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Research Article

Influence of Respiratory Muscles on the Stomatognathic System of Individuals with COPD

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Abstract

Background: We aimed to analyze the influence of respiratory disorders due to chronic obstructive pulmonary disease in the stomatognathic system.

Methods: We divided 40 participants of both genders, ranging from 40 to 80 years old, into two groups: DG, COPD group (n = 20), average age 65.65 ± 8.11 years and body mass index (BMI) 24.92 ± 2.97, stage II to IV; and CG, control group (n=20), average age 65.80 ± 8.18 years and BMI 26.19 ± 2.38, composed of individuals without the disease. The participants underwent respiratory and stomatognathic surface electromyography evaluations, and respiratory muscle strength tests through manovacuometry. The values were subjected to t-student test of independent samples ($p < 0.05$).

Results: The respiratory system showed significant alterations ($p < 0.05$) between the DG and CG groups, especially for the diaphragm muscles in the clinical conditions of rest, respiratory cycle, and maximal inspiration with a lower recruitment of muscle fibers, greater muscle activity during maximal expiration, and reduction of respiratory muscle strength. The stomatognathic system indicated greater activity ($p < 0.05$) in the recruitment of the fibers of the masseter in the clinical conditions of rest and protrusion, and in the left laterality to the temporal and right sternocleidomastoid muscles, when comparing the DG and CG groups.

Conclusion: The study suggests that alterations in respiratory muscle activity influence the postural conditions of the mandible due to the restriction of thoracic mobility, causing an increase in the recruitment of muscle fibers related to the stomatognathic system in individuals with COPD.

Keywords: *Chronic Obstructive Pulmonary Disease; Electromyography; Respiratory; Stomatognathic; Physiotherapy*

Background

Chronic obstructive pulmonary disease (COPD) is typically characterized by reduced respiratory muscle strength, increased recruitment of accessory muscles and pulmonary hyperinflation, causing a mechanical disadvantage in the thoracic cavity, skeletal muscle dysfunction, loss of muscle mass, dyspnea and adventitious noise [1].

The reduction of fiber recruitment and muscle strength depresses the diaphragmatic dome, generating work on the ineffective part of its length/tension curve [2]. In this way, the retention of air inside the lungs causes obstruction of the expiratory flow, hindering gas exchange, which increases the residual volume and the functional residual capacity [3].

Thoracic mobility depends on the costotransverse and costovertebral joints and their associated muscles. Since retraction of the inspiratory chain limits the elevation of the thorax and prevents it from returning to the initial expiratory position, movement of the diaphragm is reduced [4].

Muscle shortening promotes a series of postural deficits in the cervical spine, shoulders, and thorax, and produces changes in the ventilatory pattern and stomatognathic system, due to the excessive use of the inspiratory musculature [5]. When the balance between these structures is broken there may be severe impairments in the mandibular posture and other structures involved in chewing [6]. Such problems in the upper quadrant of the body can lead to functional limitations that affect chewing, swallowing and breathing [7,8].

Based on the information outlined above, the hypothesis of this study is that individuals with COPD have an imbalance in respiratory muscle function due to changes in the dynamics of the thoracic cavity. These changes alter stomatognathic functions by affecting the thoracic muscles, and the hyoid bone and jaw, which are the major skeletal structures that determine available airspace, therefore, the aim of this study was to analyze the influence of respiratory muscles in the stomatognathic system of individuals with COPD through electromyography and manovacuometry.

Materials and Methods

This was an observational case-control study for the electromyographic evaluation and respiratory muscle strength analysis of two groups. Data were collected at the Electromyography Laboratory at the Department of Morphology, Physiology and Basic Pathology, School of Dentistry at Ribeirão Preto (FORP-USP), the Laboratory of Biomechanics of Movement at the Claretian University Center of Batatais, and the Department of Clinical Medicine, Division of Pulmonology at the Medical School of Ribeirão Preto (FMRP-USP). The study was approved by the Ethics Committee in Research with Human Beings (Number 1.749.718) and all individuals were informed about the purposes and stages of the research, and signed the Free and Informed Consent Term, in accordance with Resolution 466/12 of the National Health Council.

