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ORIGINAL RESEARCH

Diaphragm Assessment by Multimodal Ultrasound Imaging in Healthy Subjects

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Background: In recent years, diaphragm ultrasound (DUS) has been used to identify diaphragm dysfunction in the intensive care unit (ICU). However, there are few studies on DUS parameters to evaluate function, normal ranges, and influencing factors in population. The aim of this study is to provide a methodological reference for clinical evaluation of diaphragm function by measuring different DUS parameters in a healthy population.

Methods: A descriptive study was conducted 212 (105 males, 107 females) subjects with normal spirometry underwent ultrasound imaging in this study. The diaphragm contraction and motion related parameters and shear wave velocity (SWV) were measured in the supine position. The effects of gender, age, body mass index (BMI) and lifestyle on diaphragm ultrasound parameters were analyzed.

Results: The diaphragm thickness at end-expiration (DT-exp) was 0.14 ±0.05 cm, the diaphragm thickness at end- inspiration (DT-insp) was 0.29±0.10 cm, with thickening fraction (TF) was 1.11±0.54. The diaphragm excursion (DE) was 1.68±0.37cm and diaphragm velocity was 1.45±0.41 cm/s during calm breathing. During deep breathing, the DE was 5.06±1.40cm and diaphragm velocity was 3.20±1.18 cm/s. The Diaphragm shear modulus—longitudinal view were Mean16.72±4.07kPa, Max25.04±5.58kPa, Min11.06±3.88kPa, SD2.56±0.98. The results of diaphragmatic measurement showed that the DT of males was significantly greater than that of females ($P< 0.05$), but there was no significant difference in TF. The DT-insp ($r=0.155$, $P= 0.024$) and the DT-exp ($r=0.252$, $P=0.000$) were positively correlated with age, and the DE during calm breathing was negatively correlated with age ($r=-0.218$, $P= 0.001$) and BMI ($r=-00.280$, $P= 0.000$). The DE ($R=0.371$, $P=0.000$) and velocity ($R=0.368$, $P=0.000$) during deep breathing were correlated with lifestyle.

Conclusion: Our study provides normal reference values of the diaphragm and evaluates the influence of gender, age, body mass index and lifestyle on diaphragmatic morphology.

Keywords: diaphragm, reference values, ultrasound, supine position

Introduction

The diaphragm is the most important respiratory muscle, diaphragmatic dysfunction can have significant implications for medical management and treatment, therefore, studying and evaluating diaphragmatic function in clinical practice holds significant clinical importance.

The assessment of diaphragmatic function encompasses both structural and functional aspects. At present, most of the functional measurements are invasive examinations, including maximum inspiratory pressure (MIP), maximum expiratory pressure (MEP) and trans-diaphragmatic pressure (Pdi), which are limited in clinical application. The imaging methods of diaphragmatic structures[1–3] include fluoroscopy, chest radiography, CT and magnetic resonance imaging (MRI), but there are some limitations in the use due to radiation exposure, technology, cost and other reasons. Ultrasound diagnosis offers the advantages of being non-invasive, bedside-accessible, and convenient, thus becoming a novel method for assessing diaphragmatic motion in guiding clinical decision-making.[4–8] At the same time, ultrasound assessment of the diaphragm has good inter-and intra-observer reliability and reproducibility,[9] hence it has been recommended as the preferred technique for evaluating diaphragmatic dysfunction.[7,10] Although ultrasound has been

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used in clinical diagnosis and treatment in our country for a long time, there is currently no reference value available regarding morphological changes of the diaphragm measured using multimodal ultrasound technology in China. Therefore, this study aims to evaluate the thickness, mobility, and elasticity (SWV) of diaphragm in normal individuals in supine-positioned by multimodal ultrasound technology while analyzing their gender-, age-, BMI- and lifestyle-related effects on these parameters in order to provide methodological references for clinically assessing patients' diaphragmatic function.

Methods

Subjects

Two hundred and fifteen subjects (107 males and 108 females) aged 18–69 years were enrolled from Zhoupu Hospital in Pudong New Area, Shanghai, during the period from November 2021 to October 2023. Before the start of the study, the subjects were asked to complete a questionnaire about their past medical history, smoking, and physical exercise. The study was approved by the Ethics Committee of Zhoupu Hospital and informed consent was obtained from all subjects. The study conformed with the principles outlined in the Declaration of Helsinki.

