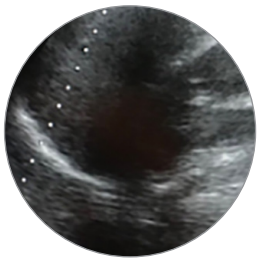

Diaphragmatic Excursion in Healthy Adults: Normal Values. Analytical Prevalence Study

Excursión diafragmática en adultos sanos: valores de normalidad. Estudio de prevalencia analítica

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Summary

Introduction: diaphragmatic excursion by ultrasound is a tool that allows to properly assess the patient with critical pathology of the airway, with pleural effusion and neurovascular injuries that generate restrictive patterns on the chest. Performing dynamic evaluation of the diaphragm before and after a procedure allows us to know the changes in the natural history of the disease. For this reason, it is essential to know the normal values of the study population, and how it interferes with the other anthropometric variables of the patients. ***Materials and methods:*** analytical prevalence study for the measurement of normal excursion variables and the correlation with anthropometric variables of patients without pulmonary or diaphragmatic pathology. ***Results:*** simple random sample of 50 diaphragms with a distribution of 68% of women, with a mean age of 39 years and a median of the abdominal perimeter of 78 cm. The thickness of the diaphragm was 3.4 mm on inspiration and 2.6 mm on expiration, with a mean diaphragmatic excursion of 15 mm. The Kendall correlation between the excursion and the anthropometric variables had a value of rho = 0.94. ***Conclusions:*** the normal values of the diaphragmatic excursion are highly variable according to the population studied, with a clinical relationship between the anthropometric variables. This allows us to recommend that we should always perform a dynamic assessment of the diaphragm before and after each procedure in order to evaluate significant changes in diaphragmatic excursion values.

Resumen

Introducción: la excursión diafragmática por ultrasonido es una herramienta que permite valorar adecuadamente al paciente con patología crítica de la vía aérea, con derrame pleural y lesiones neurovasculares que generan patrones restrictivos sobre el tórax. Realizar la valoración dinámica del diafragma antes y después de un procedimiento permite conocer los cambios en la historia natural de la enfermedad. Por esto, es primordial conocer los valores de normalidad de la población de estudio, y cómo interfiere con las demás variables antropométricas de los pacientes. ***Materiales y métodos:*** estudio de prevalencia analítico para la medición de variables normales de la excursión diafragmática y la correlación con variables antropométricas de pacientes sin patología pulmonar o diafragmática. ***Resultados:*** muestra aleatoria simple de 50 diafragmas con una distribución del 68 % de mujeres, con edad media de 39 años y una mediana del perímetro abdominal de 78 cm. El grosor del diafragma fue de 3,4 mm en inspiración y 2,6 mm en espiración. La media de la excursión diafragmática fue de 15 mm. La correlación de Kendall entre la excursión y las variables antropométricas tuvo un valor de rho= 0,94 (Spearman). ***Conclusiones:*** los valores de normalidad de la excursión diafragmática son muy variables según la población estudiada, con relación clínica entre las variables antropométricas. Esto nos permite recomendar practicar una valoración dinámica del diafragma antes y después de cada procedimiento para evaluar los cambios significativos en los valores de excursión diafragmática.

1. Introduction

Diaphragmatic excursion measured with ultrasound offers several benefits for the evaluation of diaphragmatic function and its relationship with pulmonary function (Figure 1). There are publications about the diagnostic performance of ultrasound and the pathological critical values in different population groups; however, there are no published national normal values that allow us to address the narrow range in which the pathological values are found in the diaphragm, since they are values in millimeters. Likewise, it is not known how these values vary in the Colombian population according to the correlation with patient variables that may be influencing these parameters of normality. Therefore, this research aims to demonstrate the normal values of diaphragmatic excursion in the ultrasound study and its correlation with variables of interest, such as anthropometric measurements, in a population without pulmonary disease.

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2. Materials and Methods

Ultrasound scans were performed with a Toshiba Aplio XG ultrasound machine, in healthy individuals (without described pathology of the diaphragm) who were working, studying or were patients for ultrasound study of the abdomen in the institution at the time of the research. The technique for the study was: patients in supine decubitus were examined with two transducers, convex and linear high frequency, with dynamic maneuvers of inspiration and expiration in both diaphragms. B (brightness) and M (motion) modes were used for quantitative measurements.

