TÜBİTAK

Turkish Journal of Medical Sciences

http://journals.tubitak.gov.tr/medical/

Research Article

Turk J Med Sci
(2016) 46: 1749-1754

doi:10.3906/sag-1512-52

Does CPAP treatment affect the voice?

Güleser SAYLAM[1], Mustafa ŞAHİN[2,*], Dilek DEMİRAL[1], Ömer BAYIR[1], Melike Bağnu YÜCEEGE[3], Emel ÇADALLI TATAR[1], Mehmet Hakan KORKMAZ[1]

[1]Department of Otolaryngology, Dışkapı Yıldırım Beyazıt Research and Training Hospital, Ankara, Turkey
[2]Department of Otolaryngology, Faculty of Medicine, Adnan Menderes University, Aydın, Turkey
[3]Department of Chest Diseases, Section of Sleep Disorders, Dışkapı Yıldırım Beyazıt Research and Training Hospital, Ankara, Turkey

Received: 09.12.2015 • **Accepted/Published Online:** 03.04.2016 • **Final Version:** 20.12.2016

Background/aim: The aim of this study was to investigate alterations in voice parameters among patients using continuous positive airway pressure (CPAP) for the treatment of obstructive sleep apnea syndrome.

Materials and methods: Patients with an indication for CPAP treatment without any voice problems and with normal laryngeal findings were included and voice parameters were evaluated before and 1 and 6 months after CPAP. Videolaryngostroboscopic findings, a self-rated scale (Voice Handicap Index-10, VHI-10), perceptual voice quality assessment (GRBAS: grade, roughness, breathiness, asthenia, strain), and acoustic parameters were compared.

Results: Data from 70 subjects (48 men and 22 women) with a mean age of 44.2 ± 6.0 years were evaluated. When compared with the pre-CPAP treatment period, there was a significant increase in the VHI-10 score after 1 month of treatment and in VHI- 10 and total GRBAS scores, jitter percent (P = 0.01), shimmer percent, noise-to-harmonic ratio, and voice turbulence index after 6 months of treatment. Vague negative effects on voice parameters after the first month of CPAP treatment became more evident after 6 months.

Conclusion: We demonstrated nonsevere alterations in the voice quality of patients under CPAP treatment. Given that CPAP is a long-term treatment it is important to keep these alterations in mind.

Key words: Obstructive sleep apnea, CPAP, voice, acoustic analysis, subjective evaluation

1. Introduction

Obstructive sleep apnea syndrome (OSAS) is characterized by recurrent episodes of sleep-related collapse of the upper airway and is usually associated with loud snoring, choking, and arousal episodes during sleep and increased daytime sleepiness. In studies on different populations in the 30–60-year age group, OSAS prevalence was 3.1%–7.5% in men and 2.1%–4.5% in women (1). Today the gold-standard method in the diagnosis of OSAS is polysomnography (PSG). Other than the general preventative strategies recommended to all patients, the most common and effective method of OSAS treatment involves the application of continuous positive airway pressure (CPAP) (2). A CPAP device is a machine that transfers room air to the patient's airway with an intended pressure via a low resistance snout and mask, creating a continuous positive pressure that keeps the upper airways open (pneumatic splint) (3).

The three main functional systems involved in voice production are air pressure and the vibratory and resonating systems. The air pressure system includes the diaphragm, abdominal muscles, chest muscles, and rib cage and provides and regulates air flow and pressure to cause vocal folds to vibrate. The larynx forms a vibratory system, which changes air pressure to sound waves by vibrating vocal folds (VFs) to produce voiced sound. The resonating system (vocal tract) modifies, amplifies, and transfers this immature voice to the person-specific voice. It has previously been reported that patients with sleep apnea/hypopnea syndrome who regularly used CPAP for more than 4 h per night all showed an increase in upper airway dimensions (4). CPAP treatment may result in alterations in pulmonary functions and upper airway narrowing. Moreover, air flow with positive pressure produced by the CPAP device may cause microtrauma in the VFs and dryness on the mucosal surface of the VFs. This potential VF microtrauma and mucosal dryness due to CPAP therapy may hamper the regular mucosal waveform, resulting in dysphonia, because optimal voice production depends on the viscoelastic characteristics of

