Vocal and Orofacial Myofunctional Characteristics of Individuals with Obstructive Sleep Apnea

Melissa França Lima Martins[1] Alan Luiz Eckeli[1] Fernando Gustavo Stelzer[1]
Fabiana Cardoso Pereira Valera[2] Gislaine Aparecida Folha[3]

[1] Department of Neurosciences and Behavioral Sciences, School of Medicine, Universidade de São Paulo, São Paulo, SP, Brazil
[2] Department of Ophthalmology, Otolaryngology, and Head and Neck Surgery, School of Medicine, Universidade de São Paulo, São Paulo, SP, Brazil
[3] Department of Health Sciences, School of Medicine, Universidade de São Paulo, São Paulo, SP, Brazil

Address for correspondence Gislaine Aparecida Folha, (e-mail: gislainefolha@fmrp.usp.br).

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Abstract

Introduction Obstructive sleep apnea (OSA) involves recurrent upper airway obstructions during sleep, leading to fragmentation and oxygen desaturation. Vocal complaints and orofacial myofunctional changes are common, but few studies assess both aspects in diagnosed patients.

Objective To assess vocal parameters and orofacial myofunctional conditions in adults diagnosed with OSA, comparing them to a control group at low risk for OSA.

Methods Cross-sectional study. A convenience sample ($N = 63$) was included: 33 with OSA confirmed by polysomnography and 30 controls at low risk for OSA (STOP-BANG < 3 and no reported snoring in Stanford Snoring Scale), aged between 18–60 years. Assessments included perceptual-auditory analysis of voice quality (GRBASI scale, Vocal Symptom Scale (VSS), maximum phonation time (MPT) for vowels and s/z ratio) and orofacial myofunctional evaluation (OMES-E protocol). Participants who had received previous treatment or medical conditions affecting OSA, voice or orofacial function were excluded.

Results OSA group showed significantly higher scores on VSS and lower scores on OMES-E protocol. They also displayed shorter MPT, worse performance in s/z ratio, reduced pneumophonoarticulatory coordination, and higher frequency of vocal alterations. The OSA group revealed mean apnea-hypopnea index of 45.80, indicates predominance of severe cases, as well as increased desaturation index.

Conclusion Individuals with OSA exhibit impairments in both orofacial myofunctional and vocal parameters, with negative alterations observed in MPT speech rate, pneumophonoarticulatory coordination, and s/z ratio compared with subjects with no OSA complaints. These findings highlight the importance of evaluating vocal and orofacial aspects together in OSA.

Keywords
- snoring
- obstructive sleep apnea
- voice
- orofacial motricity
- sleep
- evaluation study

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Introduction

Obstructive sleep apnea (OSA) is characterized by repetitive complete (apnea) or partial (hypopneas) upper airway obstruction during sleep, occurring in the pharyngeal region, which leads to decreased blood oxygen saturation and sleep fragmentation.[1] In OSA the nasopharynx and oropharynx become obstructed during respiratory events, with snoring being one of the primary symptoms. This frictional noise results from the difficulty of airflow passing through the pharynx, causing vibration of the soft tissues in the anterior region of the neck.[2]

Muscular alterations beyond the pharyngeal region have been observed in individuals with OSA.[3] Indeed, self-reported vocal complaints are prevalent among individuals who snore and are positively correlated with snoring intensity; the higher the risk for OSA, the greater the likelihood of experiencing severe vocal symptoms.[4]

Vocal alterations in OSA patients could be attributed to the vocal output originating primarily in the larynx mainly in the vocal folds. However, the passage of sound through the supraglottic structures of the upper airway influences voice quality, from the vocal folds to the lips, including other resonance chambers.

Previous research has found that OSA patients diagnosed via polysomnography exhibit significant differences in orofacial myofunctional conditions compared with healthy individuals, with those affected by OSA displaying worse orofacial myofunctional status.[3] However, studies in this field remain scarce and warrant further investigation, especially given the lack of studies assessing both orofacial myofunctional conditions and vocal parameters simultaneously in OSA patients. Then, this study aimed to evaluate these aspects in individuals with OSA and compare them with individuals with low risk for OSA.

Methods

Participants

A convenience sample was obtained through data collection, protocol application, and vocal and orofacial myofunctional assessment, conducted at a Sleep Respiratory Diseases Outpatient Clinic (ADRS) of a tertiary-level hospital over six months, from July to December 2024.