Recruitment was done as follows: Individuals were invited to participate in the study by electronic invitation and voice-to-voice by the investigators in the Department of Radiology, where ultrasonographic studies were subsequently carried out in administrative areas.

To calculate the sample, a probabilistic sampling analysis was performed for the analysis of means for a total population of 2000 participants, which is the approximate number of people in the clinic. A significance level of 95%, an expected standard deviation of 0.04 and a precision of 0.01 were determined. This resulted in an estimate of 40 individuals and by adding a 10 % standard expected loss, 50 diaphragms were considered for the analysis.

For the analysis plan of the study, a univariate analysis was initially proposed, which was established by means of frequency tables and percentages for qualitative variables, such as gender. On the other hand, for quantitative variables, such as age, excursion magnitude and diaphragm thickness, measures of central tendency were established. Each variable was calculated independently, such as diaphragmatic thickening fraction. Although its calculation is derived from the ratio in expiration and inspiration, the values reported are those of the patients' measures of central tendency and not those of the calculation of their related variables. The quantitative variables were subjected to normality tests using the Shapiro-Wilky Kolmogorov-Smirnov test; if they had a normal distribution, the measures of central tendency, standard deviation and mean were used, but if the distribution was not normal, the median and the minimum and maximum values were presented. For the development of the specific objective of correlation between the magnitude of diaphragmatic excursion and the anthropometric measurements, Spearman's correlation test was performed.

The investigators collected the data at the primary source, with the prior informed consent and assent of the patients. Subsequently, for analysis and interpretation, they were included in a Google format-type online database, which was exported to the SPSS and STATA 13 programs for statistical analysis.

3. Results

A homogeneous gender distribution was found in the patients evaluated, with a proportion of 68 % of women, with a mean age of 39 (19-65) years. The average weight of the patients was 69 kg, with a mean height of approximately 165 cm. The abdominal perimeter ranged from 62 to 97 cm, with a median of 78 cm (Tables 1 and 2).

Table 1. Gender distribution

Gender	Frequency	Percentage	Percentage Valid	Cumulative Percentage
Female	34	68.0	68.0	68.0
Male	16	32.0	32.0	100.0
Total	50	100.0	100.0	

Table 2. Measures of central tendency of quantitative variables

	Mean	Median	Maximum	Minimum	Standard deviation
Age	39.52	38.50	65.00	19.00	14.67
Weight (kg)	69.42	71.00	91.00	45.00	14.72
Height (cm)	164.88	164.00	181.00	151.00	10.71
Abdominal circumference (cm)	79.46	78.00	97.00	62.00	10.60
B-mode diaphragm thickness in exhalation (mm)	3.40	3.70	5.50	1.70	1.16
B-mode diaphragm thickness in inspiration (mm)	2.58	2.50	4.10	1.20	0.88
Diaphragmatic thickening fraction (%)	43.42	38.50	80.00	13.00	19.37
Average diaphragmatic excursion in M-mode	14.58	15.00	19.00	10.00	2.14
Maximum diaphragmatic excursion M mode	21.14	16.00	213.00	11.00	28.07
M-mode expiratory velocity	6.19	1.90	218.00	0.80	30.57