Population characteristics and sample

A total of 40 men and women (Figure 1) aged 40 to 80 years were divided into two groups: DG, COPD group (n = 20), average age 65.65 ± 8.11 years and body mass index (BMI) of 24.92 ± 2.97, individuals with a diagnosis of COPD who had spirometric classifications of stage II to stage IV disease [9] evaluated using the Koko® (PDS Instrumentation Inc., Louisville, CO, EUA) brand spirometer, with technical procedures, criteria of acceptability, and reproducibility according to the standards of the American Thoracic Society/European Respiratory Society; [10] CG, control group (n = 20), average age of 65.80 ± 8.18 years and BMI of 26.19 ± 2.38, composed of individuals with no history of respiratory pathologies and who did not show changes during the spirometry examination.

To determine the sample size, a prevalence of 10% was considered for adults older than 40 years [11]. We specified P = 15% for the increase in the standard deviation of the results from which to reject the null hypothesis. Under these conditions, adopting a maximum level of significance $\alpha = 0.05$ and a test power of at least 85%, with n = 16 and assuming a sample loss of 20%, the number of repetitions in each group was 20 participants (40 overall).

The groups were paired by age and body mass index (Table 1). We excluded participants with the following conditions or history: COPD stage I,9 $SpO_2 < 88\%$, BMI < 18 or > 30 kg/m^2, edentulation, strenuous physical activity in less than 12 hours, neuromuscular or orthopedic impairments, morphological changes in the face, signs of influenza seven days before collection, or demonstrated cognition problems when performing the requested tasks.

Data collection instruments

To analyze muscular activity, a twelve-channel portable MyoSystem BR1 P84 (Data Hominis Technology Inc., Uberlândia, MG, Brazil) Electromyograph was used, with eight channels for electromyography (EMG). The electrodes were positioned on the belly of the follow-

