Alterations in the Swallowing Function According to the Severity of Obstructive Sleep Apnea Syndrome

Bora Mun, M.D.¹, Min-Keun Song, M.D., Ph.D.¹, Hyung Chae Yang, M.D., Ph.D.², In Sung Choi, M.D., Ph.D.¹

¹Department of Physical and Rehabilitation Medicine, Chonnam National University Medical School and Hospital, Gwangju, ²Department of Otolaryngology-Head and Neck Surgery, Chonnam National University Medical School and Hospital, Gwangju, Korea

Objective: Obstructive sleep apnea syndrome (OSAS) is a sleep-related breathing disorder that can have a significant impact on the quality of life. According to recent studies, some OSAS patients exhibit swallowing abnormalities, such as the premature entry of food into the hypopharynx, and laryngeal penetration. We aimed to evaluate the swallowing function of OSAS patients and compare swallowing-related parameters between OSAS severity groups through a video fluoroscopic swallowing study (VFSS).

Methods: Ninety-two participants with a symptom of snoring were enrolled in this retrospective study. Eighty-four participants were diagnosed with OSAS by polysomnography. The subjects were evaluated using the apnea-hypopnea index (AHI) and divided into four groups, namely non-OSAS, mild, moderate, and severe OSAS. Since all patients reported choking symptoms, they underwent VFSS and were evaluated for penetration or aspiration. The temporal parameters evaluated were oral transit time, pharyngeal transit time, and pharyngeal delay time. The movement parameters assessed were the distance, duration, and velocity of laryngeal elevation (LE).

Results: Penetration was detected in six OSAS patients, but aspiration was not observed in any patient. Seventy-four patients showed vallecular and pyriform sinus residue, although the amount was not significantly large. There was no significant difference in any of the temporal parameters between the groups except pharyngeal transit time with 10 ml of yogurt. In the Pearson's correlation and multivariate linear regression analysis, LE distance and LE velocity, both correlated with AHI scores with 5 ml of liquid, 10 ml of liquid, and 10 ml of yogurt, respectively.

Conclusion: Severe OSAS patients showed longer and faster hyolaryngeal movement while swallowing, which may be a compensatory movement to prevent penetration or aspiration. (JKDS 2022;12:14-23)

Keywords: Obstructive sleep apnea syndrome, Deglutition, Videofluoroscopic swallowing study, Laryngeal elevation

Received: July 23 2021, Revised: July 23 2021, Accepted: November 1 2021

Corresponding author: In Sung Choi, Department of Physical and Rehabilitation Medicine, Chonnam National University Medical School and Hospital, 42 Jebong-ro, Dong-gu, Gwangju 61469, Korea
Tel: +82-62-220-5198, Fax: +82-62-228-5975, E-mail: drchoiis@hanmail.net

Co-Corresponding author: Hyung Chae Yang, Department of Otolaryngology-Head and Neck Surgery, Chonnam National University Medical School and Hospital, 42 Jebong-ro, Dong-gu, Gwangju 61469, Korea
Tel: +82-62-220-6788, Fax: +82-62-228-7743, E-mail: blessed@jnu.ac.kr

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited. Copyrights © The Korean Dysphagia Society, 2022.

INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is a sleep-related breathing disorder characterized by intermittent episodes of upper airway obstruction causing breathing cessation (apnea) or airflow reduction (hypopnea) during sleep¹. OSAS is a public health issue associated with cardiovascular and neurobehavioral impairments^{2,3}.

Respiration and swallowing rely on the same tract. Coordinated activity between respiration and swallowing is necessary for adequate ventilation without aspiration⁴. Anterior and superior displacement of the hyolaryngeal complex during swallowing closes the airway and opens the upper esophageal sphincter^{5,6}. Because swallowing inhibits respiration, respiratory disorders often compromise swallowing safety⁷.

Many studies have demonstrated that dysphagia is associated with OSAS⁸⁻¹¹. In a recent questionnaire-based study, 15% of OSAS patients had symptoms of dysphagia¹². Subclinical swallowing abnormalities were detected in more than half of the patients with snoring and OSAS, compared to only 7% of the controls^{9,10}. On fiberoptic endoscopic evaluation of swallowing (FEES), OSAS patients have subclinical swallowing abnormalities without laryngeal penetration or aspiration¹³. The relationship between the severity of OSAS and swallowing dysfunction is controversial. Teramoto et al. reported that OSAS patients had significantly higher threshold volumes and latencies for the water-stimulated swallowing reflex, leading to an increased risk for aspiration⁹. In other studies, OSAS severity was not associated with the risk for dysphagia. In addition, no significant differences were detected on FEES between moderate and severe OSAS patients¹⁴.

