Figure 2). All results in the present study are demonstrated in Figure 3, 4, and 5. During dry swallowing, the maximum values of pressures (mmHg) at the velopharynx, meso-hypopharynx, and UES regions were significantly higher with effortful swallow (155.7±59.7, 256.7±78.7, and 276.5±87.5, mean ± standard deviation) than without effortful swallow (115.3±60.8, 172.9±57.0 and195.8±61.3). Those of 5 ml ice water swallow pressures were also significantly higher with effortful swallow (169.3±69.1, 236.6±77.2, and 267.3±79.1) than without effortful swallow (119.2±59.7, 189.5±70.7, and 221.3±72.7). However, there were no significant differences in the maximum values of pressures between dry and ice-water swallows at any of the three regions regardless if the swallow was effortful or non-effortful (p=0.255 and p=0.723, p=0.136 and p=0.407, and p=0.981 and p=0.352, respectively).

The distances from the nostril to each point of maximum values of swallow pressures with effortful swallow were almost the same as those without effortful swallow at all the three regions (Table 1).

Discussion

As for effortful swallow, a more thorough investigation of this technique was needed to enable a clearer understanding of the biomechanical changes that occur in response to volitionally altered swallowing behaviors. Some publications have documented increased pressure generation [3-5], while the others report conflicting results [6]. As the novel HRM system has been established as one of the most appropriate tools for evaluating pharyngeal swallowing along the pharynx [8, 9] and esophagus [7], we conducted the present study clarifying the effect of effortful swallow pressures using it. To our best knowledge, this is the first study to investigate the effect of the effortful swallow pressures among velopharyngeal and UES regions with both dry and water swallows using HRM system.

In the present study, the maximum values of the pressures with effortful swallows at the velopharynx, meso-hypopharynx, and UES regions increased compared to those without effortful swallows without change of the positions of maximum values at any region in any swallow or any bolus type. The base of the tongue was identified as the main driving force in bolus propulsion [10, 11], and effortful swallow was designed to increase contact between the tongue base and posterior pharyngeal wall while swallowing [1, 2]. Therefore, we suppose that the base of the tongue may be a contributor for increased pharyngeal pressure in the meso-hypopharynx regions. We are not able to identify the exact point of the base of tongue in the meso-hypopharynx regions on HRM.

The pressure increase accompanied by the effortful swallows was observed not only in the meso-hypopharyngeal region, but also in the velopharyngeal and the UES regions. This suggests that the pressure increase might be caused also by voluntary stronger contractions of the superior and inferior pharyngeal constrictor muscles. Coulas et al. reported that effortful swallowing was linked to increased neck circumference, and speculated that it may reflect a number of physiological factors in combination [12]. From the present results, it was suggested that, as well as the middle pharyngeal constrictor muscle, the superior and inferior pharyngeal constrictor muscles may contribute to the increase in the pressure in all the regions of the pharynx during effortful swallowing by voluntarily constricting more strongly than usual.

In the present study, effortful swallowing revealed active changes in muscular contractions of all the three regions including velopharyngeal, meso-hypopharyngeal, and UES in healthy young participants. And these results provide us with some of the quantitative evidence of the effortful swallow as an effective rehabilitative measure, as well as its physiological information, and will hopefully be an aid to future clinical and investigative studies. As a next step, clinical extension of this research is needed to investigate the effect of the effortful swallow on patients with reduced base of tongue retraction or pharyngeal constrictor weakness in order to evaluate if this maneuver is effective for those patients as one of the rehabilitative measures for swallowing disorders.

Conclusion

The present results provide quantitative evidence of effortful swallow as well as physiological information. It also will hopefully be an aid to future clinical and investigative studies.

References

1. Logemann JA. Evaluation and treatment of swallowing disorders. 2nd edn. Austin TX: Pro-Ed; 1998. p221.

2. Kahrilas PJ, Lin S, Logemann JA, et al. Deglutitive tongue action: volume accommodation and bolus propulsion. Gastroenterology. 1993;104:152–162.