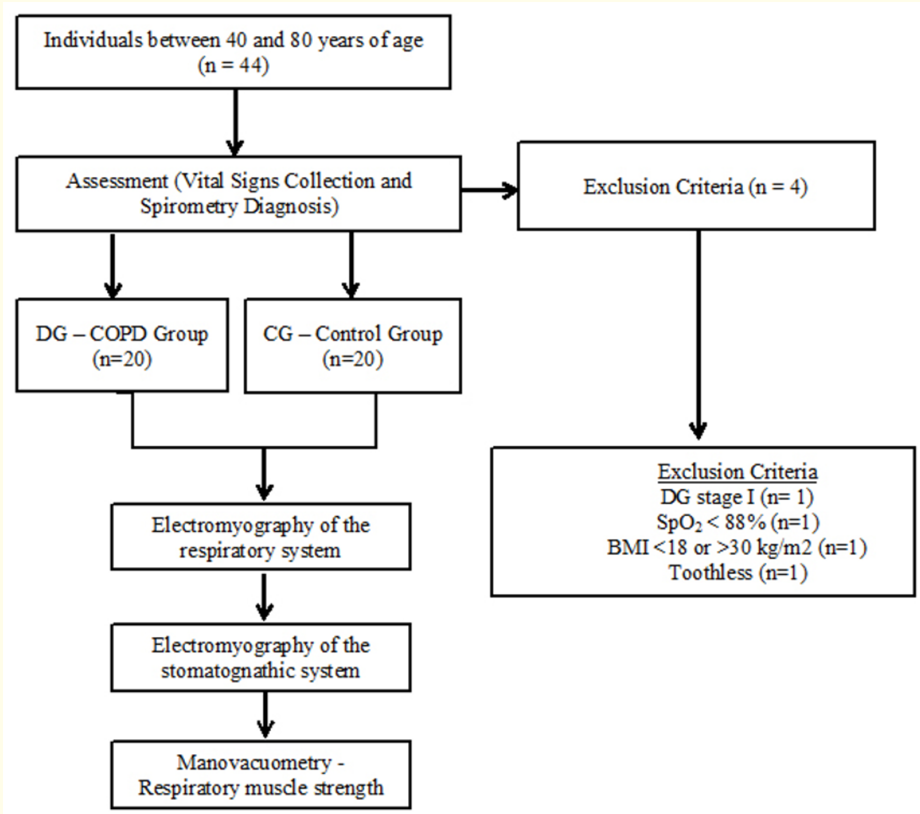

Figure 1: *Sample distribution flowchart and application of the exclusion criteria.*

Characteristics	p	DG	CG
Age (Years)	0.95^{ns}	65.65 ± 8.11	65.80 ± 8.18
Gender (M/F)	1.00^{ns}	10/10 ± 0.51	10/10 ± 0.51
BMI (kg/m^2)	0.14^{ns}	24.92 ± 2.97	26.19 ± 2.38
HR (bpm)	0.01*	80.30 ± 12.68	70.85 ± 11.07
RF (ipm)	0.00*	22 ± 3.30	18.20 ± 2.04
SpO_2 (%)	0.00*	92.30 ± 2.95	96.05 ± 0.99
SBP (mmHg)	0.01*	125.50 ± 10.99	118.00 ± 6.15
DBP (mmHg)	0.18^{ns}	80.50 ± 8.87	77.00 ± 7.32
FVC (%)	0.00*	83.05 ± 19.48	99.95 ± 15.72
FEV_1 (%)	0.00*	40.95 ± 14.18	94.50 ± 13.92
FEV_1/FVC (%)	0.00*	47.30 ± 16.10	94.80 ± 7.14
COPD stages (II/III/IV)	---	6/9/5	-/-/-

Table 1: *Clinical characteristics of the sample for groups DG and CG.*

*Legend: Body Mass Index (BMI), Heart Rate (HR), Respiratory Rate (RR), Peripheral Oxygen Saturation (SpO_2), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Forced Vital Capacity (FVC), Forced Expiratory Volume in the First Second (FEV_1) and FEV^1/FVC ratio. Significant $p < 0.05$ = *, non-significant values = ^{ns}, ± standard deviation.*

ing muscles: right temporal (RT), left temporal (LT), right masseter (RM), left masseter (LM), right sternocleidomastoid (RSCOM), and left sternocleidomastoid (LSCOM). The maneuver of maximum voluntary contraction was performed, and the best point for electromyographic analysis was determined, as defined by Criswell [12,13]. Before the placement of the electrodes, a trichotomy, superficial cleaning of the skin with 70% alcohol, and fixation of the electrodes with tape were performed [14]. The evaluation of muscular activity of the stomatognathic system was performed by an analysis of the electromyographic recordings taken while maintaining mandibular postural conditions and chewing, as shown in table 2.

Muscles	Clinical Conditions	Analysis
Temporal (right and left)	Rest (4s)	RMS
	Maximum protrusion of the jaw with dental contact (10s)	
Masseter (right and left)	Maximum right laterality with dental contact (10s)	
	Maximum left laterality with dental contact (10s)	
	Maximum dental tightness (4s) - Normalization factor	
Sternocleidomastoid (right and left)	Chewing of Parafilm M® (10s)	Integral of the envelope
	Chewing of Peanut (10s)	
	Chewing of Raisin (10s)	

Table 2: *Protocol for the collection of electromyographic data for the stomatognathic system.*

In the static postural conditions of the mandible, the root mean square (RMS) value was used for analysis, and in the usual and non-habitual masticatory cycle conditions, the integral envelope values were obtained by the average of five cycles, disregarding the first three because they showed variations in the pattern of movement [15]. All electromyographic activity was normalized by maximum bilateral clenching for four seconds.