* Correspondence: mustafa.kbb@gmail.com

the vibrating mucosal tissue structure of the VFs (5). Voice analyses of patients under CPAP therapy may give us an idea about the validity of these possible effects, which are not yet supported by firm evidence. The aim of this study was thus to investigate the effects of CPAP therapy, which is widely used for OSAS, on the voice.

2. Materials and methods

This prospective single-blinded clinical study was carried out at the voice disorders unit of the otorhinolaryngology and sleep disorders laboratory at a research hospital. It was approved by the research ethics committee of the hospital (11/10-11.11.2013). Each patient was verbally informed about the study by the specialists and signed an informed consent form.

All individuals participating in this study were selected from a patient group (over 18 years old) diagnosed with OSAS via PSG and offered CPAP treatment. All subjects underwent an overnight in-laboratory diagnostic PSG with a 64-channel PSG machine (Compumedics, Melbourne, Australia). All subjects used nasal-CPAP without a humidifier after a CPAP titration study. Demographic data and variables related to CPAP (number of hours used per night and CPAP pressure) were recorded. Patients who did not use CPAP treatment compliantly (minimum 4 h per night and 70% of all nights) or used CPAP for less than 6 months were excluded from the study.

A detailed medical and voice habituation history was obtained via a questionnaire prepared for this study. A detailed ear-nose-throat (including endoscopic nasal cavity) and neurologic examination was performed. The participants defined their voices as normal. A videolaryngostroboscopic (VLS) examination, self-administered questionnaire for voice problems, perceptual voice quality assessment, and acoustic voice analysis were performed before and after 1 and 6 months of CPAP treatment.

Exclusion criteria related to the voice were as follows: history of smoking; intensive alcohol consumption; being a professional voice user; history of any respiratory, neurological, psychiatric, or endocrinological diseases; being over 60 years old (to avoid possible presbyphonia, which may affect voice analysis); laryngeal surgery; head and neck trauma; radiotherapy to the head and neck region; chemotherapy; hearing impairment; presence of any VF organic lesion; presence of obvious nasal obstructing pathology like nasal polyposis; previous voice therapy/vocal training; any vocally abusive or misuse behaviors; and taking medications that may cause mucosal dryness such as diuretics or antihistamines.

Self-assessment of voice quality was scored using the Turkish version of the Voice Handicap Index-10 (VHI-10). The VHI-10 is a questionnaire composed of 10 questions. Subjects award a score of 0–4 for each question. Higher scores indicate greater problems (6).

Perceptual voice quality was evaluated using the GRBAS scale by four experienced specialists who did not know the subjects. The GRBAS scale is a reliable and valid scale consisting of five parameters (grade, roughness, breathiness, asthenia, strain) that is universally used in the auditory-perceptual evaluation of voice quality. For each parameter, four different scores from 0 to 3 are given according to the severity of dysphonia (0 is normal, 1 is slight degree, 2 is medium degree, and 3 is high degree of severity) (7). GRBAS scores were given by judges listening to samples (voice recordings) of a reading passage in Turkish that comprised 219 words with rich and balanced phonemes. Voice records were shuffled to prevent the listener's familiarity with voices and their order (possible order effect). The consistency between evaluators was analyzed using Fleiss' kappa and intraclass correlation prior to the study and it was found that this compatibility between the evaluators was high (84%, $P = 0.01$). If the subject's initial VHI-10 score was ≥2 and the mean GRBAS score was ≥1, the subject was not included in the study.

