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Comparison of the Reliability of Sonographic Measurements of Diaphragm Thickness and Mobility in Individuals with and without Pelvic Girdle Pain

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Abstract

Background: Various studies have reported that the pelvic girdle and lumbar spine are reflexively stabilized and braced prior to the initiation of extremity movements.
Objectives: The present study aimed to assess the reliability of the diaphragm muscle thickness and excursion measured by rehabilitative ultrasound imaging (RUSI).
Methods: This is a cross-sectional study that was done in the physiotherapy department of the Faculty of Rehabilitation at the Shahid Beheshti University of Medical Sciences (Tehran, Iran) in 2019. Images of diaphragm thickness were taken using RUSI in the intercostal space between the 7th and 8th, or 8th and 9th ribs, at which the diaphragm was more easily visualized. The diaphragm motion assessment was performed by applying the transducer on the abdomen at the right midclavicular line. Imaging was conducted in 10 participants with pelvic girdle pain (PGP) and 10 asymptomatic women and men aged 20 - 44 years. Images were obtained by one examiner, muscle thickness was measured using B mode RUSI, and the motion was assessed using M mode RUSI. All assessments were performed in quiet breathing and deep breathing states. Intraclass correlation coefficients (ICC), standard error of measurement (SEM), and minimal detectable change (MDC) were used for reliability assessment.
Results: The ICC, SEM, and MDC values revealed an excellent intrarater reliability for RUSI in both groups to measure the diaphragm thickness (ICC between 0.88 to 0.92). Measurement of diaphragm excursion demonstrated excellent reliability in the asymptomatic group (ICC between 0.80 to 0.90) and less reliability, between good and excellent, in the PGP group (ICC between 0.74 to 0.79).
Conclusions: The method of RUSI employed in the present study is recommended for measuring diaphragm thickness and motion in patients with PGP.

Keywords: Reliability, Ultrasonography, Pelvic Girdle Pain, Diaphragm Thickness, Diaphragm Excursion

1. Background

The diaphragm is well-known for its role as the principal muscle in charge of respiration. When diaphragm function is impaired, accessory muscles which are much less efficient must assume this role, resulting in the shortness of breath with exertion (1). Diaphragm, in addition to its role in respiration, helps to stabilize the spine (2-4). Lewit (5) suggested that if an individual does not demonstrate proper breathing patterns, the diaphragm likely lacks the coordination, endurance, and strength to serve its role as a postural stabilizer.

Pelvic girdle pain (PGP) is defined by pain experienced between the posterior iliac crest and the gluteal fold, particularly in the vicinity of the sacroiliac joints (SIJ). The pain may radiate in the posterior thigh and also occur in the symphysis (6). Various studies have reported that the pelvic girdle and lumbar spine are reflexively stabilized and braced prior to the initiation of extremity movements (3). Although early research by Hodges attached special relevance to the transversus abdominis (TrA) in core stability, more recent research by Hodges suggests that the inner unit is a dynamic system apparently relying on the integration of the pelvic floor, multifidus, TrA, and diaphragm

(7, 8). Diaphragm contraction increases intra-abdominal pressure, working synergistically with the pelvic floor and abdominal muscles to increase spinal stiffness and stability. Hodges et al. (9) reported that the isolated contraction of the diaphragm (via phrenic nerve stimulation) without concurrent contraction of other muscles increases intra-abdominal pressure, thereby augmenting spinal stability. In turn, the function of the diaphragm may affect how the trunk is stabilized (10).

Kolar et al. (3) evaluated diaphragm motion by dynamic magnetic resonance imaging (MRI) and showed a reduced diaphragm movement emerged when isometric flexion against the resistance of the upper or lower extremity was applied. In fact, the diaphragm is the muscle contributing to intra-abdominal pressure modulation, thus playing an important role in spinal stability (5, 9, 10).

Decreased diaphragm movement is reported in central neurological diseases, motor neuron diseases, and traumatic injuries to the phrenic nerve (1, 2). It has been shown that individuals with respiratory diseases exhibit poor movement patterns of the diaphragm (11, 12). In order to find the value of diaphragm mobility, some imagery assessment methods are used to assess the function and position of the diaphragm. These include X-ray imaging, fluoroscopy, MRI, and ultrasonography (7, 13-15). Ultrasound has the following advantages: lower cost, more available, a real-time and safe operating procedure, as described in the literature (8, 16, 17).

According to European guidelines for the diagnosis and treatment of pelvic girdle pain (6), there is little knowledge about the PGP, most research in this field has been done on low back pain and lumbopelvic pain, and there is few studies have been done on this important stabilizing part of the body.