To measure the activity of the respiratory muscles, an experimental protocol was performed using electromyographic recordings of the diaphragm muscles (RD), external intercostal (RI), sternocleidomastoid (RSCOM), pectoralis major (RP), anterior serratus (RS), abdominal rectum (RR) and outer oblique (RO), normalized by the signal obtained in the maximum inspiratory maneuver, sustained for four seconds [16-18]. However, because the respiratory musculature of the left hemithorax produced crosstalk due to cardiac interference in the acquisition of the myoelectric signal [19] and to avoid impedance, the capture of the electromyographic signal for these muscles was performed only in the right hemithorax, as proposed by Andrade., *et al*. [20] and Hawkes., *et al* [21].

To position the electrodes for data collection involving the respiratory muscles, a maneuver of maximum voluntary contraction during inspiration and expiration was performed, with positioning based on previous detailed studies of the anatomical locations (Table 3) to determine the best points for electromyographic analysis [12,13]. Since there is no consensus in the literature about the arrangement of the electrodes for the collection of data from the diaphragm muscle, we followed recommendations from studies on surface electromyography of the diaphragm muscle which indicated that positioning along the hemiclavicular line of the seventh intercostal space was associated with more successful electromyographic signal data collection [21-23].

The electromyographic evaluation was performed with each participant sitting, with arms at the side of the body and legs flexed at an angle of 90° for analysis of respiratory function [28] in the following clinical conditions: rest (10s); respiratory cycle (deep breathing

Muscle	Location of the electrodes
Sternocleidomastoid	Muscle belly [24]
Pectoralis major	Hemiclavicular line, 5 cm below collarbone [25]
External intercostal	Third intercostal space, 3 cm lateral to the body median line [23]
Diaphragm	Seventh intercostal space, in the hemiclavicular line [23]
Anterior serratus	Fifth rib in the middle axillary line [14]
Abdominal rectum	Midpoint between the xiphoid process and umbilical scar, 3 cm lateral to the body median line [26]
Outer oblique	Superior to the anterior superior iliac spine, 15 cm lateral of the umbilical scar [27]

Table 3: *Location and anatomical positioning of the electrodes for the respiratory muscles in the right hemithorax.*

with inspiratory and expiratory cycles) (10s); maximum inspiration from the residual volume (4s); maximum expiration from total lung capacity (4s); and maximum sustained inspiration (4s), as a normalization factor. There was a one-minute interval between collections. The gross electromyographic signal was used to derive electromyographic amplitude values obtained by the calculation of the root mean square (RMS) for the respiratory muscles.

To measure the maximum inspiratory (MIP) and maximal expiratory (MEP) pressures, an analog manovacuometer was used with a range of ± 300 cmH_2O from Commercial Medical® (Commercial Medicine, São Paulo, SP, Brazil). Each participant was advised on the application of the test and how to perform it, according to the protocol described by Black and Hyatt [29] measuring the MIP from the residual volume and the MEP from the total lung capacity. The respiratory pressure data were analyzed after collection of a minimum of three and a maximum of five measurements, with one minute of rest between them, and were considered acceptable with a difference of 10% or less between measurements. The highest value obtained was used for statistical analysis and compared to the values predicted by Neder., *et al* [30].

The values obtained in relation to sample characteristics, electromyography, and manovacuometry were tabulated and subjected to statistical analysis using SPSS software version 22.0 (SPSS Inc., Chicago, IL, USA). The descriptive analysis (averages, standard deviations, maximum value, and minimum value) was performed for each variable and the values obtained were compared with the Student's t-test of independent samples ($p < 0.05$).

Results and Discussion

In the analysis of the normalized electromyographic averages for the postural clinical conditions of the mandible, a greater activation of the muscular fibers was observed, as shown in figure 2.

The analysis of normalized electromyographic averages for clinical chewing conditions did not reveal significant differences in our sample. When the normalized electromyographic averages for the respiratory clinical conditions were analyzed, we found differences between the DG and CG groups in relation to the recruitment of muscle fibers, as shown in figure 3.

