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The Evaluation of Referance Values for Diaphragmatic Excursion in Turkish Population

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Abstract

Background: The diaphragm is the largest respiratory muscle that contributes to the respiratory work. The aim of this study was to measure the diaphragm excursion, which shows diaphragm function in healthy volunteers, and to determine the reference values in the Turkish population.

Material-Methods: This cross-sectional descriptive study was carried out at a university hospital between 01.01-01.04.2019. Two hundred and thirty (230) healthy subjects had no history of pulmonar or neuromusculary disease were included in the study. Age, sex and diaphragmatic excursion measurements of subjects were recorded. Measurements were obtained by lung silhouette, anterior and Right Hemidiaphmgm and Left Hemidiaphragm Ultrasonographic Method with M Mode. p<0.05 was considered statistically significant.

Results: 230 healthy subjects were included in the study. The male/female ratio was 1.04. No statistically significant difference was found between male and female in terms of age and body mass index. It is concluded that there were statistically significant higher LungSilR, Ant Ax. B Mode R, Ant Ax. B Mode L, Ant. Ax. M Mode R, Ant. Ax. M Mode L of male than female sex. There were a significantly strong positive association between LungSilR and LungSilL, Ant Ax. B Mode R and Ant Ax. B Mode L, Ant. Ax. M Mode R and Ant. Ax. M Mode L.There were a significantly strong positive association between LungSilR and Ant Ax. B Mode R, LungSilL and Ant Ax. B Mode L; significantly weak association between LungSilR and Ant Ax. M Mode R, Ant Ax. B Mode R and Ant. Ax. M Mode R, LungSilL and Ant Ax. M Mode L, Ant Ax. B Mode L and Ant. Ax. M Mode L.

Conclusion: It was concluded that diaphragmatic excursion in theTurkish population was 55.9 - 62 mm in female sex and 67.1 - 71 mm in male sex, since it was found that there was no obstacle in the creation of reference values due to changes in measurement methods and direction, and correlation was found in all methods and right-left measurements for diaphragmatic excursion results.

Keywords: Diaphragm ultrasonography; excursion; healthy subjects; referans values; Turkish population.

Introduction

The diaphragm is the largest respiratory muscle, which contributes to the respiratory effort. Although there is a displacement at a rate of 2-3 cm at resting condition, and the displacement varies according to personal differences and method in deep inspiration, it can reach 7-11 cm[1]. Diaphragmatic dysfunction is faced frequently in muscular dystrophy or in some thoracic and abdominal pathologies. Some conditions like nervous system and phrenic nerve damage may also damagethe diaphragmatic activity. Although bilateral diaphragm damage may cause difficulty in breathing during orthopnea or resting, unilateral diaphragm paralysis is usually asymptomatic[2]. However, there may be suspicion for diaphragmatic paralysis in some conditions like recurrent lung infections, hypoventilation during sleep, limitation in exercise capacity, rapid or frequent breathing, paradoxical activity of abdominal muscles during physical examination, restrictive pattern in pulmonary function tests, and unilateral diaphragm elevation in AC graphics[3]. As a result, since diaphragmatic dysfunction is a common condition that goes undiagnosed when appropriate tests are not carried out upon suspicion, the need for diaphragm evaluation is increasing in both inpatients and especially in outpatients who refer to emergency services.

The function and structure of the diaphragm can be best evaluated with the electrical or magnetic phrenic nerve stimulation. Aside from this, diaphragm paralysis may be evaluated with fluoroscopy; however, fluoroscopy contains both ionized radiation and requires that patients are transported. Another method is Ultrasonography (USG), which is easy, inexpensive and reproducible. Today, although Thorax Ultrasonography is frequently used, diaphragmatic USG is not yet accepted and used widely. The main reason for this is that

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the results of studies conducted in this field are contradictory, and standard measurement methods are not defined yet.

The purpose of the present study was to measure the diaphragm excursion, which shows diaphragm function in healthy volunteers, with some methods, and to determine the reference values in the Turkish population.

Material and Methods

This cross-sectional descriptive study was carried out at a large, tertiary referral, academic institution, after receiving institutional review board approval. All subjects have given verbal consent and signed. Between 01.01-01.04. 2019, two hundred and thirthy (230) healthy subjects had no history of pulmonar or neuromuscular disease and no shortness of breath at rest or with effort and no history of abdominal or thoracic surgery were included in the study. Age, sex and diaphragmatic excursion measurements of subjects were recorded.

