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Chest wall mobility is related to respiratory muscle strength and lung volumes in healthy subjects

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Abstract

Background: chest wall mobility is often used in clinical practice, but is not determined it´s correlation with respiratory muscle strength and lung volumes. **Objective:** to investigate the association between chest wall mobility, axilary (Cax) and thoracic cirtometry (Cthor), respiratory muscle strength (maximal inspiratory pressure – PImax, maximal expiratory pressure - PEmax) and lung volumes (expiratory reserve volume - ERV, forced expiratory volume in the first second - FEV_1, inspiratory capacity - IC, forced vital capacity - FVC), and secondarily to investigate the determinants of chest mobility in healthy subjects. **Methods:** 64 healthy volunteers; spirometry was performed to determine: IC, FVC, FEV_1 and ERV. PImax and PEmax were evaluated using a manometer to measure pressure at the mouth. Chest wall mobility was performed at axillary and thoracic levels using a measuring tape. Linear regression analysis was used to evaluate the influence of some variables on chest wall mobility. **Results:** the volunteers were 24 ± 3 years old, Cax was 6.3 ± 2.0 cm, Cthor was 7.5 ± 2.3 cm. Respiratory pressures were PImax: -90.4±10.6% pred; PEmax: +92.8±13.5% pred. Lung function IC: 99.7 ± 8.6% pred, FVC: 101.9 ± 10.6% pred, FEV_1: 98.2 ± 10.3% pred; ERV: 90.9 ± 19.9% pred. There was significant correlation between Cax and FVC, FEV_1, PImax, PEmax, IC (r: 0.32, r: 0.30, r: 0.48, r: 0.25, r: 0.24, respectively) and between Cthor and FVC, FEV_1, PImax, PEmax, IC, ERV (r: 0.50, r: 0.48, r: 0.46, r: 0.37, r: 0.39, r: 0.47, respectively). In multiple regression analysis the variable that best explained the Cax variation was PImax (R^2: 0.23), and for Cthor was FVC and PImax (R^2: 0.32). **Conclusions:** chest mobility in healthy subjects is related to respiratory muscle strength and lung function, thus the higher the Cax and Cthor greater PImax, PEmax, and lung volumes in healthy subjects.

Key words: physical therapy, lung function tests, respiratory muscles, muscle strength, thorax wall, respiratory mechanics

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Introduction

In clinical practice, the respiratory muscle function is evaluated by the maximum inspiratory pressure (PImax) and maximum expiratory pressure (PEmax). These pressures generated by the inspiratory and expiratory muscles, respectively, are responsible for volume changes in the respiratory system[1]. Based on the pressure-volume relationship of respiratory system, the higher maximal inspiratory pressure is achieved when the inspiration starts from the lowest lung volume (residual volume, RV) and vice versa. Therefore, the stronger the respiratory muscles the highest the pulmonary volume[2]. In accordance with this reasoning, Enright et al found an increase in the vital capacity and total lung capacity (TLC) after training the respiratory muscles in healthy subjects[3]. The same was observed in patients with cystic fibrosis.[4]

As well as the lungs, the chest wall is an elastic structure and follows the displacement of the lungs. Measures of the thoracic movement, from the TLC to RV, by using a measuring tape has been used a chest wall mobility index in healthy subjects[5], asthma[6], ankylosing spondylitis[7], fibromyalgia[8], COPD[9,10], and ostheoporosis[11].

Two previous studies found a significant relationship between the chest expansion and PImax and PEmax which ranged from 0.37 to 0.57[8,11] and while other two studies showed correlation between chest expansion and vital capacity[7] and inspiratory capacity[9]. However, there are no studies that have evaluated the correlation of the respiratory muscle strength, pulmonary volumes and chest expansion as well as the determinants of the latter in subjects without prior diseases. Then, this study was design to quantify the relationship between chest mobility and respiratory muscle strength and pulmonary volumes. In addition we have investigated the determinants of chest mobility.

Methods

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A prospective study was performed in the clinical exercise physiology laboratory of the University Nove de Julho (UNINOVE), São Paulo, Brazil. Healthy volunteers (normal lung function test, no acute and chronic respiratory disease, no cardiovascular disease) between 20 and 30 years old were included. Volunteers were excluded if they could not perform the tests, with chest wall deformities, respiratory or neurologic diseases. Written informed consent was obtained from all subjects, and the local ethics committee approved the protocol number 370562.