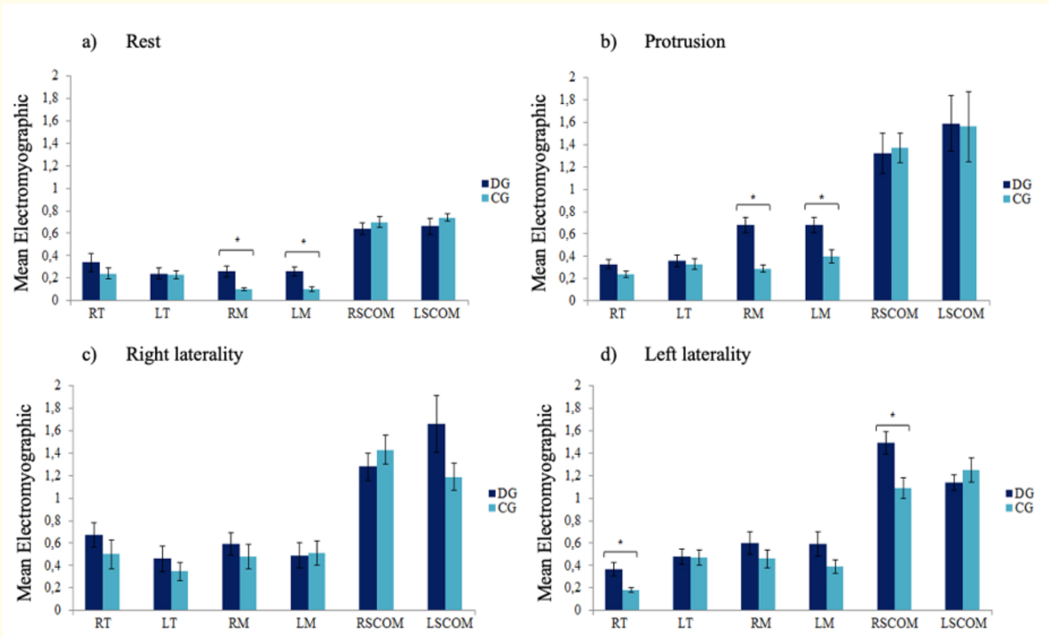

Figure 2: *Normalized electromyographic mean ± SD for the clinical conditions of the stomatognathic system. Legend: Clinical Conditions: a) Rest; b) Protrusion; c) Right laterality; d) Left laterality. Muscles: Right temporal (RT), left temporal (LT), right masseter (RM), left masseter (LM), right sternocleidomastoid (RSCOM) and left sternocleidomastoid (LSCOM). Statistically significant p < 0.05 = *.*