3. Huckabee ML, Butler SG, Barclay M, et al. Submental surface electromyographic measurement and pharyngeal pressures during normal and effortful swallowing. Arch Phys Med Rehabil. 2005;86:2144–2149.

4. Hiss SG, Huckabee ML. Timing of pharyngeal and upper esophageal sphincter pressures as a function of normal and effortful swallowing in young healthy adults. Dysphagia. 2005;20:149–156.

5. Huckabee ML, Steele CM. An analysis of lingual contribution to submental surface electromyographic measures and pharyngeal biomechanics during effortful swallow. Arch Phys Med Rehabil. 2006;87:1067–1072.

6. Bülow M, Olsson R, Ekberg O. Supraglottic swallow, effortful swallow, and chin tuck did not alter hypopharyngeal intrabolus pressure in patients with pharyngeal

dysfunction. Dysphagia. 2002;17:197–201.

7. Fox MR, Bredenoord AJ. Oesophageal high-resolution manometry—moving from research into clinical practice. Gut. 2008;57:405–423.

8. Takasaki K, Umeki H, Enatsu K, et al. Investigation of pharyngeal swallowing function using high-resolution manometry. Laryngoscope. 2008;118:1729-32.

9. Umeki H, Takasaki K, Enatsu K, et al. Effects of a tongue-holding maneuver during swallowing evaluated by high-resolution manometry. Otolaryngol Head Neck Surg. 2009;141:119-22.

10. Cerenko D, McConnel FM, Jackson RT. Quantitative assessment of pharyngeal bolus driving forces. Otolaryngol Head Neck Surg. 1989;100:57–63.

11. Kahrilas PJ, Logemann JA, Lin S, et al. Pharyngeal clearance during swallowing: a combined manometric and videofluoroscopic study. Gastroenterology. 1992;103:128–136.

12. Coulas VL, Smith RC, Qadri SS, et al. Differentiating Effortful and Noneffortful Swallowing with a Neck Force Transducer: Implications for the Development of a Clinical Feedback System. Dysphagia. 2009;24:7–12

