

Effects of Oropharyngeal Exercises on Patients with Moderate Obstructive Sleep Apnea Syndrome

Kátia C. Guimarães¹, Luciano F. Drager¹, Pedro R. Genta¹, Bianca F. Marcondes¹, and Geraldo Lorenzi-Filho¹

¹Sleep Laboratory, Pulmonary Division, Heart Institute (InCor), University of São Paulo Medical School, São Paulo, Brazil

Rationale: Upper airway muscle function plays a major role in maintenance of the upper airway patency and contributes to the genesis of obstructive sleep apnea syndrome (OSAS). Preliminary results suggested that oropharyngeal exercises derived from speech therapy may be an effective treatment option for patients with moderate OSAS.

Objectives: To determine the impact of oropharyngeal exercises in patients with moderate OSAS.

Methods: Thirty-one patients with moderate OSAS were randomized to 3 months of daily (~30 min) sham therapy (n = 15, control) or a set of oropharyngeal exercises (n = 16), consisting of exercises involving the tongue, soft palate, and lateral pharyngeal wall.

Measurements and Main Results: Anthropometric measurements, snoring frequency (range 0–4), intensity (1–3), Epworth daytime sleepiness (0–24) and Pittsburgh sleep quality (0–21) questionnaires, and full polysomnography were performed at baseline and at study conclusion. Body mass index and abdominal circumference of the entire group were 30.3 ± 3.4 kg/m² and 101.4 ± 9.0 cm, respectively, and did not change significantly over the study period. No significant change occurred in the control group in all variables. In contrast, patients randomized to oropharyngeal exercises had a significant decrease ($P < 0.05$) in neck circumference (39.6 ± 3.6 vs. 38.5 ± 4.0 cm), snoring frequency (4 [4–4] vs. 3 [1.5–3.5]), snoring intensity (3 [3–4] vs. 1 [1–2]), daytime sleepiness (14 ± 5 vs. 8 ± 6), sleep quality score (10.2 ± 3.7 vs. 6.9 ± 2.5), and OSAS severity (apnea-hypopnea index, 22.4 ± 4.8 vs. 13.7 ± 8.5 events/h). Changes in neck circumference correlated inversely with changes in apnea-hypopnea index ($r = 0.59$; $P < 0.001$).

Conclusions: Oropharyngeal exercises significantly reduce OSAS severity and symptoms and represent a promising treatment for moderate OSAS.

Clinical trial registered with www.clinicaltrials.gov (NCT 00660777).

Keywords: obstructive sleep apnea; treatment; oropharyngeal exercises

Obstructive sleep apnea syndrome (OSAS) is a significant public health problem characterized by repetitive episodes of upper airway occlusion during sleep associated with sleep fragmentation, daytime hypersomnolence, and increased cardiovascular risk (1, 2). It is well established that the most effective treatment for OSAS is continuous positive airway pressure (CPAP) (3). CPAP virtually eliminates OSAS in conjunction with elimination of snoring, reduction of daytime sleepiness, and improvement in subjective sleep quality (3, 4). The improvement is especially true

AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

Continuous positive airway pressure is the treatment of choice for obstructive sleep apnea syndrome (OSAS) but is not suitable for a large proportion of patients. Alternative treatments for OSAS have shown variable results.

What This Study Adds to the Field

This randomized controlled trial showed that oropharyngeal exercises developed for the treatment of OSAS significantly reduced OSAS severity and symptoms. This novel modality of OSAS treatment represents a promising approach for moderate OSAS.

for patients with severe OSAS, in whom the apnea-hypopnea index (AHI) is greater than 30 events/hour. However, for moderately affected patients (AHI between 15 and 29.9 events/h), CPAP therapy may not be suitable for a significant proportion of patients. Alternative treatments for moderate OSAS include mandibular advancement, weight loss, and surgery; these treatments have variable results (5). Therefore, it is necessary to test the efficacy of other modalities of treatment for moderate OSAS, particularly considering that this subset of patients makes up a significant percentage of the OSAS population.