Videofluoroscopic swallowing study (VFSS) is the gold standard for evaluation of swallowing¹⁵. VFSS identifies laryngeal penetration or aspiration, and measures hyolaryngeal complex displacement. In previous studies using VFSS, patients with OSAS or snoring had abnormal pharyngeal function, impaired bolus control, premature spillage, and a delayed

swallowing reflex compared to healthy controls^{13,14}. Although these studies measured food residues and laryngeal penetration, they did not measure swallowing dysfunction quantitatively. Various temporospatial parameters, such as laryngeal elevation (LE), oral transit time (OTT), pharyngeal transit time (PTT), and pharyngeal delay time (PDT) can be measured using VFSS. In the current study, we measured the time taken by food boluses to travel from the oral cavity to the pharynx, and the degree of LE as an index of swallowing in OSAS patients. We hypothesized that LE is reduced in OSAS patients and severe OSAS group displays severe impairment. We also investigated swallowing parameters according to OSAS severity.

MATERIALS AND METHODS

1. Study design and subjects

We retrospectively reviewed the medical records of 92 snoring patients (68 men and 24 women) between December 2016 and February 2019. The enrolled patients visited the hospital complaining of snoring, sleep disturbance or excessive daytime sleepiness. On history taking, they also reported a feeling of choking symptom and lump sensation in the throat during swallowing. The average duration of snoring was 10.5 years on the record. OSAS was diagnosed on the basis of overnight level I polysomnography, performed using the Embla N7000 instrument and RemLogic 2.0.0 (Embla Systems, Denver, CO, USA) in accordance with the American Academy of Sleep Medicine guidelines¹⁶. The apnea-hypopnea index (AHI) represents the average number of apnea (cessation of airflow for ≥ 10 s) and hypopnea (reduced airflow) events per hour of sleep. OSAS was diagnosed if AHI was ≥ 5 and there were symptoms or signs of OSAS (such as loud snoring, disturbed sleep, daytime sleepiness, or fatigue). OSAS was diagnosed in 80 participants; 8 participants did not have OSAS. Participants were divided into four OSAS severity groups on the basis of the AHI score¹⁷: non-OSAS ($< \text{AHI} < 5$; $n=8$), mild OSAS ($5 \leq \text{AHI} < 15$; $n=19$), moderate OSAS ($15 \leq \text{AHI} < 30$; $n=22$), and severe

OSAS (AHI $\geq$ 30; n=39) groups. Healthy individuals for control group were not included in this study. Non-OSAS group was compared with other three groups. None of the patients had and a history of surgery for snoring or OSAS. All patients did not have a medical history of neuromuscular diseases or brain disorders.

Table 1 summarizes the general characteristics of the participants, including age, sex, body mass index (BMI), and underlying diseases such as hypertension and diabetes mellitus. Tonsils, tongue, and nasal septum were examined using a laryngoscope. The tonsils were graded in accordance with the Friedman's grading system: within pillars (grade 1); extending to the pillars (grade 2); extending beyond the pillars (grade 3); or extending to the midline (grade 4)¹⁸. Tongue position was also analyzed in accordance with the Friedman system: uvula and tonsils/pillars visible (grade 1); most of the uvula visible, but not the tonsils/pillars (grade 2); soft palate visible up to the base of uvula (grade 3); and only a portion of the soft palate visible (grade 4)¹⁹. Deviated nasal septum was defined as a nasal septum deviated on inspection and

obstructing entry of a rigid endoscope into the nasal cavity. The Institutional Review Board of Chonnam National University Hospital approved this study (CNUH-2019-059).

2. Videofluoroscopic swallowing study

VFSS was planned because the patients complained about a feeling of choking or lump sensation during swallowing. VFSS was conducted by a physiatrist and an occupational therapist, using a modified version of the method described by Logemann²⁰. Participants were seated on a chair at an angle of 90° to the fluoroscope. They swallowed 5 ml and 10 ml water mixed with barium, followed by 5 ml and 10 ml of yogurt, a spoonful of porridge, and cooked rice. Videos were recorded and analyzed by a physiatrist. Vallecular residue, pyriform sinus residue, penetration and aspiration were checked after swallowing the liquid and yogurt. The amount of vallecular and pyriform sinus residue after swallowing was classified into four grades (grade 0, no residue; grade 1, $\leq$ 10% of all widths of the valleculae or pyriform sinus in the VFSS image; grade 2, 10-50% of all widths of the

Table 1. General characteristics of the study participants.

