Chest Expansion and Lung Function for Healthy Subjects and Individuals With Pulmonary Disease

Marion Derasse, Stéphanie Lefebvre, Giuseppe Liistro, and Gregory Reychler

BACKGROUND: The purposes of this study were to verify the correlation between chest expansion and lung function within a larger sample of subjects composed of both healthy subjects and subjects affected by pulmonary disease, and to verify the influence of age, body mass index, and gender on chest expansion. METHODS: Adults were recruited prospectively when they visited the lung function lab. Chest expansion was measured with a measuring tape at 2 different levels of the rib cage by 1 blinded examiner. Spirometry was performed for each subject. RESULTS: Data from 251 subjects between 18 and 88 y old were collected and analyzed. Among the analyzed subjects, mean upper and lower chest expansion were 4.82 ± 1.84 cm and 3.99 ± 2.15 cm, respectively. A significant but poor correlation was found between both chest expansion and all lung function parameters (total lung capacity, FVC, and FEV_1) (P = .01). Negative significant correlations were found between chest expansion and age as well as body mass index. The difference in upper chest expansion between obese and nonobese subjects was not statistically significant, but the difference in lower chest expansion was significant for these 2 groups. Finally, upper and lower chest expansion were not different between males and females. CONCLUSIONS: Based on these results, one cannot validate the use of chest expansion measurement to define lung function. In centers that have easy access to more precise and complete methods to measure lung function, the measurement of chest expansion for diagnostic purposes seems to be archaic. Additionally, age and body mass index are 2 parameters that can influence chest expansion. *Key words: thorax; chest expansion; lung function; respiratory mechanics; chest wall mobility; assessment.* [Respir Care 2021;66(4):661–668. © 2021 Daedalus Enterprises]

Introduction

Over the last 50 years, many authors have sought to find a way to measure chest wall mobility and use it as a clinical sign for diagnostic purposes[1,2] or in therapeutic responses.[3-7] Chest expansion, defined as the difference in thoracic girth after maximum inspiration and maximum expiration, is one indicator of chest wall mobility. As it is measured using a measuring tape, it is a simple, inexpensive, and noninvasive tool for assessing chest mobility.[8] Its measurement has become standardized at 2 different levels to obtain upper and lower thoracic circumference,[4] and both intra- and inter-rater reliability have been largely demonstrated in healthy populations[9-13] and in individuals with respiratory disease.[14] Its use is applied throughout the world, mainly as a clinical sign in the field of pulmonology[15] and rheumatology,[1] and as a measure of response to treatment in rehabilitation.[5,16,17] The aforementioned definition of chest expansion implies that there is a direct

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relationship between chest expansion and respiratory volumes. Such a correlation was indeed found in subjects with ankylosing spondylitis,[18,19] pneumothorax, pleural effusion,[20] asbestos-related pleural fibrosis,[21] and chest wall distortion,[22,23] However, discrepancies in this relationship have been found in subjects with COPD.[13,14,24] Moreover, factors such as age, body mass index, pain, and physical condition also have an impact on both chest expansion and lung function.[25-31] By contrast, it is not evident whether gender influences chest expansion, although it is related to the lung function.[8,32-34] The correlation between chest expansion and lung function has mainly been studied in specific conditions such as restrictive disease, and then only using small samples sizes.

The primary objective of this study was to verify the correlation between chest expansion and lung function within a larger sample of subjects composed of both healthy subjects and subjects affected by pulmonary diseases. The goal was to identify whether chest expansion measurements could be applicable in clinical practice. The secondary objective was to verify the influence of age, body mass index, and gender on chest expansion, which would help to optimize interpretation of this test in clinical practice. If this validity is verified, chest expansion measurement could be used in centers or countries where precise measures of lung function are not available.