2. Objectives

To the best of our knowledge, this is the first study to investigate the thickness and excursion of diaphragm muscle in individuals with PGP. To this end, this paper sought to assess the reliability of ultrasound for measuring diaphragm motion and thickness in relax and deep breathing states with M and B mode in a group with PGP and a control group.

3. Methods

3.1. Participants

This is a cross-sectional study that was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.RETECH.REC.1397). A total of 20 female and male participants were recruited to this study (according to Joseph L. Fleiss 1999, the design and analysis of clinical experiments), 10 with PGP (six females and four males) and 10 people without PGP (six females and four males) (See Table 1 for demographic details). Samples were selected from patients referring to the physiotherapy department by physicians, according to the inclusion criteria. Healthy individuals were selected from the staff and students of the Rehabilitation College and volunteers, and the groups were matched in terms of demographic characteristics. Inclusion criteria for the participants with PGP were being symptomatic, aged between 20 - 50 years, BMI between 20 - 30, VAS > 3, positive pain provocation test of PGP according to the European guidelines for the diagnosis and treatment reference of PGP (6), and having unilateral or bilateral pain in the pelvic area for at least three months. The inclusion criteria for the control group were being asymptomatic, aged between 20 - 50 years, BMI between 20 - 30, no history of any neuromusculoskeletal pain and problem in the last three months, and negative pain provocation test of PGP. The exclusion criteria for both groups were any breathing disorders; a history of dislocation or fracture in the lower extremities, spine, or pelvis; significant spinal abnormality; malignancy; systemic and metabolic disease; any musculoskeletal or neuromuscular disorder; previous spinal or abdominal surgery; and a history of pregnancy or smoking. The participants who had received any physical therapy or chiropractic treatment or injection within the last three months, as well as menopausal women, were excluded from the study. During RUSI, five people dropped out of the study (three in the PGP group and two in the control group); one person in the PGP group had a paradoxical motion of the diaphragm during the breathing cycle of deep breathing, and in four people excessive adipose tissue existed in the abdomen area and; therefore, M mode studies were difficult to perform.

3.2. Procedures

This study comprised three assessments. The first assessment was performed in the morning, the second assessment about one hour later and finally, the third assessment was conducted one day apart, at the same time of the day. All participants were recommended to consume light breakfast, approximately two to three hours before the measurements. The participants completed self-report measures, including a demographic information sheet. The participants with PGP marked the visual ana-

Table 1. Demographic Characteristics of the Participants[a]

Group	Age	Weight	Height	BMI
PGP	26.10 ± 5.87	73.40 ± 7.84	1.73 ± 0.10	24.43 ± 2.03
Control	30.90 ± 7.73	67.80 ± 11.61	1.70 ± 0.10	23.48 ± 2.32
Total	28.50 ± 7.12	70.60 ± 10.06	1.71 ± 0.10	23.96 ± 2.18

Abbreviations: BMI, body mass index; PGP, pelvic girdle pain.
[a]Values are expressed as mean ± SD

logue scale (VAS) for quantifying the pain intensity ranging from 0 to 10 in order to estimate the pain intensity in the past week (0: no pain, 10: the highest possible pain).

In the next step, the following tests (recommended for clinical examination of PGP by European guidelines for the diagnosis and treatment reference of PGP) were used for all participants in both groups. The PGP can be diagnosed by pain provocation tests (P4/thigh thrust, Patrick's Faber, Gaenslen's test, and modified Trendelenburg's test), and pain palpation tests (long dorsal ligament test and palpation of the symphysis). All images were taken at least one day apart from the physical examination using a RUSI apparatus (Ultrasonic Scanner, Q sono, China) with a 5-cm linear or curve transducer 3 - 13 Hz (The device calibration is approved by the company).

All imaging procedures were performed by the same operator who was an experienced physiotherapist in musculoskeletal ultrasonography. To obtain ultrasonography images, the participants were requested to lie in the relaxed supine hook-lying position, keep their knees flex with a pillow under them, and maintain their head and neck in the neutral position. They were asked to keep their upper arms in resting position by their sides and forearms and hands on the sides (12, 18, 19).

The diaphragm thickness at the end of expiration in quiet breathing and deep breathing was imaged on both sides in brightness (B) mode with a 7 - 13 MHz linear array transducer. To find the most appropriate intercostal space, the linear transducer was positioned anterior to the anterior axillary line in the intercostal space between the 7th and 8th, or 8th and 9th ribs, at which the diaphragm was more easily visualized. The appropriate position is where the diaphragm becomes obscured by the lung with deep inspiration (20, 21). After finding the best position, whenever the researcher found the best image on the monitor, three images of the target area were frozen and stored at the same point at the end of expiration. Then, the participant was instructed to take slow, deep breaths in and out, and three images were captured at the point of maximum diaphragm thickening as visually identified by the examiner (or at the point at which the diaphragm became obscured by the lung).