The inclusion criteria for the Control group (CG) were between 18 and 60 years old, having a low probability or absence of symptoms suggestive of OSA based on the STOP-BANG Questionnaire (cut off score < 3),[5] and no reported snoring according to the Stanford Snoring Scale (ERS) (cutoff score 0). Polysomnography was not performed on any individuals in the CG.

All participants in the OSA group were diagnosed with obstructive sleep apnea (OSA) through type 1 polysomnography AASM 3.0 Manual.[1]

For both the OSA and CG, the inclusion criterion was age between 18 and 60 years, and the exclusion criteria included having undergone any form of OSA treatment (such as orofacial myofunctional therapy, mandibular advancement device therapy, soft tissue or bone surgery, or positive airway pressure therapy), having a medical condition that could negatively affect voice and orofacial myofunctional status, or to make professional use of the voice. Participants from the CG who met this cutoff score and/or reported snoring at any severity level on the Stanford Snoring Scale were excluded from the study.

Methods

Vocal Assessment

Vocal assessment was performed using perceptual-auditory analyses. The GRBASI scale[6,7] was used to evaluate voice quality, is widely used in clinical and research contexts and consists of five parameters: (G) general degree of alteration, (R) roughness/hoarseness, (B) breathiness, (A) asthenia, (S) strain, and (I) instability. Each parameter is rated on a four-point ordinal scale ranging from 0 to 3, where 0 = normal, 1 = mild, 2 = moderate, and 3 = severe.

The Vocal Symptom Scale (Escala de Sintomas Vocais – ESV) was used to assess the presence and severity of self-perceived vocal symptoms. This validated instrument for the Brazilian population consists of 30 statements covering physical, functional, and emotional-social aspects of voice.[8] Participants are asked to rate each statement using a five-point Likert scale (0 = never to 4 = always), indicating how frequently each symptom occurs. The total score ranges from 0 to 120, with higher scores reflecting greater vocal symptomatology and greater impact on vocal quality.[9]

The maximum phonation time (MPT) for vowels /a/, /i/, /u/ and fricative phonemes /s/ and /z/ were also characterized to analyze glottal efficiency and respiratory control during sustained vocal emission. Participants were instructed to take a deep breath and sustain the vowel /a/ at a comfortable pitch and loudness for as long as possible in a single exhalation (seconds). Three consecutive trials were performed, with ~30-second intervals between them. The longest duration among the three attempts was considered for analysis. The task was performed in a quiet environment, with the participant seated, and a digital stopwatch was used to measure the time in seconds. The s/z ratio was performed as a complementary measure to assess phonatory efficiency, values close to 1.0 are indicative of efficient glottal function, whereas values above 1.4 may suggest glottal air leakage, as reported in the literature.[10]

Additionally, vocal onset was classified as isochronic, abrupt, or aspirated. The voice was also analyzed in terms of intensity (loudness) (weak, adequate, or strong) and resonance (balanced, hypo-, or hypernasal). Frequency (pitch), speech intelligibility, rhythm, speed, breathing, pneumophonoarticulatory coordination, and modulation were classified as binary variables (adequate or altered). These evaluations were conducted during spontaneous dialogue situations and during the vocal assessment described below.

The evaluations were performed by a speech and language pathologist blinded to the polysomnographic data of the participants in the OSA group.

Orofacial Myofunctional Assessment

Orofacial myofunctional assessment was conducted using the Expanded Orofacial Myofunctional Evaluation Protocol (OMES-E). This protocol evaluates orofacial myofunctional conditions using numerical scales and was designed to provide a detailed and standardized clinical analysis of orofacial functions, encompassing both morphological and functional aspects of the stomatognathic system. Includes the observation and description of orofacial structures (such as lips, tongue, cheeks, palate, face and mandible), as well as the functional evaluation of motor acts (including breathing, chewing and swallowing) and the mobility of the orofacial structures (lips, tongue, cheeks and mandible), using both qualitative and quantitative scoring. The total score of the protocol, i.e., 232 points, corresponds to the sum of the scores of all evaluated items and was used in this study. It has been validated for adult populations with and without OSA.[3]

Sleep Questionnaires

The Stanford Snoring Scale (ERS) was applied to assess self-perception of snoring, and the STOP-BANG Questionnaire[5] was used to identify symptoms suggestive of OSA.

The STOP-BANG Questionnaire[5] consists of eight yes/no questions. Individuals who answered "yes" to three or more items were considered at high risk for OSA.