QUICK LOOK

Current knowledge

Chest expansion is a simple, inexpensive, and noninvasive tool for assessing chest mobility. Its intra-rater and inter-rater reliability has been largely demonstrated in healthy populations and in individuals with respiratory disease. A correlation between chest expansion and lung function was found in subjects with ankylosing spondylitis, pneumothorax, pleural effusion, asbestos-related pleural fibrosis, and chest wall distortion.

What this paper contributes to our knowledge

Based on our results, the use of chest expansion measurement to define lung function can not be validated. In clinical practice, the measurement of chest expansion can be used as a parameter that imperfectly provides an idea of lung volume in centers or countries with limited access to tools to assess lung function. Additionally, age and body mass index are 2 parameters that can influence chest expansion.

Methods

Subjects were recruited prospectively from the pulmonology unit of the Cliniques Universitaires Saint-Luc in January 2017. The inclusion criteria were age $>$ 18 y, spirometry assessment in the aforementioned unit, and freedom from any acute organic pathology that could compromise lung function (eg, acute respiratory disease such as an exacerbation of COPD[35] or sepsis). Exclusion criteria included a lack of understanding of the instructions (eg, cognitive impairment or language barrier) based on a medical interview or the absence of the assessor for the day of the lung function test. Patients who were unable to perform measurements or who were confined to bed were also excluded. The experiment was approved by the Institutional Medical Ethics Committee of the Cliniques Universitaires Saint-Luc (2010/25fev/270). Before each experiment, written informed consent was obtained from the subjects based on the Good Clinical Practice guidelines from the Declaration of Helsinki.

Chest expansion was measured using a measuring tape at 2 different levels of the rib cage by 1 blinded examiner. The anatomical markers used to define upper chest expansion were the third intercostal space at the level of the clavicular line and the spinous processus of the fifth thoracic vertebrae.[9] To define lower chest expansion, the tip of the xiphoid process and the spinous process of the tenth thoracic vertebrae were used as markers.

Instructions were given to the subjects and the procedure was demonstrated to ensure adequate understanding. The 2 measurements of chest diameter were taken at the end of deep inspiratory and expiratory maneuvers. Upper and lower chest expansion were obtained by subtracting the inspiratory diameter from the expiratory diameter, according to the designated anatomical markers. Subjects were sitting with their arms at their sides, with the trunk and chest uncovered. The examiner performed 1 measurement of upper chest expansion and then 1 measurement of the lower chest expansion consecutively, holding the measuring tape at both ends with thumb and index finger around the subject's body. The measuring tape was snug but not tight.

Spirometry and plethysmography were performed by a qualified and blinded technician as recommended by the American Thoracic Society.[36] Subjects were seated when they received the instructions. Data recorded were total lung capacity, FEV_1, FVC, and FEV_1/FVC. Three trials were completed by all subjects, and the best result was selected for analysis. An obstructive defect was defined as $FEV_1/FVC < 0.7$, and a nonobstructive respiratory defect included all subjects with $FEV_1/FVC \geq 0.7$. A restrictive defect was defined as total lung capacity $<$ 0.8 of the predicted value, and a nonrestrictive respiratory defect included all subjects with a total lung capacity $\geq$ 0.8 of the predicted value. A mixed pattern was characterized by the association of both patterns.[37] Body weight and height were

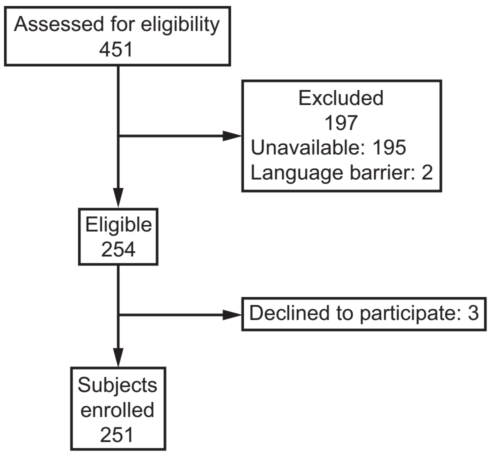

Fig. 1. Flow chart.