Inclusion criteria: subjects with no previous history of respiratory disease, no history of thoracic and abdominal organ surgery, no chest deformity, no chronic metabolic disease, no pleural or peritoneal effusion or huge tumors, no use of drugs affecting muscle structure and no nervous system diseases, and no history of respiratory infection in the past 4 weeks. Spirometry: 1 second forced expiratory volume (FEV1) were ≥80% predicted, respectively, and FEV1 /forced vital capacity (FVC) was ≥80% predicted. The subjects who met the above spirometry were eligible for inclusion.

Exclusion criteria: (1) age <18 years old; (2) pregnant women; (3) diaphragmatic palsy, phrenic nerve injury, diaphragmatic bulging; (4) a history of chest and abdomen trauma in the past 3 months; (5) patients with organ dysfunction or tumor.

Additional note: we excluded diaphragmatic palsy by means of spirometry criteria and bilateral diaphragmatic ultrasonography. At the beginning of the diaphragmatic ultrasound examination, we examined the bilateral diaphragmatic muscles of all subjects for position and motion abnormalities in B-mode in order to exclude potential diaphragmatic palsy[11] or deformity.

Research Methods

Main Instruments

Resona 8 ultrasound system (Mindray Medical International, China), with convex array probe SC6-1, linear array probe L11-3U; Master Screen Diffusion pulmonary function instrument (Jager, Germany).

Method

Detection Methods of Lung Function

Smoking history and recent drug use (recent withdrawal of long-acting β-agonists, inhaled corticosteroids and anticholinergic drugs) were inquired before spirometry. All subjects did not take β-agonists, theophylline and other bronchodilator drugs within 12 hours, and did not drink tea, coffee and other caffeinated drinks. Examinations were performed according to the American Thoracic Society/European Society (ATS/ARS) criteria. The whole process of spirometry was performed by professional technicians in the pulmonary function room using the German Jager company Master Screen Diffusion pulmonary function instrument to complete the lung ventilation and diffusion function test, including FEV1, FEV1/FVC. The subjects were asked to sit up straight, keep the head at a natural level, pinch the nose clip, bite the teeth tightly, not leak air, and avoid too tight clothes. The subjects were asked to breathe calmly during the measurement, and the vital capacity was measured after the breathing was stable. Before the test, the subjects were asked to practice 1–2 times. During the measurement process, the subjects were required to check at least 3 times, and the error-difference between the two times was less than 5%.

Ultrasonic Diaphragmatic Examination (B-Mode, M-Mode, Shear Wave Ultrasound Elastography)

DT and TF. The 3–11 MHz linear array probe was placed in the 8–10 intercostal section of the right midaxillary line of the patient. The diaphragm and the lower chest were opposite to the chest wall area, and the liver was used as the acoustic window to obtain two parallel linear hyperechoic layers: the side close to the probe was the pleural layer, and the side away from the probe was the peritoneal layer. The diaphragm is a hypoechoic tissue structure located between these two linear echoes and normally moves in the direction of the probe during inspiration. The subjects were asked to breathe calmly and smoothly. The DT was measured after two-dimensional ultrasound clearly showed the diaphragm, or the sampling line was perpendicular to two parallel lines, and the DT at the end of inspiration and expiration was measured by B-mode, respectively. The TF was calculated. TF= (DT-insp - DT-exp)/ DT-exp ×100% (Figure 1).

Diaphragmatic Mobility and Contraction Velocity. The periodic movement of the diaphragm during respiration can be observed by M-ultrasound mode. The 1–6MHz convex array probe was held and placed at the intersection of the right midclavicular line or right anterior axillary line and the lower edge of the costal arch, and pointed to the medial, cephalic and dorsal sides. After the subjects were asked to breathe calmly and smoothly, satisfactory two-dimensional images were obtained. The ultrasound beam was perpendicular to the posterior 1/3 of the diaphragm, and M-ultrasound was used to monitor the movement of the right diaphragm. DE in a single breath was obtained by using the menu of measurement speed, which marked the trough and peak of the waves. In the same way, the subjects were instructed to breathe deeply, and the DE and contraction velocity were measured. The above data were measured three times and averaged (Figure 2).