Lungsilhouettemethod: Measurement of the upward and downward movement of the lung silhouette in the scapular line. All participants were evaluated in a sitting position. Ultrasound was performed with a Terason Usmart 3200T (77 Terrace Hall Avenue Burlington, MA 01803 United States) and a 3.5-MHz curved probe. The transducer was placed at the lowest part of the lung silhouette in the scapular line. The participant was instructed to exhale as deeply as possible (to RV) and then to inhale deeply to total lung capacity. This maneuver was filmed, and afterward, the distance between the highest and the lowest point of the lung silhouette was measured. This maneuver was performed on the right and the left side. For comparison between this method and the anterior method, only the right side value was used because the anterior method was only used on the right side because of the well-known difficulties on the left side with the anterior method[4, 5, 6, 7,8]**.** The median value was calculated.

Anteriormethod: Measurement of the up- and downward movement of the right diaphragmatic dome from anterior. All participants were evaluated in a lying position. Ultrasound was performed with a **Hitachi ultrasoundsystem (Sono MR, EUB-7500 HV**) using a 3.5 MHz curved probe. The transducer was placed in an area between anterior axillar line and midclavicular line and using the liver as ultrasound window directed toward the diaphragmatic dome. The participant was instructed to exhale as deeply as possible (to RV) and then to inhale deeply to total lung capacity. This maneuver was filmed, and afterward, the distance between the highest and the lowest point of the right hemidiaphragmatic dome was measured. This method was used only on the right side because of the known difficulties with the measurement on the left side with the spleen as ultrasound window[4, 5, 6, 7,8]**.**

Right Hemidiaphmgmand Left Hemidiaphragm Ultrasonographic Method with M Mode

The probe was placled between the midclavicular and anterior axillary lines and intlu- subcostal area, and directed medially, craniallv, and dorsallv, so that the ultrasound beam reached perpendicularlv the posterior third of the right hemidiaphragm Diaphragm movements were recorded in M-mode. Ultrasonographic measurements were performed during quiet breathing (QB) and deep breathing (DB). This maneuver began at the end of normal expiration, and the volunteers were asked to breathe in as deeply as they possibly could.

A subcostal or low intercostal probe position was chosen between the anterior and midaxillary lines to obtain the best imaging of the left hemidiaphragmatic dome. The motion was recorded during the same respiratory maneuvers as for the right hemidiaphragm.

The diaphragm's inspiratory amplitudes (excursions) were measured from the M-mode sonography. For the QB and DB measurements, the first caliper was placed at the foot of the inspiration slope on the diaphragm echoic line and the second caliper was placed at the apex of this slope. Several respiratory cycles were recorded, and measurements were averaged from at least three different cycles.

All evaluations were made by the same rediology spesialist who was blinded to the pulmonary function status of each patient and who has experienced in lung and diaphragmatic ultrasound[8]**.**

Statistical analysis

The data that were obtained in the study were recorded in the SPSS 25.0 Program (Armonk, NY: IBM Corp.). The fitness of the continuous variables to the normal distribution was analyzed with the Kolmogorov-Smirnov test and was recorded as median (quartiles). In this respect, the Mann Whitney U-test was used for the differences between the genders for these parameters that do not show normal distribution. The significance level of the continuous measurements among the four groups was accepted as $P<0.05/6$. The Spearman Test Analysis was used for correlation analyzes among Lung SilR and LungSilL, Ant Ax. B Mode R and Ant Ax. B Mode L, Ant. Ax. M Mode R and Ant. Ax. M Mode L; and $P<0.05$ value was considered to be statistically significant.