Measurements

Spirometry. Spirometry (CPFS/D USB, Medical Graphics, St Paul, Minnesota), was performed with a calibrated pneumotachograph. The technical procedures and the acceptability and reproducibility criteria were as recommended by the American Thoracic Society[12]. All the subjects completed at least 3 acceptable maximal forced expiratory maneuvers. The following variables were recorded: forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), FEV_1/FVC ratio. The slow vital capacity was performed to record inspiratory capacity (IC) and expiratory reserve volume (ERV). The values were compared with those predicted by Pereira et al[13] for Brazilian adult populations.

Anthropometry. Total body mass was established to the nearest 0.1 kg, using a calibrated balance (110F, Welmy, São Paulo, Brazil), and body height was determined to the nearest 0.5 cm, using a stadiometer. Body mass index was calculated as the ratio of weight to height in meters squared.

Chest Wall Mobility. The volunteer remained standing with the hands on the hips for measuring chest wall mobility. This method consisted of measuring the chest circumference using a measuring tape at 2 levels: axillary (Cax) and thoracic (Cthor). For the axillary and thoracic the landmarks were, respectively, the anterior axillary line

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and tip of the xiphoid process. The standardized procedure for making the measurements was that the observer should keep the 0 point of the tape fixed on the midline of the body, aligned horizontally with the landmarks, while the other end of the tape was mobile to allow tape displacement. Furthermore, the tape had to be held snuggly but not tightly, so that the soft-tissue contours remained unchanged. For each level evaluated, the volunteers were asked to perform maximal inspiration and expiration again. The measurements were made twice at each level, during separate breaths: at the end of the maximal inspiration and at the end of the maximal expiration as previous described[14]. The volunteers were asked to maintain the maximal inspiration and expiration for at least 2 seconds, in order to gather data. All the measurements were done for the same trained observer.

Maximal respiratory pressures: Maximal inspiratory pressure (PImax) followed by maximal expiratory pressure (PEmax) was obtained from residual volume and total lung capacity, with the subjects seated wearing nose clips and with a rigid, plastic flanged mouthpiece in place. The subjects were connected to a manual shutter apparatus with the maximal pressures measured using a manometer, aneroid-type gauge (120 cmH_2O - GerAr®, Sao Paulo – Brasil). A small leak was introduced between the occlusion and the mouth in order to prevent glottic closure and in addition the subjects held their cheeks with one hand during the maneuver. Inspiratory or expiratory effort was sustained for at least 1 s. The volunteers performed five acceptable and reproducible maximal maneuvers (i.e., differences of 10% or less between values): the recorded value was the highest[15]. The PImax and PEmax were expressed as absolute value and as percentage of predict based on Brazilians values[16]

Statistical Analysis

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The normality of the data was assessed by the Kolmogorov-Smirnov test. The variables are expressed as mean ± SD. The following variables were correlated by using Pearson's correlation analysis: chest wall mobility, maximal respiratory pressure, FVC, FEV_1, IC and ERV. Weak correlation was considered if $r < 0.50$, moderate correlation if $0.50 > r < 0.70$, and good correlations if $r > 0.70$. Linear regression analysis was used to evaluate the influence of some variables on chest wall mobility. *P* values less than 0.05 were considered significant. Statistical tests were assessed by SPSS 14.0, Chicago, Illinois.

Results

There were recruited 71 subjects, however 5 were excluded because they could not perform correctly the manouvers, and two because they had obstructive disturbance on spirometry. Thus, 64 volunteers (34 men) were included at protocol. All the subjects had normal values of maximal respiratory pressure based on Brazilians values[16]. The baseline characteristics of anthropometry and spirometry are presented in Table 1.

The Cax was significantly correlated with PImax (r: 0.48; $p < 0.001$), the same was observed at Cthor and PImax (r: 0.46; $p < 0.001$- Figure 1A). The Cax and Cthor showed significant weak correlation with PEmax (Cax *vs* PEmax r: 0.25; $p = 0.047$; Cthor *vs* PEmax r: 0.37; $p = 0.003$ - Figure 1A).