Shear Wave Elastography of the Diaphragm. The 3–11 MHz linear array probe was placed in the 8–10 intercostal space of the anterior axillary line, and the parallel structure of the diaphragm could be observed. The probe Angle was fine-adjusted to obtain the best section of the diaphragm, pleura and peritoneum. The subjects were asked to breathe calmly and smoothly,

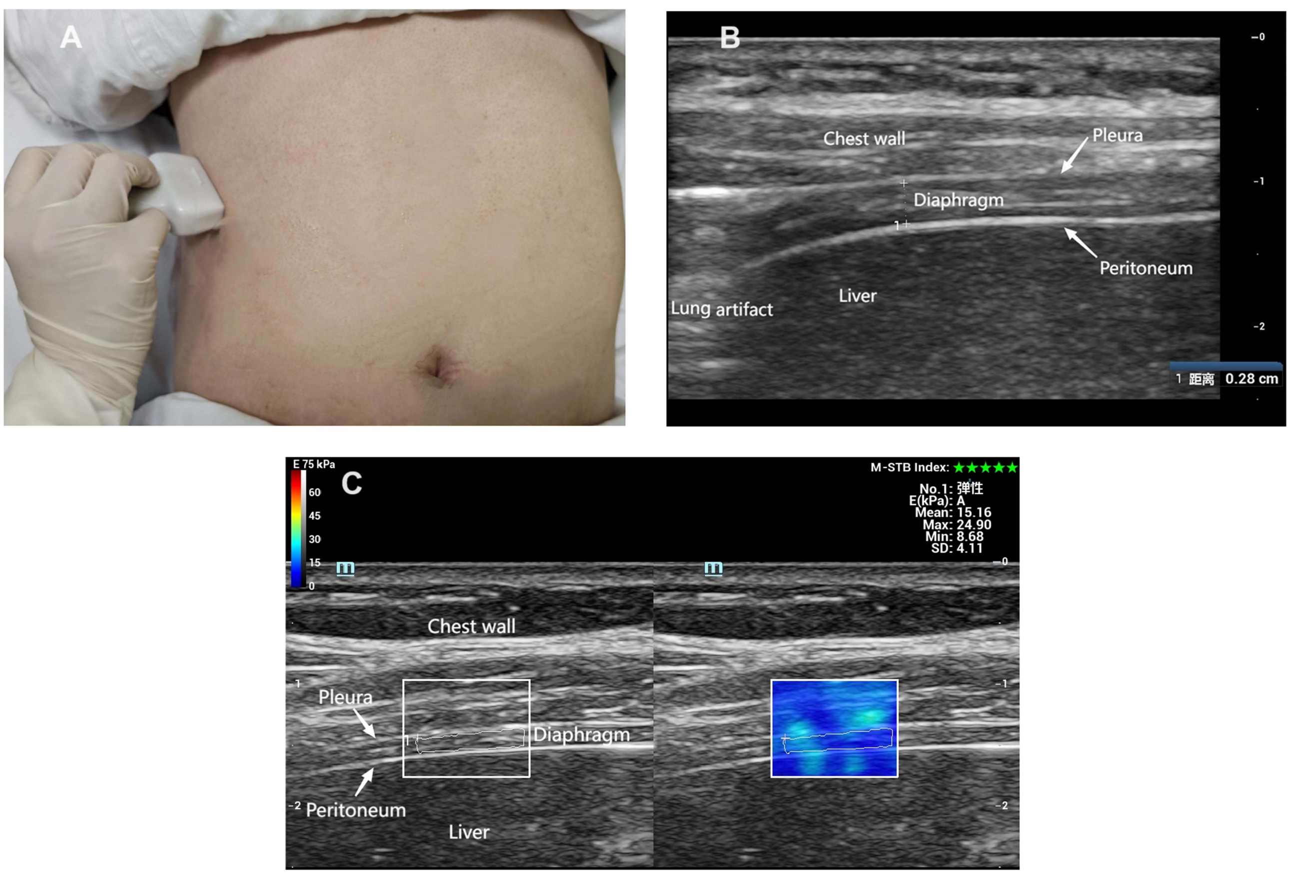

Figure 1 Linear array probe examination. (**A**) The transducer is positioned on the right intercostal space in the anterior axillary line. (**B**) Measurement of DT in B mode. (**C**) Measurement of shear wave elastography of the diaphragm.