The risk for obstructive sleep apnea (OSA) also was assessed using the Berlin Questionnaire, a validated and widely used screening tool designed to identify individuals at increased risk for OSA. Consists of 10 items grouped into three categories[1]: snoring behavior and witnessed apneas,[2] daytime sleepiness or fatigue, and[3] presence of hypertension or a high body mass index (BMI). According to the criteria established by Netzer et al.,[11] individuals are classified as high risk for OSA if they have positive scores in two or more categories. In this study, we used the version adapted and validated for the Brazilian population.[12]

Polysomnography

Full-night type 1 polysomnography (PSG) included high-resolution electroencephalogram, electrooculogram, electrocardiogram, thoracic and abdominal respiratory inductive plethysmography straps, pulse oximetry, heart rate, nasal pressure transducer system and oronasal thermocouple airflow sensor, microphone to detect snores, body position, chin and anterior tibialis muscles eletromyography, and a video camera to monitor the patient during sleep. The scoring of sleep stages and all the technical parameters applied were performed using the AASM 3.0 Manual.[1]

Ethical Aspect

The human subject research was approved by the Human Research Ethics Committee of the Ribeirão Preto School of Medicine, University of São Paulo (São Paulo, Brazil) (CAAE 78132124.3.0000.5440, opinion no. 6.793.824).

All participants were informed about the study, including its objectives, and were invited to voluntarily participate by signing the informed consent form (ICF), in accordance with Resolution No. 466/2012 of the National Health Council (CNS/MS).

Statistical Analysis

Descriptive statistics were performed for all investigated variables, presenting frequencies, means, and standard deviations. The Shapiro-Wilk test was used to assess data normality. Since the normality hypothesis was rejected for at least one variable in each group, the non-parametric Mann-Whitney test was used to compare the groups. Spearman correlation was performed, and the BMI was controlled in partial out. A significance level of $p < 0.05$ was adopted, and calculations were performed using SPSS software (IBM Corp., Version 23.0, Armonk, NY, USA).

Results

Sixty-three individuals were included in this study, 33 in the OSA group and 30 in the control group. A statistically significant difference was noticed between the groups regarding age and the proportion of individuals that have a BMI exceeding 35. Regarding the STOP-BANG and Stanford scores, these were better in the Control group, as expected based on the eligibility criteria. The main characteristics of the sample are shown in ►**Table 1**.

As observed in ►**Table 2**, the OSA group had worse myofunctional orofacial condition and vocal symptoms. In the vocal assessment, the CG performed better, showing higher scores for maximum phonation time (MPT) and

Table 1 Descriptive information of the study sample

	Control Group ($n = 30$)	OSA ($n = 33$)	p
Age (years old), mean (SD)	38.43 (10.41)	45.33 (9.93)	0.01*
Women, n (%)	22 (73.33)	18 (54.54)	0.12
BMI > 35, n (%)	2 (6.66)	15 (45.45)	0.00**
Stanford, mean (SD)	0.00 (0.00)	7.52 (2.55)	0.00*
Berlin questionnaire, mean (SD)	2.93 (2.7)	13.56 (5.02)	0.00*
STOP-BANG questionnaire, mean (SD)	0.83 (0.91)	4.36 (1.59)	0.00*

Abbreviations: %, relative value; BMI, body mass index; n,= absolute value; SD, standard deviation.
*Statistical significance for the difference ($p < 0.05$) between the GOSA and GC groups in the Mann-Whitney test.
**Statistical significance for the difference ($p < 0.05$) between the GOSA and GC groups in the Chi-square test.

Table 2 Description of the Orofacial Myofunctional and Voice Assessment

	Control ($n = 30$)	OSA ($n = 33$)	p
Voice Symptom Scale, mean (SD)	9.70 (9.84)	24.61 (12.54)	0.00*
OMES, mean (SD)	206.63 (12.86)	172.09 (17.42)	0.00*
Maximum phonation time /a/ (seconds), mean (SD)	16.17 (5.82)	11.35 (5.56)	0.01*
Maximum phonation time /i/ (seconds), mean (SD)	18.56 (6.80)	11.69 (6.05)	0.00*
Maximum phonation time /u/ (seconds), mean (SD)	18.83 (6.81)	11.31 (5.41)	0.00*
Maximum phonation time - s/z ratio, mean (SD)	0.928 (0.33)	1.040 (0.37)	0.17

Abbreviations: OMES, orofacial myofunctional evaluation with scores protocol; SD, standard deviation.
*Statistical significance for the difference ($p < 0.05$) between the GOSA and CG groups in the Mann-Whitney test.
**Statistical significance for the difference ($p < 0.05$) between the GOSA and CG in the Chi-square test.

sustained emission of the vowels /I/ and /U/ and the fricatives /s/ and /z/ (►**Table 2**).

