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QUANTIFICATION OF DIAPHRAGM AND INTERCOSTAL MUSCLE THICKNESS AMONG OLDER ADULTS USING ULTRASOUND IMAGING. A RELIABILITY STUDY

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Abstract

Measurement of respiratory muscle thickness is clinically important in the assessment of respiratory function. The present study was performed to establish the intra-class correlation coefficient (ICC) of measuring the diaphragm and intercostal muscles thickness using ultrasound images. Diaphragm and intercostal muscles images were captured using a 7-10 MHz transducer head at the end of quiet inspiration and expiration among 64 community- dwelling older adults. The mean± standard deviation (cm) of diaphragm and intercostal muscles thickness during quiet inspiration and expiration were 0.29±0.06; 0.21±0.05 and 0.54±0.11; 0.62±0.13 respectively. The present study using average measures of muscle thickness (two-way mixed model) of three images and the means of five points along the muscle fibers demonstrated moderate to excellent reliability (ICC, 0.63-0.98). The five-point method using the mean values of three measurements may be recommended for assessment in the clinical and research settings.

Keywords: Ultrasound imaging; diaphragm; intercostal; muscle

1.0 INTRODUCTION

Breathing activity is primarily forced by diaphragm muscle [1] and assisted by intercostal muscles [2]. Effective ventilation is brought about by effective contractions of the diaphragm and intercostal muscles. Muscle architectural changes have been observed with ageing in skeletal muscles [3,4]. These changes can affect its force production capabilities [3,4].

Common assessment tool of respiratory muscles includes balloon catheter system and electrophysiological technique. However, these techniques are invasive and not practical for clinicians [5]. Examination of diaphragm muscle thickness has been performed using fluoroscopy but this method involves ionizing methods [6]. Non-ionizing and non- invasive method of measuring respiratory muscle function using ultrasound imaging has been reported previously [2,5, 7,8,9]. Diaphragm thickness or length zone of apposition length has been measured among healthy participants and with chronic obstructive pulmonary disease [5,9,10].

Decrease in respiratory muscle thickness measured using ultrasound has been reported in patients with mechanical ventilation [11] and respiratory illnesses [12]. Measurements of respiratory muscles thickness are important in explaining its function, namely strength. A correlation between respiratory muscle thickness and strength has been reported [12]. Numerous studies have highlighted the changes of skeletal muscles with ageing [3,13,14,15,16]. Correlation between skeletal muscle thickness and its strength has also been demonstrated [3,17]. However, there is no information regarding neither respiratory muscle atrophy with ageing nor its association with respiratory muscle strength. The probable reason for this may be due to the difficulty in assessing respiratory muscle thickness.

The recent study by Herper et al. reported the usage of ultrasound imaging in measuring diaphragm thickness during quiet breathing [18]. However, they failed to state and standardize the level and position of intercostals space during repeated ultrasound imaging of diaphragm muscle on different days and operators. It can also be argued that measurements of the diaphragm thickness performed in supine lying did not allow maximum expansion of the diaphragm. This may have under estimated the measurements of diaphragm muscle thickness during tidal breathing. In addition, the differentiation between the lung border and diaphragm muscle line was not clearly specified.

Quantification of intercostal muscles has also been reported using ultrasound imaging by Diab et al. [2]. Measurement of intercostals muscle thickness was done by measuring the distance between the relevant ribs corresponding to the diameter of the intercostal muscle area on screen using vernier calipers. These authors found that there was no significant inter-observer variability in the measurements between left and right intercostal muscle thickness neither during maximal inhalation or exhalation in one participant. These results suggest that during normal circumstances, intercostal muscle expansions are symmetrical. However, the authors' only reported the mean value for all measurements but did not provide individual values for each measurement; such as the intercostals muscle thickness during full inhalation and exhalation for each side (left and right intercostals muscle thickness) and levels.

Moreover, there is a variation in methodology and details of respiratory muscle thickness measurements are not known. The objective of the present study was to determine the reliability of measuring diaphragm and intercostal muscle thickness during quiet breathing among community dwelling older adults.

2.0 METHODOLOGY

Ethical approval was obtained from Research Ethics and Governance Committee of Universiti Kebangsaan Malaysia (NN-110-2011). Participants were given verbal and written information regarding the procedures that were performed. Informed written consent was obtained from the participants, prior to the study. Confidentiality and identity of the participants' anonymity was provided using a coding system in all hard and soft copies of data sheets and images saved. The data obtained were coded for reference purposes. Participants were allowed to withdraw during any period of the study.

