Comparison of Diaphragm Thickness and Excursion between Patients with Pelvic Girdle Pain and Healthy Individuals

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Abstract

Introduction: Inspiratory muscles play an important role in respiration and spinal control. Therefore, diaphragm thickness and excursion must logically be correlated to the dual action of the diaphragm. This study investigated the difference between diaphragm thickness and excursion in quiet and deep breathing between patients with pelvic girdle pain (PGP) and healthy individuals by using rehabilitative ultrasound imaging (RUSI). **Materials and Methods:** Images of diaphragm thickness were taken using Brightness (B) mode RUSI in the intercostal space between the 7th and 8th, or 8th and 9th ribs, and diaphragm excursion was assessed using Motion (M) mode RUSI at the right midclavicular line. Imaging was performed in 30 participants with PGP and in 30 asymptomatic women and men (control group) aged 20-48 years in both groups. **Results:** In individuals with PGP, the diaphragm thickness and excursion were significantly lower than the control group at end-expiration in the deep and quiet breathing. **Conclusion:** The PGP group showed reduced diaphragm thickness and excursion. Therefore, it seems that breathing training and exercise should be performed along with other forms of training.

Keywords: Diaphragm; Thickness; Excursion; Ultrasonography; Pelvic Girdle Pain

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Introduction

The diaphragm is known for its role as the principal muscle of respiration. When diaphragm function is impaired, accessory muscles of breathing must assume this role but are much less efficient, resulting in shortness of breath with exertion. In addition to its role in respiration, the diaphragm also helps the mechanical stabilization of the spine (1-3). Lewit (4) suggested that if an individual does not demonstrate proper breathing patterns, the diaphragm will likely lack the coordination, endurance, and strength to perform its role as a postural stabilizer.

Pelvic girdle pain (PGP) is defined as the pain experienced between the posterior iliac crest and the gluteal fold, particularly in the vicinity of sacroiliac joints (SIJ). The pain may radiate in the posterior thigh and can also occur in conjunction with/or separately in the symphysis (5). Various studies have reported that pelvic girdle and lumbar spine are reflexively stabilized and braced prior to the initiation of lower extremity movements (3). Although in an early research by Hodges, more attention was paid to the special role of the Transverse Abdominis (TrA) in core stability (6), more recent research by Hodges suggests the inner unit is a dynamic system which seems to rely on the integration of the pelvic floor, Multifidus, TrA, and the diaphragm (7). The diaphragm contraction and working synergistically with the pelvic floor and abdominal muscles increases intra-abdominal pressure and cause increase spinal stiffness and stability. Hodges *et al.* (8) reported that isolated contraction of the diaphragm (via phrenic nerve stimulation) without the 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, especially during postural activity (9).

Kolar *et al.* (3) evaluated diaphragm motion by dynamic MRI. They reported that diaphragm excursions are decreased when the isometric flexion against the resistance of the upper or lower extremity is applied. The synergistic activity of all the muscles modulating intra-abdominal pressure (*i.e.*, spinal extensors, abdominal muscles, the diaphragm, and the pelvic floor) keeps trunk bracing and maintains all spinal segments in a proper position during the course of any movement in the body. In fact, the diaphragm is the muscle which contributes to intra-abdominal pressure modulation and plays a key 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 (10, 11). In order to find the value of diaphragm mobility, several imaging methods are used to assess the function and position of the diaphragm. These methods include X-ray imaging, fluoroscopy, magnetic resonance imaging (MRI), and ultrasonography (6, 12-15). Currently, in many institutions, the fluoroscopy is utilized to assess diaphragmatic motion by a number of different maneuvers. The fluoroscopy requires the patient's transportation, which is often difficult, and uses the ionizing radiation ultrasonography which shows all abnormalities seen on the fluoroscopy (11). X-ray is an another method for assessment of diaphragm mobility, but it is not as safe as sonography and is not real-time (15). Ultrasonography is more sensitive to motion than fluoroscopy, requires no radiation, and may be used at the patient's bedside (11). It would be ideal if sonography could replace fluoroscopy for the evaluation of diaphragm motion. Ultrasound has the advantage of being a safe operating procedure, as described in the literature (7, 16, 17) (, and holds the advantage of assessing both the structural and functional components of the diaphragm. The aim of this study was to investigate how the diaphragm muscle works in people with chronic PGP. The muscle that alone covers the upper part of the abdominal capsule and plays an important role in creating intra-abdominal pressure. The assessment was performed by measuring the thickness of the muscle strength, and the amount of diaphragm movement.