Table 1. Subject Anthropometric and Lung Function Data

Age, y	54.3 ± 15.9
Sex	
Male	156
Female	95
Body mass index, kg/m^2	27.3 ± 5.6
Body mass index > 30 kg/m^2	160 (62.3)
Smoker status	
Ex-smoker	100 (39.8)
Current smoker	48 (19.1)
Nonsmoker	103 (41)
FEV_1, % of predicted	86.7 ± 24.4
Total lung capacity, % of predicted	100.2 ± 17.6
FEV_1/FVC measured	71.1 ± 12.8
FVC, % of predicted	94.7 ± 24.9
Upper chest expansion, cm	4.8 ± 1.8
Coefficient of variation	0.38
Minimum, cm	4.6
Maximum, cm	5.0
Lower chest expansion, cm	4.0 ± 2.2
Coefficient of variation	0.54
Minimum, cm	3.7
Maximum, cm	4.3

Data are presented as *n* (%) or mean ± SD. $N = 251$ subjects.

determined using a calibrated balance and a stadiometer, respectively, and body mass index was calculated. Obesity was defined as a body mass index ≥ 30 kg/m^2.

Statistical analyses were performed with SPSS 25.0 (IBM, Armonk, New York). Data are presented as means and standard deviations. Pearson coefficients were calculated to assess correlations between chest expansion measurements (lower and upper chest expansion, separately) and lung function parameters. The significance level was set at $P < .05$ for all tests. The correlation coefficient was characterized as follows: > 0.80 was very good, 0.61–0.80 was good, 0.41–0.60 was moderate, 0.21–0.40 was poor, and < 0.21 was very poor.[38] The *t* test was used to compare the means.

Results

A total of 451 patients were eligible. Among them, 195 were not included because their appointments were not during the therapist's schedule. Two patients were excluded for language incomprehension. Among the 254 remaining patients, 3 declined to participate. Data from 251 subjects between 18 and 88 y old were collected and analyzed (Fig. 1). The baseline characteristics of anthropometry and spirometry of the whole sample are presented in Table 1. There was a predominance of males (62%) in the sample. The spirometric data showed that 12% of the subjects had a restrictive respiratory defect and 38% had an obstructive respiratory defect. These patients had, on average, a mild degree of air-flow obstruction.

Among the analyzed subjects, mean upper and lower chest expansion measurements were 4.8 ± 1.8 cm and 4.0 ± 2.2 cm, respectively. A significant correlation was found between both chest expansion and all lung function parameters (total lung capacity, FVC, and FEV_1) ($P = .01$) (Fig. 2). All of these correlations were poor; the coefficient of correlation between chest expansion (upper or lower) and all lung function parameters (FEV_1, FVC, and total lung capacity) ranged from 0.27 to 0.38 (Table 2).

Significant negative correlations were found between chest expansion and age as well as body mass index (Table 2, Fig. 3). The difference of the upper chest expansion between obese and nonobese subjects was not statistically significant, but the difference was significant for the lower chest expansion between these 2 groups (Table 3). Finally, upper and lower chest expansion were not different between males and females (Table 3).

Discussion

To our knowledge, this is the first study assessing chest expansion based on a large cohort composed of unspecific subjects and assessing its relationship with the lung function. The most important finding of the study was the significant but poor correlations between both upper and lower chest expansion and the analyzed lung function parameters (ie, total lung capacity, FVC, and FEV_1) ($P = .01$). Indeed, because chest expansion is only weakly correlated with lung function, this calls into question the utility of chest expansion measurement in clinical examination. Previous studies have reported average chest expansion values ranging from 5.5 cm to 7.5 cm among healthy subjects, and from 2.2 cm to 6.3 cm among subjects with respiratory diseases (such as ankylosing spondylitis, COPD) (see the supplementary materials at http://www.rcjournal.com). Our