Participant

Sixty-four older adults aged 60 years and above participated in the present study. Participants were excluded if they had any history of respiratory problems, unstable medical problems, neurological dysfunctions, spinal deformities, cognitive impairments, cardio-respiratory diseases, previous surgery of the back; serious trauma leading to fractures or dislocation of the spine, or any pathologies such as tumors, spinal infection, tuberculosis, inflammatory joint disease, rheumatoid conditions, spondylolisthesis and spondylolysis. They were also excluded if they were smokers or exsmokers and if their body mass index (BMI) was more than 30kg/m2.

Study Protocols

Participants were required to fill a demographic data sheet and Modified Beacke physical activity questionnaire. The participant's body weight and height were taken and their body mass index (BMI) was calculated. Ultrasound images of diaphragm and intercostal muscles were recorded during quiet breathing using real-time B-mode ultrasound (between 7.0-10.0 MHz) utilizing a linear probe (Siemen Acuson X300, Siemens Medical Solutions USA, Inc.) with the participants sitting on a chair with back rest.

Figure 1: Ultrasound probe position during right diaphragm muscle imaging

Figure 2: Ultrasound probe position during right intercostals muscles imaging

The ultrasound probe was coated with ultrasound coupling gel and held perpendicular to the chest wall in the 8th or 9th right intercostals space, between the antero and mid-axillary lines (Fig. 1). This position aimed to capture diaphragm muscle images. Imaging of intercostal muscles was performed with the ultrasound probe placed perpendicular to the skin surface at the 8th posterior right intercostal space at medial right scapula line (Fig. 2). Three ultrasound images were captured during quiet end of inspiration and end of expiration, for both muscles. The ultrasound imaging was performed by a radiographer trained in ultrasound imaging. The examination was performed with static placement of the probe. The images were saved and analyzed later using MATLAB® (The Mathworks Inc., MA, US) with measurement rounded off to the nearest to 0.10cm.

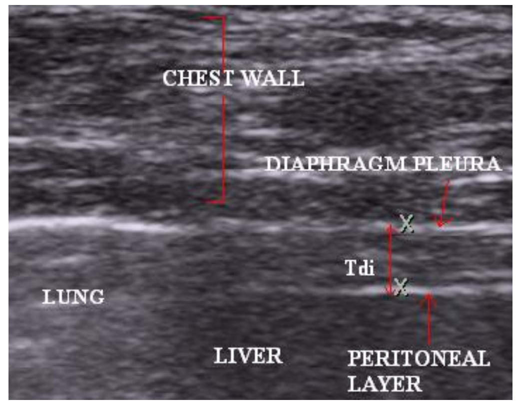

Figure 3: Ultrasound probe position during right intercostals muscles imaging

Measurement of Diaphragm Muscle Thickness: Measurements of diaphragm muscle thickness was performed by taking five points along the zone of apposition between the outer layer of pleural line to the inner layer of peritoneal layer of the diaphragm muscle (Tdi) (Fig. 3). The mean of 5 points was used as the standard deviation of diaphragm thickness was not small enough to justify that the 2 lines were parallel and thickness at any points along the zone of apposition were the same. The mean value of 5 points was used as the diaphragm muscle thickness for each image.

Figure 4: Measurement of intercostals thickness of older adult.

Measurement of Intercostal Muscles Thickness: Measurement of intercostal muscle was made nearest to 0.10cm of five points along the muscle fiber. The intercostal muscles thickness (Ti) was defined as the thickness measured between outer layer and inner layer of intercostals muscles as in figure 4. All the recorded images were analyzed using MATLAB® (The Mathworks Inc., MA, US). The mean value of the 5 points was used as the intercostals muscle thickness for each image.

Data Analysis

Data was analyzed using the Static Product for Statistical Solutions (SPSS) software version 17 (SPSS Inc Chicago, USA). Two-way mixed model of Intra-class correlation coefficient, ICC was performed to calculate the reliability of diaphragm and intercostal muscles thickness from the three images.

3.0 RESULTS

The diaphragm and intercostal muscles thickness are as in table 1. The difference in diaphragm muscle thickness during quiet inspiration and expiration was small (0.07cm). The intercostal muscle thickness during quiet expiration was more compared to the thickness during quiet inspiration.

Table 1: The diaphragm and intercostal muscle thickness

Variables	Mean ±Standard Deviation (n=64)
Diaphragm Muscle Thickness during Quiet Inspiration (cm)	0.29±0.06
Diaphragm Muscle Thickness during Quiet Expiration (cm)	0.21±0.05
Intercostal Muscle Thickness during Quiet Inspiration (cm)	0.54±0.11
Intercostal Muscle Thickness during Quiet Expiration (cm)	0.62±0.13

There was a very small difference between the mean of five points of three measurements' of muscles thickness for both diaphragm and intercostal muscles at end of quiet inspiration, ranged between 0.02-0.03 cm with no difference in muscle thickness at end of expiration for both muscles (Table 2).