Materials and Methods

Participants

A total of 60 people were recruited in this study, including 30 people (21 female, nine male) with PGP and 30 healthy people(21 female, nine male) as a control group, aged between 20-50 with BMI 20-30 (see Table 1 for demographic information). The inclusion criteria for participants with PGP were being symptomatic, visual analog scale (VAS)> 3, positive pain provocation test of PGP according to the European Guidelines for the Diagnosis and Treatment Reference of Pelvic Girdle Pain (5), 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 individuals, no history of any neuromusculoskeletal pain or problems in the last three months, and negative pain provocation test of PGP. The exclusion criteria for both groups were: the existence of any breathing disorders; a history of dislocation or fracture in the lower extremities, spine and pelvis; significant spinal abnormality; malignancy; systemic and metabolic disease; any musculoskeletal or neuromuscular disorder; previous spinal or abdominal surgery; and any history of pregnancy or smoking. Participants who had received any physical therapy or any chiropractic treatment or injection within the last three months and menopausal women were ruled out from the study. During RUSI, 12 people dropped out of the study, 11 of whom in the PGP group and 1 in the control group; 2 people in the PGP group and 1 in the control group had paradoxical motion of the diaphragm, and in 5 individuals in PGP and 4 in the control group, the M mode studies were difficult to assess probably because of excessive adipose tissue in the abdominal area.

Procedures

This study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.RETECH.REC.1397.1358). That was included two assessments. In the first assessment performed in the morning, all subjects were recommended to have light breakfast about 2-3 hours before the measurements. Participants completed self-reported measures, including a demographic information sheet. The participants with PGP marked the VAS for quantifying the pain intensity ranging from 0 to 10 in order to estimate the current pain intensity in the past week (0: no pain, 10: the highest possible pain). Then, the following tests (recommended for the clinical examination of PGP by European Guidelines for the Diagnosis and Treatment of Pelvic Girdle Pain) were performed for all participants in both groups. PGP can be diagnosed by the pain provocation tests (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).

Second assessment was taken at least one day apart from the physical examination by using a RUSI apparatus (Ultrasonic scanner, Q sono, China) with a 5-cm linear or curved transducer 3-13 Hz.

All imaging procedures were performed by the same operator who was an experienced physiotherapist and trained in the musculoskeletal ultrasonography. To obtain ultrasonography images, participants were requested to lie in a relaxed supine hook-lying position, keep their knees flexed with a pillow under them, and

Figure 1. Position of the transducer just anterior to the anterior axillary line

maintain their head and neck in the neutral position. They were asked to keep their upper arms in a resting position by their sides and the forearms and hands on the sides (11, 18, 19).

The diaphragm thickness at the end of expiration in quiet and deep breathing was imaged on both sides in brightness (B) mode with a 7-13 MHz linear array transducer (Figure 1). To find the most appropriate intercostal space linear transducer positioned just anterior to the anterior axillary line at the intercostal space between the 7thand 8th, or 8thand 9thribs, at which the diaphragm was most easily visualized (with the transducer spanning between two ribs), 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. Subsequently, the participants were instructed to take slow, deep breaths in and out, and three images were captured at the point of maximum diaphragm thickening as identified visually 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 for each position, then averaged to give a thickness at resting and maximal breathing at end of expiration (1-2). Muscle thickness was defined as the distance between the inside edges of each muscle border 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 the pleural and peritoneal fascia. The hypoechoic muscle will significantly thicken during mid- to end-range of deep inspiration, and the image can be obscured with deep inspiration when the lung is displaced downwards toward the abdomen (11, 22).

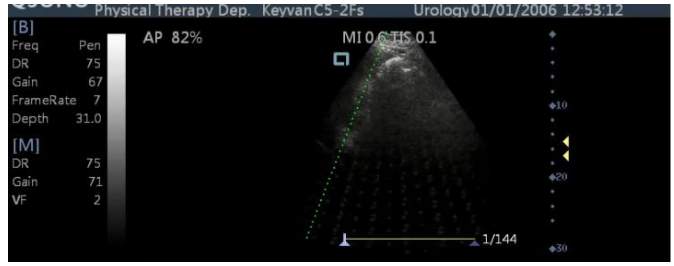

Figure 2. Diaphragm contraction causes caudal dome displacement, moving toward the transducer with M-mode application