	Non-OSAS (n=8)	Mild OSAS (n=23)	Moderate OSAS (n=22)	Severe OSAS (n=39)	P-value
AHI	2.3 $\pm$ 1.4	9.8 $\pm$ 2.9	21 $\pm$ 4.2	54 $\pm$ 15.5	<*.001
Age (years)	43.9 $\pm$ 12.4	46.3 $\pm$ 11.6	57.7 $\pm$ 12.4	49.5 $\pm$ 11.4	*.005
Sex (male)	4	17	13	34	*.031
Symptom period (years)	10.5 $\pm$ 13.6	9.6 $\pm$ 7.0	15.2 $\pm$ 15.0	8.3 $\pm$ 8.7	.174
Hypertension	1 (12.5%)	7 (36.8%)	5 (22.7%)	14 (35.9%)	.565
DM	1 (12.5%)	1 (5.3%)	3 (13.6%)	4 (10.3%)	.658
Tonsil grade					
1	5	11	12	29	.339
2	0	6	3	4	
3	0	3	1	2	
4	0	0	0	0	
Palate grade					
1	2	4	5	8	.383
2	0	1	3	1	
3	1	2	6	11	
4	5	9	4	16	
Deviated septum	6	17	19	28	.672
BMI	25.8 $\pm$ 3.0	26.5 $\pm$ 4.7	25.8 $\pm$ 2.4	28.5 $\pm$ 4.2	*.041

Values are means $\pm$ standard deviations. *P<.05

OSAS: obstructive sleep apnea syndrome, HI: apnea-hypopnea index, DM: diabetes mellitus, BMI: body mass index.

Non-OSAS: AHI<5; mild: 5 $\leq$ AHI<15; moderate: 15 $\leq$ AHI<30; severe: AHI $\geq$ 30.

valleculae or pyriform sinus; and grade 3, $\geq 50\%$ of all widths of the valleculae or pyriform sinus)²¹. Temporal and movement parameters were measured using a video analysis tool (VEGAS[®] Pro video editor; MAGIX, Berlin, Germany). The temporal parameters were OTT, PTT, and PDT. OTT was defined as the time between bolus entry into the mouth and the bolus head reaching the lower border of the mandible after crossing the tongue base. PTT was defined as the time between the start of bolus head entry at the lower border of the mandible and bolus tail passage through the cricopharyngeal region. PDT was defined as the time between the bolus head at the lower border of the mandible crossing the tongue base and the starting point of LE¹⁵. Movement parameters were the distance, duration, and velocity of LE. LE was defined as the vertical distance between the uppermost point of the larynx at rest and the maximal laryngeal excursion²². (Fig. 1) The duration of LE was defined as the time between the start of LE and the maximum elevation. The LE velocity was calculated by dividing the LE distance by the LE duration.

3. Statistical analysis

Statistical analyses were performed using SPSS Statistics software (version 23.0; IBM Corp., Armonk, NY, USA). Data are presented as means and standard deviations. Differences among the groups were analyzed using one-way analysis of variance (ANOVA)

and post hoc tests. Pearson's correlation coefficient was used to evaluate the relationship between swallowing parameters and OSAS severity. Multivariate linear regression analysis was used to determine the association between parameters and OSAS severity using Stata (version 16.0; StataCorp, College Station, TX, USA) and the data result was confirmed by a statistician. A P -value $< .05$ was taken to indicate statistical significance.

RESULTS

In biomedical characteristics, there were no significant differences among the four groups, except in sex and BMI. Compared to the other groups, the severe OSAS group had a male predominance ($P=.031$) and the highest BMI ($P=.041$). (Table 1)

During VFSS, vallecular residue and pyriform sinus residue were observed in non-OSAS ($n=6$), mild OSAS ($n=16$), moderate OSAS ($n=17$), and severe OSAS ($n=35$) groups. However, the grades of vallecular or pyriform sinus residue were 0 or 1 in all groups, indicating that there was no considerably large amount of food residue. Subglottic penetration was observed infrequently in the mild ($n=2$), moderate ($n=2$), and severe ($n=2$) OSAS groups, whereas subglottic penetration was not observed in the non-OSAS group. Tracheal aspiration was not seen in any group.

