ORIGINAL ARTICLE

Thorax Expansion and Its Correlation to Spirometry

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ABSTRACT

Objective: To obtain normal value of thorax expansion in relation with age, gender, body weight, and body height and also its correlation with normal values of spirometry.

Methods: Values of three levels of thorax expansion were attained from 196 normal healthy subjects (aged 21-40 years old) whose spirometry results were within normal range.

Results: This study revealed mean thorax expansion in level I (axilla) as 6.03 (1.44) cm, level II (4th intercostal space) 6.69 (1.43) cm and level III (xyphoid process) 6.9 (1.7) cm. Male subjects showed bigger value of thorax expansion. In association with spirometry, thorax expansion positive-correlated significantly with FVC (p 0.01) and FEV1 (p 0.04).

Conclusion: Normal values of thorax expansion and its relations with several variables were described from within 196 normal-healthy subjects. Its correlation with spirometry values showed the ability to predict the expansion of lung from the expansion of the external thorax.

Keywords: *thorax expansion, spirometry*

INTRODUCTION

Respiratory system diseases have been the spotlight of Indonesia considering its high morbidity and mortality rate, such as tuberculosis, pneumonia and chronic obstructive pulmonary disease.[1-3] It shows the high risk of acquired respiratory system diseases as mentioned before. These are preventable and early detection is possible with a better health system. Regardless the characteristic of signs and symptoms of the diseases, they share similar limitation of thorax expansion (TE).[4,5]

Measuring TE externally has been known widely as an indirect method to detect any abnormalities in the lungs internally. Decreasing TE as found also in ankylosing spondylitis and other diseases illustrates a deviation in the thorax cavity and it's contents which can lead to obstructive or restrictive anomalies.[6-8] Increased in TE is shown on a health individual through his cardiorespiratory endurance during breathing exercise.[6-8]

While expanding thorax in three dimensions indicates the probability of wider expansion of

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lung areas, datas of normal value will be of great importance to screen, diagnose and evaluate abnormalities especially with the nonexistance in Indonesia and also its correlation with lung function.[9-11] Normal values of TE were found in divergence in several studies such as illustrated by Lee in healthy Korean as 4.8 (0.1) cm[12] and Swedish in the study by Widberg with mean of 4.5 (1.3) cm[13] These diversity are predisposed by several factors such as age, gender, body weight and height.[14] While correlating the TE with spirometry values have been conducted through studies by Hurtado and Pray and found significant correlation with vital capacity (coefficient of + 0.16 (0.08)).[15, 16]

TE is measured during maximal inspiration and expiration cycle in a number of levels using measuring tapes which are considered cheap and easy to employ.[17,18] This method has also been proven reliable (intratester reliability (0.81 – 0.91) and mean of SD 0.6 cm).[18] Bockenhauer also found that small difference would occur when measurements performed by different persons.[17]

Up to now, screening tools for lung diseases have relied on spirometry as the gold standard as declared by the American Thoracic Society. Predicted values for each forced expiratory volume in one second (FEV1) dan forced vital capacity (FVC) are dissimilar in different factors involved, such as age, body height[19]and also race as standardized in Pneumobile Project for each Country in 1992. Screening needs to be implemented in the rural areas, especially in the primary public health services, yet several obstacles are in the way, for instance, the unavailability of human resources who are able to interpret the results of spirometry, lack of quality control and accuracy of the results and the messy spreading of the calibrated spirometry itself. These aspects call for a better and easier tool for screening lung diseases.[20]

Since the nonexistance of normal values of TE and its correlation with lung function have not been established, this research was aimed at obtaining normal value of TE in relation with age, gender, body weight, and body height and also its correlation with normal values of spirometry.

METHODS

This research was a descriptive analytical cross-sectional study that included 196 healthy adult subjects aged 21-40 years old. Subjects were chosen in limited consecutive randomization from healthy visitors of Hasan Sadikin General Hospital, Bandung, Indonesia, from the period of March to April 2012. The inclusion criteria were conscious adult within the age range mentioned above who were healthy. Healthy means scored healthy from a modified SF-36 questionnaire form (no health complaints in the last three months) which were then confirmed in physical examination: in the range of 18 – 23 kg/m^2 for body mass index, normal vital signs and general physical exams.

We excluded subjects with thorax and limb deformities (including limitation in range of motion of upper extremities); kyphoscoliotic with cardiorespiration symptoms; active smoker; pregnant women; have undergone operative procedure on heart and lungs in the last three weeks or have experienced heart attack.

Drop out criterion were unable to follow procedural instructions and spirometry results interpreted as obstructive/restrictive/ combination. This study was approved by Hasan Sadikin General Hospital ethical committee.