VLS examination was performed in three different periods. There was no sign of upper airway infection during any evaluation. The VLS procedure (Xion Endo-Strob DX, Berlin, Germany) was performed by an otolaryngology specialist who did not know the subjects (blindly on shuffled video recordings) to evaluate VF movements and the mucosal waveform. VLS evaluation was based on the protocol of the European Laryngological Society (8). Basic VLS parameters evaluated were glottic closure, regularity, mucosal waveform, and symmetry. For each stroboscopic parameter, a four-point grading scale (0, no deviance; 3, severe deviance with maximum total score of 12) was used. The glottal gap was evaluated at the maximum closed point of a vibratory cycle during patient's modal pitch at a comfortable intensity on a sustained vowel [i]. Type of insufficient closure was not categorized if it was observed. If a mucosal waveform irregularity was identified (any VLS parameter with score of >1), the subject was not included in the study.

Voice samples were recorded in a sound-insulated room at a sound level at which the patients felt relaxed while seated upright with a high-quality omnidirectional microphone (Shure SM48, Niles, IL, USA). The distance between the microphone and mouth was adjusted to approximately 10 cm. The microphone was positioned at an angle of 90° to the mouth. Each patient was given a short practice period prior to the first recording to become familiar with the procedure. The subject was instructed to phonate a sustained vowel [a] at a habitual pitch and comfortable loudness for at least 5 s. The task was repeated three times by each subject and each trial was captured

on hard disk at a 44.100-Hz sampling rate and 16-bit resolution. Computerized Speech Lab (Kay PENTAX CSL Model 4500, Montvale, NJ, USA) software (CSL main program and MDVP) was used to capture and analyze the voice samples. One second at the beginning and one at the end of the analyzed voice samples were removed to avoid unintended irregularities and variability on voicing onset and offset. The mean values were then calculated for each subject. Acoustic parameters of voice samples were fundamental frequency (F0), sound pressure level (SPL), jitter percent (Jitt), shimmer percent (Shimm), noise-to-harmonic ratio (NHR), and voice turbulence index (VTI). Maximum phonation time (MPT) was calculated as the longest possible duration of sustained vowel \a\ on a continuous expiration after a maximum inspiration.

SPSS 20.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. The Shapiro–Wilk test was used to assess normality. Differences between different time periods within patients were evaluated by paired sample t-test. Differences in voice parameter values related to CPAP pressure were evaluated by independent sample t-test. The numerical results are presented as mean ± SD. Statistical significance was set at $P < 0.05$.

3. Results

A total of 112 volunteer patients with the defined criteria were included in this study. Among these, 36 (32.1%) did not use CPAP regularly for 6 months and 6 (5.3%) did not come to the check-ups on time and so they were excluded. The results reported in this manuscript were collected from 48 men (mean age: 43.5 ± 5.7 years) and 22 women (mean age: 45.3 ± 6.8 years), giving a total of 70 patients (mean age: 44.2 ± 6.0 years). The mean body mass index (BMI) of patients was 32.8 ± 6.2 kg/m^2 (min: 28, max: 41); the mean apnea-hypopnea index (AHI) determined in PSG was 30.4 ± 2.7 (min: 25, max: 37), nightly mean CPAP usage time was 5.7 h (min: 4, max: 7), and mean pressure of CPAP treatment was 10.9 ± 2.6 (min: 8, max: 16) cmH_2O.

The voice-associated parameters determined in the pre-CPAP treatment period and after 1 and 6 months of treatment are summarized in Table 1 for men and women separately. The P-values showing the statistical significance of differences in these parameters determined in three different periods are shown in Table 2. In all patients, the VHI-10 score was significantly higher after 1 month of treatment (3.4 ± 1.71) than in the pre-CPAP treatment (1.68 ± 0.88) period ($P = 0.014$), and it was again significantly higher ($P = 0.000$) after 6 months of treatment (6.30 ± 1.36). The mean GRBAS score, which was 0.89 ± 0.63 in the pre-CPAP treatment period, increased slightly after 1 month of treatment (1.18 ± 0.46) and was significantly higher ($P = 0.013$) after 6 months of treatment (3.04 ± 0.85). There were no significant alterations in the F0, SPL, or MPT values. Regarding the perturbation (Jitt and Shimm) and spectral parameters (NHR and VTI), there were no significant differences between results obtained in the pre-CPAP treatment period and after 1 month of treatment; however, there was a significant difference after

Table 1. The vocal analysis parameters of subjects for three different periods.