There were no significant differences in temporal parameters among the groups except PTT with 10 ml

Fig. 1. Measurement of laryngeal elevation using lateral view image of videofluoroscopic swallowing study. (A) At the laryngeal rest position, (B) maximal laryngeal excursion position. d: the distance between rest and maximal laryngeal excursion state, r: reference diameter (2.4 cm).

of yogurt.(Table 2) PTT with 10 ml of yogurt was significantly different among the groups ($P=.033$), moderate OSAS group being the fastest. The LE distance in liquid 5 ml, 10 ml was significantly different among the groups ($P=.001$ and $P=.036$, respectively). The LE velocity in liquid 5 ml and yogurt 10 ml was significantly different among the groups ($P=.006$ and $P=.037$, respectively). With 5 ml of liquid, the LE distance and velocity were significantly greater in the severe OSAS group compared to the other groups. Post hoc Bonferroni correction revealed longer and faster LE movements in the severe OSAS group compared to the non-OSAS group ($P=.012$ and $P=.010$, respectively).(Table 3) In Pearson's correlation, symptom period was not correlated with temporal parameters and movement parameters for all food consistencies. The OTT, PTT, and PDT did not correlate with the AHI. However, the LE distance was significantly correlated with the AHI for all food consistencies ($r=0.510$, $P<.001$; $r=0.358$, $P=.001$; $r=0.323$, $P=.002$; $r=0.371$, $P<.001$; $r=0.322$, $P=.002$; and $r=0.242$, $P=.020$ with progressively increasing food consistency). The LE velocity was also

positively correlated with the AHI, for all food consistencies ($r=0.427$, $P<.001$; $r=0.275$, $P=.010$; $r=0.262$, $P=.012$; $r=0.374$, $P=.001$; $r=0.311$, $P=.003$; and $r=0.254$, $P=.015$ with progressively increasing food consistency).(Fig. 2)

In multivariate linear regression analysis adjusted for age, sex, BMI, diabetes mellitus, and hypertension, there was no notable association between AHI score and temporal parameters of swallowing. As the AHI score increases, LE distance tend to increase in 5 ml, 10 ml of liquid and 5 ml, 10 ml of yogurt ($P<0.001$, $P=.033$, $P=.037$ and $P=0.010$, respectively). LE velocity also significantly correlated with AHI score in 5 ml, 10 ml of liquid and 10 ml of yogurt and porridge ($P=0.001$, $P=0.049$, $P=0.010$ and $P=0.043$, respectively).(Table 4)

DISCUSSION

Respiration and swallowing rely on the same tract. As respiration is inhibited during swallowing, respiratory disorders often compromise swallowing safety⁷. Recent systematic reviews have demonstrated

Table 2. Temporal parameters of swallowing according to the severity of OSAS.

Parameters	Diet	Amount	Non-OSAS	Mild OSAS	Moderate OSAS	Severe OSAS	P-value
OTT (s)	Liquid	5	0.78±0.48	0.78±0.38	0.64±0.33	0.65±0.44	.530
		10	0.72±0.26	0.61±0.29	0.69±0.37	0.70±0.41	.757
	Yogurt	5	0.83±0.57	0.83±0.43	0.76±0.45	0.76±0.37	.877
		10	0.77±0.53	0.63±0.35	0.65±0.29	0.74±0.35	.577
	Porridge		0.43±0.26	0.63±0.35	0.63±0.31	0.65±0.37	.405
	Cooked rice		1.00±1.26	0.65±0.51	0.69±0.33	0.80±0.44	.400
	Liquid	5	0.36±0.22	0.36±0.23	0.33±0.19	0.31±0.22	.835
		10	0.46±0.18	0.46±0.22	0.34±0.22	0.45±0.24	.239
PTT (s)	Yogurt	5	0.37±0.19	0.33±0.20	0.35±0.30	0.38±0.35	.908
		10	0.44±0.22	0.42±0.19	0.30±0.17	0.47±0.22	*.033
	Porridge		0.35±0.19	0.36±0.22	0.43±0.45	0.39±0.32	.904
	Cooked rice		0.37±0.15	0.43±0.26	0.39±0.44	0.52±0.67	.769
	Liquid	5	0.17±0.10	0.14±0.10	0.15±0.10	0.13±0.10	.726
		10	0.09±0.04	0.10±0.08	0.10±0.07	0.10±0.05	.953
	Yogurt	5	0.12±0.08	0.11±0.08	0.14±0.13	0.14±0.09	.760
		10	0.07±0.02	0.09±0.04	0.09±0.05	0.11±0.07	.428
PDT (s)	Porridge		0.178±0.15	0.15±0.13	0.21±0.37	0.15±0.10	.716
	Cooked rice		0.11±0.091	0.21±0.19	0.19±0.36	0.19±0.19	.764

Values are means±standard deviations.

OSAS: obstructive sleep apnea syndrome, OTT: oral transit time, PTT: pharyngeal transit time, PDT: pharyngeal delay time.

Non-OSAS: AHI<5; mild: 5≤AHI<15; moderate: 15≤AHI<30; severe: AHI≥30.