Table 2: Table 2 Mean of five points of diaphragm and intercostals muscle thickness of three measurements

	Measurement 1 (cm)	Measurement 2 (cm)	Measurement 3 (cm)
Diaphragm muscle thickness at end of quiet inspiration	0.27±0.06	0.29±0.06	0.29±0.06
Diaphragm muscle thickness at end of quiet expiration	0.21±0.05	0.21±0.05	0.21±0.05
Intercostals muscle thickness at end of quiet inspiration	0.55±0.12	0.55±0.12	0.52±0.20
Intercostals muscle thickness at end of quiet expiration	0.62±0.13	0.62±0.13	0.62±0.13

The intra class correlation co-efficient of the diaphragm and intercostal muscles thickness showed moderate to excellent level of reliability (Table 3) with minimum value was 0.63 (intercostal muscles thickness at end of inspiration) and maximum value was 0.98 (intercostal muscle thickness at end of expiration). Poor reliability was demonstrated of single measures of intercostal muscle thickness at the end of inspiration. The present study also revealed small standard error of measurements either during diaphragm muscle thickness measurements or intercostal muscle thickness measurements.

Table 3: Intra class correlation coefficient

	Single Measures	Average Measures	SEM
Diaphragm Quiet Inspiration	0.89	0.96	0.01
Diaphragm Quiet Expiration	0.90	0.96	0.01
Intercostals Quiet Inspiration	0.36	0.63	0.07
Intercostals Quiet Expiration	0.94	0.98	0.02

4.0 DISCUSSION

The aim of this present study was to determine the reliability of measurements of respiratory muscles particularly diaphragm and intercostal muscles. The present method of measuring diaphragm thickness using mean of five points along the zone of apposition showed moderate to excellent reliability of three images of diaphragm and intercostal muscles during quiet inspiration and expiration.

The mean diaphragm thickness at end of inspiration (0.29cm) and at end of expiration (0.21cm) obtained in the present study is within normal range of diaphragm thickness at quiet breathing, in the range of 0.17cm and 0.33cm [7,8,12,18,19,20]. However, results of the present study was slightly lower compared to a recent study by Harper et al. [18]. This may be due to the difference in methodology and participants' age in the study by Harper et al. During inspiration, diaphragm muscles were noted to be thicker compared to during expiration phase. The probable reason for this may be due to the thinning and thickening of these muscles during contraction at inspiration and expiration phase respectively.

The mean intercostal muscle thickness was 0.54cm at end of inspiration and 0.62cm at end of expiration with the difference of approximately eight percent. These measurements were not in agreement with previous report [2]. This again may be due to the differences in the methods and positions employed for measuring intercostal muscle. The ultrasound imaging of participants' in the present study was performed at sitting position as compared to the previous study which was in the prone position.

Diaphragm thickness measurement technique accuracy and reproducibility using ultrasound has been demonstrated to be excellent with R2= 0.89, $p<0.001$ in comparison to using a ruler, performed in 26 cadavers [9]. The present study showed better average intra-rater reliability for diaphragm muscle thickness (0.96) and intercostal muscles thickness (0.98). The result of the present study also demonstrated that single measurement of intercostal muscles resulted in poor reliability levels (0.36). It is noteworthy that the measurements in the present study were determined using 2D mathematical functions in Matlab compared to printed images or direct on screen measurements in the earlier study [9].

The study by Harper et al. reveal an excellent ICC, both inter (inspiration= 0.97; expiration=0.98) and intra rater (inspiration=0.94; expiration=0.98) of diaphragm muscle thickness in supine using B-mode ultrasound imaging with measurement done by electronic calipers [18]. The similar result shown in the present study. The present study positioned participants in sitting upright position.

The limitation of the present study was that it was confined to a single rater assessment. Future studies should include inter-rater reliability of respiratory muscle thickness quantification.

5.0 CONCLUSION

In conclusion, the present technique of diaphragm and intercostal muscles thickness quantification using ultrasound imaging is reliable and can be used to study respiratory muscle related issues among older adults. The respiratory muscle thickness, particularly intercostal muscles should be calculated from a number of measurements as a single measurement was demonstrated to be unreliable in the present study.

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References

[1] D.R. Hess, W.F. Galvin, N.R. MacIntyre, A.B. Adams, S.C. Mishoe, Respiratory Care: Principles and Practice. Jones & Bartlett Learning, second ed., USA, 2012.