The genesis of OSAS is multifactorial and includes anatomical and physiological factors. Upper airway dilator muscles are crucial to the maintenance of pharyngeal patency and may contribute to the genesis of OSAS (6, 7). A recent study showed that upper airway muscle training while awake with the use of didgeridoo playing significantly ameliorated OSAS severity and associated symptoms (8). A set of oropharyngeal exercises, cited hereafter as “oropharyngeal exercises” for the sake of simplicity, is derived from speech therapy and consists of isometric and isotonic exercises involving the tongue, soft palate, and lateral pharyngeal wall, including functions of suction, swallowing, chewing, breathing, and speech. Oropharyngeal exercises have been previously shown to be effective in small and noncontrolled studies (9). In the present study, recently presented in the form of an abstract (10), we tested in a randomized controlled trial the effects of oropharyngeal exercises in patients with moderate OSAS on objective measurement of severity derived from polysomnography as well as subjective sleep symptoms, including snoring, daytime sleepiness, and sleep quality.

METHODS

Patients

We considered eligible patients between 25 and 65 years of age with a recent diagnosis of moderate OSAS evaluated in the sleep laboratory, Pulmonary Division, Heart Institute (InCor), University of São Paulo Medical School. We excluded patients with one or more of the following conditions: body mass index (BMI) 40 kg/m² or greater,

(Received in original form June 27, 2008; accepted in final form February 19, 2009)

Supported by the Fundação de Amparo à Pesquisa do Estado de São Paulo, Conselho Nacional de Desenvolvimento Científico e Tecnológico, and the E. J. Zerbini Foundation.

Correspondence and requests for reprints should be addressed to Geraldo Lorenzi-Filho, M.D., Ph.D., Sleep Laboratory, Pulmonary Division, Heart Institute (InCor), University of São Paulo Medical School, Av Dr Enéas Carvalho de Aguiar, 44, CEP 05403-904, São Paulo, Brazil. E-mail: geraldo.lorenzi@incor.usp.br

This article has an online data supplement, which is available from the issue's table of contents at www.atsjournals.org

Am J Respir Crit Care Med Vol 179, pp 962–966, 2009

Originally Published in Press as DOI: 10.1164/rccm.200806-981OC on February 20, 2009
Internet address: www.atsjournals.org

craniofacial malformations, regular use of hypnotic medications, hypothyroidism, previous stroke, neuromuscular disease, heart failure, coronary disease, or severe obstructive nasal disease. The local ethics committee approved the study, and all patients gave written informed consent.

Polysomnography

All patients were evaluated by full polysomnography using the following electrophysiological parameters: EEG (C3-A2, C4-A1, O1-A2, O2-A1), electrooculogram (two channels), submentonian and anterior tibial EMG, snoring sensor, air flow (two channels) measured with oronasal thermistor and nasal pressure cannula, thoracic and abdominal belts, ECG, position detector, oxygen saturation, and heart pulse, as previously described (11). Moderate OSAS was defined by an AHI between 15 and 29.9 events per hour of sleep (1). The person who analyzed the sleep study was blinded to the group allocation.

Questionnaire

Snoring frequency, ranging from 0 (never) to 4 (every day) and intensity 1 (similar to breathing) to 3 (very loud) were derived from the Berlin questionnaire (12, 13). Subjective daytime sleepiness was evaluated with the Epworth questionnaire that evaluates the propensity to sleep from no (0) to intense (3) in eight different situations. Total score greater than 10 is considered excessive daytime sleepiness (14). Quality of sleep was evaluated with the Pittsburgh sleep quality questionnaire that evaluates seven sleep components on a scale of 0 to 3, 0 indicating no difficulty and 3 indicating severe difficulty. The results are expressed as a global score (ranging from 0–21). Values greater than 5 are consistent with poor sleep quality (15).

Control Group

Sham therapy consisted of a weekly, supervised session (~30 min) of deep breathing through the nose while sitting. The patients were also instructed to perform the same procedure at home once a day (30 min), plus nasal lavage with application of 10 ml of saline in each nostril three times a day. At study entry bilateral chewing was recommended when eating meals.

Study Group

The same schedule and set of instructions applied to the control group were given to these patients with the substitution of deep breathing by effective therapy. Oropharyngeal exercises are derived from speech-language pathology and include soft palate, tongue, and facial muscle exercises as well as stomatognathic function exercises. The patients were instructed by one single speech pathologist (K.C.G.) to perform the following tasks (*see* online supplement, which includes a film of the exercises).