Thorax Expansion (TE) Measurement

Subjects were asked to stand and position both arms behind their head above shoulders' level so as to prevent further contraction and involvement of pectoralis major muscle and latissimus dorsi muscle in the prejudice of measuring thorax expansion and also to fix the position of mammae in place.

Anatomical markers (Figure 1 and 2) in Level 1 (L1) of 3rd intercostal space (ICS) (front aspect) and 5th thoracal spinous process (back aspect) is expected to measure lung expansion for upper and medial lobe. In L2 of 4th ICS (front) and 6th thoracal spinous process (back) is to predict lung expansion in medial lobe while L3 of xyphoid process (front) and 10th thoracal spinous process (back) is done to measure expansion in lower lobe.[8, 19, 21]

Figure 1. Marking of External Thorax

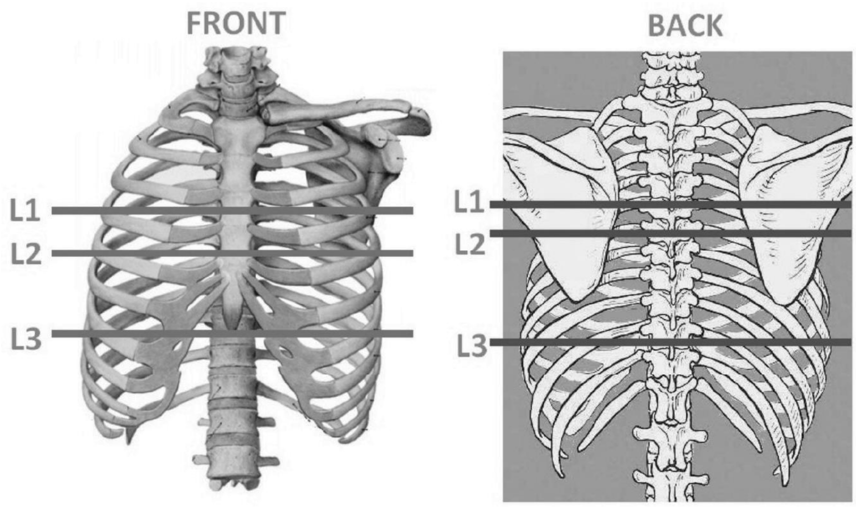

Figure 2. Anatomical Marker

Note: L1 front level to 3rd ICS, L2 front level to 4th ICS, L3 front level to xiphoid process.

Holding measuring tape was standardized by crossing the tape close to the skin (Figure 3).[18]

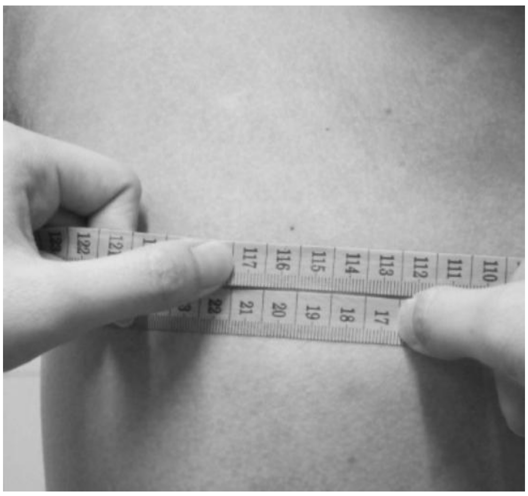

Figure 3. Measuring Tape Holding Technique

First instructions was given as 'exhale maximally until there's no other air inside your lung, and then inhale slowly and as much air as you can until your lung is full'. During this time, measuring tape would follow the diameter of thorax in each level and mark the maximum inspiratory measurement. Then the second instruction was 'exhale all the air out until nothing is left' and the assessor would mark the diameter and calculate the difference as thorax expansion. This measurement was taken three times and the biggest value was collected for each level.

Lung Function Measurement

Lung function was assessed using Enraff Nonius Spiro 601 spirometry that has been caliberated before conducting the study. Each subjects was sitting during spirometry test. They were asked to blow into 2 cm diameter of straw and measure the FEV1 and FVC. Values were then calculated for the predicted FEV1 and FVC compared to the values taken from the Pneumobile Indonesia.

Data Analysis

Descriptive statistics were first carried out to describe the normal TE. Hypotheses were tested using t-test for two variables and anova for more than two variables. Analysis of correlation is completed with Pearson or Spearman correlation test.