The M-mode ultrasonography was used to evaluate the diaphragmatic motion. The right diaphragm can be visualized through the liver window. Because of the smaller window of the spleen, it is impossible in many cases to measure diaphragm mobility from the inferior of the diaphragm (21). As a result, only left diaphragm mobility assessments were performed in this study (Figure 2). For better visualization and enhanced tracing of the lowest gain setting, the slowest sweep speed (10s per screen) equipped with a 3-4 MHz convex transducer was selected. Before each examination, all participants remained in a relaxed position and breathed quietly for a few minutes. Then, they were examined with a curve transducer in a longitudinal position. An anterior approach was adopted by 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 respectively shortened and lengthened the probe-diaphragm distance. The highest diaphragmatic point could be searched as the maximal distance from the top of the screen along a craniocaudal direction. In this mid-posterior diaphragm portion, the greatest craniocaudal excursion is observed (23). The M-mode cursor was rotated and placed on the exact axis of the diaphragm. After finding the best position for diaphragm visualization and recording the diaphragm motion in the quiet breathing mode, forced breathing over the inspiratory capacity was recorded, and every patient was instructed to inhale and soon exhale as quickly and as deeply as possible. After recording, offline assessments were performed on sinusoidal curves. The initial cursor should 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 would be obtained (24, 25).

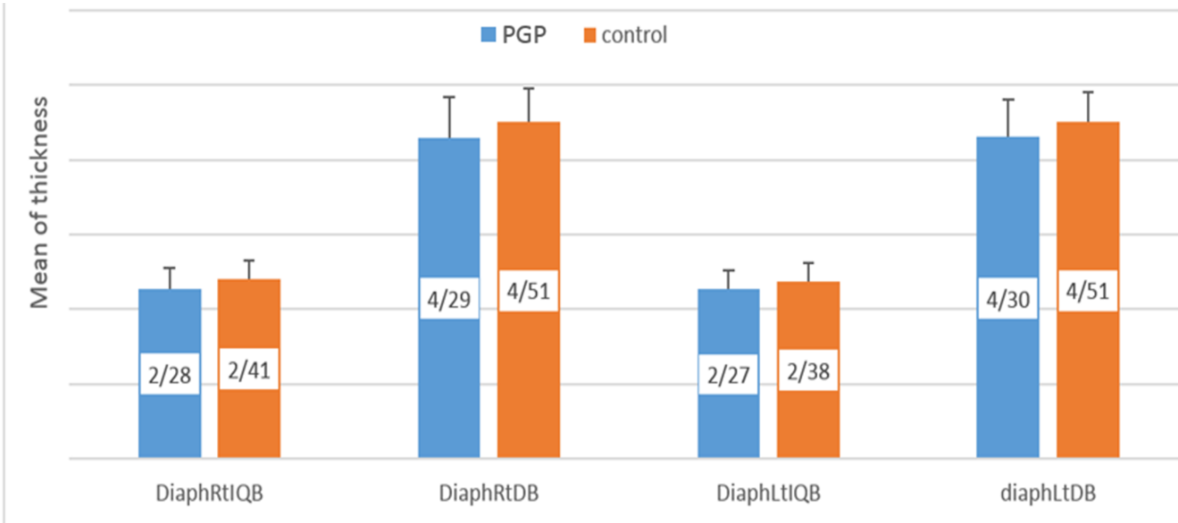

Figure 3.Distribution of right and left diaphragm thickness during quiet breathing (QB) and deep breathing (DB) in both groups