Results

A total of 230 healthy participants were included in the present study. A total of 48.9% (n=112) of these were women with a median age of 33.0 (quartile 30.0-36.0); and 51.1% (n=117) were men with a median age of 34.0 (quartile 31.0-

Table 1. Age, body mass index and ultrasonographic measurements of participants of the study and significance level between these results.

	female (n=112)	male (n=117)	P value
Age, median (quartile)	33.0 (30.0- 36.0)	34.0 (31.0-37.0)	0.141
BMI, median (quartile)	23.1 (20.9-26.6)	24.5 (22.7-26.1)	0.095
LungSilR(mm), median (quartile)	55.9 (47.7-64.4)	67.1 (63.8-78.8)	**<0.001**
LungSilL(mm), median (IQR)	57.8 (49.3-66.5)	68.0 (64.1-79.0)	**<0.001**
Ant Ax. B Mode R(mm), median (quartile)	59.1 (49.8-68.5)	69.8 (66.6-80.1)	**<0.001**
Ant Ax. B Mode L(mm), median (quartile)	60.2 (50.6-70.2)	70.1 (67.0-82.1)	**<0.001**
Ant. Ax. MModeR (cm), median (quartile)	6.0 (5.0-7.0)	7.1 (6.5-8.0)	**<0.001**
Ant. Ax. M Mode L (cm), median (quartile)	6.2 (5.2-7.2)	7.1 (6.8-8.5)	<0.001

(Data are expressed as median) (BMI: Body MassIndex)

37.0). The median BMI of the women was 23.1 (quartile 20.9-26.6), and the median BMI of the men was 24.5 (quartile 22.7-26.1). The difference levels of the ultrasonographic findings between the genders are given in **Table 1**. In this respect, it was determined that the Lung SilR (67.1 vs 55.9; p<0.001), LungSilL (68.0 vs 57.8; p<0.001), Ant Ax. B Mode R (69.8 vs 59.1; p<0.001), Ant Ax. B Mode L (70.1 vs 60.2; p<0.001), Ant. Ax. M Mode R (7.1 vs 6.0; p<0.001), Ant. Ax. M Mode L (7.1 vs 6.2; p<0.001) of the men were higher at a significant level compared to the women.

The correlation levels between the right and left ultrasonographic findings of the participants of the study are given in **Table 2**. There was a strong, significant and positive relation between the Lung SilR and LungSilL, Ant Ax. B Mode R and Ant Ax. B Mode L, Ant. Ax. M Mode R and Ant. Ax. M Mode L (r=0.949, P<0.001; r=0.985, P<0.001; r=0.949, P<0.001).

The correlation and significance levels of the ultrasonographic findings with each other are given in **Table 3**. There was a strong positive correlation between Lung SilR and Ant Ax. B Mode R, Lung SilL and Ant Ax. B Mode L(r=0.946, P<0.001; r=0.979, P<0.001; r=0.949, P<0.001). There was a significant and weak relationship between LungSilR and Ant Ax. M Mode R, Ant Ax. B Mode R and Ant. Ax. M Mode R, LungSilL and Ant Ax. M Mode L, Ant Ax. B Mode L and Ant. Ax. M Mode L (r=0.260, P<0.001; r=0.292, P<0.001; r=0.282, P<0.001; r=0.282, P<0.001).

Discussion

The diaphragm excursion measurements differ at significant levels in female or male gender; the changes in the diaphragmatic excursion according to the measurement method; however, this change not reaching a statistical significance level and the lack of statistically significant differences in the right or left side measurements are among the main results of the present study of ours. Based on this, it is possible to argue that the average diaphragm displacement of the male gender in the Turkish population is 67.1-71 mm,

Table 2. The corellation between right and left side of ultrasonographic findings

Variables	Correlationcoefficient	*P value*
LungSilR(mm)and LungSilL(mm)	0.949	**<0.001**
Ant Ax. B Mode R(mm) and Ant Ax. B Mode L(mm)	0.985	**<0.001**
Ant. Ax. M Mode R (mm) and Ant. Ax. M Mode L (mm)	0.949	**<0.001**

Table 3. The corellation between ultrasonographic findings

Variables	Correlationcoefficient	*P value*
LungSilR(mm) and Ant Ax. B Mode R(mm)	0.949	**<0.001**
LungSilR(mm) and Ant. Ax. M Mode R (mm)	0.260	**<0.001**
Ant Ax. B Mode R(mm) andAnt. Ax. M Mode R (mm)	0.292	**<0.001**
LungSilL(mm)and Ant Ax. B Mode L(mm)	0.979	**<0.001**
LungSilL(mm) and Ant. Ax. M Mode L (mm)	0.282	**<0.001**
Ant Ax. B Mode L(mm) andAnt. Ax. M Mode L (mm)	0.282	**<0.001**

and between 55.9-62 mm in female gender regardless of the measurement method and the sides (i.e. right or left).

