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ORIGINAL RESEARCH

The relation between diaphragmatic mobility and spinal curvatures in patients with chronic obstructive pulmonary disease

Relação entre a mobilidade diafragmática e as curvaturas da coluna vertebral em pacientes com doença pulmonar obstrutiva crônica

Relación entre la movilidad diafragmática y las curvaturas de la columna vertebral en los pacientes con la enfermedad pulmonar obstructiva crónica

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ABSTRACT | In the chronic obstructive pulmonary disease (COPD), patients may have reduced diaphragmatic mobility and a series of compensations in the thoracic spine, the scapular and pelvic girdles. However, the relation between diaphragmatic mobility and postural changes in these individuals' vertebral column and pelvis is not clear. The aim of this study was to verify if there is a relation between diaphragmatic mobility and spinal curvatures in patients with COPD and in apparently healthy individuals. Were evaluated 22 patients with COPD and 22 apparently healthy individuals. The evaluations consisted of: anthropometry, spirometry, diaphragmatic mobility and postural evaluation. Four postural alterations were analyzed: cervical lordosis, thoracic kyphosis, lumbar lordosis, pelvic position. There was no statistically significant difference between the groups, in relation to the variables age, body mass, stature and BMI, confirming that the groups were paired. There was no statistically significant difference in any of the variables related to spinal curvatures and pelvic position between the studied groups. In the COPD group, there was a correlation between diaphragmatic mobility and thoracic kyphosis ($r=-0.543$; $p=0.009$). Regarding the group of apparently healthy individuals, there was no correlation of mobility as the apparently healthy individuals presented the same angles of curvature of the vertebral column and the same position of the pelvis. However, there was a relation between diaphragmatic mobility and the angle of the thoracic curvature in patients with COPD.

Keywords | Pulmonary Disease Chronic Obstructive; Diaphragm; Spine.

RESUMO | Na doença pulmonar obstrutiva crônica (DPOC), os pacientes podem apresentar redução da mobilidade diafragmática e uma série de compensações na coluna torácica, nas cinturas escapular e pélvica. No entanto, não está clara a relação da mobilidade diafragmática com alterações posturais na coluna vertebral e na pelve desses indivíduos. Objetivou-se verificar se existe relação entre a mobilidade diafragmática com as curvaturas da coluna vertebral de pacientes com DPOC e em indivíduos aparentemente saudáveis. Foram avaliados 22 pacientes com DPOC e 22 indivíduos aparentemente saudáveis. As avaliações foram: antropometria, espirometria, mobilidade diafragmática e avaliação postural. Foram analisadas quatro alterações posturais: lordose cervical, cifose torácica, lordose lombar, posição pélvica. Não houve diferença estatisticamente significativa entre os grupos, em relação às variáveis idade, massa corporal, estatura e IMC, confirmando que os grupos foram pareados. Não houve

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diferença estatisticamente significante em nenhuma das variáveis referentes às curvaturas da coluna vertebral e à posição da pelve entre os grupos estudados. No grupo DPOC houve correlação da mobilidade diafragmática com a cifose torácica (r=-0,543; p=0,009). Já em relação ao grupo de indivíduos aparentemente saudáveis, não houve correlação da mobilidade quanto os indivíduos aparentemente saudáveis apresentaram os mesmos ângulos de curvatura da coluna vertebral e a mesma posição da pelve. Contudo, os pacientes com DPOC apresentaram relação entre a mobilidade diafragmática e o ângulo da curvatura torácica.
Descritores | Doença Pulmonar Obstrutiva Crônica; Diafragma; Coluna Vertebral.