Table 3. Movement parameters of laryngeal elevation according to the severity of OSAS.

Parameters	Diet	Amount	Non-OSAS	Mild OSAS	Moderate OSAS	Severe OSAS	P-value
LE distance (cm)	Liquid	5	2.11±0.46	2.18±0.51	2.38±0.34	2.58±0.38	*.001
		10	2.09±0.49	2.32±0.53	2.58±0.45	2.55±0.45	*.036
	Yogurt	5	2.34±0.61	2.30±0.51	2.49±0.50	2.56±0.41	.118
		10	2.515±0.58	2.33±0.50	2.42±0.51	2.58±0.43	.084
	Porridge		2.35±0.55	2.41±0.56	2.61±0.36	2.63±0.53	.231
	Cooked rice		2.35±0.553	2.41±0.56	2.61±0.36	2.69±0.53	.407
LE duration (s)	Liquid	5	0.96±0.13	0.84±0.17	0.91±0.24	0.85±0.18	.320
		10	0.92±0.11	0.85±0.16	0.94±0.21	0.90±0.18	.718
	Yogurt	5	0.82±0.09	0.79±0.14	0.88±0.22	0.83±0.17	.390
		10	0.82±0.05	0.86±0.16	0.94±0.22	0.83±0.17	.164
	Porridge		0.67±0.70	0.37±0.18	0.76±0.18	0.71±0.13	.404
	Cooked rice		0.72±0.09	0.75±0.17	0.77±0.16	0.72±0.13	.684
LE velocity (cm/s)	Liquid	5	2.81±0.93	2.97±0.77	2.71±0.57	3.12±0.67	*.006
		10	1.96±0.96	2.88±0.88	2.60±1.05	2.82±0.97	.165
	Yogurt	5	2.81±0.92	2.97±0.71	2.93±0.74	3.21±0.82	.368
		10	2.34±1.22	2.74±0.60	2.40±1.04	3.00±1.01	*.037
	Porridge		3.54±0.85	3.37±0.85	3.57±0.82	3.82±0.99	.306
	Cooked rice		3.40±0.84	3.52±1.07	3.83±0.99	3.66±0.98	.536

Values are means±standard deviations. *P<.05

OSAS: obstructive sleep apnea syndrome, LE: laryngeal elevation.

Non-OSAS: AHI<5; mild: 5≤AHI<15; moderate: 15≤AHI<30; severe: AHI≥30.

Fig. 2. Correlation between AHI score and the LE distance (A) and LE velocity (B). AHI: apnea-hypopnea index, LE: laryngeal elevation.

that OSAS patients have impaired swallowing, such as premature bolus loss, residue in the hypopharynx, and laryngeal penetration^{13,14,23,24}. The most frequently reported abnormality was premature spillage of food^{9,10}.

The prevalence of dysphagia in OSAS patients varies among studies^{12,24}. In a study of FEES in

patients with symptomatic OSAS, 34 out of 35 patients had dysphagia¹². Similarly, another study of FEES in OSAS patients demonstrated that 27.3% of patients had dysphagia²⁵. However, despite the presence of objective swallowing abnormalities, OSAS patients did not voluntarily report symptoms of dysphagia^{23,26}. In a recent study, 15% of OSAS patients

Table 4. Multivariate linear regression analysis for the association between AHI and movement parameters of laryngeal elevation.

Parameters	Diet	Amount	Adjusted	
			Coefficient (95% CI)	P-value
LE distance	Liquid	5	0.008 (0.004-0.012)	*<.001
		10	0.005 (0.001-0.010)	*.033
	Yogurt	5	0.005 (0.000-0.010)	*.037
		10	0.007 (0.002-0.011)	*.010
	Porridge		0.005 (0.000-0.010)	.073
	Cooked rice		0.004 (-0.001-0.010)	.124
LE duration	Liquid	5	-0.001 (-0.003-0.001)	.399
		10	0.000 (-0.002-0.001)	.620
	Yogurt	5	0.000 (-0.002-0.002)	.921
		10	0.000 (-0.002-0.001)	.610
	Porridge		-0.001 (-0.002-0.001)	.505
	Cooked rice		0.000 (-0.002-0.001)	.778
LE velocity	Liquid	5	0.012 (0.005-0.019)	*.001
		10	0.008 (0.000-0.017)	*.049
	Yogurt	5	0.006 (-0.002-0.014)	.122
		10	0.010 (0.002-0.017)	*.010
	Porridge		0.010 (0.000-0.019)	*.043
	Cooked rice		0.007 (-0.003-0.017)	.169

LE: laryngeal elevation.