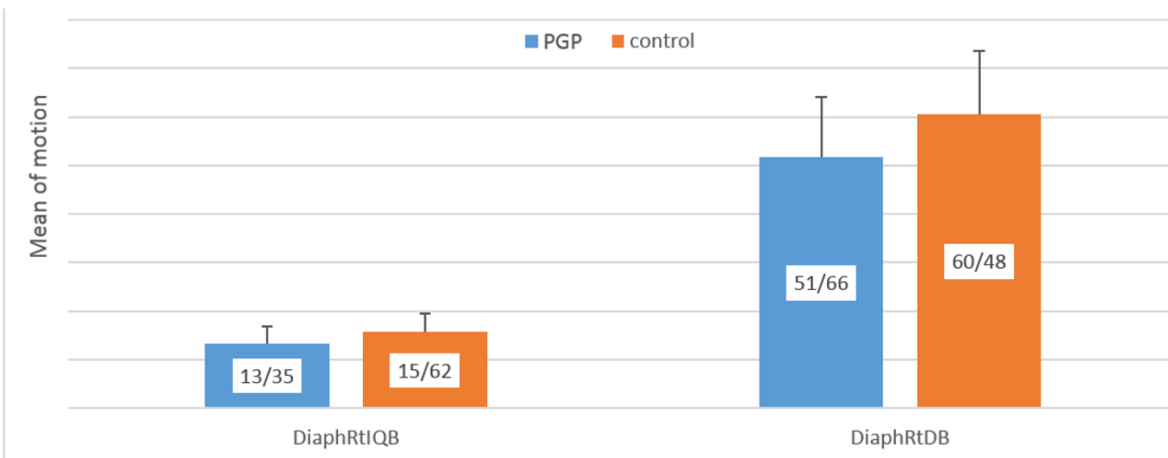

Figure 4. Distribution of left diaphragm excursion during quiet breathing (QB) and deep breathing (DB) in both groups

Statistical analyses

Statistical analyses were performed using SPSS 17.0 (SPSS Inc., Chicago, IL). Results were considered significant at a *P*-value of <0.05. Assessment of reproducibility for both groups was performed by the intraclass correlation coefficient (ICC), standard error of the mean (SEM), and minimal detectable change (MDC).

The Kolmogorov–Smirnov test was performed to examine the normality of the data distribution. To analyze the diaphragm muscle thickness, two-factor measures ANOVA with two intra-item factors of diaphragm side (left and right) and respiration mode (deep and quiet) and one inter-item status factor (healthy and affected) was used. To assess the effect of group and breathing mode on right side of diaphragm excursion data, an analysis of Covariance (ANCOVA) was used.

Results

The results of the ICC, SEM, MDC values revealed an excellent intra-rater reliability for RUSI to measure diaphragm thickness and motion in both groups. Measurement of diaphragm motion demonstrated excellent reliability in the asymptomatic group and a lower reliability, between good and excellent, in the PGP group (see in Table 2 and Table 3 (26).

The results of normality tests indicated that data distribution of two groups was normal, except for BMI, and there was no significant difference between them. BMI was significantly higher in the affected group than in the control group. However, statistical analysis revealed that this difference did not affect on the statistical results.

Table 1. Demographic Characteristics of the Participants (PGP: pelvic girdle pain)

	Group	Mean (SD)	Std. Error Mean
Age	PGP	32.17 (8.79)	1.60
	Control	32.20 (7.95)	1.45
Weight	PGP	73.23 (9.08)	1.65
	Control	67.60 (11.07)	2.02
Height	PGP	1.70 (0.1)	0.1
	Control	1.68 (0.09)	0.1
BMI	PGP	25.20 (2.35)	0.43
	Control	23.57 (2.08)	0.38

Table 2. PGP Group Intra-rater Reliability

Within-Day				**Between-Day**		
Measures	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

RtDiQB: right diaphragm quit breathing; LtDiQB: left diaphragm quit breathing; RtDiDB: right diaphragm deep breathing; LtDiDB: left diaphragm deep breathing; DimotionQB: diaphragm motion quiet breathing; DimotionDB: diaphragm motion deep breathing; ICC: intraclass correlation coefficient; SEM: standard error of the mean; MDC: minimal detectable change

Table 3. Control Group Intra-rater Reliability

	Within-Day			**Between-Day**		
Measures	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 (0.64, 0.97)	1.10	3.06

RtDiQB: right diaphragm quit breathing; LtDiQB: left diaphragm quit breathing; RtDiDB: right diaphragm deep breathing; LtDiDB: left diaphragm deep breathing; DimotionQB: diaphragm motion quiet breathing; DimotionDB: diaphragm motion deep breathing; ICC: intraclass correlation coefficient; SEM: standard error of the mean; MDC: minimal detectable change

The results showed that diaphragm thickness in deep breathing was significantly higher than quiet breathing ($P<0.001$), In comparison, the control group's muscle thickness was significantly higher than that of the affected group in quiet and deep breathing, and this difference was significant in deep breathing mode($P=0.014$). The side of the diaphragm muscle difference (left vs. right) was not significant ($P=0.882$), suggesting that diameters of the two sides did not significantly differ in the same group (Table 4).