The chest wall mobility was correlated with lung capacities. Cax was significantly correlated with IC (r: 0.24; $p = 0.012$), but not with ERV (r: 0.31; $p = 0.057$). The Cthor was correlated with both IC and ERV (r: 0.39; $p = 0.02$; r: 0.47; $p < 0.001$, respectively - Figure 1B).

Correlation between Cthor and FVC was moderate (r: 0.50; $p < 0.0001$), and between Cthor and FEV_1 was weak (r: 0.48; $p < 0.0001$). Although significant, the correlations between Cax and FVC and FEV_1 were weak (Table 2). Weak correlation

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was also observed between Cax and FVC and FEV_1 (r: 0.32; p = 0.009; r: 0.30; p = 0.017, respectively).

In linear regression, PImax was the variable which was associated with Cax (R^2: 0.23; $p < 0.0001$); FVC and PImax was both associated with Cthor (R^2: 0,32; $p < 0,0001$).

Discussion

At the present study there were observed correlations between the chest wall mobility, respiratory muscle strength, and lung function in healthy volunteers. After linear regression analysis, PImax was the variable which explains Cax; and both, PImax and FVC explain Cthor.

We observed that Cax and Cthor have significant correlation with FVC (r: 0.32, r: 0.50, respectively). Significant correlations were also found between the chest wall mobility, the FEV_1 and IC in our study (Cax *vs* FEV_1 r = 0.30; Cthor *vs* FEV_1 r = 0.48; Cax *vs* IC r = 0.24; Cthor *vs* IC r = 0,39). Until now, it was not clear if the chest wall mobility could be associated with lung volumes in healthy subjects. We found that the greater the volume, the greater chest wall mobility evaluated by measuring circumferences. To our knowledge, this is the first study to evaluate this correlation, although it is very justifiable from the standpoint of respiratory mechanics in subjects without cardiopulmonary diseases. Similar observation was made by Malaguti et al in COPD patients, and it was observed a positive correlation between inspiratory capacity and abdominal chest wall mobility[9]. The authors found no correlation between other lung function variables (FEV_1 and FVC) and other circumferences (axillary or thoracic), justified by the reduced chest wall mobility of those patients, in contrast to that observed in our group of healthy individuals. The reduction in chest wall mobility of patients with chronic lung disease had been observed by other authors[6,10].

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The ERV was significantly correlated with Cthor ($r = 0.47$, $p < 0.001$), but not with Cax ($r = 0.37$, $p = 0.057$) in our study, although there was a tendency. We speculate that this occurred due to respiratory muscle is recruited during the ERV maneuver. The expiratory muscle has its insertion on the lower rib cage, which reduces the chest diameter during the ERV maneuver, accumulating elastic energy and facilitating further expansion in the next inspiration, which results in increased on chest wall mobility. We found no studies that have done such correlation. Knook et al suggest that the reduction in respiratory muscle strength in children with juvenile arthritis decreases the ERV, and consequently, FVC, which infers worsening chest wall mobility[17].

Similar to lung volumes, respiratory muscle strength was related to chest wall mobility in this study. The positive correlation observed between Cax, Cthor and PImax (r: 0.48, r: 0.46, respectively) is justified, since the greater the inspiratory muscles strength greater expansion of the rib cage both in the upper and in the lower rib cage. Such correlations were observed in other than respiratory diseases. Cimen et al found significant correlation between the strength of respiratory muscles and axillary cirtometry (r: 0.37) in women with osteoporosis[11]. In patients with fibromyalgia, there were correlation between chest wall mobility, PImax and PEmax ($r = 0.49$, $r = 0.51$, respectively), similar values observed in the present study[8]. Unlike the exposed, Sahin et al found no significant correlation between chest wall mobility, PImax and PEmax (r: 0.10, r: 0.09) in women with fibromyalgia[18]. The authors explain this result due to pain and muscle fatigue observed in these, which reduces the strength of respiratory muscles and hence the chest wall mobility. It is not possible to explore more specifically Sahin et al results, but we believe that linear correlation probably was not observed, because different intensity of pain can result in different muscles activities.

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The correlation of chest wall mobility and PEmax, although significant, was considered weak. It was expected the PEmax had worst correlation with chest wall mobility than PImax. This fact can be explained because the mobility of chest wall is greater as stronger the diaphragm´s effort at inspiratory phase. The same does not happen at expiratory phase, which the mobility is not related to expiratory muscles effort.