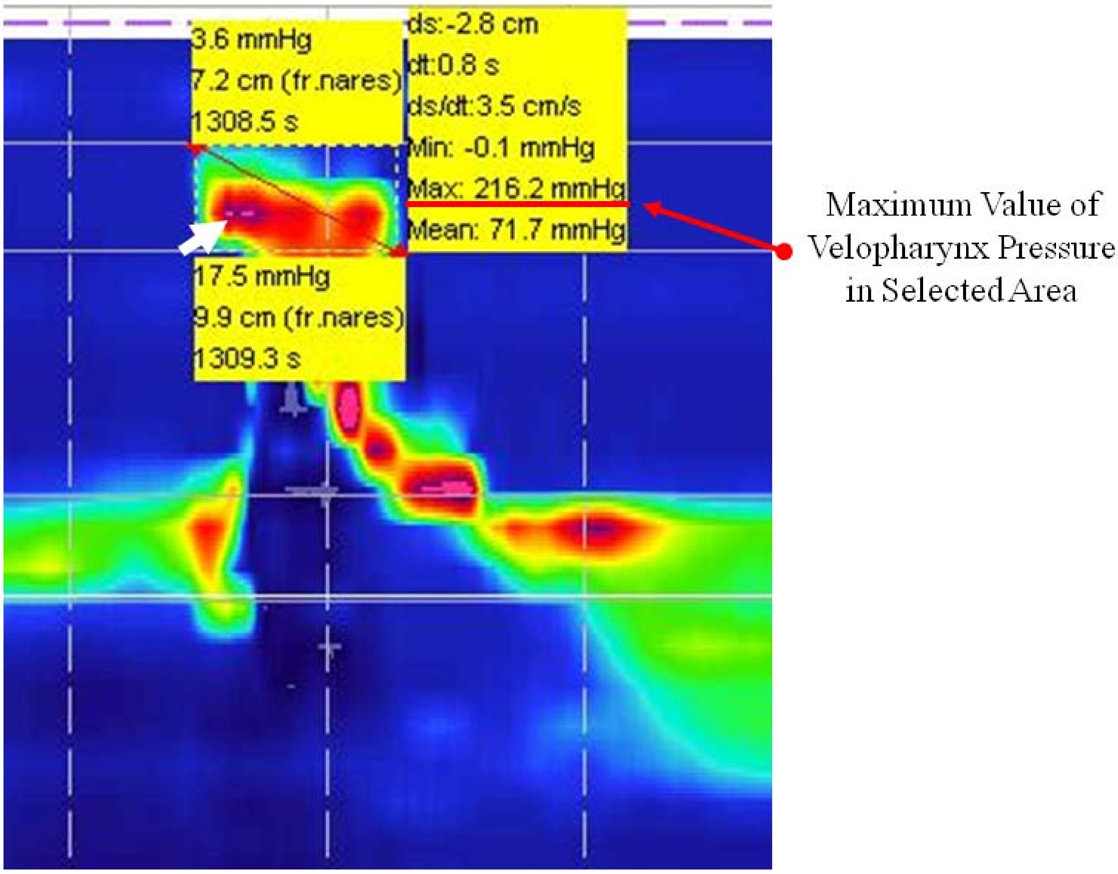

Figure 1.

Using ManoView™ analysis software, the maximum value of swallowing pressure in mmHg is demonstrated. A selected area (dotted line) shown in this figure is the velopharyngeal region. White Arrow revealed the maximum value of swallowing pressure in the area.

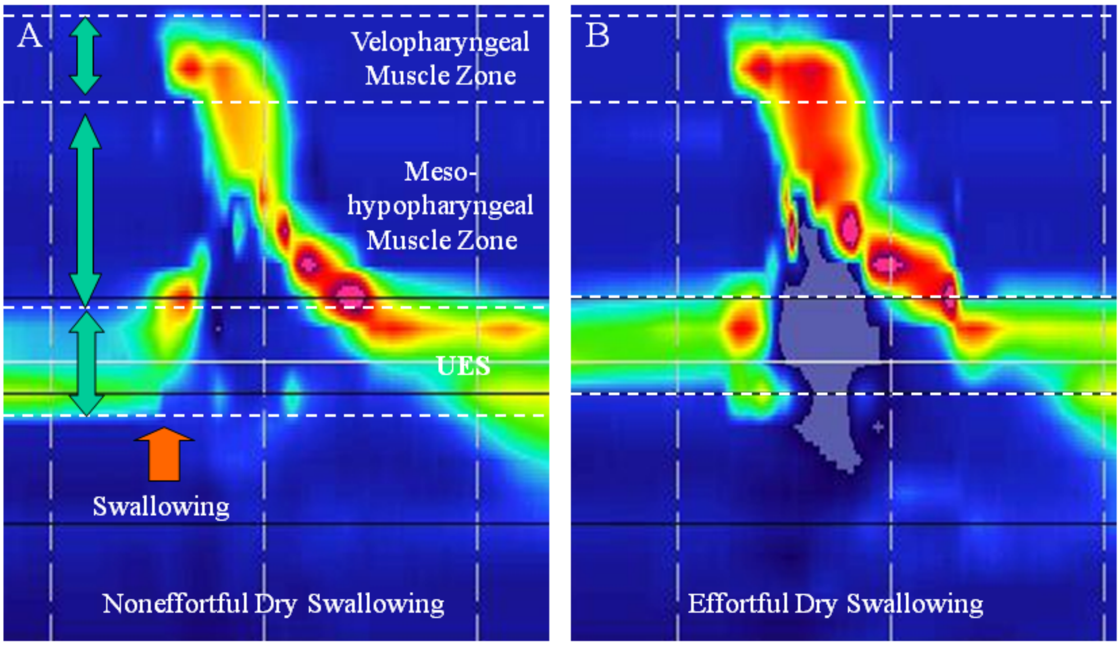

Figure 2.

Typical change of the color-graphic pattern during dry swallow without (A) and with (B) effortful swallow was demonstrated. The red color during dry swallow pressure was stronger and wider with effortful swallow (B) than without effortful swallow (A). The indicates that the pressure increased and lasted longer with the effortful swallow in all regions. UES: upper esophageal sphincter.