RESULTS

For about 211 out of 250 subjects were screened in and underwent the procedure. Fifteen subjects were then dropped out due to failing the spirometry step. The remaining 196 subjects (99 males and 97 females) fell into four categories of age: group age 1 (21-25 y.o.), 2 (26-30 y.o.), 3 (31-35 y.o.), and 4 (36-40 y.o.) and divided evenly between age groups. Demographic data were shown in Table 1.

Table 1. Demographic Data

Variables	Mean	Minimum	Maximum	SD
Age (y.o.)	30.32	21	40	6.01
BW (kg)	57.64	39	79	8.15
BH (m)	1.62	1.45	1.84	0.08
FVC (liter)	3.08	2.04	5.52	0.70
FEV1 (liter)	2.79	1.77	4.75	0.63
Percentage FVC (%)	96.55	80.15	200.07	13.01
Percentage FEV1 (%)	100.24	80.06	180.37	12.75
FEV1/FVC Ratio	90.90	67.31	138.08	8.60
L1 (cm)	6.03	1.5	9	1.44
L2 (cm)	6.69	2.5	10	1.43
L3 (cm)	6.90	1.5	11.5	1.71

Note: y.o = years old; BW= body weight; BH= body height; SD= standard deviation

Mean TE in males were higher than females (Table 2) and consistently larger to inferior parts. Results from Spearman Correlation test showed significant correlation between BH with all levels of TE. Sex was correlated significantly only with L3 of TE.

Table 2. Mean TE

Male	Mean (cm)	Minimum (cm)	Maximum (cm)	SD
L1	6.21	1.5	9	1.51
L2	6.86	2.5	10	1.43
L3	7.25	3	11.5	1.52
Female			5.52	0.70
L1	5.84	3	8	1.35
L2	6.51	3.5	9.5	1.42
L3	6.55	1.5	11	1.82

Even between levels of TE itself, they showed significant correlation, which indicated that each level can be in place for another level (Table 3).

Table 3. Spearman Correlation Between TE, Age, BW, BH and Sex

Variables	Minimum	Maximum	SD
Age **Classification**	r – 0.09 p 0.22	r – 0.09 p 0.10	r -0.00 p 0.98
BW	r + 0.10 p 0.17	r + 0.12 p 0.11	r + 0.11 p 0.13
BH	r + 0.23 p 0.001*	r + 0.24 p 0.001*	r + 0.26 p 0.00*
Sex	r – 0.13 p 0.07	r - 0.14 p 0.05	r - 0.18 p 0.01*
L1		r + 0.88 p 0.00*	r + 0.62 p 0.00*
L2			r + 0.62 p 0.00*

Note: *= significant ($p < 0.05$)

Correlation between TE in three levels and values of spirometry showed significancy ($p < 0.05$) between FVC and all levels of TE, while other significancy correlated with FEV1 was found only in conjunction with L2 and L3 of TE (Table 4).

Table 4. Spearman Correlation between TE and Spirometry Values

	FVC	FEV1	FEV1/FVC
L1	r = + 0.18 p = 0.01*	r = + 0.14 p = 0.05	r = - 0.12 p = 0.13
L2	r = + 0.18 p = 0.01*	r = + 0.15 p = 0.04*	r = - 0.07 p = 0.35
L3	r = + 0.24 p = 0.00*	r = + 0.22 p = 0.00*	r = - 0.05 p = 0.54

Note: *= significant ($p < 0.05$)

DISCUSSION

This study showed larger me an TE than what Lee found in Korean adults of almost the same group age (16-40 y.o.) in 1996 in level L1 and L2 which was 4.8 (0.1) cm.[12] Comparing with previous study by Widberg in Caucasian race of Sweden in 2008, this study also showed larger mean TE. Widberg conducted the study of level L2 and L3 in 23-53 y.o. normal adults that showed mean of 4.5 (1.3) cm and 4.6 (1.1) cm.[13]

Variable anthropometric data are found among different ethnicities. Asian races, such as Mongoloids, Polynesians and Australasians have their own ethnic characteristics. Indonesian itself has those three races mentioned before which is opposite to Mongoloids in Korea. Anthropometric data in BW and BH didn't differ remotely (57.6 (8.1) kg Indonesian vs 64.5 (0.4) kg Korean; 1.62 (0.08) m Indonesian vs. 1.7 (0.03) m Korean). Yet another factor that might interfere is the time period difference which were 1996 (Lee Y and Song G) and 2012 (current study) that might show nutritional support and culture modification over the time.[12] This showed the need for anthropometric study.