[2] K.M. Diab, A. Shalabi, J.A. Sevastik, P. Guntner, A method for morphometric study of intercostals muscles by high-resolution ultrasound, Eur Spine J 7 (1998) 224-228.

[3] D.K.A. Singh, M. Bailey, R.Y.W. Lee, Ageing modifies the fibre angle and biomechanical function of the lumbar extensor muscles, Clinical Biomechanics 26(2011) 543–547.

[4] M.V. Narici, C.N. Maganaris, N.D. Reeves, P. Capodaglio, Effect of Aging on Human Muscle Architecture, Journal of Applied Physiology. (Bethesda, Md. : 1985) 95 (6) (2003) 2229–34.

[5] H. Kaneko, K. Yamamura, S. Mori, Y. Nagai, K. Yoshizumi, T. Shimoda, Ultrasonographic Evaluation of the Function of Respiratory Muscle during Breathing Exercise, J. Phys. Ther. Sci. 21(2009) 135- 139.

[6] E. Cohen, A. Mier, P. Heywood, K. Murphy, J. Boultbee, A. Guz, Excusion-volume relation of the right hemidiaphragm measured by ultrasonoghraphy and respiratory airflow measurements, Thorax. (1994) 29: 885-889.

[7] J.L. Wait, P.A. Nahormek, W.T. Yost, D.P. Rochester, Diaphragmatic thickness-lung volume relationship in vivo, J.Appl. Physiol. 67(4) (1989) 1560-1568.

[8] J. Ueki, P.F. DeBruin, N.B. Pride, In vivo assessment of diaphragm contraction by ultrasound in normal subject, Thorax. 50(1995) 1157-1161.

[9] D. Cohn, J.O. Benditt, S. Eveloff, I F.D. McCoo, Diaphragm Thickening during Inspiration. J. Appl. Physiol. 83(1) (1997) 291-296.

[10] D.K. McKenzi, R.B. Gorman, J. Tolman, N.B. Pride, S.C. Gandevia. Estimation of diaphragm length in patient with severe chronic obstructive pulmonary disease, Respiration Physiology 123(2000) 225-234.

[11] H.B. Grosu, Y.I. Lee, J. Lee, E. Eden, Diaphragm Muscle Thinning in Patients Who Are Mechanically Ventilated, Chest 142(6) (2012) 1455-1460.

[12] P.F. DeBruin, J. Ueki, A. Watson, N.B. Pride, Size and strength of the respiratory and quadriceps muscles in patient with chronic asthma, Eur Respir J 10 (1997) 59-64.

[13] J.D. Crane, M.C. Devries, A. Safdar, M.J. Hamadeh, M.A. Tarnopolsky, The Effect of Aging on Human Skeletal Muscle Mitochondrial and Intramyocellular Lipid Ultrastructure, Journal Of Gerontology: Biological Sciences 65A(12) (2010) 119-128.

[14] G.N. Williams, M.J. Higgins, M.D. Lewek, Aging skeletal muscle: physiologic changes and the effects of training, Phys Ther. 82(2002) 62–68.

[15] P. Aagaard, C. Suetta, P. Caserotti, S.P. Magnusson, M. Kjaer, Role of the nervous system in sarcopenia and muscle atrophy with aging: strength training as a countermeasure, Scandinavian Journal of Medicine & Science in Sports. 20(1) (2010) 49–64.

[16] W.R. Frontera, V.A. Hughes, R.A. Fielding, M.A. Fiatarone, W.J. Evans, R. Roubenoff, Aging of skeletal muscle: a 12-yr longitudinal study, J Appl Physiol 88(2000) 1321-1326.

[17] E.M. Summerhill, N. Angov, C. Garber, F..D McCool, Respiratory muscle strength in physically active elderly, Lung 185(2007) 315-320.

[18] C.J. Harper, L. Shahgholi, K. Cieslak, N.J. Hellyer, J.A. Strommen, A.J. Boon, Variability in diaphragm motion during normal breathing, assess with B-mode ultrasound, Journal of orthopaedic & Sport Physical Therapy. 43(12) (2013) 927-931.

[19] N. Taniguchi, J. Miyakoda, K. Itoh, J. Fukui, M. Nakamura, O. Suzuki., Ultrasonographic images of diaphragm and respiratory changes on their thickness, Jpn J Med Ultrasonic. 18(1991) 93-98.

[20] F.D. McCool, J.O. Benditt, P. Conomos, L. Anderson, C.B. Sherman, F.G. Jr. Hoppin, Variability of diaphragm structure among healthy individuals, Am J Respir Crit Care Med. 155(1997) 1323-1328.