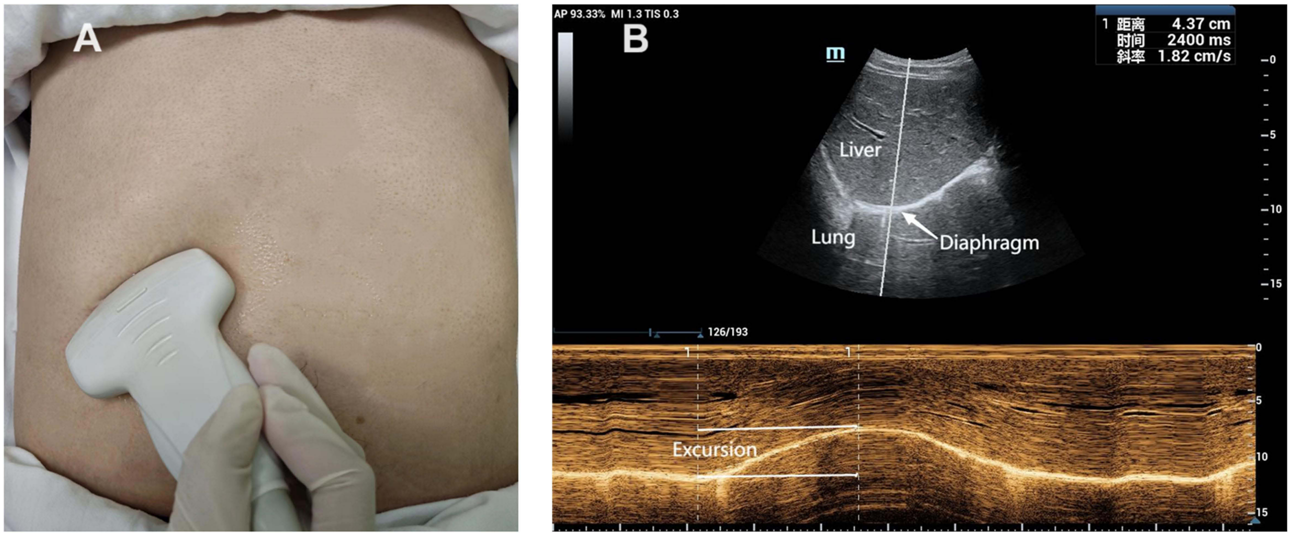

Figure 2 Convex array probe examination. (**A**) The transducer is positioned on the right mid-clavicular line and pointed to the medial, cephalic and dorsal sides. (**B**) Measurement of diaphragm mobility in M mode.

and the diaphragm was placed in the middle of the sampling frame. After the ruler was five stars, a uniform light blue color was selected in the frame, and a dynamic picture was stored. The dynamic picture was retrospectively analyzed to find the most uniform and consistent color frame of the elastogram in the sampling frame. Shear wave velocity (SWV) and dispersion (SD) of diaphragm were measured. The size of the sampling frame of the region of interest was fine-tuned according to the thickness of the individual diaphragm, and in principle the full layer of the diaphragm was placed in the region of interest. The diaphragm elasticity values of each subject were measured three times and averaged (Figure 1).

All ultrasound measurements were performed when the subjects had regular respiratory rhythms and collected by the same sonographer with 10 years of experience in DUS. If there was an abnormal breathing rhythm, the subjects were asked to sit quietly for half an hour and then measure when they reached a regular breathing pattern.

Grouping Method

According to the latest criteria,[12] the subjects were divided into young group (20–39 years old), adult group (40–59 years old) and elderly group (60–79 years old).

The subjects were divided into low weight group (BMI<18.5 kg/m^2), normal weight group (18.5 kg/m^2≤BMI<22.9 -kg/m^2), overweight group (23 kg/m^2≤BMI<24.9 kg/m^2) and obesity group (BMI≥25 kg/m^2).[13] (Data were self-reported height and weight of subjects, and calculated the BMI: weight (kg)/height^2 (m^2).

According to the International Physical Activity Questionnaire (IPAQ),[14] the subjects was divided into a sedentary group with ≥8 hours of desk bending every day, ≤1.5 hours of moderate-intensity physical activity per week, and ≥12 months. Subjects who engaged in moderate or above intensity physical activity ≥6 hours per week and regular exercise for more than 1 year were divided into physical group. Others were divided into the general group.