Soft palate. Pronounce an oral vowel intermittently (isotonic exercise) and continuously (isometric exercise). The palatopharyngeus, palatoglossus, uvula, tensor veli palatini, and levator veli palatini muscles are recruited in this exercise. The isotonic exercise also recruits pharyngeus lateral wall. These exercises had to be repeated daily for 3 minutes and were performed once a week under supervision to ensure adequate effort.

Tongue. (1) Brushing the superior and lateral surfaces of the tongue while the tongue is positioned in the floor of the mouth (five times each movement, three times a day); (2) placing the tip of the tongue against the front of the palate and sliding the tongue backward (a total of 3 min throughout the day); (3) forced tongue sucking upward against the palate, pressing the entire tongue against the palate (a total of 3 min throughout the day); (4) forcing the back of the tongue against the floor of the mouth while keeping the tip of the tongue in contact with the inferior incisive teeth (a total of 3 min throughout the day).

Facial. The exercises of the facial musculature use facial mimicking to recruit the orbicularis oris, buccinator, major zygomaticus, minor zygomaticus, levator labii superioris, levator anguli oris, lateral pterygoid, and medial pterygoid muscles. The exercises include: (1) Orbicularis oris muscle pressure with mouth closed (isometric exercise). Recruited to close with pressure for 30 seconds, and right after, requested to realize the posterior exercise. (2) Suction movements contracting only the buccinator.

These exercises were performed with repetitions (isotonic) and holding position (isometric). (3) Recruitment of the buccinator muscle against the finger that is introduced in the oral cavity, pressing the buccinator muscle outward. (4) Alternated elevation of the mouth angle muscle (isometric exercise) and after, with repetitions (isotonic exercise). Patients were requested to complete 10 intermittent elevations three times. (5) Lateral jaw movements with alternating elevation of the mouth angle muscle (isometric exercise).

Stomatognathics functions.

1. Breathing and Speech: (1) Forced nasal inspiration and oral expiration in conjunction with phonation of open vowels, while sitting; (2) Balloon inflation with prolonged nasal inspiration and then forced blowing, repeated five times without taking the balloon out of the mouth.
2. Swallowing and Chewing: Alternate bilateral chewing and deglutition, using the tongue in the palate, closed teeth, without perioral contraction, whenever feeding. The supervised exercise consisted of alternate bread mastication. This exercise aims for the correct position of the tongue while eating and targets the appropriate functionality and movement of the tongue and jaw. The patients were instructed to incorporate this mastication pattern whenever they were eating.

Experimental Design

After fulfilling entry criteria, the patients were randomized for 3 months into either the control or treatment group, with oropharyngeal exercises. All patients were evaluated by the speech-language pathologist once a week for 30 minutes. All patients had to fill a diary recording compliance to exercises (yes or no). The query was subdivided in three distinct domains: tongue, palate, and face. Overall, adequate compliance was evaluated on a weekly basis and defined by the performance of 85% or more of the exercises proposed in all domains. Patients who failed to return for three consecutive weeks or failed to comply with the exercises at home (performing <85% of the exercises) were excluded from the study. Polysomnography and questionnaires were performed at the beginning and end of the study. The primary outcome was AHI. Secondary outcomes included lowest oxygen saturation and sleep-related questionnaires.

Statistical Analysis

Data were analyzed with STATISTICA 5.0 software. Baseline characteristics of patients with OSAS according to the group assigned were compared by two-tailed unpaired *t* tests for continuous variables and Fisher exact test for nominal variables. For variables with skewed distribution, we performed Mann-Whitney test. Two-way repeated-measures analysis of variance and Tukey test were used to compare differences within and between groups in variables measured at baseline and after 3 months. In addition, we performed Pearson correlations between changes in AHI with changes in possible explanatory variables, including BMI, abdominal circumference, and neck circumference. A value of $P < 0.05$ was considered significant.

RESULTS

We screened more than 50 patients in whom moderate OSAS had been recently diagnosed in our sleep laboratory. Because of our exclusion criteria, we recruited 39 patients. Eight patients (3 in the active treatment arm) were excluded due to low adherence as defined in the METHODS section. The 31 patients included in the final analysis were predominantly middle-aged males, overweight or obese. The demographic and sleep characteristics and symptoms of the population, according to the group assigned, are presented in Table 1. Patients assigned to control and therapy groups had similar baseline characteristics (Table 1). No changes in weight or abdominal circumference during the study period were observed in either group (Table 2). After 3 months, no significant changes were observed in the control group (Table 2). In contrast, patients randomized to