Electronic calipers were used to measure the thickness of the diaphragm muscle and three images were taken for each position, then averaged to give a thickness at rest end-expiration and thickness at maximal inspiration (1, 2). Muscle thickness was defined as the distance between the inside edges of each muscle border and was measured as the distance between the superior and inferior hyperechoic lines. The diaphragm is composed of a thick layer of hypoechoic (dark) muscle tissue encased between two hyperechoic (bright) lines of pleural and peritoneal fascia. The hypoechoic muscle will significantly thicken during mid- to end-range of deep inspiration (12, 18, 22).

M-mode ultrasonography was performed to study diaphragmatic motion. The right diaphragm can be visualized through the liver window. Because of the small window of the spleen, measuring diaphragm mobility from the inferior of the diaphragm is impossible in many cases (21). Therefore, only left diaphragm mobility assessments were performed in this study. For better visualization and enhancement of the trace lowest gain setting, the slowest sweep speed (10 s per screen) equipped with a 3 - 4 MHz convex transducer was selected. Before each examination, all of the participants were in a position described in a previous study and breathed quietly for a few minutes. Then, they were examined with a curve transducer in a longitudinal position. An anterior approach was adopted, applying the transducer on the abdomen at the right midclavicular line immediately below the costal margin with firm pressure, and directed medially, cephalad, and dorsally so that the ultrasound beam would reach nearly perpendicularly the posterior part of the vault of the right diaphragm around 5 cm lateral to the inferior vena cava foramen. The inspiratory and expiratory craniocaudal displacement of the diaphragm shortened and lengthened the probe-diaphragm distance, respectively. The highest diaphragmatic point could be searched as the maximal distance from the top of the screen along the craniocaudal direction. In this mid-posterior diaphragm portion, the greatest craniocaudal excursion is observed by Harris et al., 1983. The M-mode cursor was rotated and placed on the exact axis of the diaphragm. After finding the best position for diaphragm visualization, and then recording the diaphragm motion in the quiet breathing mode, forced breathing over the inspiratory capacity was recorded. The participants were instructed to inhale and soon exhale as quickly and as deeply as possible. After recording, offline assessments were made on sinusoidal curves. The initial cursor must be placed at the end of expiration and the second cursor at the maximum height of the peak of inspiration. Both cursors must be placed either above or below the line of the tracing so that an accurate measurement of the diaphragmatic craniocaudal excursions is obtained (12, 23, 24).

3.3. Statistical Analyses

Intra-class correlation coefficients (ICC) with a 95% confidence interval (CI) were calculated to assess intrarater reliability both within- and between days (25). The standard error of measurement (SEM) was calculated as the pooled standard deviation $\times \sqrt{(1 - ICC)}$ (26), and (MDC) minimal detectable change (MDC) was calculated as SEM $\times \sqrt{2}$, representing the minimal change in thickness that must occur to be 95% confident that a true change has occurred (27). Statistical analyses were performed using SPSS 17.0 (SPSS Inc., Chicago, IL).

4. Results

Demographic characteristics of the subjects are mentioned in Table 1.

The baseline characteristics of the participants are provided in Table 2, and a summary of statistics for intrarater within- and between-day RUSI measurements in both groups are provided in Tables 3 and 4, respectively. The reliability of thickness measurements of the right and left diaphragm in the PGP group in relaxed and deep breathing ranged from 0.88 to 0.92 for same-day comparisons and from 0.88 to 0.91 for between-day comparisons. This value for the control group ranged from 0.91 to 0.94 for same-day comparisons and 0.88 to 0.94 for between-day comparisons. Furthermore, the reliability of right diaphragm motion in the PGP group in relaxed and deep breathing ranged from 0.74 to 0.76 for same-day comparison and 0.78 to 0.79 for between-day comparison, and this value for the control group ranged from 0.81 to 0.88 and 0.80 to 0.90, respectively.