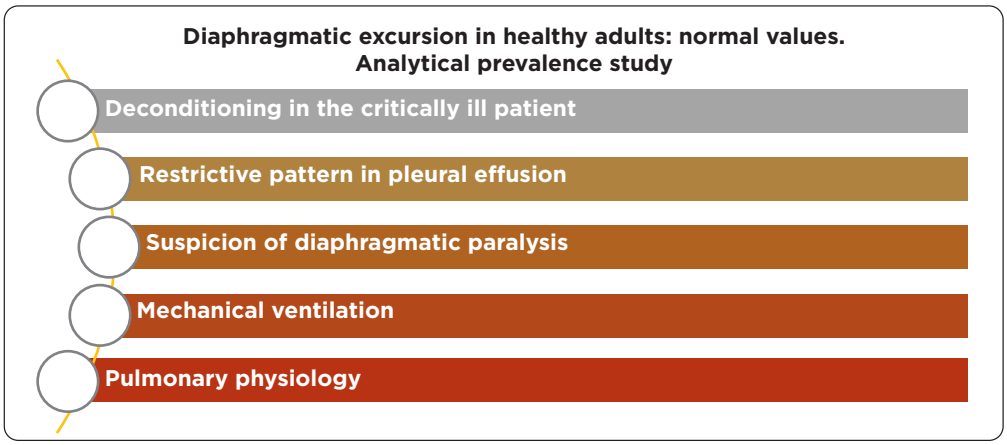

Figure 1. Diagram of usefulness of ultrasound assessment in diaphragmatic excursion