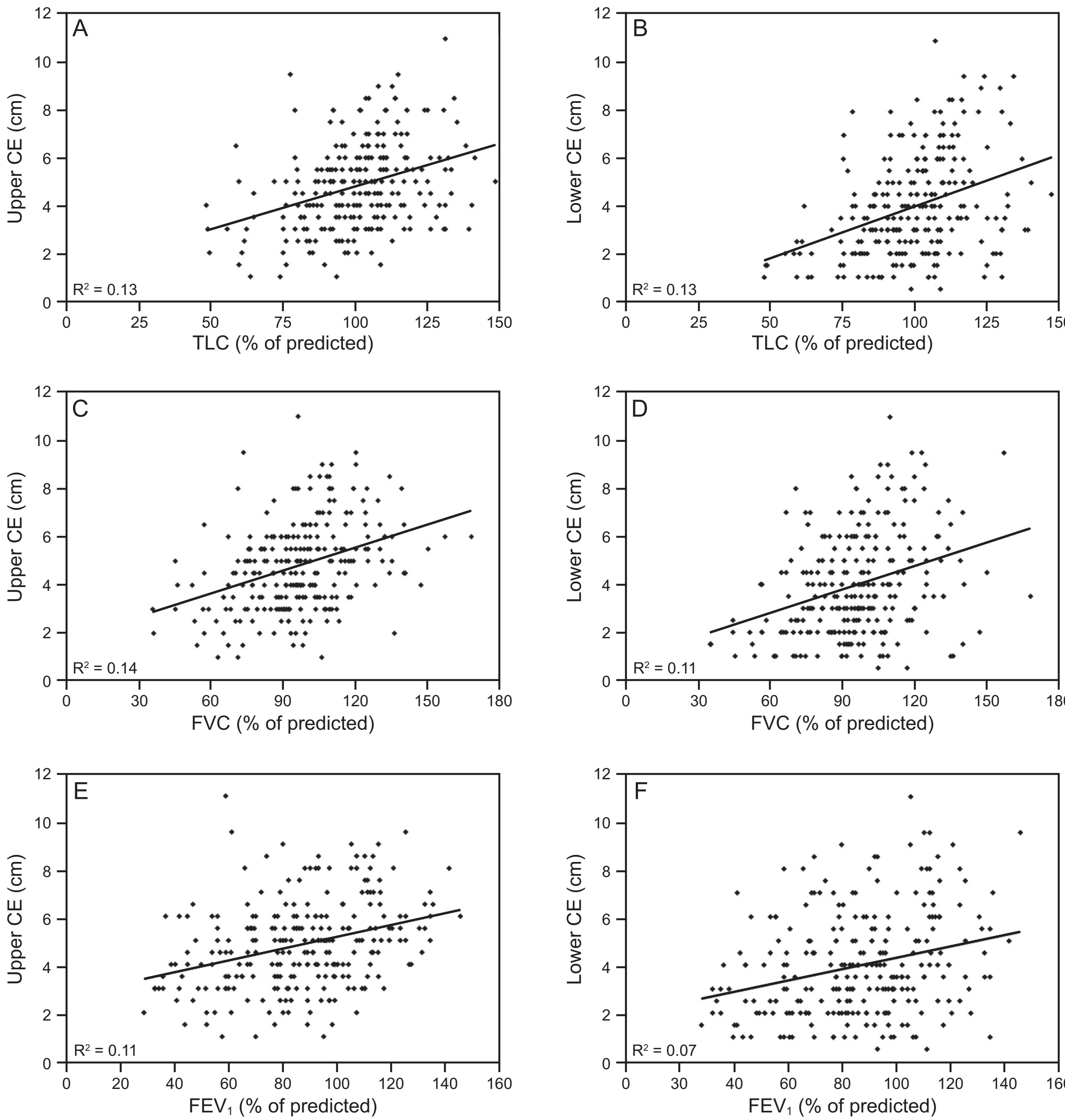

Fig. 2. Correlation between chest expansion (upper and lower) and TLC (A and B), FVC (C and D), and FEV_1 (E and F). CE = chest expansion; TLC = total lung capacity, FVC = forced vital capacity.

results indicate average values of 4.8 cm and 4.0 cm for upper and lower chest expansion, respectively. These values are slightly below the values found in previous studies for healthy subjects but are within the range of values found in previous studies for subjects with respiratory diseases. However, considering that our study is based on a larger sample of subjects and includes both healthy subjects and those affected by pulmonary disease, one could argue that the values of this study are aligned with previous findings.