5. Discussion

This study evaluated the intrarater reliability in obtaining RUSI thickness measurements of right and left diaphragm muscles and right diaphragm mobility. According to a previously reported scheme (28) for defining the degree of reliability, ICC values: > 75 denote high reliability; 0.40 - 0.74 indicate adequate reliability; and < 40 demonstrate fair reliability. The ICC value in the present study has an excellent intrarater reliability for diaphragm thickness and an adequate to excellent reliability for diaphragm motion in relaxed and deep breathing in both groups. The within-day and between-day reliability of diaphragm muscle thickness measurements in both groups was excellent (ranged from 0.88 to 0.94). In comparison to the literature on the same topic, the results of the present study were nearly similar to those reported by Boon et al. (1). They reported the within-day intrarater reliability ICCs of 0.94 (0.79 - 0.98) for resting thickness and 0.89 (95% CI: 0.69 - 0.97) for thickness at the end of the maximal inspiration. Their study was conducted on normal healthy subjects. The within-day reliability of the measurement of diaphragm muscle movements in both groups was estimated in good to excellent (ranged from 0.74 to 0.88) and the between-day reliability was estimated at excellent (ranged from 0.78 to 0.90). In comparison to the previous studies, the results differed from those reported by Orde et al. (14). They reported the within-day intra-rater reliability ICCs: 0.94 (0.79 - 0.98), and their study focused on 50 healthy adults imaged with the M-mode sonography of diaphragms at 60% maximal inspiratory. The findings of the present study showed that the within-day and between-day ICC in the control group was slightly better than that of the PGP group, and the difference between the first and third measurements was very small. It is concluded that the application of RUSI is a reliable method to assess the diaphragm thickness and motion in patients with PGP.

Footnotes

Authors' Contribution: Mohsen Abedi: study design, Keyvan Nassiri: sampling, Alireza Akbarzadeh Baghban: analysis, Maryam Heydarpour Meymeh: writing, Farideh Dehghan Manshadi: revision.

Conflict of Interests: The authors declare that they have no conflict of interests.

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Table 2. The Mean ± SD Values of Right- and Left-Side Diaphragm Muscle and Right Diaphragm Motion in Rest and Deep Breathing (mm)

Group	RtDiQB	LtDiQB	RtDiDB	LtDiDB	DimotionQB	DimotionDB
PGP	2.3320 ± 0.25464	2.3910 ± 0.21268	4.6070 ± 0.54697	4.7410 ± 0.38530	13.6990 ± 3.61036	63.0700 ± 17.22916
Control	2.5280 ± 0.28507	2.4170 ± 0.28729	4.9910 ± 0.61044	5.0420 ± 0.55357	16.4720 ± 3.49111	73.2520 ± 12.04301

Abbreviations: DimotionDB, diaphragm motion deep breathing; DimotionQB, diaphragm motion quiet breathing; LtDiDB, left diaphragm deep breathing; LtDiQB, left diaphragm quit breathing; RtDiDB, right diaphragm deep breathing; RtDiQB, right diaphragm quit breathing

Table 3. PGP Group Intrarater Reliability

Measures	Within-Day			Between-Day		
	ICC (95% CI)	SEM	MDC	ICC (95% CI)	SEM	MDC
RtDiQB	0.92 (0.73, 0.98)	0.31	0.677	0.90 (0.66, 0.97)	0.29	0.69
LtDiQB	0.90 (0.66, 0.97)	0.27	0.70	0.91 (0.82, 0.989)	0.25	0.73
RtDiDB	0.88 (0.61, 0.97)	0.37	0.652	0.88 (0.59, 0.96)	0.30	0.73
LtDiDB	0.88 (0.60, 0.97)	0.47	1.321	0.89 (0.64, 0.97)	0.50	1.39
DimotionQB	0.76 (0.29, 0.93)	1.43	3.98	79 (0.35, 0.94)	1.65	4.58
DimotionDB	0.74 (0.25, 0.93)	8.78	24.33	78 (0.33, 0.94)	8.07	22.38

Table 4. Control Group Intrarater Reliability

Measures	Within-Day			Between-Day		
	ICC (95% CI)	SEM	MDC	ICC (95% CI)	SEM	MDC
RtDiQB	0.93 (0.76, 0.98)	0.180	0.50	0.92 (0.72, 0.98)	0.17	0.49
LtDiQB	0.94 (0.78, 0.98)	0.15	0.43	0.94 (0.79, 0.98)	0.18	0.50
RtDiDB	0.91 (0.69, 0.97)	0.36	0.99	0.89 (0.60, 0.97)	0.36	1.00
LtDiDB	0.91 (0.68, 0.97)	0.331	0.91	0.88 (0.75, 0.98)	0.41	1.15
DimotionQB	0.88 (0.60, 0.97)	1.20	3.35	0.90 (64, 0.97)	1.10	3.06
DimotionDB	0.81 (0.40, 0.94)	5.24	14.54	0.80 (40, 0.94)	5.38	14.92

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