	Men			Women		
	Pre-CPAP	1 month	6 months	Pre-CPAP	1 month	6 months
VHI-10	1.84 ± 0.78	3.27 ± 1.32	6.63 ± 1.73	1.59 ± 1.05	3.62 ± 1.45	6.45 ± 1.71
GRBAS	0.96 ± 0.62	1.16 ± 0.61	2.97 ± 0.73	0.75 ± 0.28	1.22 ± 0.65	3.31 ± 1.76
F0	135.9 ± 20.2	137.3 ± 21.1	138.4 ± 20.9	212.6 ± 29.4	209.5 ± 28.1	213.7 ± 26.8
SPL	71.1 ± 3.2	70.3 ± 3.7	70.7 ± 3.6	67.8 ± 3.5	66.1 ± 2.1	68.1 ± 3.1
Jitt	0.56 ± 0.24	0.58 ± 0.21	0.82 ± 0.23	0.71 ± 0.28	0.69 ± 0.31	0.88 ± 0.27
Shimm	2.54 ± 0.52	2.76 ± 0.55	3.35 ± 0.55	2.51 ± 0.49	2.75 ± 0.57	3.34 ± 0.51
NHR	0.13 ± 0.01	0.12 ± 0.03	0.20 ± 0.09	0.13 ± 0.02	0.13 ± 0.04	0.18 ± 0.07
VTI	0.051 ± 0.01	0.052 ± 0.021	0.063 ± 0.01	0.05 ± 0.012	0.051 ± 0.01	0.062 ± 0.01
F1	707.2 ± 73.5	687.5 ± 78.3	685.7 ± 70	857.5 ± 72.1	842.6 ± 65	843 ± 58.1
F2	1391 ± 166	1354 ± 170	1344 ± 194	1877 ± 199	1863 ± 166	1864 ± 219
F3	2535 ± 215	2428 ± 167	2424 ± 156	2983 ± 184	2870 ± 226	2864 ± 209
MPT	18.6 ± 3.2	17.4 ± 2.6	18.9 ± 3.4	15.4 ± 2.9	16.7 ± 2.4	16.2 ± 2.5

VHI-10: Voice Handicap Index-10; SPL: sound pressure level; F0: fundamental frequency; Jitt: jitter percent; Shimm: shimmer percent; NHR: noise-to-harmonic ratio; VTI: voice turbulence index; F1, 2, 3: first, second, and third formant frequency; MPT: maximum phonation time. Values are expressed as mean ± SD.

Table 2. P-values showing the significance of differences between vocal analysis parameters for three different periods.

	I	II	II
VHI-10	0.000† / 0.000*	0.015† / 0.175*	0.000† / 0.000*
GRBAS	0.256† / 0.110*	0.000† / 0.015*	0.000† / 0.000*
F0	0.888† / 0.729 *	0.126† / 0.238*	†0.149 / 0.629*
SPL	0.253† / 0.630*	0.245† / 0.913*	0.123† / 0.515*
Jitt	0.632† / 0.799*	0.000† / 0.240*	0.000† / 0.026*
Shimm	0.104† / 0.126*	0.000† / 0.000*	0.000† / 0.000*
NHR	0.256† / 0.942*	0.000† / 0.020*	0.000† / 0.040*
VTI	0.082† / 0.675*	0.046† / 0.053*	0.027† / 0.030*
F1	0.745† / 0.817*	0.09† / 0.748*	0.052† / 0.685*
F2	0.558† / 0.229*	0.065† / 0.743*	0.083† / 0.256*
F3	0.801† / 0.704*	0.092† / 0.083*	0.087† / 0.124*
MPT	0.466† / 0.563*	0.856† / 0.685*	0.640† / 0.514*