In previous studies, forced breath excursion values were reported at a wide range; 42±16 to 75±10 mm. At resting condition, on the other hand, the same measurement results were determined to be much lower with 15±2 mm[9]. These differences in the results can be attributed to the parallax error rates, which are observed in lateral approach (both longitudinal and intercostal or subcostal imaging), or in measurements obtained with transverse images[10, 11]. These approaches may cause various transducer positions in the chest or abdomen wall and this might affect the reproducibility preventing maximal diaphragmatic excursion recording because of the oblique orientation in the USI rays, which may cause loss of accuracy in the outcomes[12, 13].

The diaphragm thickness measurements reported in the literature for the male and female gender are limited. Boon et al. reported the diaphragm thickness that was measured in healthy controls as 3.3 mm; however, gender was not reported in this study[14]. Cimşit et al. reported lower diaphragm thickness measurement results in women;however, this difference was not at a statistically significant level[15]. Cohn et al.,on the other hand, reported higher diaphragmatic thickness in males at a statistically significant level[5].The gender differences in these studies, in which diaphragm thickness values were mentioned, are probably stem from the higher muscle mass in males compared to females.

This supports the viewpoint arguing that the thickness is higher in men, not only in the diaphragm muscle, but also in any other muscles in any parts of the body. However, evaluations that are made not only by sex but by body mass index or lean muscle mass will be supportive in this regard to support these findings[16]. All these studies that have been mentioned so far were conducted on the diaphragm thickness. However, the results of the studies conducted on the effect of gender on diaphragm excursion are contradictory. In a study that was published by Testa et al. in 2011, no differences in terms of gender were reported; however other studies reported an increased diaphragm excursion in male gender[7, 13, 9]. In the present study of ours, statistically significant and increased diaphragm excursion values were detected in the male gender, which is consistent with the literature. However, as mentioned above, this may be attributed to the increased lean muscle mass in male gender. Although no significant differences were detected in the Body Mass Indices according to gender in the participants who were included in the study, the fact that lean muscle mass was not measured is one of the limitations of the present study.

The M-Mode and B-Mode Ultrasonography were first identified by Haber et al. in 1975 in evaluating the movements of the diaphragm[17]. In previous studies, it was shown that lung silhouette method was well-correlated with the anterior axillary method, it could be carried out easily in all patients including obese patients, it was easy to apply with US and it was suitable for evaluation of both hemidiaphragms[7,18]. In our study, no significant differences were detected between the techniques in terms of measuring diaphragmatic dysfunction when compared to the anterior method; and the correlation of both techniques was found to be strong. Although there were no significant differences between the right and left evaluations in both methods, it is seen useful to make the evaluations by using the right anterior method especially in patients who cannot be given interscapular image position with point of care US.

Studies that reported right-left correlation have been mentioned in the literature[14]. A difference reaching up to 0.33 cm is acceptable in excursion measurements between the right and left diaphragm halves. However, it is not known which diaphragm half must be thinner, and which one might vary among people. If the displacement in one half of the diaphragm is bigger than this value, the half of the diaphragm of that person might be basically thinner, or that side might have been affected by any disease,which caused muscular atrophy. In such cases, it may help to consider that there is a decrease in the thickening ratio, which must be above 1.2 to detect abnormality[19].

In the present study of ours, although there was a difference that does not exceed normal limitsin the diaphragm halves excursion measurements, which is in line with the literature, the right-left half measurements were found to be correlated with all measurement methods. In this case, the right or left side might be preferred based on the position in which the patient feels comfortable or based on the experience of the practitioner. As it is known, creating the window and capturing the appropriate image may be more difficult on the left side due to gastric gas[20] and right side can be preferred for the convenience of the imaging[21].

Conclusion

The diagnosis methods that involve ionized radiation have increased in our present day, and it is important to useinexpensive, easily applicable and reproducible methods for diagnostic purposes. It was concluded that there is no obstacle in the creation of reference value according tothe changes in the measurement methods and the direction for diaphragmatic excursion results; and since correlation was detected in all methods and in all right-left measurements, the diaphragmatic excursion was 55.9-62 mm in female gender and 67.1-71 mm in male gender in the Turkish population.

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