Thorax shape and size in different diameters are also influenced by ethnics in various races in the core of genetics. Other aspects such as economic development, social environment and occupation or profession. A study by Lin illustrated at least 33 factors of anthropometric existed in various ethnics in one Mongoloid race in four Asian countries, especially in a variety of anteroposterior diameter of thorax.[22] Indonesian anthropometric study by Harrianto in 2003 find smaller anteroposterior diameter in Indonesian in contrast with the Taiwanese (Lin, 2004) or Singaporean (Chuan, 2010).[22-24]

Anatomical markers stand an important point in different anthropometric combination. This assumption came as the researchers found different markers for measuring TE in posterior. The markers once were taken from Bellemare study in 2001 in Caucasian subjects.[25] When putting the measuring tape in the subject with the consented anterior and posterior markers, we found the tape was not aligned with the ground. Adjustment to correct the alignment were made and in L1 the anterior marker of axilla or third intercostals was aligned with fourth thoracal of spinous process in the posterior. The same thing happened for L2 in which alignment was made in the posterior to fifth thoracal of spinous process. Alignment for L3 was made to seventh thoracal of spinous process in most female subjects and to eight thoracal of spinous process for most male subjects. These findings showed dissimilar thorax diameter and marker in various ethnicity and race that impact in the need to prevent bias in future study by marking each anterior and posterior aspect individually in each race and ethnicity.

TE in all three levels were found successively increase with the decreasing level to inferior. This finding is consistent to what Widberg and Bellemare found owing to the increase in diameter of thoracal cage as the level descends.[13, 26] Lateral sides of thorax are expanding the most during inspiration due to inclination of 6th costal as the same level as xiphoid process (L3). When comparing between sex, as shown in Table 2 and 3, the better size of male's TE than female's was found significantly different only in level 3. This finding is also confided by Bellemare who revealed different inclining degree in 6th costal in females.[26]

Female thorax grows smaller than males in anteroposterior diameter and craniocaudal diameter due to the position of diaphragm, yet bigger in the latero-horizontal diameter due to higher degree of the 6th costal inclination. This higher degree compared to males was created to compensate the overall smaller thoracal volume by higher intensity in intercostals muscle work and thereby to gain adequate lung function.

BH was found to be correlated with TE as also confirmed in a study by Lee.[12] Height of a human being is composed of the stature of bones in one alignment. The arrangement of thorax cage grows through a proportion of growth that also shares the growth rate of thorax height in line with other growth (Whittaker, 2005).[27]

BW as a variable have no correlation with TE. This is consistent with many studies in non obesity subjects. However, theoretically, obesity does make BW correlate significantly with TE as in the distribution of fat as the main factor. Fat percentage and distribution especially in the abdominal area predisposing factor in decreasing TE. This statement is confirmed through studies by Bellemare, Saxena and Ochs-Balcom.[26, 28, 29] Thus, this study cannot explain the decreasing of TE correlated with the observed bigger area of abdomen. Majority of male and female subjects in group age 3 and 4 appeared to have bigger area of abdomen although the body mass index were normal. We didn't perform any examination to determine the percentage of fat in the abdomen, while for future references some extra variables in fat deposit would be better to explain the correlation.

In the physiology of respiration, the effort of producing FVC will be impaired with the presence of fat in the abdominal area by reducing the area for the descending of diaphragm and increasing intrathoracic pressure. These things eventually will reduce expiratory reserve volume by compressing lung and diaphragm and in the end causing the decreased FVC.

Significant correlation between FVC and TE in this study is also supported by Hurtado and Fisher studies.[15,16] This positive correlation demonstrates sufficient volume in the end of maximum inspiration to generate FVC and FEV1. Furthermore, TE is equivalent with lung expansion and vice versa. This also means that the selection of all three levels in measured TE was also considered ideal to illustrate the expansion of lung.

Axillar level of L1 in the anterior thorax is covered by pectoralis and intercostal muscles which have a role in lifting the thorax superiorly and laterally during maximal inspiration to form FVC. In L3, superficial thorax muscles over the xiphoid process and diaphragm, which locates below the xiphoid process and inserts in the same point help in producing pressure to form FEV1.[8] Some bias might interfere in the measurement of L2 through the consistency and position of mammae organs in female subjects, yet an effort has been done by fixating them through positioning both arms behind the head. Thus far, this limitation could be overcome by measuring anteroposterior diameter of thorax in the mid-sternal line with a caliper which were not performed in this study.

CONCLUSION

Normal values of TE in the range of 21 – 40 years old in this study was correlated to BH to all levels of TE and sex to only the level of xiphoid process. Between TE and spirometry values, FVC and FEV1 were significantly correlated with TE. These correlation showed the ability to predict the expansion of lung from the expansion of the external thorax. Yet further studies are needed to analyze other factors, such as fat deposit in the abdominal area and basic anthropometric variables in people of Indonesian in correlation with TE.

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