RESUMEN | En la enfermedad pulmonar obstructiva crónica (EPOC), los pacientes pueden presentar reducción de la movilidad diafragmática y muchas compensaciones en la columna torácica, en las cinturas escapular y pélvica. No obstante, no está clara la relación de la movilidad diafragmática con las alteraciones posturales en la columna vertebral y en la pelvis de esos individuos. Se tuvo el objetivo de ver si hay relación entre la movilidad diafragmática con las curvaturas de la columna vertebral de los pacientes con la EPOC y en los individuos aparentemente saludables. Fueron evaluados 22 pacientes con la EPOC y 22 individuos aparentemente saludables. Las evaluaciones fueron: la antropometría, la espirometría, la movilidad diafragmática y la evaluación postural. Fueron analizadas cuatro alteraciones posturales: la lordosis cervical, la cifosis torácica, la lordosis lumbar, la posición pélvica. No hubo diferencia estadísticamente significativa entre los grupos, en relación a las variables edad, la masa corporal, la estatura y el IMC, confirmando que los grupos fueron pareados. No hubo diferencia estadísticamente significante en ninguna de las variables referentes a las curvaturas de la columna vertebral y a la posición de la pelvis entre los grupos estudiados. En el grupo EPOC hubo correlación de la movilidad diafragmática con la cifosis torácica (r = -0,543; p = 0,009). Ya en relación al grupo de los individuos aparentemente saludables, no hubo correlación de la movilidad cuanto a los individuos aparentemente saludables que presentaron los mismos ángulos de curvatura de la columna vertebral y la misma posición de la pelvis. No obstante, los pacientes con la EPOC presentaron relación entre la movilidad diafragmática y el ángulo de la curvatura torácica.
Descritores | Enfermedad Pulmonar Obstructiva Crónica; Diafragma; Coluna Vertebral

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is the fourth leading cause of death in the world. It is a common, preventable and treatable disease characterized by persistent limitation of airflow, which is usually progressive, associated with an increase in the chronic inflammatory response in the airways and lungs to the exposure of noxious particles or gases[1]. There is evidence that COPD causes losses in respiratory mechanics and posture[2,3].

In COPD, respiratory mechanics is impaired by several factors, including changes in lung volumes and capacities that occur due to the pathophysiological processes of the disease such as loss of elastic recoil, airflow obstruction, air trapping[4] and pulmonary hyperinflation[5]. Studies have shown that these mechanisms are related to the reduction of diaphragmatic mobility that occurs by reducing the tension-length relation in the apposition zone and in the radius of curvature of the diaphragm muscle[6].

Previous studies have already established that patients with COPD have reduced diaphragmatic mobility due to their disease[7-12]. However, few studies have investigated the impairment in postural alignment[2,3]. Despite the scarcity of quantitative descriptions of postural changes in patients with COPD in the literature, postural impairments seem to be more evident in clinical practice, especially in patients at more advanced stages of the disease[3].

Some evidence suggests that the postural attitude of the hyperinflamed thorax can lead to a series of alterations in the cervical spine, thoracic spine, scapular and pelvic girdles[2,3,13]. In addition, another hypothesis would be that the biomechanics of the thoracic cavity can influence the overall body mechanics and any abnormalities of the thoracic cavity may result in alterations in the posture and balance of the whole body[14]. It is still not clear how much a variable can influence the other, thus, it is necessary to conduct more studies.

Based on the abovementioned information, it is verified that the reduction of diaphragmatic mobility and postural changes are frequently observed in patients with COPD. However, there are no studies aimed at evaluating the alteration of diaphragmatic mobility and thoracic curvatures in this population. Therefore, the objective of the study was to verify if there is a relationship between diaphragmatic mobility and spinal curvatures in patients with COPD and apparently healthy individuals.

METHODOLOGY

The present study is an analytical, cross-sectional and quantitative approach. The study was approved by the Human Research Ethics Committee of Universidade do Estado de Santa Catarina, Florianópolis (CAAE: 08857612.2.0000.0118). All individuals were informed about the research and signed a free consent form, as determined by Resolution 466/12 of the National Health Council.

A total of 44 subjects (21 men and 23 women) of both sexes participated in the study. They were divided into two groups: group 1, consisted of 22 patients with COPD, aged 65.8 (±8.0) years and group 2, consisted of 22 apparently healthy individuals, with 63.7 (±5.2) years of age.

The COPD group was comprised of patients with a diagnosis of COPD, according to the classification of the *Global Initiative for Chronic Obstructive Lung Disease* (GOLD)[1], and who met the following inclusion criteria: 1) clinical stability in the last month and at the beginning of the evaluation protocol; 2) patients who did not use oxygen supplementation; 3) non-existence of other associated respiratory or cardiovascular diseases; 4) patients without involvement in pulmonary rehabilitation programs in 6 months prior to the beginning of the present study; 5) patients who did not undergo recent spinal or lower limb surgeries and/or who did not have fractures in the previous 6 months.