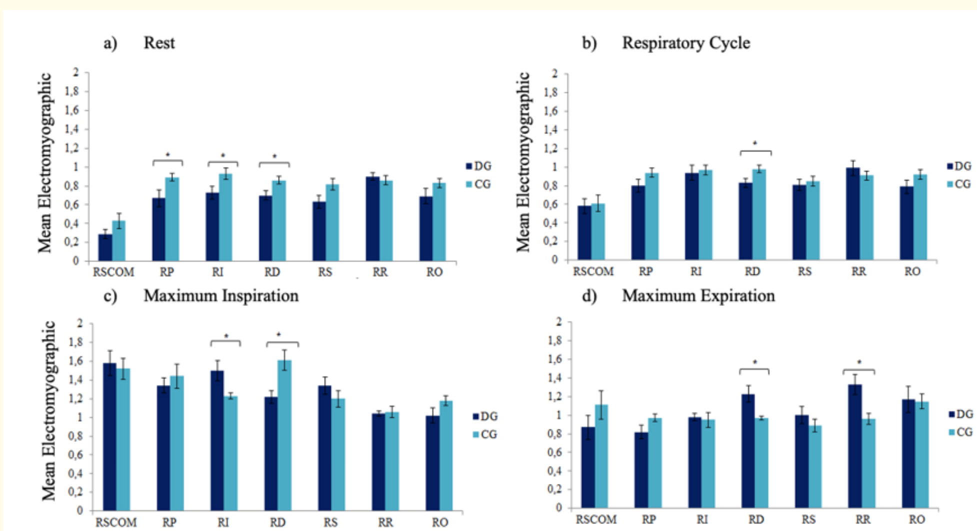

Figure 3: *Normalized electromyographic mean ± SD for the clinical conditions of the respiratory system. Legend: Clinical Conditions: a) Rest; b) Respiratory Cycle; c) Maximum Inspiration; d) Maximum Expiration. Muscles: right sternocleidomastoid (RSCOM), right pectoralis (RP), external intercostal right (RI), right diaphragm (RD), right anterior serratus (RS), right abdominal rectum (RR) and right outer obliquus (RO). Statistically significant p < 0.05 = *.*

In the analysis of respiratory muscle strength in the maximum inspiratory clinical conditions from the residual volume and maximal expiration from the total lung capacity, we found that the DG group had lower averages of respiratory force when compared to the CG group (Figure 4).

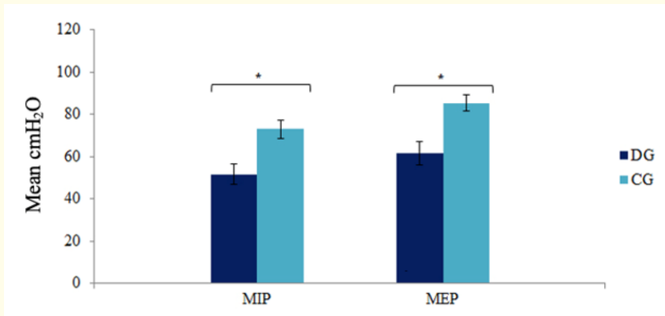

Figure 4: *Comparison of mean ± SD for respiratory muscle strength.*
Legend: Maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP), expressed in cmH$_2$O.
*Statistically significant $p < 0.05$ = *.*

The main results when comparing to group DG to group CG were: (I) changes due to the respiratory can influence the stomatognathic system; (II) the recruitment of fibers of the respiratory muscle can cause stomatognathic system imbalances; and (III) the strength of the respiratory muscles was reduced in the DG group.

The influence of thoracic mechanics on the recruitment of respiratory muscle fibers can establish an inadequate pattern, which causes important changes in the position of the mandible and head, contributing to the imbalance of the stomatognathic system [31,32]. According to the electromyographic analysis of the respiratory muscles, it was possible to observe a lower recruitment of muscle fibers in the clinical conditions of rest and respiratory cycle. For the conditions of inspiration and maximum expiration, there is greater participation of the accessory muscles to overcome the resistance imposed by the reduction of thoracic mobility. The restriction of thoracic mobility induces a person with COPD to reach the elastic limits of ventilatory mechanics, with the muscles not returning to their initial position due to the retention of carbon dioxide. Therefore, the imbalance of the respiratory muscles, especially the diaphragm, leads to changes in tension patterns on the hyoid muscles and, consequently, results in changes in the stomatognathic system. This suggests that individuals with COPD in stages II to IV need to perform greater recruitment of muscle fibers and greater respiratory effort during maximal inspiration and expiration when compared to individuals without the disease, to improve pulmonary capacity. According to Pinheiro., *et al*. [33] the higher the COPD stage, the higher the level of thoracic restriction and the degree of dysfunction in the stomatognathic system.

Body changes associated with COPD may affect the mandibular position and postural dysfunctions below the craniomandibular complex and are responsible for disorders in the stomatognathic system [34-36]. In the present study, similar characteristics were observed, with significant alterations in the postural conditions of the mandible at rest, protrusion, and left laterality, and greater recruitment of fibers to the muscles RT, LT, RM, LM, RSCOM, and LSCOM when comparing the individuals of the DG group to the CG group. Therefore, there was greater muscular effort required to perform the test activities for the stomatognathic system, mainly for the masseter muscles during rest and protrusion, and the temporal muscles and right sternocleidomastoid during the left laterality condition. This inefficiency of the masticatory system results in an increased respiratory rate due to the short duration of the inspiratory and expiratory phases, with the potential to interrupt the coordination of breathing and swallowing, which is exhibited by the high risk of aspiration in these individuals. Changes in breathing patterns may influence the coordination between chewing and breathing and interfere with the protection of the lower airways. An ineffective protection mechanism may increase the risk of bronchoaspiration and, consequently, exacerbations in chronic obstructive pulmonary disease [37].