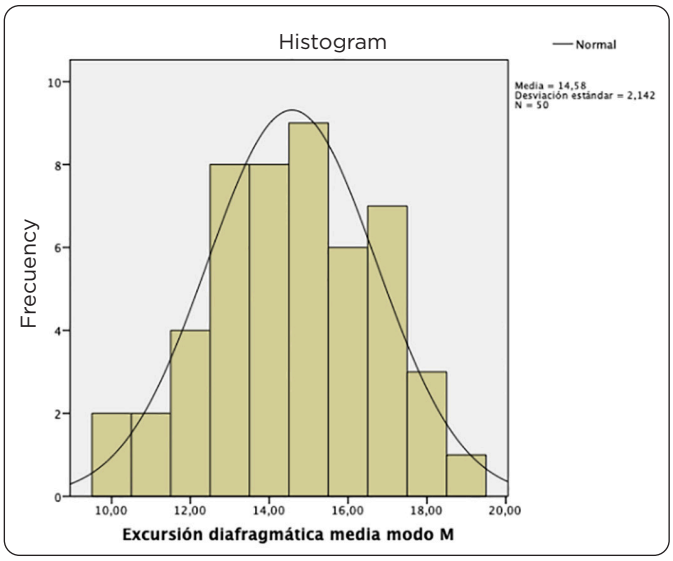

Figure 2. Normal distribution of diaphragmatic excursion measured in M-mode

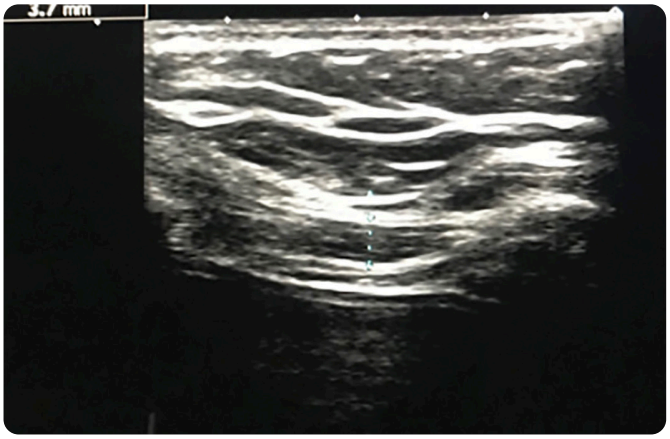

Figure 3. Diaphragmatic thickness measured in B-mode

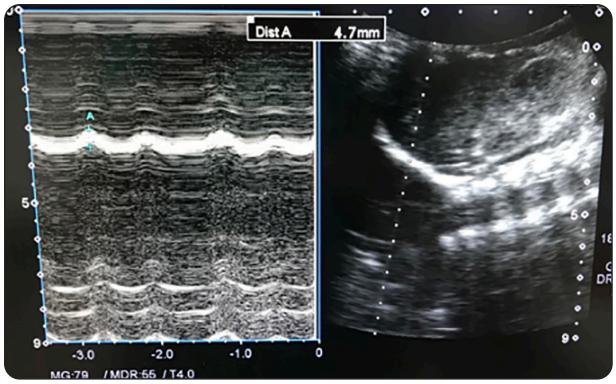

Figure 4. Diaphragmatic thickness measured in M-mode

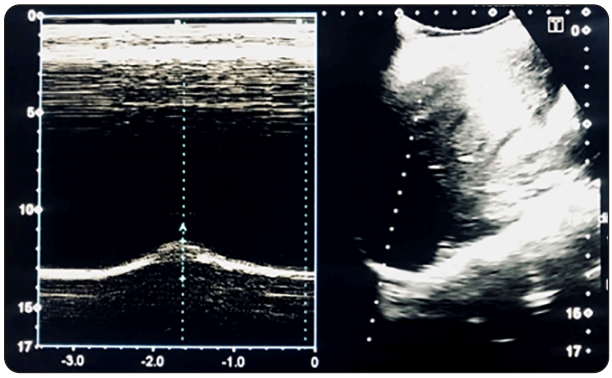

Figure 5. Right diaphragmatic excursion measured in M-mode

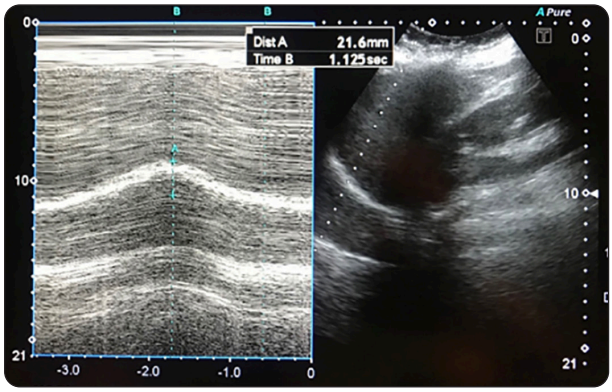

Figure 6. Left diaphragmatic excursion measured in M-mode

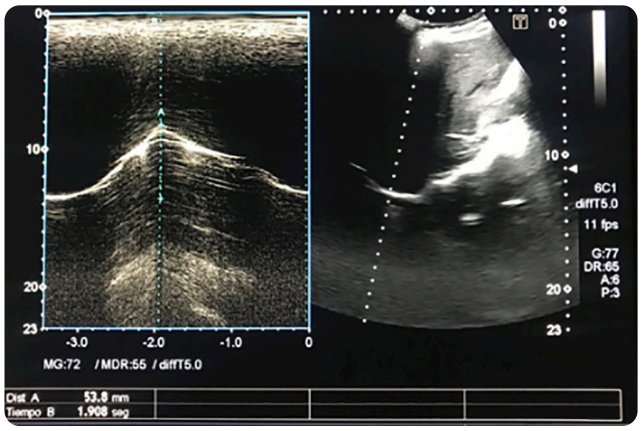

Figure 7. Exhalation time of diaphragmatic excursion

3.1 Specific results of diaphragmatic excursion by ultrasound.

The mean diaphragmatic thickness measured during expiration was 3.4 mm, while in inspiration it was 2.58 mm; with a thickening fraction of approximately 43 %. The mean diaphragmatic excursion measured in M-mode was 15 mm and maximum 21 mm, and was the only variable with normal distribution under the Gaussian bell (Figure 2). Exhalation velocity had a median of 1.9 seconds (Table 2).

3.2 Bivariate analysis of independent variables and diaphragmatic excursion

The advanced analysis of the relationship between the anthropometric variables of the patients and diaphragmatic excursion showed a value of rho = 0.94 (Spearman), with a clinical relationship that showed that the greater the abdominal perimeter and the greater the thickness of the diaphragm, the lower the diaphragmatic excursion. No significant relationship was found between abdominal perimeter and expiratory speed or the thickening fraction.