Statistical Analysis

Statistical analyses were performed using SPSS version 23.0. Measurement data were expressed as (x ± s), and comparison between the two groups was analyzed using the group *t* test. The count data were expressed as relative numbers, and the comparison between the two groups was analyzed by chi-square test, and the comparison among the three groups was analyzed by one-way analysis of variance. Correlation analysis: Pearson method was used for normal distribution data, and Spearman method was used for non-normal distribution data. $P < 0.05$ was considered statistically significant.

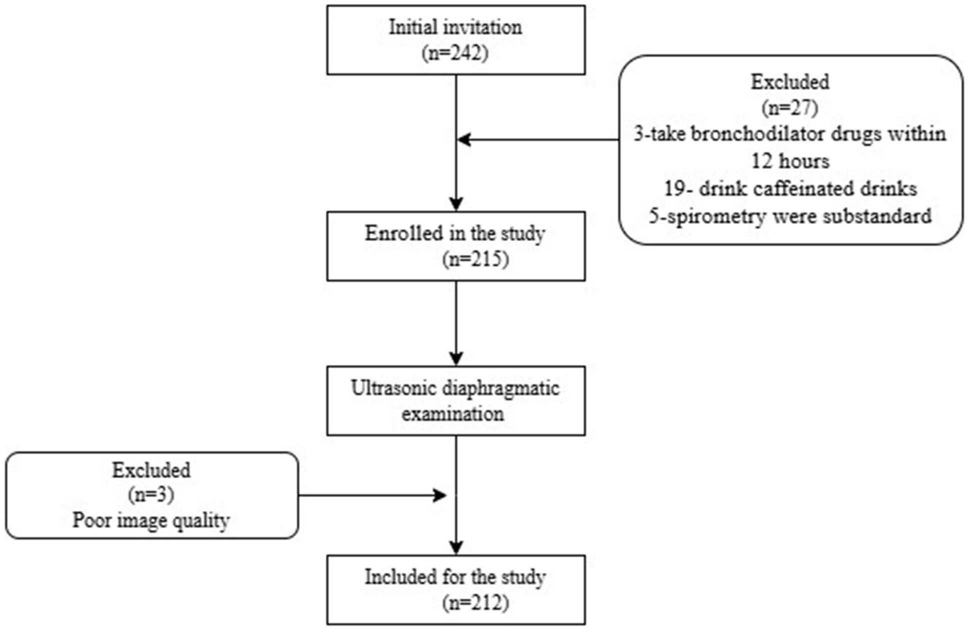

Figure 3 Flow chart.

Results

General Information

Two hundred and fifteen subjects (107 males and 108 females) were enrolled in this study. The diaphragm excursion could not be measured in three persons due to the falling lung shielding the diaphragm during inspiration. Finally, 212 subjects (105 males and 107 females) completed all data collection and included for this study (Figure 3). The basic clinical data are shown in Table 1. The results showed that the minimum thickness of the diaphragm was 0.07 cm while the maximum was 0.33 cm. All the measurement data are shown in Table 2.

Relationship Between Gender and Diaphragm Function

The measurement data of different genders are shown in Table 3. The results of diaphragmatic measurement showed that the DT of males was significantly greater than that of females ($P< 0.05$), but there was no significant difference in TF. The results also indicated that there were significant gender differences in DE and elasticity parameters during calm breathing ($P< 0.05$).

Relationship Between Age and Diaphragm Function

DT and DE during calm breathing differed with age ($P<0.05$), and there was no significant difference in elasticity (Table 4). The DT -insp ($r=0.155$, $P= 0.024$) and the DT-exp ($r=0.252$, $P=0.000$) were positively correlated with age, and the DE during calm breathing ($r=-0.218$, $P= 0.001$) was negatively correlated with age.