In our study, mean upper chest expansion was curiously shorter than mean lower chest expansion. While lower chest expansion was systematically higher than upper chest expansion in previous studies,[9,12,13,26,39] only Malaguti et al[14] reported upper chest expansion to be slightly higher than lower chest expansion in a COPD population. Three hypotheses could explain this observation. First, the average body mass index in this study was higher than in the other studies. In previous studies, the mean body mass index did not exceed 24.1 kg/m^2 compared to 27.3 kg/m^2 in our study, and 62.3% of our sample had a body mass index > 30 kg/m^2.[2,9,10,12,13,26,39] A negative correlation has been demonstrated between chest expansion and body mass index.[8,27,40,41] This is explained by the fact that adipose tissue accumulation and decreased muscle strength related to obesity cause a restricted expansion of the thoracic cavity, thus limiting diaphragmatic displacement and decreasing FVC.[27] This is confirmed by the significantly negative correlation found between both upper and lower chest expansion and body mass index in this study. More specifically, lower chest expansion measurements were significantly smaller among obese subjects compared to nonobese subjects. This observation is also supported by the fact that, in obese subjects, ventilation was preferentially distributed to the upper zones of the lung,[27,42-45] leaving the lower, dependent zones relatively underventilated, consistent with relative air trapping in the bases.[27] Second, as expected, a wide heterogeneity in respiratory status was found in our

Table 2. Correlation Coefficients (r) Between Lung Function Parameters and Chest Expansion

	Upper Chest Expansion	Lower Chest Expansion
Total lung capacity	0.35	0.37
FVC	0.37	0.34
FEV_1	0.33	0.27
Age	0.37	0.28
Body mass index	0.43	0.31

Table 3. Comparison of Chest Expansion Between Different Groups

	Upper Chest Expansion	Lower Chest Expansion
Obesity		
Obese	4.2 ± 1.7	2.9 ± 1.5
Not obese	5.1 ± 1.8	4.4 ± 2.2
P	.72	< .001
Sex		
Male	4.4 ± 1.7	3.4 ± 1.9
Female	5.5 ± 1.9	5.0 ± 2.1
P	.37	.16