Regarding the GRBASI scale, the OSA group presented a higher percentage of vocal alterations than the GC, although this was not statistically significant (Chi-square Test = 2,39; $p < 0.12$), as shown in ►**Table 3**.

Pneumophonoarticulatory coordination was more frequently classified as "Coordinated" in the Control group than in the OSA group (96.7% versus 60.6%) (chi-square test = 11.82; $p = 0.01$). There was a significant difference (chi-square test = 11.92; $p = 0.01$) between the groups for the percentage of MPT, which was higher than expected in the Control group compared with the OSA group (56.7% versus 15.2%). The Control group predominantly exhibited time classifications within the expected range (84.8%), whereas a substantial proportion of the OSA group (43.3%) fell below the expected thresholds.

The polysomnographic variables performed only in the group with obstructive sleep apnea (OSA group) showed an AHI mean of 45.80 (±78.60), indicating a predominance of moderate to severe sleep apnea. The desaturation index was 32.47 (±27.46), demonstrating a high frequency of oxygen desaturation episodes during sleep. There was variation in respiratory disturbances according to body position (Supine RDI: 46.92 ± 37.28, Non-supine RDI: 21.36 ± 21.21). Despite the significant respiratory disturbances, sleep efficiency remained relatively preserved (80.95 ± 10.90%), with an average total sleep time of 354.78 ± 56.09 minutes in the population.

►**Fig. 1** presents the Spearman correlations between polysomnographic parameters and vocal and orofacial variables, controlling for BMI. A trend toward statistical significance ($p = 0.05$) was observed for the negative correlation between the total OMES-E score and the STOP-BANG questionnaire. The Voice Symptom Scale showed a significant negative correlation ($p = 0.04$) with the AHI during NREM sleep. In addition, Maximum Phonation Time (vocals) was negatively correlated with the Oxygen Desaturation Index ($p = 0.022$).

Discussion

The current study demonstrates that individuals with OSA exhibit deficiencies in orofacial myofunctional and vocal parameters compared with individuals without OSA symptoms. There were adverse changes noted in maximum

Table 3 Distribution of categorical variables of the GRBASI Scale

	Control group n (%)	OSA group n (%)
Within normal limits	22 (73.3)	18 (54.5)
Presence of mild vocal instability	1 (3.3)	0 (0)
Presence of mild tension and instability	0 (0.0)	1 (3.0)
Presence of mild asthenia and instability	0 (0.0)	1 (3.3)
Presence of mild breathiness;	1 (3.3)	0 (0.0)
Presence of mild breathiness and instability	2 (6.7)	0 (0.0)
Presence of mild roughness	4 (13.3)	12 (36.4)
Presence of mild tension	0 (0.0)	1 (0.0)
Number of participants	30 (100%)	33 (100%)

Abbreviations: GRBASI, scale used to assess vocal quality, where G – overall grade of dysphonia, R – roughness, B – breathiness, A – asthenia, S – strain, I – instability. Each parameter is scored on a scale from 0 to 3, where 0: no perceptual alteration, 1: mild alteration, 2: moderate alteration, and 3: severe alteration.