4. Discussion

Diaphragmatic excursion measured with ultrasound is increasingly useful in the thoracoabdominal assessment of patients. Perhaps the most widely used is in the critically ill patient, to define muscle deconditioning, which is crucial in predicting successful extubation in ventilated patients who meet clinical criteria. The evidence determines that patients with clinical criteria for extubation, but with ultrasound values of diaphragmatic deconditioning, have a higher risk of early ventilatory failure after extubation (1). In spite of this, caution should be exercised with reference static measurements in the literature, because for an older adult patient with low height and low weight, the abnormal values of the average American patient are normal values, whereas, if a reference normal value of this patient is available before initiation of mechanical ventilation therapy, it is easier to establish its cut-off values to predict extubation success. In the evaluation of the physical deconditioning of the diaphragm, it has been established that once the patient is intubated in the critical care unit, the thickness of the diaphragm decreases 6-7.5% per day (2, 3) and 3.4% in children (4). Despite this, the initial value is not established, but the follow-up values of the study in these patients. It has also been documented that a thickening fraction less than 20 % or a diaphragmatic excursion less than 10 mm is established as a diaphragmatic dysfunction (5). When the diaphragmatic excursion is between 11 and 14 mm and the thickening fraction between 30 and 36 %, a successful extubation with low risk of reintubation in the first hours could be predicted (6-9). The research described here has been performed with patients without known pulmonary or diaphragmatic pathology, with results different from those published. Diaphragm thickness can be measured in B-mode, ideally with a linear transducer; or in M-mode, with a low-frequency transducer. It has been found that patients with values lower than 2 mm have a longer extubation time (10). In this study the measurement was performed in B (figure 3) and M (figure 4) modes, but it is more practical to measure in B mode, as described in the literature (11). Mean thickness values were found between 2.6 and 3.4 mm, but minimum values of 1.2 to 1.7, especially in patients with smaller abdominal perimeter; however, with no statistically significant association.

On the other hand, diaphragmatic ultrasound is also useful in the assessment of pleural effusion, to define which hemidiaphragm is more compromised when the effusion is bilateral. It is crucial to define which hemithorax to drain when the effusion is bilateral, since it is not possible to drain both at the same time, due to the risk of pulmonary edema by re-expansion. This problem is very frequent in oncologic patients with parapneumonic effusion who require frequent intermittent drainage. Diaphragmatic ultrasound allows us to know which hemithorax has greater restriction and which has its pulmonary function more affected, and the latter is the one chosen for percutaneous drainage (1, 2).

Finally, the assessment of diaphragmatic hypotonia in suspected paralysis is an important utility of diaphragmatic ultrasound, since, unlike fluoroscopy, it allows real-time evaluation of diaphragmatic mobility. Additionally, it facilitates quantification of diaphragmatic motion values, comparison with the contralateral side, and comparative assessment before and after patients undergo surgical plication.

The assessment of diaphragmatic excursion in this investigation had a normal distribution (Figure 2), with well distributed behavior that approached the population parameter. It was found that the assessment of the right hemidiaphragm (figure 5) was more practical than the left hemidiaphragm (figure 6), due to the fact that the left insonation window is more superior and posterior. All values in the sample were greater than 10 mm, as described in the literature; however, an inverse relationship was also found between abdominal circumference and excursion, and diaphragmatic movement is more difficult in patients with greater circumference. In spite of this, patients with greater perimeter, but with greater height, have greater diaphragmatic excursion.

The diaphragmatic thickening fraction in this investigation also had a wider range in relation to the values in expiration and inspiration (Table 2), and was also in relation to the abdominal perimeter and height of the patients. Likewise, in the expiratory time there was a wide variance, because it is closely related to the peak diaphragmatic excursion (Figure 7); however, the expiratory time serves for the evaluation of gas exchange and indirectly to evaluate the extrapulmonary restrictive pattern of the patients, such as the increase in intra-abdominal pressure. Due to all of the above, it is very important to know the anthropometric

values of the patients and to always have an initial measurement value to interpret pathological values in the prediction of diaphragm deconditioning, since a value of 1.7 mm in thickness and a diaphragmatic excursion of 10 mm may be normal in a patient of short stature and with a smaller abdominal perimeter, while in a patient of greater stature with a wide abdominal perimeter, it is frankly pathological.

Limitations of the study: This study has limitations in its methodological design that does not allow causal associations because it is a cross-sectional study of the situation of healthy patients with diaphragmatic excursion measurement. Likewise, it has sampling limitations. Due to the above, we recommend the development of studies with a larger sample of analysis and analytical methodology for external validation of the results and analysis proposed.

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Conclusion

The values of normality in diaphragmatic thickness and excursion have a wide range of normality and are related to the anthropometric values of the patients, so researchers recommend always having a baseline value of thickness measured in B mode, diaphragmatic excursion measured by M, thickening fraction and expiratory time, in order to predict abnormal values in all studies performed on patients during the dynamic assessment in the evolution of the history of the disease.

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