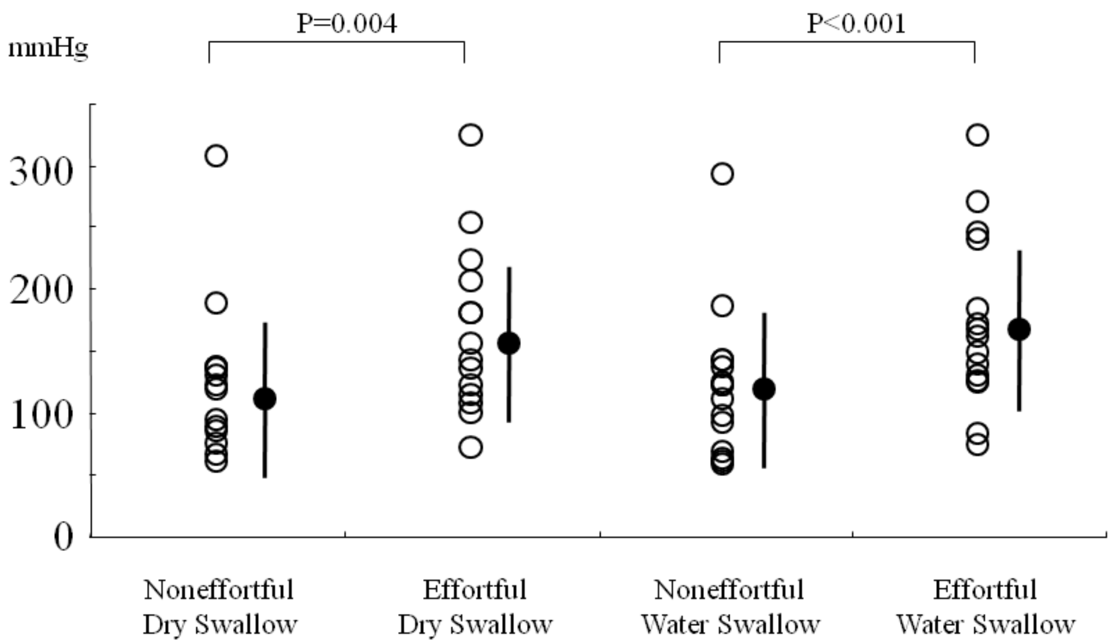

Figure 3.

Results of the maximum values of the dry and water swallow pressures with and without the effortful swallow at velopharyngeal region were demonstrated. Solid circles and bars indicated mean values and standard deviations, respectively.