Table 1 Basic Information of the Included Subjects

Sex (male), n (%)	105(49.53)
Age (years)	43.56±14.37
BMI (kg/m^2)	22.81±2.59
Smoking exposure, n (%)	21(9.91)
Sedentary work, n (%)	67(31.60)
Physically active, n (%)	87(41.04)

Table 2 Ultrasound Imaging Measurements in Subjects

Variable	Mean	SD	Min	Max
B-mode _Thickness (cm)				
DT-exp	0.14	0.05	0.07	0.33
DT-insp	0.29	0.10	0.12	0.66
TF	1.11	0.54	0.27	2.87
M-mode_ Excursion				
DE-CB (cm)	1.69	0.37	1.05	3.24
Velocity -CB (cm/s)	1.45	0.41	0.95	2.99
DE-DB (cm)	5.06	1.40	2.14	9.28
Velocity-DB (cm/s)	3.20	1.18	1.25	8.12
SWE_ Shear modulus (kPa)				
Mean	16.72	4.07	9.14	37.12
Max	25.04	5.58	13.22	54.31
Min	11.06	3.88	4.24	25.95
SD	2.56	0.98	0.49	6.69

Abbreviations: DT-exp, diaphragm at the end of tidal expiration; DT-insp, diaphragm at the end of tidal inspiration; TF, thickening fraction; CB, calm breathing; DB, deep breathing; Data expressed as mean _ standard deviation.

Relationship Between BMI and Diaphragm Function

The results showed that the DE in the low BMI group was greater than that in the high BMI group during calm breathing, and the difference was statistically significant (P<0.05), but there was no significant difference in DT and elastic parameters (Table 5). At the same time, BMI was negatively correlated with DE during calm breathing (r=−00.280, P= 0.000).

Relationship Between Lifestyle and Diaphragmatic Function

The results showed that during deep breathing, the movement and velocity of the diaphragm in the exercise group were greater than those in the sedentary group, and the differences were statistically significant (P<05), but there was no

Table 3 Ultrasound Imaging Measurements Between Genders

Variable	Male (105)	Female (107)	P
B-mode _Thickness (cm)			
DT-exp	0.16 ±0.05	0.12 ±0.04	0.000
DT-insp	0.32 ±0.10	0.26 ±0.09	0.000
TF	1.08 ±0.53	1.14±0.54	0.426
M-mode_ Excursion			
DE-CB (cm)	1.75 ±0.37	1.63±0.35	0.019
Velocity -CB (cm/s)	1.46±0.38	1.44±0.44	0.697
DE-DB (cm)	5.05±1.36	5.07±1.45	0.911
Velocity-DB (cm/s)	3.17±1.14	3.24±1.22	0673
SWE_ Shear modulus (kPa)			
Mean	17.90 ±4.45	15.56±3.28	0.000
Max	26.53 ±5.96	23.57±4.77	0.000
Min	11.95 ±4.31	10.19±3.19	0.001
SD	2.63 ±1.02	2.49±0.94	0.308

Abbreviations: DT-exp, diaphragm at the end of tidal expiration; DT-insp, diaphragm at the end of tidal inspiration; TF, thickening fraction; CB, calm breathing; DB, deep breathing; Data expressed as mean _ standard deviation.

Table 4 Ultrasound Imaging Measurements Between Age Groups

Variable	Young Group (97)	Adult Group (82)	Elderly Group (33)	F	P
B-mode _Thickness (cm)					
DT-exp	0.13±0.04	0.15±0.05	0.15±0.05	6.466	0.002
DT-insp	0.27±0.09	0.31±0.11	0.30±0.09	5.132	0.007
TF	1.19±0.61	1.14±0.56	1.08±0.64	0.384	0.682
M-mode_ Excursion (cm)					
DE-CB	1.79±0.37	1.57±0.33	1.68±0.37	9.099	0.000
Velocity -CB (cm/s)	1.50±0.41	1.39±0.39	1.46±0.45	1.828	0.163
DE-DB	5.06±1.38	4.99±1.38	5.21±1.56	0.274	0.761
Velocity-DB (cm/s)	3.19±1.20	3.17±1.23	3.33±1.01	0.223	0.801
SWE - Shear modulus (kPa)					
Mean	17.22±4.06	16.06±3.87	16.86±4.45	1.858	0.159
Max	25.73±5.51	24.46±5.61	24.46±5.65	1.362	0.258
Min	11.16±3.74	10.61±3.71	11.91±4.60	1.383	0.253
SD	2.70±0.92	2.51±1.07	2.98±0.90	2.255	0.107

Abbreviations: DT-exp, diaphragm at the end of tidal expiration; DT-insp, diaphragm at the end of tidal inspiration; TF, thickening fraction; CB, calm breathing; DB, deep breathing; Data expressed as mean _ standard deviation.