TABLE 1. BASELINE DEMOGRAPHIC AND SLEEP CHARACTERISTICS OF THE PATIENTS ASSIGNED TO CONTROL OR OROPHARYNGEAL THERAPY

	Control (N = 15)	Therapy (N = 16)	P Value
Age, years	47.7 ± 9.8	51.5 ± 6.8	0.23
Males, %	73	63	1.0
Whites, %	71	60	0.97
BMI, kg/m ²	31.0 ± 2.8	29.6 ± 3.8	0.24
Neck circumference, cm	40.9 ± 3.5	39.6 ± 3.7	0.30
Abdominal circumference, cm	103 ± 7	100 ± 10	0.37
Smoking, %	20	6.3	0.33
Hypertension, %	33.3	18.8	0.43
Diabetes, %	6.7	6.3	1.0
Epworth Sleepiness Scale	14 ± 7	14 ± 5	0.83
Snoring frequency	4 (3.3–4)	4 (4–4)	0.21
Snoring intensity	3 (2.3–4)	3 (3–4)	0.33
Sleep quality, Pittsburgh	11 ± 4	10 ± 4	0.69
Sleep efficiency	86 ± 10	87 ± 8	0.72
Arousals	148 (73–173)	140 (102–236)	0.26
AHI (events/hour)	22.4 ± 5.4	22.4 ± 4.8	0.98
Apnea index (events/hour)	9.1 ± 6.6	6.6 ± 4.7	0.35
Hypopnea index (events/hour)	14.8 ± 8.4	14.7 ± 6.6	0.20
Lowest Sa _{O₂} , %	82 ± 4	83 ± 6	0.56

Definition of abbreviations: AHI = apnea-hypopnea index; BMI = body mass index.

Plus-minus values are mean ± SD. Snoring frequency, snoring intensity, and arousals were presented as median (25–75%) because of skewed distribution.

therapy had significantly decreased neck circumference, snoring symptoms, subjective sleepiness, and quality of sleep score (Table 2). In addition, patients assigned to oropharyngeal exercises experienced a significant decrease in AHI compared with control subjects (Figure 1). There was a small but significant decrease in minimal oxygen saturation in the control group and a significant increase in minimal oxygen saturation in the treatment group (Figure 2). In the treatment group, 10 patients (62.5%) shifted from moderate to mild (n = 8) or no (n = 2) OSAS. Considering the entire group, changes in AHI did not correlate significantly with changes in anthropometric measurements except with changes in neck circumference (Figure 3).

DISCUSSION

This randomized controlled study is the first to investigate the effects of upper airway muscle training by a series of

oropharyngeal exercises in patients with moderate OSAS. Three months of exercise training reduced by 39% the severity of OSAS evaluated by the AHI and lowest oxygen saturation determined by polysomnography. The significant OSAS improvement in the patients randomized to muscle training occurred in conjunction with a reduction in snoring, daytime sleepiness, and quality of sleep score. Despite no significant changes in body habitus, patients randomized to oropharyngeal therapy had a significant reduction in neck circumference, suggesting that the exercises induced upper airway remodeling. Changes in AHI correlated negatively with changes in cervical circumference.

The set of oropharyngeal exercise used in the current study was developed over the last 8 years and has previously been shown to be effective in uncontrolled studies (9). There is proof of the concept that muscle training while awake will reduce upper airway collapsibility during sleep in patients with OSAS. Tongue muscle training during the daytime for 20 minutes twice a day for 8 weeks reduced snoring, but did not change AHI significantly in a randomized controlled study (16). A recent trial found that in patients with moderate OSAS 4 months of training of the upper airways by didgeridoo playing reduced daytime sleepiness, snoring, and AHI (8). However, in contrast to our study, the study was not a fully controlled group (control group consisted of subjects on the waiting list for didgeridoo playing), sleep was not monitored (cardiorespiratory studies), the primary outcome was subjective sleepiness, and the reduction of AHI was marginal ($P = 0.05$) (8). In our study, the oropharyngeal exercises were developed with the primary objective of reducing OSAS severity (9). The reduction in the AHI observed in patients with moderate OSAS was remarkable and in the same order of magnitude as that previously reported by a review of randomized studies that used a mandibular advancement appliance for OSAS (17) (39 vs. 42%, respectively) (17, 18). The effects of oropharyngeal exercises were observed not only in the AHI and lowest oxygen saturation, but also in the symptoms associated with OSAS. In the control group no significant changes were reported in all parameters. The effect of oropharyngeal exercises on daytime somnolence was quite effective, reducing the Epworth sleepiness scale an average of 6 units (Table 2). For severely affected patients, the minimum significant difference on this scale was suggested to be around 4 units (19). Oropharyngeal exercises also induced significant improvements in several subjective sleep scales, including Pittsburgh and snoring symptoms.