As exclusion criteria, the authors adopted: 1) presence of exacerbations of the disease during the research; 2) clinical intercurrences of cardiorespiratory nature during the evaluations; 3) inability to perform any of the study evaluations (lack of understanding or collaboration) and; 4) patient withdrawal during the evaluation period.

The study included apparently healthy individuals with normal spirometry (FEV_1/FVC ≥0.7, FEV_1 ≥80% of predicted, FVC ≥80% of predicted), without any associated comorbidities and with age, weight, and BMI compatible with patients with COPD. Individuals who were unable to perform any of the study evaluations (lack of understanding or collaboration) and/or who withdrew from the study during the evaluation process were excluded from this group.

Evaluated parameters

Anthropometry

For the anthropometric measurements, a previously calibrated scale was used to measure body mass and a stadiometer was used to measure height. Once the anthropometric values were obtained, the body mass index (BMI) was calculated by means of the equation: body mass/stature^2. Thus, the individuals were classified, according to BMI, in low weight (≤18,5 kg/m^2), normal (18,5-24,9 kg/m^2), overweight (25-29,9 kg/m^2) and obese (≥30 kg/m^2)[15]. Patients were instructed to wear light clothing, to remove their shoes and remain upright until the measured values were assessed.

Spirometry

The spirometry was performed to verify the pulmonary capacity of the study subjects using the *Easy One ndd Medical Technologies* portable digital spirometer, previously calibrated according to the methods and criteria recommended by the *American Thoracic Society* and *European Respiratory Society*[16]. The following parameters were measured: forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1) and FEV_1/FVC ratio before and 15 minutes after the inhalation of bronchodilator (BD) salbutamol (400µg) in COPD patients. At least three acceptable maneuvers and two reproducible maneuvers were performed. The spirometric variables are expressed in absolute values and in percentage values of the predicted values of normality, as determined by Pereira et al.[17]. The normal lung function test criteria consist of FVC and FEV_1 ≥80% of the predicted values and FEV_1/FVC ≥0.7.

Diaphragmatic mobility

The diaphragmatic mobility was evaluated by means of chest radiographs with anteroposterior incidence. Initially, a radiopaque graduated ruler was placed on the right hemithorax of the subject, in the longitudinal direction and in the craniocaudal direction, close to the thoracoabdominal transition. The subjects were then positioned on the radioscopy table in dorsal decubitus and they were previously instructed to perform two sets of ten repetitions of diaphragmatic breathing with the objective of developing proprioception of the diaphragmatic movement and enable the evaluation of the maximum diaphragm amplitude during the X-ray examination.

After the diaphragmatic breathing training, the subjects performed two slow vital capacity (SVC) maneuvers using a *Wright Respirometer Brit.®* spirometer Pat. 765206 – UK. The first maneuver was close to the total lung capacity (TLC) and almost to the residual volume (RV); and the second, starting from RV and almost to the TLC. The highest value was recorded for comparison with the value measured during the diaphragmatic mobility test to verify if the individuals performed the same respiratory effort (inspiratory and expiratory) before and during the assessment of diaphragmatic mobility.

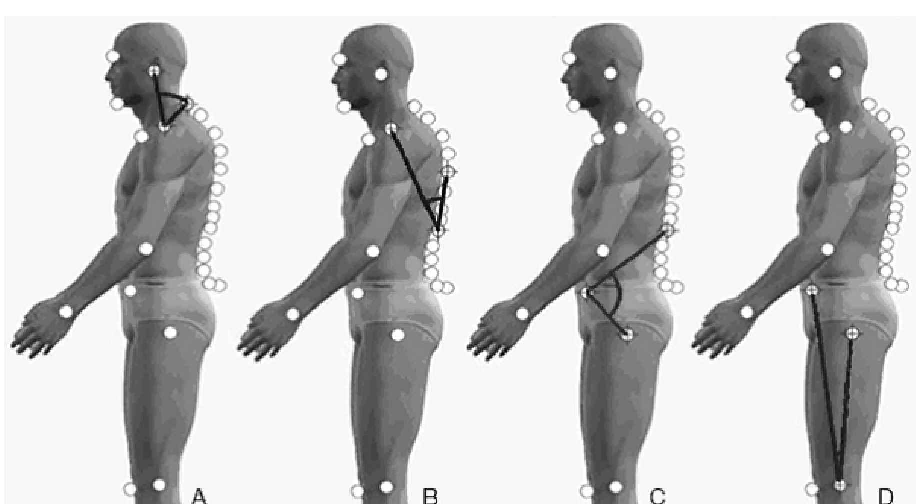
The maximum inspiratory and expiration images were recorded in the same film. The measurement of diaphragmatic mobility was determined by the method of distance (MD_{dist})[18].