Table 5 Ultrasound Imaging Measurements Between BMI Groups

Variable	Low Weight Group (17)	Normal Weight Group (92)	Overweight Group (56)	Obesity Group (47)	F	P
B-mode _Thickness (cm)						
DT-exp	0.14±0.06	0.13±0.04	0.15±0.05	0.15±0.04	2.042	0.109
DT-insp	0.28±0.12	0.28±0.08	0.30±0.11	0.31±0.11	1.74	0.160
TF	1.07±0.42	1.16±0.54	1.05±0.51	1.13±0.61	0.541	0.655
M-mode_ Excursion (cm)						
DE-CB	1.85±0.30	1.78±0.41	1.61±0.28	1.53±0.31	7.43	0.000
Velocity -CB (cm/s)	1.53±0.34	1.46±0.44	1.48±0.41	1.38±0.37	0.804	0.493
DE-DB	5.31±1.04	4.97±1.20	5.12±1.50	5.06±1.75	0.337	0.799
Velocity -DB (cm/s)	3.40±0.92	3.06±1.03	3.23±1.19	3.38±1.49	0.946	0.419
SWE_ Shear modulus (kPa)						
Mean	16.01±3.10	17.12±3.98	16.19±3.68	16.82±4.91	0.78	0.506
Max	24.69±3.96	25.06±5.39	24.56±5.13	25.69±6.90	0.372	0.773
Min	10.09±4.08	11.60±3.81	10.83±3.70	10.64±4.13	1.21	0.307
SD	2.71±0.92	2.51±1.00	2.48±0.88	2.73±1.09	0.799	0.496

Abbreviations: DT-exp, diaphragm at the end of tidal expiration; DT-insp, diaphragm at the end of tidal inspiration; TF, thickening fraction; CB, calm breathing; DB, deep breathing; Data expressed as mean _ standard deviation.

significant difference in DT and elastic parameters (Table 6). The DE (R=0.371, P=0.000) and velocity (R=0.368, P=0.000) during deep breathing were correlated with lifestyle.

Discussion

In this research, we established the standard range and lower limit of diaphragm movement in supine position for healthy adults. We also conducted a grouping analysis to investigate how gender, age, body mass index, and lifestyle affect diaphragm morphology.

Our findings indicated that during calm breathing, the minimum thickness of the diaphragm was 0.07cm with an average thickness of 0.14±0.05cm, these values were smaller than those reported in previous studies,[15] but similar to

Table 6 Ultrasound Imaging Measurements Between Lifestyle Groups

Variable	Physical Group (87)	General Group (58)	Sedentary Group (67)	F	P
B-mode _Thickness (cm)					
DT-exp	0.15±0.05	0.14±0.04	0.14±0.05	0.55	0.578
DT-insp	0.30±0.11	0.29±0.09	0.28±0.10	0.665	0.515
TF	1.11±0.53	1.13±0.59	1.10±0.51	0.054	0.948
M-mode_ Excursion					
DE-CB (cm)	1.67±0.38	1.73±0.34	1.67±0.37	0.54	0.584
Velocity -CB (cm/s)	1.18±0.29	1.21±0.31	1.26±0.32	1.395	0.25
DE-DB (cm)	1.47±0.39	1.51±0.45	1.38±0.39	1.614	0.202
Velocity -DB (cm/s)	5.90±1.25	4.85±1.29	4.14±1.00	42.835	0.000
SWE_ Shear modulus (kPa)					
Mean (kPa)	17.29±4.17	16.27±4.38	16.37±3.45	1.498	0.226
Max (kPa)	25.66±5.91	24.78±5.92	24.40±4.56	0.98	0.377
Min (kPa)	11.31±3.76	11.36±3.85	10.48±4.04	1.122	0.328
SD	2.61±1.01	2.41±0.84	2.64±1.06	1.03	0.359

Abbreviations: DT-exp, diaphragm at the end of tidal expiration; DT-insp, diaphragm at the end of tidal inspiration; TF, thickening fraction; CB, calm breathing; DB, deep breathing; Data expressed as mean _ standard deviation.