Comparisons of I: pre-CPAP with 1 month of therapy, II: 1 month with 6 months of therapy, III: pre-CPAP with 6 months of therapy. VHI-10: Voice Handicap Index-10; SPL: sound pressure level; F0: fundamental frequency; Jitt: jitter percent; Shimm: shimmer percent; NHR: noise-to-harmonic ratio; VTI: voice turbulence index; F1, 2, 3: first, second, and third formant frequency; MPT: maximum phonation time. Values are expressed as mean ± SD. $P \leq 0.05$ indicates statistical significance. †: P-value for difference between men, *: P-value for differences between women.

6 months (P = 0.01 for Jitt, P = 0.000 for Shimm, P = 0.021 for NHR, and P = 0.030 for VTI). Formant frequencies were found to decrease over time, in both sexes, and this decrease was not statistically significant.

The total score of the VLS evaluation before treatment was 0.25. After 1 month of treatment it was 0.24 and after 6 months it was 0.43, with no significant difference between evaluations. Regarding individual VLS parameters, there was a significant increase only for the 6-month results for the glottal closing score (0.21 for pre-CPAP, 0.23 after 1 month, and 1.1 after 6 months of treatment).

When the voice alterations of all patients were evaluated according to the median CPAP treatment pressure value of 9 cmH_2O, there was no significant difference in voice parameters of patients below or above this pressure level.

4. Discussion

OSAS is associated with increased mortality and morbidity. CPAP remains the predominant treatment for OSAS because it is efficient and safe (9). However, this method may not offer a definite cure for patients and the necessity of lifelong usage and its adverse effects cause adherence problems. The main side effects of CPAP treatment related to the upper airways are nasal/oral dryness, epistaxis, nose and throat irritation, and insufflation of tear ducts and the middle ear. There are also insufficient published data about the effects of this treatment method on the voice. When compared with healthy individuals, some commonly observed anatomical features of the upper airways of OSAS patients are thickening of soft tissue of the soft palate and pharynx wall, hypertrophy of the tonsils and tongue root, and an elongated and flaccid velum. Some studies have reported a decline in increased tissue bulk in the vocal tract (probably due to a decrease in edema) and an increase in the cross-sectional volume of the airways at the pharynx and tongue root level with CPAP treatment (10). As previously reported by Corda et al. this expansion takes place not only during CPAP usage while sleeping (mechanical effect) but also takes place while the patient is awake (11). Distinctive frequency components in the sound spectrum of voiced sound produced by resonating system are formants. Formant frequencies could be changed according to the dimensional features of the resonator units (pharynx, oral and sinonasal cavity). With a decrease in the cross-sectional area of the resonator unit, formant frequency increases. After OSAS surgery, alterations in these frequencies were reported (12). In this study, there was a nonsignificant decrease in the first three formant frequencies after CPAP treatment, which may be an indirect sign of alterations in the upper airway cross-sectional volume. In this study, the high BMI values of the patients may be the reason for this result. Studies are also required in nonobese OSAS patients to determine voice alterations after CPAP treatment.