The difficulty in maintaining a prolonged inspiratory phase demonstrates the incoordination between the respiratory and stomatognathic systems, therefore, when we analyzed the inspiratory activity of the diaphragm muscles in the clinical test conditions, we observed a smaller recruitment of muscle fibers for the DG group individuals in relation to the CG group. These findings are similar to those described by Clayton., *et al*. [38] who observed an imbalance between the breathing and swallowing process in individuals with COPD.

The results from evaluating the recruitment of respiratory muscle fibers suggest that there is a significant reduction of diaphragm muscle activity under rest conditions, respiratory cycle, and maximal inspiration for the DG group. These findings demonstrate the difficulty of the main breathing muscles to transpose the thoracic restriction imposed by the disease, and the corresponding greater use of accessory muscles for inspiration. According to Dos Santos Yamaguti., *et al*. [39] there is a correlation between diaphragmatic mobility and inspiratory capacity in individuals with moderate to severe COPD, reinforcing the notion that that air trapping may have a significant influence on diaphragmatic mechanics and, consequently, the stomatognathic system [40]. Reduction of diaphragmatic activity during inspiration increases the requirement for respiratory muscle activity. In the maximal inspiratory clinical condition, it was possible to observe a greater activity of the intercostal muscles for the DG group, which supplements the reduction of the diaphragmatic activity, predominated by short and fast breathing. This finding is compatible with that described by Vieira., *et al*. [41] who observed that contraction of the intercostal muscles favors regional transpulmonary pressure.

The low inspiratory capacity may be related to the low ventilatory capacity associated with increased pulmonary obstruction [42] therefore, the influence of carbon dioxide retention and chest immobility requires increased activity of the expiratory muscles to expel air from the lungs. When the electromyographic patterns were evaluated in the clinical condition of maximal expiration, greater activity of the diaphragm and abdominal rectum muscles was observed as a form of adaptation to overcome the resistance imposed by the reduction of thoracic mobility. This analysis corroborates a previous electromyographic study, where the expiratory muscles of individuals with COPD showed a considerable increase in activity when compared to individuals in the control group [43,44]. When the maximal inspiratory and expiratory pressures were evaluated, we observed a reduction of respiratory muscle strength in individuals with COPD; these values may be associated to an imbalance in the recruitment of the diaphragm muscle fibers. The respiratory muscle weakness observed in individuals with COPD contributes to hypercapnia, dyspnea, nocturnal oxygen desaturation, and reduced walking distance [45].

Individuals with respiratory muscle weakness respond well to exercise and especially to inspiratory muscle training, which is an effective treatment modality for individuals with COPD to improve strength and endurance, resulting in reduced dyspnea and improved functional exercise capacity [46,47].

Increased muscle strength and diaphragm resistance, as well as training of respiratory muscles and better ventilation, help provide an adequate supply of oxygen to the tissues, lower energy requirements, and improve the quality of life of individuals with COPD.

Observation of the parameters used in this study permits an analysis of the balance between the evaluated systems since changes in the recruitment of respiratory muscle fibers affect the clinical conditions of the mandible, in turn requiring a greater recruitment of the muscle fibers in the stomatognathic system.

Conclusion

The study suggests that the imbalance in the recruitment of respiratory muscle fibers promotes an increase in muscle activity of the stomatognathic system in individuals with chronic obstructive pulmonary disease.

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Conflict of Interest

We declare that there are no conflicts of interest.

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