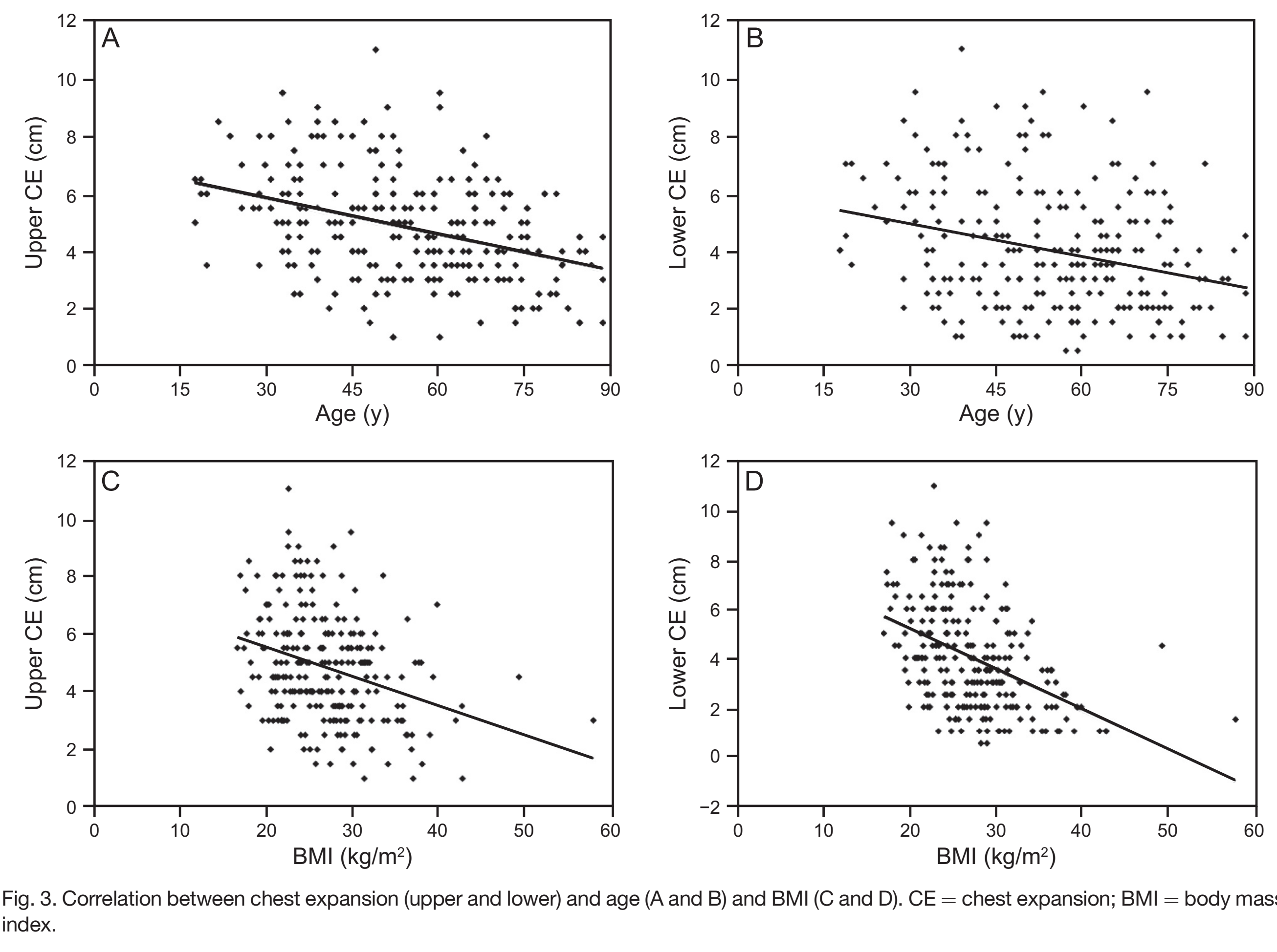

Fig. 3. Correlation between chest expansion (upper and lower) and age (A and B) and BMI (C and D). CE = chest expansion; BMI = body mass index.

cohort; this can be explained by our recruitment process, which was not based on the subjects' clinical condition. Indeed, our sample was composed of both healthy and unhealthy subjects, including those with obstructive and restrictive lung diseases. We know that up to 70% of patients with severe airway obstruction present the Hoover's sign,[46] which refers to inspiratory retraction of the lower intercostal spaces resulting from alterations of the dynamics of diaphragmatic contraction due to hyperinflation and a flattened diaphragm. This implies that the lower chest circumference of patients with obstructive ventilatory defect is reduced. As 38% of our sample had an obstructive respiratory defect, it could decrease the average value of lower chest expansion. This hypothesis is supported by the observation of Malaguti et al,[14] who also noted that lower chest expansion values were inferior to upper chest expansion values within a population of COPD. Third, the subjects were in a sitting position in our study, while the standing position was used in most other studies.[8,9,11-13,26,39] Body position has a considerable impact on lung volume, which will affect the movement of the ribcage and the abdomen, as well as the degree of diaphragm displacement.[27,47] Thereby an increase in upper chest movement was observed in a sitting position in compensation of a decreased lower chest movement.[48]