Postural evaluation

The Postural Analysis Software (SAPO) was used in an electronic medium and validated by Ferreira et al.19. The male subjects were instructed to wear shorts for the photographs and the female, shorts and a top. Initially, anatomical points were identified, through palpatory anatomy, in the following regions of the body: acromion, seventh cervical vertebra (C7), tragus of the ear, seventh thoracic vertebra (T7), first lumbar vertebra (L1), anterior superior iliac spine (ASIS), greater trochanter (Figure 1). After identification of the points, they were marked with styrofoam balls, with a diameter of 20 mm, fixed to the body parts with double-sided adhesive tape.

All subjects were placed in the static orthostatic position, remaining in the left side view, at a distance of 50 cm in front of a black wall and next to a plumb line marked with three styrofoam balls with a distance of 50 cm between each, enabling the calibration of the photograph. Their feet were placed freely on top of a black Ethylene-vinyl acetate (EVA) rug. The individual was informed to stay in a comfortable position, through a verbal command, with their gaze fixed on a point in their line of sight, keeping their posture relaxed.

A camera (Sanyo BD 200 14.1 mega pixels, DSC – W610) was used to take the photographs. It was positioned on a tripod (height of 97 cm) and at a distance of 2,30 m from the participant. The photographs were transferred to the computer and analyzed with the postural evaluation software (SAPO). The analysis of angles and measurements of the photographs were made with the Excel Program from the coordinates of the anatomical points obtained with SAPO. To mark the points and define the postural changes that would be evaluated, the protocol of Yi et al.[20] was used:



Source: Yi et al., 2008.

Figure 1. Angular measure of the curvatures of the vertebral column: A) Angular measure of cervical lordosis; B) angular measure of thoracic kyphosis; C) angular measure of lumbar lordosis; D) angular measure of pelvic position.

1) Cervical Lordosis: angle formed from three anatomical points: tragus of the ear, C7 and acromion, the acromion being the apex of the angle. The greater the angular measure, the more anterior the position of the head and the lower the cervical lordosis;
2) Thoracic kyphosis: angle formed from three anatomical points: acromion, T7 and L1, with L1 as the apex of the angle. The larger the angular measure, the greater the thoracic kyphosis;
3) Lumbar lordosis: angle formed from three anatomical points: L1, anterior superior iliac spine (ASIS) and greater trochanter, with ASIS as the vertex of the angle. The smaller the angular measure, the greater the lumbar lordosis;
4) Pelvic position: angle formed from three anatomical points: ASIS, greater trochanter and the midpoint of the knee joint interlining on the lateral face, with the midpoint of the articular interline as the apex of the angle. The larger the angular measure, the greater the anteversion of the pelvis.

Statistical analysis

Data were analyzed using SPSS for Windows, version 20.0 and treated with descriptive analysis as mean and standard deviation that were applied to all variables. To verify the normality of the data the Shapiro-Wilk test was applied. To compare the variables age, weight, height, FEV_1 (%prev), FVC (%prev), diaphragmatic mobility, cervical lordosis, thoracic kyphosis, lumbar lordosis, pelvic position between COPD groups and apparently healthy individuals, Student's t-test was used. To compare the variables BMI and FEV_1/FVC (L) the Mann Whitney U test was used. To correlate diaphragmatic mobility with cervical lordosis, thoracic kyphosis, lumbar lordosis and pelvic position, Pearson's linear correlation coefficient (r) was used. A significance level of 5% was adopted.

RESULTS

The anthropometric and pulmonary characteristics and diaphragmatic mobility of the studied groups are presented in Table 1. There was no statistically significant difference between age, body mass, stature and BMI, confirming that the groups were paired in relation to the anthropometric variables.

Regarding pulmonary function, there was a statistically significant difference in all variables of the spirometry, especially in the forced volume in the first second (FEV_1), which characterizes the presence of COPD. The COPD group showed a degree of severe obstruction, whereas apparently healthy individuals presented spirometric values within normal limits (FEV_1% predicted 49.6±15.7 and 95.0±10.3, $p<0.001$ respectively).