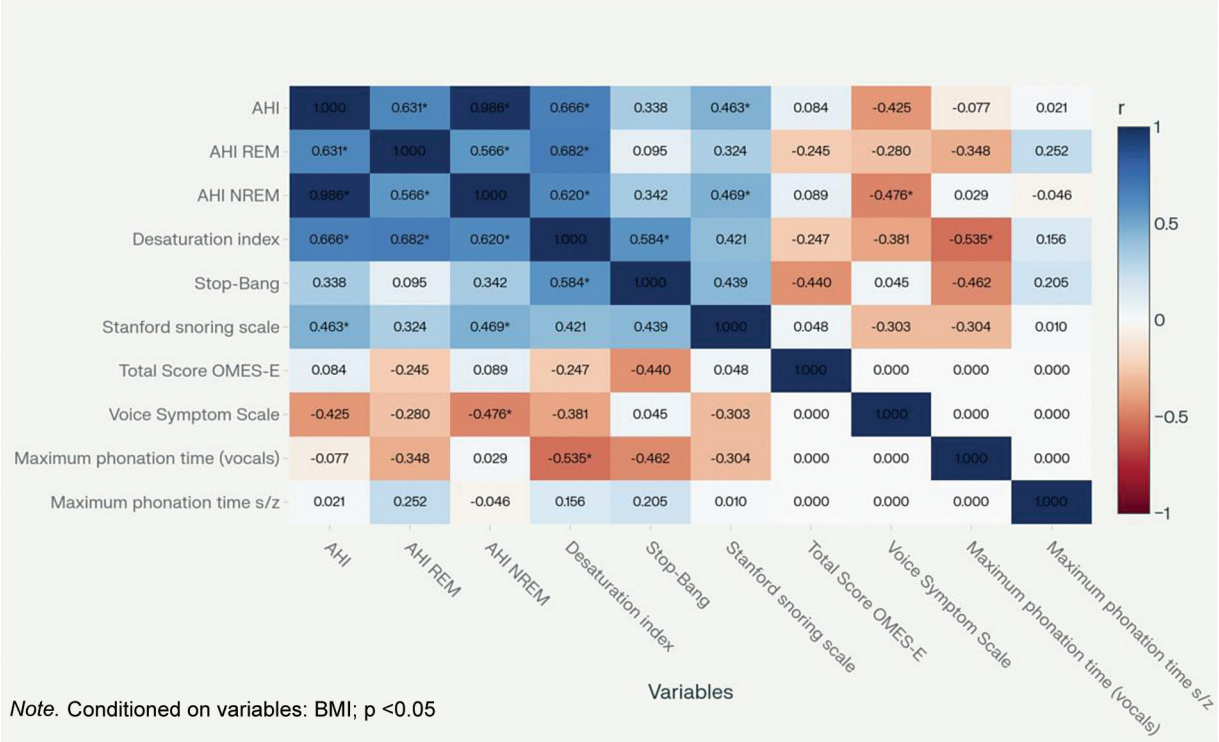

Fig. 1 Spearman correlation between variables, controlling for BMI (Partial out). * $p < 0.05$.

phonation time, speech rate, pneumophonoarticulatory coordination, sustained vowel emission, and fricative phonemes. The growing awareness that sleep-related breathing disorders are a public health problem and their connection to vocal[4,13,14] and orofacial myofunctional changes has resulted in more studies being done,[3] explaining the recent interest in this area of research.

The participants in the OSA group demonstrated lower scores in the OMES-E Protocol and negative correlation between the total OMES-E score and the STOP-BANG questionnaire (trend to significance), indicating poorer orofacial myofunctional condition in individuals at higher risk for apnea and hypopnea events. This finding has been previously raised in studies where individuals with OSA commonly present with orofacial myofunctional disorders.[3,15,16] Regarding the orofacial alterations already described in other studies, such as increased tongue volume, tonsils, uvula, and posterior oropharyngeal wall, arched hard palate, reduced facial symmetry, low resting tongue position, inferior positioning of the hyoid bone, upper airway narrowing, and altered swallowing and chewing functions,[17–19] the current work confirmed that patients with OSA have deficits in orofacial myofunctional conditions, in addition to vocal issues that will be described below.

Concerning voice, the OSA group performed worse than the control group in all voice tests used in this study (Vocal Symptom Scale and Maximum Phonation Times) and showed more issues with pneumophonoarticulatory incoordination and slower speech rate. Although the relationship between sleep-related breathing disorders and vocal alterations is complex, individuals with OSA are more likely to present vocal symptoms that negatively affect their voice-related quality of life compared with healthy subjects.[13] Additionally, people with OSA can exhibit irregular vocal fold vibration, incomplete glottal closure, hoarseness, and various other voice-related issues.[19]

The current investigation found no significant differences in sex between the studied groups. We observed the prevalence of women with OSA was slightly higher than that of men, but this difference was not statistically significant. This result may have arisen due to the OSA group's average age of 54 years. At this age, the prevalence of OSA is comparable between the sexes, unlike in lower-age groups, where the male prevalence is much higher.