All values are presented as the beta coefficient (95% confidence interval). *P<.05

Multivariate linear regression models were adjusted for age, sex, BMI, diabetes, hypertension.

reported symptoms of dysphagia¹². During preoperative evaluation, 17% of the primary snoring and OSAS patients had symptoms of dysphagia, and more than half had swallowing abnormalities during VFSS²⁶. Swallowing dysfunction does not appear to be serious in OSAS patients²⁵. In a previous study, laryngeal penetration was observed in 5% of the OSAS patients, but subglottic aspiration was not observed⁹. In another study, penetration occurred in only 2 out of 60 OSAS patients²⁸. In the present study, large amount of vallecular or pyriform sinus residue was not checked. Penetration was detected in 6 out of 84 OSAS patients, but aspiration was not observed. Penetration or aspiration may even occur in healthy people²⁹, which may explain why many OSAS patients do not complain of dysphagia.

The definite association between OSAS and dysphagia is not known yet. Some studies suggests that neurogenic disorders of the oropharynx impair mucosal sensory function and swallowing reflex triggering, as upper airway can be impaired in OSAS patients^{9,10,30}. Other studies also reported the anatomi-

mical differences of oropharyngeal structures in OSAS patients. Craniofacial disharmony such as inferiorly placed hyoid bone, longer airway length to vocal cord, reduced pharyngeal airway space and increased anterior facial heights have been suggested to be significant in OSAS patients³¹⁻³³. These differences are also important in dysphagia. The depressed resting position of hyoid bone can disturb the temporal coordination of laryngeal closure, and as a result, the risk of choking symptom increases^{34,35}. The exact pathophysiologic relationship between OSAS and dysphagia still remains unclear, but it seems to be multifactorial.

Previous studies only assessed qualitative parameters of swallowing, such as premature bolus loss, food residue, penetration, or aspiration during instrumental evaluation; quantitative parameters were not evaluated. In this VFSS, temporal and movement parameters of swallowing were measured in patients with OSAS of varying severity. There were no significant differences among the four groups in terms of OTT, PDT, PTT, or LE duration except PTT with 10 ml of yogurt.

These results are in agreement with those of previous studies. The frequency and severity of swallowing dysfunction are not correlated with the severity of OSAS^{8,9,14}. The fastest PTT with 10 ml of yogurt in moderate OSAS group may be a non-specific finding considering the tendency of PTT in other food consistencies.

During swallowing, LE plays an important role in airway protection. Contraction of the suprahyoid muscles results in forward and upward movement of the hyolaryngeal complex, which closes the airway and opens the upper esophageal sphincter during swallowing^{5,6,36}. We initially hypothesized that LE is reduced in OSAS patients due to repetitive low-frequency vibrations causing impaired neuromuscular function and thus anticipated severe impairment in the severe OSAS group. Contrary to our hypothesis, LE was within the normal range in all patients exceeding the reference values of our laboratory. There were significant differences in LE distance and velocity among the groups. The LE distance was greatest in the severe OSAS group. A meta-analysis reported reduced pharyngeal airway space and inferiorly placed hyoid bones in adult OSAS patients³¹. Yamashiro et al. performed polysomnography and computed tomography in 249 OSAS patients, and demonstrated an association between OSAS severity and the distance between the posterior edge of the hard plate and vocal cords³². Similarly, there was a significant association between the position of the hyoid bone in the vertical plane and OSAS severity³³. Our study result is in accord with these previous studies³¹⁻³³. We found associations of LE distance and velocity with OSAS severity. Considering that there was no significant difference in laryngeal movement pattern among groups, the difference in LE distance and velocity suggests that the hyolaryngeal complex needs to move faster and travel longer distance because of its lower position. Faster movement of the hyolaryngeal complex may be a compensatory movement to prevent laryngeal penetration or aspiration events in the severe OSAS group. And this result was more prominent in less

viscous diet like water or yogurt. The reason of lower displacement of hyolaryngeal complex in OSAS patients is not yet known. In our opinion, repetitive micro-injury such as vibration or mucosal dryness in OSAS patients not only leads to sensory disturbance in neuromuscular junction³⁰ but also may cause alteration of muscle tone of hyolaryngeal complex, which is known to increase the risk of aspiration^{34,35}.