TABLE 2. ANTHROPOMETRIC, SYMPTOM, AND SLEEP CHARACTERISTICS AT BASELINE AND AFTER 3 MONTHS OF RANDOMIZATION

Variables	Control (N = 15)			Therapy (N = 16)		
	Baseline	3 mo	P Value	Baseline	3 mo	P Value
BMI, kg/m ²	31.0 ± 2.8	30.8 ± 3.0	0.34	29.6 ± 3.8	29.5 ± 4.3	0.65
Neck circumference, cm	40.9 ± 3.5	40.7 ± 3.7	0.53	39.6 ± 3.6	38.5 ± 4.0	0.01*
Abdominal circumference, cm	102.9 ± 7.3	102.3 ± 7.4	0.26	100.0 ± 10.4	98.9 ± 12.1	0.33
Epworth Sleepiness Scale	14 ± 7	12 ± 6	0.35	14 ± 5	8 ± 6	0.006*
Snoring frequency	4 (3.3–4)	4 (3–4)	0.79	4 (4–4)	3 (1.5–3.5)	0.001†
Snoring intensity	3 (2.3–4)	3 (2–3)	0.30	3 (3–4)	1 (1–2)	0.001*
Sleep quality, Pittsburgh	10.7 ± 3.7	10.8 ± 4.1	0.88	10.2 ± 3.7	6.9 ± 2.5	0.001†
Sleep efficiency, %	86 ± 10	87 ± 11	0.79	87 ± 8	86 ± 9	0.58
Apnea index, events/hour	9.1 ± 6.6	9.6 ± 6.0	0.94	6.6 ± 4.7	3.3 ± 3.2	0.009†
Hypopnea index, events/hour	14.8 ± 8.4	14.7 ± 6.6	0.90	14.7 ± 6.6	9.5 ± 5.8	0.07
AHI REM, events/hour	29.9 ± 11.6	39.3 ± 21.0	0.06	29.8 ± 12.7	17.4 ± 15.9	0.007†
AHI NREM, events/hour	20.3 ± 9.6	23.7 ± 8.8	0.75	19.8 ± 7.0	15.2 ± 10.3	0.13

Definition of abbreviations: AHI = apnea-hypopnea index; BMI = body mass index; NREM = non-rapid eye movement; REM = rapid eye movement.

Plus-minus values are mean ± SD. Snoring frequency and snoring intensity were presented as median (25–75%) because of skewed distribution.

* $P < 0.05$ for the comparisons between the groups.

† $P < 0.01$ for the comparisons between the groups.