There was a significant difference in the values of diaphragmatic mobility between the studied groups, with COPD patients showing lower values when compared to healthy individuals (41.7±18.3 mm and 62.9±11.5 mm, respectively, $p<0.001$)

There was no statistically significant difference in any of the variables related to vertebral column curvatures and pelvic position, which indicates the similarity of the body posture of COPD patients and apparently healthy individuals.

Table 1. Comparison of pulmonary function, diaphragmatic mobility and postural changes between COPD groups and apparently healthy individuals (n=44)

Variables	COPD (n=22)	Healthy (n=22)	*p value*
Demographic and anthropometric data			
Gender (M/F)	11/11	10/12	-
Age (years)	65.8 ± 8.0	63.7 ± 5.2	0.312
Body mass (kg)	71.1 ± 16.4	75.5 ± 14.1	0.345
Stature (cm)	164.5 ± 8.0	164.9 ± 11.3	0.915
BMI (kg/m²)	26.2 ± 5.8	27.6 ± 3.6	0.110
Pulmonary Function			
FEV_1/FVC (L)	0.56 ± 0.10	0.79 ± 0.04	<0.001*
FEV_1 (%prev)	49.6 ± 15.7	95.0 ± 10.3	<0.001*
FVC (%prev)	68.2 ± 15.4	95.0 ± 10.7	<0.001*
DM (mm)	41.7 ± 18.3	62.9 ± 11.5	<0.001*
Cervical Lordosis (º)	85.3 ± 18.0	81.1 ± 13.1	0.380
Thoracic Kyphosis (º)	29.5 ± 3.2	29.5 ± 4.2	0.975
Lumbar Lordosis (º)	96.3 ± 8.7	98.5 ± 8.6	0.413
Pelvic Position (º)	4.7 ± 2.4	4.6 ± 1.9	0.884

Values are expressed as mean and ± standard deviation; BMI (kg/m2): body mass index in kilograms per meter2; FEV1 (%prev): percentage of predicted forced expiratory volume in the first second; FVC (%prev): percentage of predicted forced vital capacity; DM: diaphragmatic mobility. Mm: milimeters; º: degree. *p<0.05.

Figure 2 shows that there was a statistically significant correlation in the COPD group between diaphragmatic mobility and the angle of curvature of thoracic kyphosis (r=-0.543; p=0.009). However, there was no correlation of diaphragmatic mobility with the other studied variables (Table 2).

In relation to the group of apparently healthy individuals there was no correlation of diaphragmatic mobility with any of the variables of the vertebral column and pelvis position.

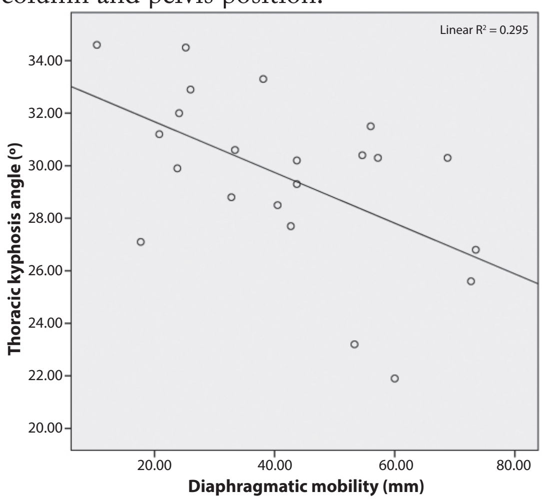


Figure 2. Correlation of the thoracic kyphosis angle (º) with diaphragmatic mobility (mm) in the COPD group (n=22) (r=-0.543; p=0.009)

Table 2. Relation between diaphragmatic mobility and spinal curvatures in the COPD group (n=22) and the group of apparently healthy individuals (n=22)

Groups	Correlation coefficient®	p
Cervical Lordosis		
COPD	- 0.085	0.708
Healthy	0.122	0.589
Thoracic Kyphosis		
COPD	- 0.543	0.009*
Healthy	0.211	0.346
Lumbar Lordosis		
COPD	0.031	0.892
Healthy	0.324	0.142
Pelvic Position		
COPD	0.132	0.559
Healthy	- 0.327	0.138

r: Pearson's Correlation Coefficient. *p<0.05

DISCUSSION

The present study aimed to verify the relation between diaphragmatic mobility and spinal curvatures in patients with COPD and in healthy individuals. The results showed that there was a negative correlation between the diaphragmatic mobility and the angle of the thoracic curvature only in the COPD group, showing that the lower the diaphragmatic mobility, the greater the degree of thoracic kyphosis. However, there was no correlation with the other vertebral curvatures evaluated. In the group of healthy individuals, there was no correlation with any of the studied variables.