BMI is acknowledged to directly affect the frequency of OSA episodes, with obesity being a contributing factor to this disorder.[20] The current study found a higher prevalence of people with a BMI over 35 in the OSA group. This discovery aligns with existing understanding. Excess adipose tissue in the cervical area and tongue promotes upper airway collapse by diminishing its lumen. Additionally, obesity may correlate with laryngeal inflammation, impacting vocal output, while the increased pressure on the upper airway can modify resonance and voice quality.[13] Individuals with morbid obesity frequently exhibit harsh, breathy, unsteady, and strangled vocal qualities. These people demonstrate reduced maximal phonation time compared to those with a normal BMI. This modification is attributed to the excessive adipose tissue in the larynx, leading to difficulties in optimal voice output due to the lack of movement of aerodynamic myoelastic

forces.[21,22] In the correlations analysis the BMI was controlled and Maximum Phonation Time (vocals) still was negatively correlated with the Oxygen Desaturation Index, suggesting that a higher frequency of desaturation episodes is associated with reduced phonatory capacity. These findings highlight the association between sleep-disordered breathing and impairments in vocal functions, independently of BMI.

In addition to its direct role in the pathophysiology of OSA, BMI may also influence both vocal and orofacial myofunctional outcomes observed in this study. Obese and overweight individuals not only have higher risk and severity of OSA but also exhibit more pronounced orofacial myofunctional impairments (Silva et al., 2023). The greater the BMI, the higher the prevalence and severity of OSA, the poorer the sleep quality, and the more compromised the orofacial myofunctional condition are related. Although BMI has been statistically controlled in the correlation analysis of the present study, AHI role as a compounding factor in the overall profile of patients with OSA must be acknowledged, particularly considering the mechanical and inflammatory effects of obesity on both the UA and laryngeal structures.

This study contains noteworthy limitations, including the absence of a PSG exam in the control group, a lack of age matching, and a subjective voice assessment reliant on the examiner's auditory impression. Regarding the first limitation, due to the very low pre-test probability of OSA in the control group—characterized by the absence of clinical symptoms and negative results on validated screening tools—the diagnostic yield of performing PSG in this population was considered negligible. Therefore, overnight PSG assessment was not conducted in the CG, in line with clinical practice guidelines that emphasize the importance of pre-test probability in determining the appropriateness of sleep studies.[1] Other studies also did not include a PSG exam in their control groups[3] and they argue that these people failed to satisfy the minimum requirements for polysomnography indication, including symptoms of snoring, excessive daytime drowsiness, gasping, choking, or obesity, as evidenced by normal scores on the STOP-BANG and Stanford scales. It is essential to acknowledge that clinical assessments or symptom-based group classifications lack the diagnostic precision for sleep disorders that PSG provides.[3,13]

Prior studies also evaluated individuals with OSA utilizing the GRBASI scale, yielding analogous outcomes with this subjective perceptual scale. The GRBASI scale and the Vocal Symptom Scale correlate with instrumental voice evaluations. These scales are acknowledged for their precision in identifying vocal alterations, demonstrating favorable psychometric properties,[23,24] although perceptual-auditory evaluation is not advised as the main instrument for vocal health assessment.

Nonetheless, it is important to consider that aging itself can influence both vocal parameters and orofacial functions. Changes in the throat and face structures due to aging can affect how we understand voice and muscle function tests, regardless of whether OSA is present. Also, aging can affect auditory-perceptual and acoustic voice measures, with variations observed across age decades and between sexes.[25] Similarly, studies have shown that the aging process leads to physiological and functional decline of the stomatognathic system, with negative consequences for orofacial mobility, muscle strength, and precision of movement.[7,26] These changes can compromise orofacial functions, nutritional status, and overall health, underscoring the relevance of age as a potential confounding variable in studies involving voice and orofacial myofunction.

Conclusions

This study evaluated and described both vocal parameters and orofacial myofunctional conditions in patients with OSA compared with a group of low-risk subjects without clinically relevant snoring. It was found that OSA patients have deficits in orofacial myofunctional and vocal conditions compared with subjects without OSA complaints, with negative alterations identified in maximum phonation time, speech rate, pneumophonoarticulatory coordination, sustained emission of vowels, and fricative phonemes.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

Gislaine Aparecida Folha: conceptualization, methodology, investigation, writing – original draft preparation, review, and editing.

Melissa França Lima Martins: investigation, writing – review and editing.

Fernando Stelzer: formal analysis, writing – review and editing.

Fabiana Cardoso Pereira Valera: resources, review and editing.

Alan Luiz Eckeli: resources, methodology, formal analysis, writing – review and editing.

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Conflict of Interest

None.

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