The ability to combine phonation with articulation and resonance allows for human speech. Biomechanical responses and adaptations at the VF level may accompany the alterations in upper airway anatomy that take place after CPAP treatment (5,12). Namely, voice production requires that several mechanical properties be met. Favorable pliability and vibratory capacity of the tissues of the VFs is an essential part of voice production. Once air passes between the VFs, the body-cover concept of phonation takes effect. The body-cover theory describes the wave-like motion of the loose mucosa of the VFs over the stiffer, more densely organized vocal ligament and vocalis muscle. This motion is known as the mucosal wave (13). A smooth and moist VF mucosal surface is required to maintain proper phonatory function. The surface of the VFs is covered by a thin layer of liquid (the mucous blanket, sol and gel layers). This layer serves as a physical and biochemical barrier that protects the underlying tissue. It is also an important factor for a healthy mucosal wave pattern that increases the efficiency of VF oscillation and promotes normal voice quality (14). However, this layer is highly sensitive to irritants inhaled from the air (15). Besides, systemic and superficial VF hydration is an important part of vocal hygiene and it was reported by Witt et al. that superficial dehydration of the VFs may decrease the amplitude and frequency of the mucosal wave (16). The dry air with high airflow rate produced by CPAP may adversely affect this layer and destroy the vibratory pattern. This alteration results in an increase in perturbation and some spectral parameters in voice analysis, and in this study we also found significant increases in the % Jitt, % Shimm, NHR, and VTI values. Our results are consistent with those of Hamdan et al., who reported an increase in shimmer and RAP values after CPAP usage (17). A reduction in voice quality after this alteration was also found in evaluations made by both patients (VHI-10) and listeners (GRBAS). Conversely, Atan et al. revealed that both subjective and objective voice parameters had improved after CPAP treatment in a study including 27 patients (18).

In our study, the mean total VHI-10 score after 6 months of CPAP treatment was 6.45 (max: 9), and the GRBAS score was 3.31 (max: 5). These results are lower than the mean total VHI-10 (>11 could be considered as abnormal) and GRBAS scores reported in the literature for patients with hoarseness. This decrease in perceived voice quality is not at the same level of alterations found in patients with organic benign VF pathologies (19,20). Moreover, the lack of any alterations in MPT and SPL (aerodynamic parameters) values may suggest that it is not so much changes in pulmonary functions that may affect the voice. However, MPT and SPL are also related to glottal efficiency. Hence, other aerodynamic parameters involving pulmonary function tests like averaged phonation air flow could have been evaluated. This is a limitation of this study. In our study, CPAP treatment did not cause severe voice alteration in patients without any voice problems but its probable effects on patients with voice problems are not known. For that reason, studies about the effects of CPAP treatment on patients with voice problems are warranted. On the other hand, since such alteration, though mild, may cause substantial problems in patients who use their voices professionally, studies on this population are also required.

The configuration of glottic closure is the shape of the glottis at maximum closure. In VLS evaluation a complete glottal closure was assumed when the visible glottis was completely closed. It was thought that the mild increase in glottal closing score on VLS, which was not at a pathological level, may have been caused by an increase in VF strain during voice production. This finding may be associated with an increase in strain due to increase in phonation threshold pressure for the production of normal mucosal waves in the probable presence of VF surface dryness due to an increase in surface resistance on the VFs. Superficial VF dehydration results in decreased efficiency of VF vibration and compromised voice quality. Ionic and osmotic composition of airway surface liquid overlying the VF impacts the ionic environment of underlying tissue. This may cause epithelial cell damage. The relative contribution and mechanisms affecting the VF surface liquid await further study. Electroglottographic evaluation may also be discussed for glottal closure assessment in further studies (21).

In conclusion, patients without any voice problems using 6 months of regular CPAP may have mild voice disturbances after this treatment. This probable mild unfavorable effect of CPAP treatment is not thought to adversely affect the patients' quality of life. However, this effect of CPAP should be kept in mind when recommending this treatment for professional voice users, and also in patients who have organic VF problems. Further studies should be done to investigate any precautions that may be required and to compare the results of different treatment methods in patients with and without dysphonia.

References

1. Punjabi NM. The epidemiology of adult obstructive sleep apnea. Proc Am Thorac Soc 2008; 5: 136-143.

2. Freedman N. Treatment of obstructive sleep apnea syndrome. Clin Chest Med 2010; 31: 187-201.

3. Chowdhuri S. Continuous positive airway pressure for the treatment of sleep apnea. Otolaryngol Clin North Am 2007; 40: 807-827.