Among a mixed population composed of both healthy and unhealthy subjects, all parameters of lung function (total lung capacity, FVC, and FEV_1) were poorly correlated with chest expansion measurements with the same intensity for lower and upper chest expansion ($r = 0.3–0.4$) (Table 2), which was reported previously.[13] On the contrary, a stronger correlation between lower chest expansion and lung function than between upper chest expansion and lung function was found within a healthy and young sample (see the supplementary materials at http://www.rcjournal.com).[12,39] The hypothesis is that young age and good health favor the correlation between lower chest circumference and lung function because a greater thoracic displacement and compliance is found among these patients compared to older individuals, those with respiratory disease, or those with obesity.[2,26,45,46]

A significant and inverse correlation between chest expansion and age was found, especially considering upper chest expansion, as observed by several authors.[8,11,25,26,49] Indeed, the literature describes a decline in lung function tests (FEV_1 and FVC) associated to an increase in chest rigidity with age.[11,49] Ruivo et al[25] reported that chest expansion increases from the age of 11 y to 34 y, after which it begins to drop slowly to around 2.5 among individuals > 74 y old. This decrease in chest wall compliance is related to the calcification of the costal cartilage and the costovertebral articulations and results in a natural decrease of chest expansion. Upper chest expansion is more correlated with age than lower chest expansion. Adachi et al[26] also found a correlation between age and upper chest expansion, but not for lower chest expansion or chest expansion measured at the tenth rib. These findings can be explained by the fact that the tenth rib does not have a sternal articulation and the anterior portion of the tenth rib is covered by abdominal muscles.[26] Therefore, the movement of the inferior part of the thorax would not be as markedly affected by age-related changes in chest wall compliance.

The findings of this study are particularly relevant in light of current medical practice in European countries, where patient age averages 43.7 y. Indeed, in previous studies associating chest expansion with lung function, the average subject's age was never > 28 y, whereas it was 54.3 y in our study.[10,12,13,39] Most previous studies only evaluated healthy subjects, whereas 50% of our subjects presented with a pulmonary defect.

No significant difference in either upper or lower chest expansion was found between male and female subjects. Despite the difference in the size of the lungs between gender, males and females maintain the same respiratory movement and thoraco-abdominal configuration.[32,33]

Limitations

Debouche et al[12] collected information about the physical condition of subjects, considering arbitrarily that these subjects were physically active because they were exercising for > 2 h/week. These authors[12] found no influence of physical status on upper or lower chest expansion ($P = .97$ and $P = .46$, respectively).[12] However, a broad literature review proved the major role of physical capacity on variations in chest expansion measurements, namely that physically well-conditioned individuals have higher inspiratory muscle strength and lung volumes compared to individuals in poor physical condition.[6,50] Also, an increase in chest expansion has been observed after muscle training.[7,51,52] We did not analyze physical condition in this study. As explained above, the subject position can influence chest expansion measurements.[27,46] For ease of handling and secondary to improvements in chest movement compared to abdominal movement, we chose the sitting position.[13,32] Different results might have been obtained if a standing or supine position had been used. No data were collected on the state of pain felt by the subject at the time of the chest expansion measurements. However, it has been observed that a state of pain can influence chest expansion values.[28,30] We did not not consider psychometric properties such as reliability or responsiveness, which were discussed in previous studies.[9]

Conclusions

Based on our results, we can not validate the use of chest expansion measurement to define lung function. In developed centers, which have easy access to more precise and complete methods to measure lung function, the measurement of chest expansion for diagnostic purposes seems to be archaic and illusory. In clinical practice, the measurement of chest expansion can be used as a parameter that imperfectly provides an idea of lung volume in centers or countries with limited access to tools to assess lung function. Additionally, age and body mass index are 2 parameters that can influence chest expansion.

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