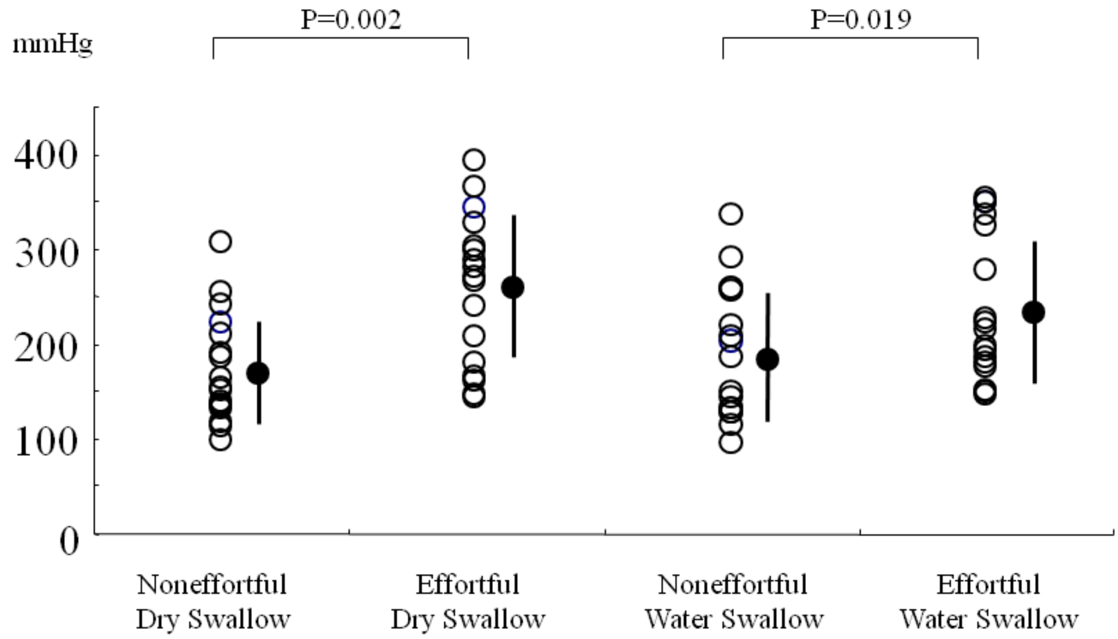

Figure 4.

Results of the maximum values of the dry and water swallow pressures with and without the effortful swallow at meso-hypopharyngeal region were demonstrated. Solid circles and bars are same as in Figure 3.

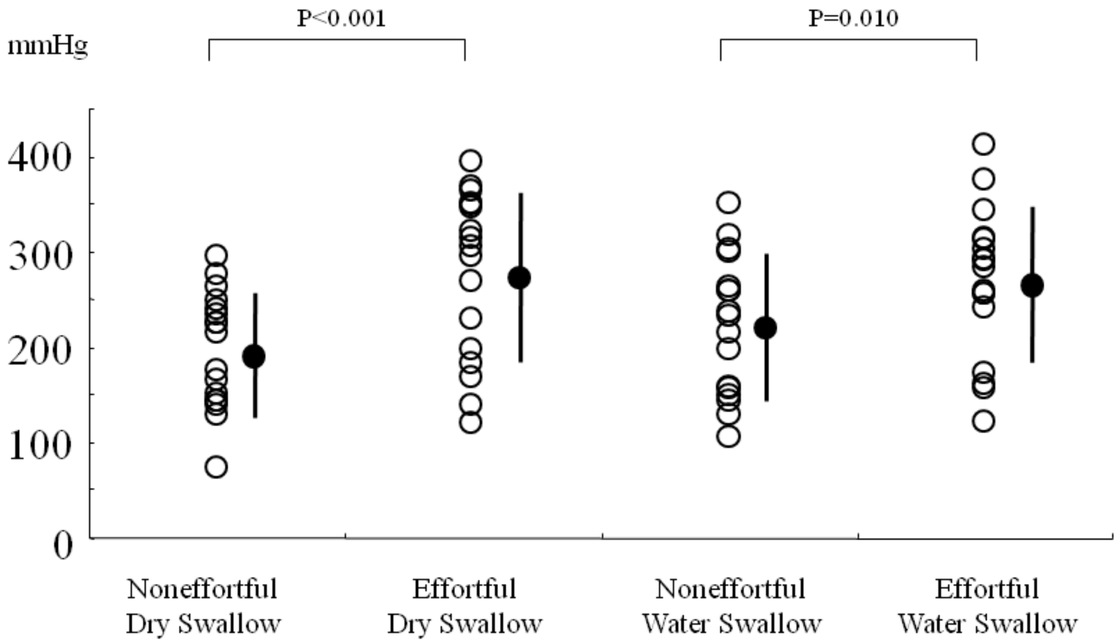

Figure 5

Results of the maximum values of the dry and water swallow pressures with and without the effortful swallow at the upper esophageal sphincter region were demonstrated. Solid circles and bars are same as in Figure 3.

Table 1: Distances (centimeter) from Nostril to Maximum Pressure Point of Velopharyx, Meso-hypopharyx and UES Regions

	Velopharyx	Meso-hypopharyx	UES
Noneffortful Dry Swallow	10.1±1.2	14.1±1.1	17.0±1.4
Effortful Dry Swallow	10.1±1.1	14.0±1.3	17.7±1.1
Noneffortful Water Swallow	10.6±1.5	14.0±1.1	17.2±1.5
Effortful Water Swallow	10.2±1.2	14.1±1.3	17.4±1.5

UES: Upper Esophageal Sphincter, ±:Standard Deviation