The hypothesis for this finding would be the presence of reduced diaphragmatic mobility in patients with COPD. Some evidences suggest that the reduction of diaphragmatic mobility due to inefficiency of the diaphragm muscle can lead to an inevitable compensatory increase in the activity of the thoracic cavity muscles and accessory muscles of ventilation that play an important role in patients with COPD[21,22]. With the recruitment of accessory muscles and thoracic cavity muscles[23], the apical respiratory pattern occurs. This respiratory pattern elevates the action potentials of muscles such as the sternocleidomastoid, resulting in postural changes[24,25].

Regarding the thoracic kyphosis angle, there was no significant difference between the COPD groups and healthy individuals. Our results are consistent with the study by Dias et al.[3] who evaluated the kinematics of the thoracic, cervical, and scapular girdle of 19 patients with COPD and 19 healthy individuals and found only a greater elevation of the scapula. In contrast, Pachioni et al.[2] compared 15 COPD patients with 15 healthy subjects and observed three important postural changes in patients with COPD: thoracic kyphosis, posterior pelvic unevenness and anterior pelvic tilting. The discrepancy between measurements may be related to differences in methodologies for postural evaluation and lack of standardization in the thoracic curvature evaluation technique.

The traced relation between diaphragmatic mobility and thoracic kyphosis angle is of concern, as studies have shown that increased thoracic curvature may impair lung function[26,27,28], increase dyspnoea[27], affect the performance of daily life activities[29,30], reduce quality of life[30] and predict mortality independent of underlying vertebral osteoporosis[31]. As the patients already present all these damages due to their disease, their condition can be aggravated in the presence of an increase in the angle of the thoracic curvature.

The present study compared the angles of spinal curvatures and pelvic position between COPD groups and healthy individuals. A similarity was observed between the groups. This fact is probably due to the homogeneity of the age of the studied groups, since aging is a common feature in both populations, and it may be a determining factor for the development of impairments in the musculoskeletal system and consequently postural alterations. In the natural process of aging, several alterations can cause damage to the different systems of the organism[32]. With the progression of age, postural changes such as head anteriority, shoulder protrusion (antero-pulsion), increased thoracic kyphosis, reduced lumbar lordosis and knee/hip flexion may arise[33].

Patients with COPD already suffer from these natural processes due to aging, however, with the progression of their disease, these changes may be intensified due to the pathophysiological factors of their disease. It is evident in the scientific literature that the worsening of postural changes in the vertebral column can interfere with respiratory function, however, it should be taken into account that the patient with COPD already has respiratory impairments and their condition may be further aggravated by the postural alteration.

The methodological rigor to conduct the evaluations was a strong point of this research. However, there are limitations inherent to this study, it is possible to mention the fact that this cross-sectional feature makes it difficult to verify the cause-effect relationship between increased thoracic kyphosis angle and reduced diaphragmatic mobility. For this, it would be important to conduct a longitudinal prospective study to demonstrate the real influence between these variables. Another limitation is the lack of standardization in the technique for evaluation of the curvatures of the vertebral column by the SAPO method. But despite this, the results obtained provide important subsidies regarding spinal curvatures and diaphragmatic mobility in patients with COPD and healthy individuals. It is also worth noting the clinical relevance of the present study in the early detection of postural changes alongside the evaluation of diaphragmatic mobility in patients with COPD, enabling professionals to plan and execute the most appropriate treatment.

CONCLUSION

In order to analyze the correlation between the diaphragmatic mobility and the angles of the vertebral curvatures and the position of the pelvis, the researchers conclude that only the COPD group presented a negative correlation between the variables. The researchers observed that lower the diaphragmatic mobility, the greater the angle of curvature of thoracic kyphosis.

Regarding the postural changes, it was verified that COPD patients, as well as apparently healthy individuals, present the same angles of curvature of the vertebral column and the same position of the pelvis. However, only the COPD group presented reduction in diaphragmatic mobility.

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