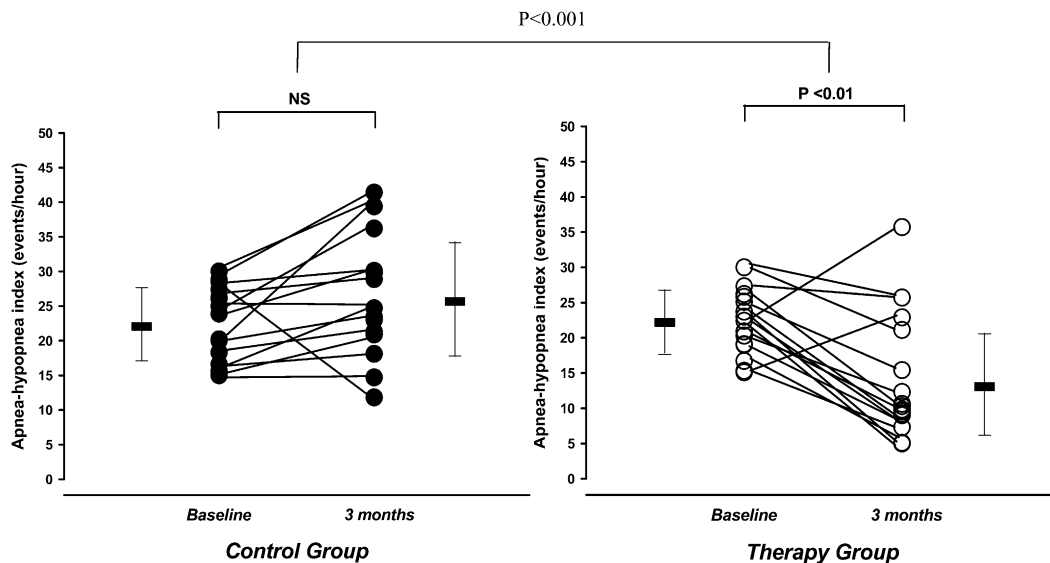


Figure 1. Individual values for apnea-hypopnea index (AHI). In the control group, the AHI from baseline to 3 months (from 22.4 ± 5.4 to 25.9 ± 8.5 events/h) was similar. In contrast, the AHI significantly decreased in the group randomized to oropharyngeal exercises (from 22.4 ± 4.8 to 13.7 ± 8.5 events/h; $P < 0.01$). The differences between groups remained significant ($P < 0.001$). Short horizontal lines and bars are mean \pm SD. NS = not significant.

This study describes a new method of upper airway exercise training for which there is no comparable study available to date. The series of exercises was primarily developed to increase upper airway patency and is based on the concept that the functions of sucking, swallowing, chewing, breathing, and speech are closely related and are part of the stomatognathic system (20). The exercises were developed based on this integrated concept of overlapping functions of the upper airways as well as on the clinical observation of patients with OSAS. Patients with OSAS typically had elongated and floppy soft palate and uvula, enlarged tongue, and inferior displacement of the hyoid bone (21–23). The exercises targeting soft palate elevation use speech exercises that recruit several upper airway muscles. In addition to the recruitment of the tensor and levator veli palatine, these exercises also recruit muscle fibers of the palatopharyngeal and palatoglossus muscle. Based on the evidence that tongue posture appears to have a substantial effect on upper airway structures (16, 24), specific exercises were developed targeting tongue repositioning. The facial muscles are also recruited during chewing and were also trained with the intention of training muscles that promote mandibular

elevation, avoiding mouth opening. We speculate that this treatment modality may affect the propensity to upper airway edema and collapsibility (25). It must be stressed that this study was not designed to explore the exact mechanisms by which this set of oropharyngeal exercises improves OSAS severity and symptoms. However, the observation of a moderate association between changes in neck circumference with changes in AHI (Figure 3) suggests that the exercises induce upper airway remodeling that in turn correlates with airway patency during sleep (26).

Our study has limitations. First, the therapy is based on an integrative approach and therefore does not allow determining the effects of each specific exercise on the overall result. Moreover, these exercises are derived from oral motor techniques to improve speech and/or swallowing activity, an area that lacks the empirical support necessary for evidence-based practices (27). On the other hand, this approach allowed us to select an appropriate sham intervention, wherein patients were given breathing exercises and nasal lavage. Second, the generalization of oropharyngeal exercises for moderate OSAS must be viewed with caution, because it will depend on the training speech