This study had several limitations. First, the sample size might be not enough to compare swallowing parameters between OSAS group and non-OSAS group. Furthermore, the healthy participants with no OSAS symptom and choking symptom were not included in our study. As a retrospective study, it was unavailable to collect the data of normal participants since only patients with choking symptom visited for VFSS. A prospective study with larger number of normal control group would be helpful to verify our findings. Second, the method used for measurement of LE in this study was different from previous studies, in which anterior and superior displacement of the hyoid bone and larynx were measured separately. We only measured vertical movement of the uppermost point of the larynx. Therefore, the values obtained in our study cannot be compared to those of other studies. Third, we did not subdivide the cause of OSAS and dysphagia. Both OSAS and dysphagia are closely related with the function of oropharyngeal muscle, but the pathophysiology of OSAS and dysphagia are highly heterogeneous. Subgroup analysis according to the pathogenesis of these diseases would be helpful to evaluate the clear association between OSAS and dysphagia. However, not only it is clinically difficult to figure out the exact cause of OSAS and dysphagia, but also there is no widely accepted classification for OSAS yet. Further studies about the categorization of OSAS and correlation with dysphagia would be needed.

In conclusion, severe OSAS patients showed longer and faster hyolaryngeal movement while swallowing, which may be a compensatory movement to prevent laryngeal penetration or aspiration events. To confirm the definite pathophysiologic association between

OSAS and dysphagia, large-scale prospective studies are required.

ACKNOWLEDGEMENTS

This study was supported by National Research Foundation of Korea (NRF-2019R1F1A1062089) and a grant (BCRI-20071) from Chonnam National University Hospital Biomedical Research Institute.

REFERENCES

1. Strollo PJ, Rogers RM. Obstructive sleep apnea. *N Engl J Med*. 1996;334:99-104.
2. Shamsuzzaman AS, Gersh BJ, Somers VK. Obstructive sleep apnea: implications for cardiac and vascular disease. *JAMA*. 2003;290:1906-14.
3. Punjabi NM, Caffo BS, Goodwin JL, Gottlieb DJ, Newman AB, O'Connor GT et al. Sleep-disordered breathing and mortality: a prospective cohort study. *PLoS Med*. 2009;6:e1000132.
4. Nishino T. The swallowing reflex and its significance as an airway defensive reflex. *Front Physiol*. 2013;3:489.
5. Kahrilas PJ, Lin S, Rademaker AW, Logemann JA. Impaired deglutitive airway protection: a videofluoroscopic analysis of severity and mechanism. *Gastroenterology*. 1997;113:1457-64.
6. Jacob P, Kahrilas PJ, Logemann JA, Shah V, Ha T. Upper esophageal sphincter opening and modulation during swallowing. *Gastroenterology*. 1989;97:1469-78.
7. Groher ME, Crary MA. *Dysphagia. Clinical management in adults and children*. 2nd ed. St. Louis, Missouri: Elsevier, 2016.
8. Jäghagen EL, Frankli KA, Isberg A. Snoring, sleep apnoea and swallowing dysfunction: a videoradiographic study. *Dentomaxillofac Radiol*. 2003;32:311-6.
9. Teramoto S, Sudo E, Matsuse T, Ohga E, Ishii T, Ouchi Y et al. Impaired swallowing reflex in patients with obstructive sleep apnea syndrome. *Chest*. 1999;116:17-21.
10. Jäghagen EL, Berggren D, Isberg A. Swallowing dysfunction related to snoring: a videoradiographic study. *Acta Otolaryngol*. 2000;120:438-43.
11. Jobin V, Champagne V, Beauregard J, Charbonneau I, McFarland DH, Kimoff RJ. Swallowing function and upper airway sensation in obstructive sleep apnea. *J Appl Physiol* (1985). 2007;102:1587-94.
12. Pizzorni N, Radovanovic D, Pecis M, Lorusso R, Annoni F, Bartorelli A et al. Dysphagia symptoms in obstructive sleep apnea: prevalence and clinical correlates. *Respir Res*. 2021;22:117.
13. Valbuza JS, de Oliveira MM, Zancanella E, Conti CF, Prado LB, Carvalho LB et al. Swallowing dysfunction related to obstructive sleep apnea: a nasal fibroscopy pilot study. *Sleep Breath*. 2011;15:209-13.
14. Schindler A, Mozzanica F, Sonzini G, Piebani D, Urbani E, Pecis M et al. Oropharyngeal dysphagia in patients with obstructive sleep apnea syndrome. *Dysphagia*. 2014;29:44-51.
15. Logemann JA. *Evaluation and treatment of swallowing disorders*. 2nd ed. Texas: Austin, 1998.
16. American Academy of Sleep Medicine. *International classification of sleep disorders, 2nd Edition : Diagnostic and coding manual*. Westchester, IL : American Academy of Sleep Medicine, 2005.
17. American Academy of Sleep Medicine Task Force. Sleep-related breathing disorders in adults: Recommendations for syndrome definition and measurement techniques in clinical research. The Report of an American Academy of Sleep Medicine Task Force. *Sleep*. 1999;22:667-89.
18. Friedman M, Tanyeri H, La Rosa M, Landsberg R, Vaidyanathan K, Pieri S et al. Clinical predictors of obstructive sleep apnea. *Laryngoscope*. 1999;109:1901-7.
19. Friedman M, Ibrahim H, Joseph NJ. Staging of obstructive sleep apnea/hypopnea syndrome: a guide to appropriate treatment. *Laryngoscope*. 2004;114:454-9.
20. Logemann JA. *Manual for the Videofluorographic Study of Swallowing*. 2nd ed. Texas: Austin, Texas, 1993.
21. Han TR, Paik NJ, Park JW. Quantifying swallowing function after stroke: A functional dysphagia scale based on videofluoroscopic studies. *Arch Phys Med Rehabil*. 2001;82(5):677-82.
22. Zhang J, Zhou Y, Wei N, Yang B, Wang A, Zhou H et al. Laryngeal Elevation Velocity and Aspiration in Acute Ischemic Stroke Patients. *PLoS One*. 2016;11:e0162257.
23. Bhutada AM, Broughton WA, Focht Garand KL. Obstructive sleep apnea syndrome (OSAS) and swallowing function-a systematic review. *Sleep Breath*. 2020;24:791-9.
24. Ghannouchi I, Speyer R, Doma K, Cordier R, Verin E. Swallowing function and chronic respiratory diseases: Systematic review. *Respir Med*. 2016;117:54-64.
25. Campanholo MAT, Caparroz FA, Stefanini R, Haddad L, Bittencourt LRA, Tufik S et al. Dysphagia in patients with moderate and severe obstructive sleep apnea. *Braz J Otorhinolaryngol*. 2019;15:S1808-8694(19)30137-5.
26. Corradi AMB, Valarelli LP, Grechi TH, Eckeli AL, Aragon DC, Küpper DS et al. Swallowing evaluation after surgery for obstructive sleep apnea syndrome: uvulopalatopharyngoplasty vs. expansion pharyngoplasty. *Eur Arch Otorhinolaryngol*. 2018;275:1023-30.
27. Jäghagen EL, Berggren D, Dahlqvist A, Isberg A. Prediction and risk of dysphagia after uvulopalatopharyngoplasty and uvulopalatoplasty. *Acta Otolaryngol*. 2004;124:1197-203.
28. Valarelli LP, Corradi A, Grechi TH, Eckeli AL, Aragon DC, Küpper DS et al. Cephalometric, muscular and swallowing changes in patients with OSAS. *J Oral Rehabil*. 2018;45:692-701.
29. Butler SG, Stuart A, Markley L, Rees C. Penetration and aspiration in healthy older adults as assessed during en-