All the correlations between muscle strength and chest wall mobility observed at the present study was considered weak, even though statically significant. We believe that other factors, such as elastic recoil, can contribute in all those correlations. Lung volumes are related not only to respiratory muscle strength, but also with compliance and resistance of respiratory system. Even thought healthy volunteers were evaluated in the present study, the physiological mechanism influences the lung volumes and not only muscles strength. Similar findings were made by other investigators in patients with respiratory and musculoskeletal diseases, [18-21] after rehabilitation program[22,23].

The linear regression analysis was performed to determine which variable could explain better that chest wall mobility variation. To Cax, PImax was the variable that better explained the variation (R^2: 0.23; $p < 0.0001$). To our knowledge, this is the first time this result is described. Even thought the Cax may be associated with lung volumes, the inspiratory muscle strength is the most important factor. In a series of studies, Enright et al reported that high intensity of respiratory muscle training (80% PImax) increases PImax, vital capacity and total lung capacity in healthy subjects[3,24] and in patients with cystic fibrosis[4]. Although the authors have not described the correlation between those variables, it was expected that there was a positive correlation

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between them, corroborating with our findings that respiratory muscle strength is related to the circumference and consequently lung volume.

The PImax and FVC were both associated with Cthor at linear regression (R^2: 0,32; $p < 0{,}0001$). The same justifications previously fit for Cax must be considered, however permanence of FVC can be explained because during the FVC maneuver there is great movement of the rib cage, more pronounced on the last ribs, because there is greater mobility of the thoracic cage in this area.

As limitations of our study we describe that it was not used the gold standard chest wall mobility evaluation (optoelectronic plethysmography[25]), because for such assessment is required, highly trained personnel for both the exam and to interpret the findings of this assessment. In this context, thoracic mobility seems to be an interesting and simpler alternative for clinical practice. Abdominal cirtometry was not included in this study, although it has been evaluated, since most of the individuals, when they were asked to deep inspiration, the movement was opposite to that observed by the abdomen in a quiet breath. Smilar situation was described by Basso et al[6]. Thus, this variable was excluded from the analysis due to inconsistency in its evaluation. We understand that there was no bias on the present results, since most studies assess mobility including chest circumferences in the axillary and xiphoid process areas, as we done.

Based on our data, chest wall mobility is a useful alternative, not only to assess the chest wall mobility, but also to inform the interaction of the components of respiratory system (respiratory muscles and lung volumes), especially when a robust method is not available in the clinical practice, such as optoelectronic plethysmography[25]. The results of this study are going to help in clinical practice, because the chest wall mobility, technique widely used for evaluation of breathing pattern in clinical practice, it is an additional tool in the interpretation of respiratory

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muscle performance. Based on this study, we infer the interaction between chest wall mobility, lung volumes, and respiratory muscles. Thus, chest wall mobility can also be used in the monitoring of patients with different diseases because is easy to perform and its improvement after training is expected, as described before, and finally as observed in the present study, may reflect an increase in lung volume and respiratory muscle strength.

We conclude that chest mobility in healthy subjects is correlated with respiratory muscle strength, lung function, thus the higher the Cax and Cthor, the greater PImax, PEmax, FVC, FEV_1 and IC.

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Table 1: Subjects variables (n=64).

Cax: axillary cirtometry, Cthot: thorax cirtometry, BMI: body mass index, PImax: maximal inspiratory pressure, PEmax: maximal expiratory pressure, FVC: forced vital capacity, FEV_1 : forced expiratory volume at first second, IC: inspiratory capacity, ERV: expiratory reserve volume.

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Table 2: Correlation between axillary cirtometry (Cax), thoracic cirtometry (Cthor), forced vital capacity (FVC) and forced expiratory volume at first second (FEV_1).

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Graphic 1: Correlation between axillary cirtometry (Cax), thoracic cirtometry (Cthor), and respiratory muscle strength (PImax - maximal inspiratory pressure; PEmax - maximal expiratory pressure) in (A); between Cax and Cthor and IC (inspiratory capacity) and ERV (expiratory reserve volume) in (B).