4. Mortimore IL, Kochhar P, Douglas NJ. Effect of chronic continuous positive airway pressure (CPAP) therapy on upper airway size in patients with sleep apnoea/hypopnoea syndrome. Thorax 1996; 51: 190-192.

5. Li L, Zhang Y, Maytag AL, Jiang JJ. Quantitative study for the surface dehydration of vocal folds based on high-speed imaging. J Voice 2015; 29: 403-409.

6. Kılıç MA, Okur E, Yıldırım I, Öğüt F, Denizoğlu I, Kızılay A, Oğuz H, Kandoğan T, Doğan M, Akdoğan O et al. Reliability and validity of the Turkish version of the Voice Handicap Index. Kulak Burun Bogaz Ihtis Derg 2008; 18: 139-147 (in Turkish with English abstract).

7. Eadie T, Sroka A, Wright DR, Merati A. Does knowledge of medical diagnosis bias auditory-perceptual judgements of dysphonic voice. J Voice 2011; 25: 420-429.

8. Dejonckere PH, Bradley P, Clemente P, Cornut G, Crevier-Buchman L, Friedrich G, Van De Heyning P, Remacle M, Woisard V. Committee on Phoniatrics of the European Laryngological Society (ELS). A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques. Guideline elaborated by the Committee on Phoniatrics of the European Laryngological Society (ELS). Eur Arch Otorhinolaryngol 2001; 258: 77-82.

9. Hsu AA, Lo C. Continuous positive airway pressure therapy in sleep apnoea. Respirology 2003; 8: 447-454.

10. Shrivastava D. Impact of sleep-disordered breathing treatment on upper airway anatomy and physiology. Sleep Med 2014; 15: 733-741.

11. Corda L, Redolfi S, Montemurro LT, La Piana GE, Bertella E, Tantucci C. Short- and long-term effects of CPAP on upper airway anatomy and collapsibility in OSAH. Sleep Breath 2009; 13: 187-193.

12. Bertino G, Matti E, Migliazzi S, Pagella F, Tinelli C, Benazzo M. Acoustic changes in voice after surgery for snoring: preliminary results. Acta Otorhinolaryngol Ital 2006; 26: 110-114.

13. Hirano M. Morphological structure of the vocal cord as a vibrator and its variations. Folia Phoniatr (Basel) 1974; 26: 89-94.

14. Sivasankar M, Leydon C. The role of hydration in vocal fold physiology. Curr Opin Otolaryngol Head Neck Surg 2010; 18: 171-175.

15. Finkelhor BK, Titze IR, Durham PL. The effect of viscosity changes in the vocal folds on the range of oscillation. J Voice 1990; 4: 142-151.

16. Witt RE, Taylor LN, Regner MF, Jiang JJ. Effects of surface dehydration on mucosal wave amplitude and frequency in excised canine larynges. Otolaryngol Head Neck Surg 2011; 144: 108-113.

17. Hamdan AL, Sabra O, Rifai H, Tabri D, Hussari A. Vocal changes in patients using nasal continuous positive airway pressure. J Voice 2008; 22: 603-616.

18. Atan D, Özcan KM, İkincioğulları A, Köseoğlu S, Çetin MA, Ensari S, Dere H. The effect of obstructive sleep apnea syndrome and continuous positive airway pressure treatment on voice performance. Sleep Breath 2015; 19: 777-782.

19. Arffa RE, Krishna P, Gartner-Schmidt J, Rosen CA. Normative values for the Voice Handicap Index-10. J Voice 2012; 26: 462-465.

20. Jones SM, Carding PN, Drinnan MJ. Exploring the relationship between severity of dysphonia and voice-related quality of life. Clin Otolaryngol 2006; 31: 411-417.

21. Ayache S, Ouaknine M, Dejonckere P, Prindere P, Giovanni A. Experimental study of the effects of surface mucus viscosity on the glottic cycle. J Voice 2004; 18: 107-115.