- doscopy evaluation of swallowing. *Ann Otol Rhinol Laryngol.* 2009;118:190-8.
30. Nguyen AT, Jobin V, Payne R, Beauregard J, Naor N, Kimoff RJ. Laryngeal and velopharyngeal sensory impairment in obstructive sleep apnea. *Sleep.* 2005;28:585-93.
 31. Neelapu BC, Kharbanda OP, Sardana HK, Balachandran R, Sardana V, Kapoor P et al. Craniofacial and upper airway morphology in adult obstructive sleep apnea patients: a systematic review and meta-analysis of cephalometric studies. *Sleep Med Rev.* 2017;31:79-90.
 32. Yamashiro Y, Kryger M. Is laryngeal descent associated with increased risk for obstructive sleep apnea?. *Chest.* 2012;141:1407-13.
 33. Young JW, McDonald JP. An investigation into the relationship between the severity of obstructive sleep apnoea/hypopnoea syndrome and the vertical position of the hyoid bone. *Surgeon.* 2004;2:145-51.
 34. Yamazaki Y, Tohara H, Hara K, Nakane A, Wakasugi Y, Yamaguchi K. et al. Excessive anterior cervical muscle tone affects hyoid bone kinetics during swallowing in adults. *Clin Interv Aging.* 2017;12:1903-10.
 35. Logemann JA, Pauloski BR, Rademaker AW, Colangelo LA, Kahrilas PJ, Smith CH. Temporal and biomechanical characteristics of oropharyngeal swallow in younger and older men. *J Speech Lang Hear Res.* 2000;43(5):1264-74.
 36. Ertekin C, Aydogdu I. Neurophysiology of swallowing. *Clin Neurophysiol.* 2003;114:2226-44.