Discussion

To the best of the authors' knowledge, this was the first study to assess the diaphragm thickness and the excursion during quiet and deep breathing by RUSI, by comparing subjects with PGP (27)with healthy individuals. The PGP group demonstrated less diaphragm thickness (Figure 3) and less diaphragm excursion (Figure 4) in the quiet breathing and the deep breathing in compered with the control group, and this difference was most obvious in deep breathing. This result indicated the importance of diaphragm roles which was in line with the prior suggestions made by other authors showing the diaphragm muscle plays a key role as a deep muscular stabilizer of the central part of the body (25-29). The lack of previous research on the subject restricts our ability for the comparison of our results with the literature. Our findings in terms of thinner diaphragm thickness and decrease diaphragm excursion are in agreement with those of a prior MRI study by Vostatek *et al.* (16) which reported a thinner thickness and lesser excursion in participants' diaphragm with low back pain in comparison with the control group.

A sonography study by Kim *et al.* (30) on stroke patients demonstrated the diaphragm thickness significantly was decreased in the affected side compared with the unaffected side as well as compared with healthy participants (32). Moreover, Jung *et al.* (2) examined the diaphragmatic motion via M-mode ultrasonography in stroke patients and reported that all stroke patients had the restrictive pulmonary dysfunction. Compared to the controls, stroke patients showed a significant unilateral reduction in motion on the hemiplegic side, primarily during the volitional breathing. Diaphragmatic excursion in right-hemiplegic patients was reduced on both sides compared to the controls. However, diaphragmatic excursion was reduced only on the left side and increased on the right side in left-hemiplegic patients compared to the controls.

Boussuges *et al.* studied on normal individuals for defining the normal value of diaphragm excursion in the quiet and deep breathing in the standing position with RUSI. Their findings showed the diaphragm excursion value is more dependent on participants' height and weight. They reported that mean normal value excursion was 1.8 (1.1-2.5) for men and 1.6 (1.6-2) for women in quiet breathing, and increased to 7 (4.7-9.2) and 5.7 (3.6-7.7) in deep breathing, respectively (10).

A sonography study by Kim *et al.* on stroke patients demonstrated the diaphragm thickness significantly decreases in the affected side compared with the unaffected side and compared with healthy participants (30). Moreover, Jung *et al.* (2) examined diaphragmatic motion via M-mode ultrasonography in stroke patients and reported that all stroke patients had restrictive pulmonary dysfunction. Compared to that exhibited by the controls, stroke patients exhibited a significant unilateral reduction in motion on the hemiplegic side, primarily during volitional breathing. Diaphragmatic excursion in right-hemiplegic patients was reduced on both sides compared to the controls. However, diaphragmatic excursion was reduced only on the left side and increased on the right side in left-hemiplegic patients compared to the controls (31).

It sounds logical that there was no significant difference between the two sides of the diaphragm. This system is an integrated system called the abdominal capsule, and the muscles of this capsule interact with each other to optimize the pressure inside the capsule. As the forces inside the capsule increase, this pressure must be the same for all structures. Thus, logically, if there is pain on the right, left, or both sides, there must be weakness and disorder nearly in all parts of this integrated system, and probably the side of difficulty should depend on other things.

This study was limited by the fact that left diaphragm was not measured. Based on the explanations given above, it was preferred only to perform the right-side measurements.

Conclusions

We found that PGP subjects decreased thickness and excursion of diaphragm, independent of the side of the injury in comparison with healthy individuals. Today's sedentary lifestyle and increased mental stress have caused some muscles and tissues to be used less and some more; so, the diaphragm muscle roles changed due to inactivity and changing the pattern of breathing from abdominal to apical breathing. The diaphragm is the only muscle which covers the upper part of the abdominal capsule, and has important roles in increase of abdominal pressure and has many connections with various organs. So, any movement disorders and weakness of this muscle should be considered important. Unfortunately, breathing exercises do not have a good place in therapeutic and daily exercise (except yoga exercises). According to this study, diaphragm muscle should be given more attention and focus during exercise therapy. Future research is needed to investigate which side is probably affected first, and which factor is likely to play the most important role. Moreover, it remains to be answered whether improper breathing due to respiratory, internal, mental, or postural diseases causes changes in diaphragm thickness and motion. Because of the importance of this muscle, it affects motor control system and movement dysfunction, leading to musculoskeletal problems; or the opposite is true, i.e. impairment of movement control and dysfunction affects it, or maybe both play a role. Future research can examine the priority of therapeutic exercise in people with PGP by comparative intervention between the two groups of conventional exercise therapy and respiratory exercises.

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