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	Mean±SD
Age (year)	24 ± 3
BMI (kg/m^2)	24,1±5,3
PImax (cmH$_2$O) [%]	-93,8±30,2 [-90,4±10,6]
PEmax (cmH$_2$O) [%]	+103,2±38,1[+92,8±13,5]
Cax (cm)	6,3±2,0
Cthor (cm)	7,5±2,3
FVC(L) [%]	4,4±0,9[101,9±10,6]
FEV$_1$(L) [%]	3,7±0,7[98,2±10,3]
FEV$_1$/FVC	86,5±6,9
IC(L) [%]	2,8±0,7[99,7±8,6]
ERV(L) [%]	1,5±0,3[90,9±19,9]

Cax: axillary cirtometry, Cthot: thorax cirtometry, BMI: body mass index, PImax: maximal inspiratory pressure, PEmax: maximal expiratory pressure, FVC: forced vital capacity, FEV$_1$: forced expiratory volume at first second, IC: inspiratory capacity, ERV: expiratory reserve volume.

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		FVC	**FEV_1(L)**
Cax	**r**	0,32	0,30
	p	0,009	0,017
Cthor	**r**	0,50	0,48
	p	<0,0001	<0,0001

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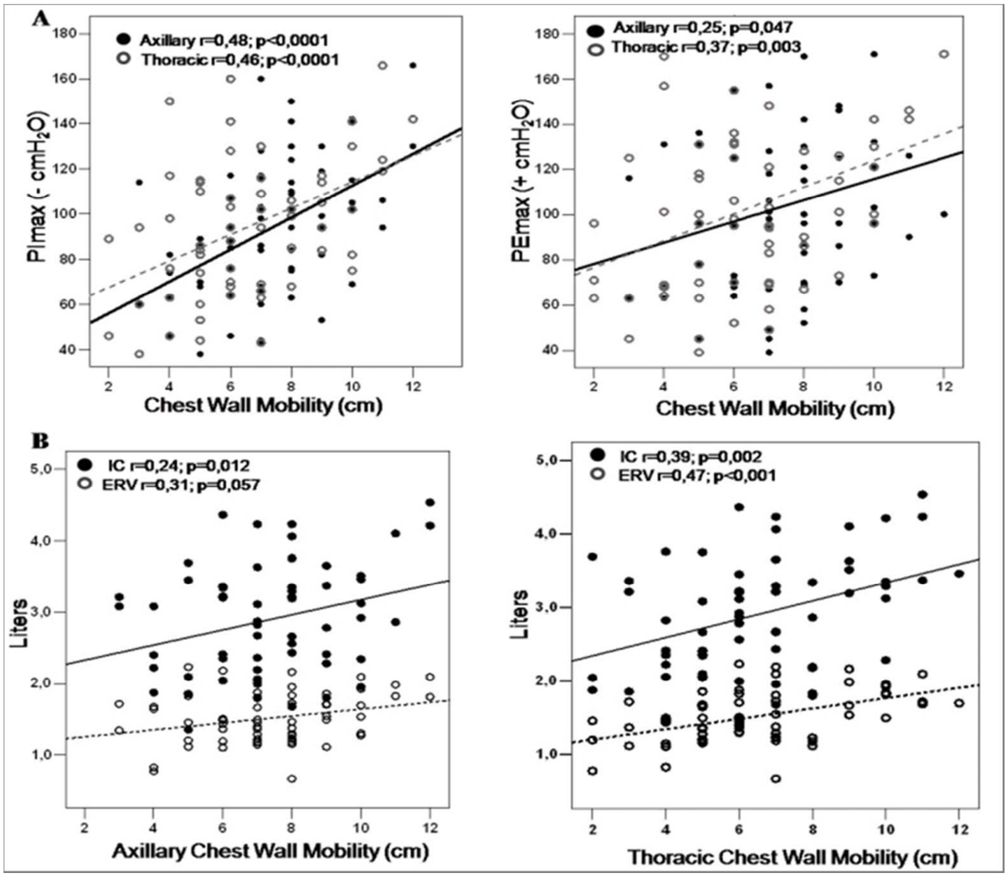

Graphic 1: Correlation between axillary cirtometry (Cax), thoracic cirtometry (Cthor), and respiratory muscle strength (PImax - maximal inspiratory pressure; PEmax - maximal expiratory pressure) in (A); between Cax and Cthor and IC (inspiratory capacity) and ERV (expiratory reserve volume) in (B).