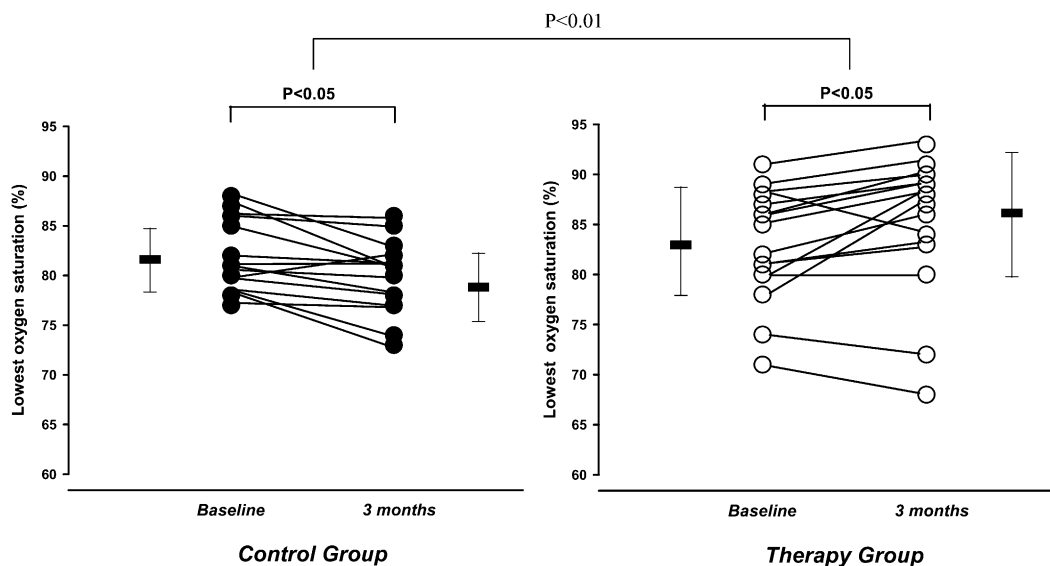


Figure 2. Individual values for lowest oxygen saturation. In the control group, the lowest oxygen saturation significantly decreased from baseline to 3 months (from 82 ± 4 to $80 \pm 4\%$). In the group randomized to oropharyngeal exercises, the lowest oxygen saturation significantly increased (from 83 ± 6 to $85 \pm 7\%$). The differences between groups remained significant ($P < 0.01$). Short horizontal lines and bars are mean \pm SD.

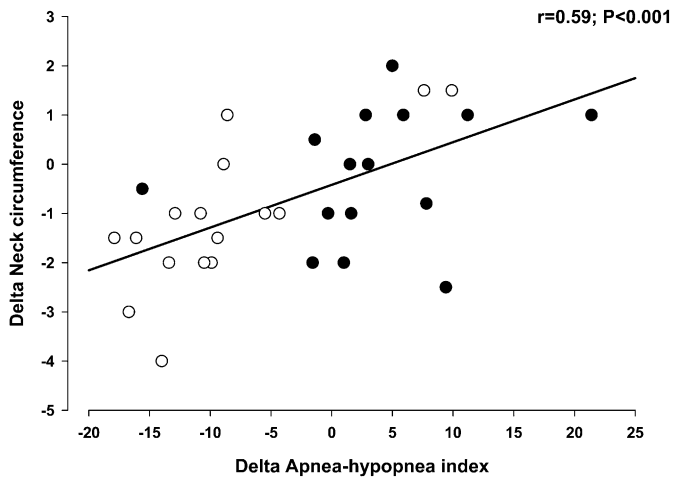


Figure 3. Correlations between apnea-hypopnea index with neck circumference. Solid circles, control group; open circles, therapy group.

pathologists. Based on our experience over the last 8 years (9), these patients will need to continuously exercise the upper airway muscles, which will raise an important issue related to treatment compliance. Finally, we observed that the overall effects of oropharyngeal exercises were present both in rapid eye movement (REM) and non-REM sleep, reaching statistical significance in REM sleep but not in non-REM sleep. We believe that this result may be justified by the relatively small sample size involved in this randomized study. However, we would like to stress that this study was designed to test the hypothesis that a set of oropharyngeal exercises is effective in reducing the severity of OSAS, as measured by the overall AHI across the night.

In conclusion, in patients with moderate OSAS, oropharyngeal exercises improved objective measurements of OSAS severity and subjective measurements of snoring, daytime sleepiness, and sleep quality. Our results suggest that this set of oropharyngeal exercises is a promising alternative for the treatment of moderate OSAS.

Conflict of Interest Statement: None of the authors has a financial relationship with a commercial entity that has an interest in the subject of this manuscript.