Cardenas'[16] results, this may be due to differences in measurement and race. The TF proved to better reflect the intrinsic ability of the diaphragm,[17] Our study recorded a TF value of 111±54%, with a wider range compared with earlier research,[18] and the lowest value was 27%, lower than those in previous studies.[19] The results of this study also suggest that males have significantly greater DT compared to females, this finding aligns with recent studies.[20] The significant difference in body size between men and women may also explain the imaging of DT by sex. Additionally, we found a positive correlation between age and DT, but TF did not show statistical correlation with gender, age, BMI and lifestyle, so it was also confirmed that TF is the least affected parameter.[21]

Given that every centimeter elevation in diaphragm leads to an increase of ventilation volume by approximately 250–300mL;[22] it is evident that maintaining the proper function of the diaphragm is crucial for generating the intrapulmonary pressure required for alveolar ventilation. M-mode ultrasound enables real-time visualization of contraction motion along time axis within the diaphragm, thus allowing us to measure its activity accurately during respiratory cycles without any invasive procedures or radiation exposure concerns. In this study, the diaphragm movement and velocity were measured by M-mode ultrasound. It showed that during calm breathing the DE was 1.68±0.37cm, the lower limit was 1.05cm, and the velocity was 1.45±0.41 cm/s. During deep breathing, the DE was 5.06±1.40cm, and the velocity was 3.20±1.18 cm/s. In a study of 210 healthy adults, Boussuges[23] found that the lower limit of normal value was 1cm in men and 0.9cm in women. On this basis, Kim[24] studied the critical value of DE for weaning patients with mechanical ventilation, which was 1.4cm for the right and 1.2cm for the left. Therefore, this study provides an important reference for the diagnosis of clinical diaphragmatic dysfunction by measuring the range of DE in healthy adults by ultrasound.

Most studies have found significant gender differences in diaphragmatic mobility, the DE of men is significantly greater than that of women.[23,25] In addition, this study also found that the DE was negatively correlated with age and BMI, that is, the increase of age, the increase of body weight, and the decrease of diaphragm mobility. Studies have shown that older people become more and more obese with the increase of age, their visceral fat increases and their muscle mass decreases[26] which in turn decreases the contractility of the diaphragm and the mobility of the diaphragm. This study also found that the movement and speed during deep breathing in regular exercise people are greater than those in sedentary people, which may be related to the greater muscle mass and reserve capacity of exercise people.

Ultrasound elastography can be used to evaluate and monitor muscle mass and contractile properties in vivo. Studies have shown that the contractile capacity of diaphragm is correlated with the Young's modulus value measured by SWE,[27] and the change of Young's modulus value is positively correlated with trans-diaphragmatic pressure.[28] Flatres[29] used quantitative SWE to measure limb muscles and diaphragm in healthy subjects and critically ill patients, and found that the intra-class correlation coefficient of inter-operator repeatability and reliability was more than 0.9. Moreover, the sensitivity and accuracy of elastography technology are higher than those of two-dimensional ultrasound, which can make up for the shortcomings of two-dimensional ultrasound.[30] At present, there is no uniform standard of diaphragm shear wave elasticity in normal people. The results of this study showed that during calm breathing, the diaphragm elasticity values were Mean16.72±4.07, Max25.04±5.58, Min11.06±3.88, SD2.56±0.98, and there were gender differences. The possible reason is that the weight of the diaphragm in men is heavier than that in women, and the weight of the diaphragm can directly affect the muscle mass of the diaphragm. The more muscle mass, the more abundant muscle fibers, the greater contractility of the diaphragm, and therefore the greater elasticity.[31] Only one phase was measured in this study, and additional relevant phase studies are needed in the follow-up.

The limitation of this study is the lack of a large sample and the inability to conduct a fine stratified study, we will conduct a multi-center study with large sample size, which aims to further investigate the findings of the present study. Meanwhile, other factors could be added, including ethnic differences and the effect of regular consumption of caffeinated beverages on diaphragm activity.

Conclusion

Our study mainly provides the parameters of ultrasonic assessment of diaphragmatic morphology in normal subjects in the supine position, and found the influence of gender, age, body mass index and lifestyle on diaphragmatic morphology, which in turn will help the clinicians detection and follow-up of diaphragm disorders in early.

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Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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