References

- American Academy of Sleep Medicine (AASM) Task Force. Sleep-related breathing disorders in adults. Recommendation for syndrome definition and measurement techniques in clinical research. *Sleep* 1999;22:667–668.
- Marin JM, Carrizo SJ, Vicente E, Agusti AG. Long-term cardiovascular outcomes in men with obstructive sleep apnoea-hypopnea with or without treatment with continuous positive airway pressure: An observational study. *Lancet* 2005;365:1046–1053.
- Sullivan CE, Issa FG, Berthon-Jones M, Eves L. Reversal of obstructive sleep apnoea by continuous positive airway pressure applied through the nares. *Lancet* 1981;1:862–865.
- D'Ambrosio C, Bowman T, Mohsenin V. Quality of life in patients with obstructive sleep apnea: effect of nasal continuous positive airway pressure—a prospective study. *Chest* 1999;115:123–129.
- Bloch KE. Alternatives to CPAP in the treatment of the obstructive sleep apnea syndrome. *Swiss Med Wkly* 2006;136:261–267.
- Malhotra A, White DP. Obstructive sleep apnoea. *Lancet* 2002;360:237–245.
- Schwartz AR, Patil SP, Laffan AM, Polotsky V, Schneider H, Smith PL. Obesity and obstructive sleep apnea: pathogenic mechanisms and therapeutic approaches. *Proc Am Thorac Soc* 2008;5:185–192.
- Puhan MA, Suarez A, Cascio CL, Zahn K, Heitz M, Braendli O. Didgeridoo playing as alternative treatment for obstructive sleep apnoea syndrome: randomised controlled trial. *BMJ* 2005;332:266–270.
- Guimarães KCC, Protetti HM. The phonological work at obstructive sleep apnea [abstract]. *Sleep* 2003;26:A209.
- Guimarães K, Drager LF, Marcondes B, Lorenzi-Filho G. Treatment of obstructive sleep apnea with oro-pharyngeal exercises: a randomized study [abstract]. *Am J Respir Crit Care Med* 2007:A755.
- Drager LF, Bortolotto LA, Lorenzi MC, Figueiredo AC, Krieger EM, Lorenzi-Filho G. Early signs of atherosclerosis in obstructive sleep apnea. *Am J Respir Crit Care Med* 2005;172:613–618.
- Netzer NC, Stoohs RA, Netzer CM, Clark K, Strohi KP. Using the Berlin Questionnaire to identify patients at risk for the sleep apnea syndrome. *Ann Intern Med* 1999;131:485–491.
- Moreno CR, Carvalho FA, Lorenzi C, Matuzaki LS, Prezotti S, Bighetti P, Louzada FM, Lorenzi-Filho G. High risk for obstructive sleep apnea in truck drivers estimated by the Berlin questionnaire: prevalence and associated factors. *Chronobiol Int* 2004;21:871–879.
- Johns MW. A new method for measuring daytime sleepiness. The Epworth Sleepiness Scale. *Sleep* 1991;14:540–559.
- Buysse DJ, Reynolds CF III, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res* 1989;28:193–213.
- Randerath WJ, Galetke W, Domanski U, Weitkunat R, Rühle KH. Tongue-muscle training by intraoral electrical neurostimulation in patients with obstructive sleep apnea. *Sleep* 2004;27:254–258.
- Hoffstein V. Review of oral appliances for treatment of sleep-disordered breathing. *Sleep Breath* 2007;11:1–22.
- Chan AS, Lee RW, Cistulli PA. Dental appliance treatment for obstructive sleep apnea. *Chest* 2007;132:693–699.
- Weaver TE. Outcome measurement in sleep medicine practice and research. Part 1: assessment of symptoms, subjective and objective daytime sleepiness, health-related quality of life and functional status. *Sleep Med Rev* 2001;5:103–128.
- Bailey RD. Dental therapy for obstructive sleep apnea. *Semin Respir Crit Care Med* 2005;26:89–95.
- Sforza E, Bacon W, Weiss T, Thibault A, Petiau C, Krieger J. Upper airway collapsibility and cephalometric variables in patients with obstructive sleep apnea. *Am J Respir Crit Care Med* 2000;161:347–352.
- Davidson MT. The Great Leap Forward: the anatomic basis for the acquisition of speech and obstructive sleep apnea. *Sleep Med* 2003;4:185–194.
- Arens R, Marcus CL. Pathophysiology of upper airway obstruction: a developmental perspective. *Sleep* 2003;27:997–1019.
- Fogel RB, Malhotra A, White P. Pathophysiology of obstructive sleep apnoea/hypopnoea syndrome. *Thorax* 2004;59:159–163.
- Chiu KL, Ryan CM, Shiota S, Ruttanaumpawan P, Arzt M, Haight JS, Chan CT, Floras JS, Bradley TD. Fluid shift by lower body positive pressure increases pharyngeal resistance in healthy subjects. *Am J Respir Crit Care Med* 2006;174:1378–1383.
- Hiemae KM, Palmer JB. Tongue movements in feeding and speech. *Crit Rev Oral Biol Med* 2003;14:413–429.
- Clark HM. Neuromuscular treatments for speech and swallowing: a tutorial. *Am J Speech Lang Pathol* 2003;12:400–415.