

Asymmetry in Paraspinal Muscles as a Predictor of the Development of Pregnancy-Related Low Back and Pelvic Pain: A Prospective Study.

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Abstract

Background: The etiology of pregnancy-associated lumbopelvic pain (LPP) is not clear at present. This condition is highly heterogeneous with different development and subtypes, including low back pain (LBP) and pelvic girdle pain (PGP). Paraspinal muscles are of importance to maintain the spine's functional stability, and their weakness participates in the occurrence of LPP. Therefore, this study aims to determine the asymmetry in the paraspinal muscle before pregnancy and evaluating its association with pregnancy-associated LPP.

Methods: This was a prospective case-control study conducted from January 2017 and December 2018. 171 subjects (mean age \pm SD, 27.4 \pm 5.8 years) were finally divided into the LBP group, PGP group, and no LPP group. The mean value of F-CSA's ratio to T-CSA (F/T CSA) was used to determine whether the bilateral paraspinal muscle was asymmetrical. Total muscle CSA (T-CSA), functional CSA (F-CSA), and F/T CSA were measured unilaterally and compared between groups. Logistic regression was performed to determine the risk factors for pregnancy-associated LPP. The Pearson correlation coefficient was performed to test the relationship between asymmetry in F/T-CSA and pain rating.

Results: 124 subjects (72.5%) (28.5 \pm 5.2 years) had the LPP during the pregnancy. 48 (38.7%) individuals had LBP, and 76 (61.3%) had PGP. A total of 39 (31.5%) women unrecovered from LPP. F/T-CSA was significantly decreased in LBP than those in the PGP group and control group (0.03 \pm 0.02 vs. 0.05 \pm 0.03 vs. 0.12 \pm 0.05, $P < 0.001$). Meanwhile, significant differences were detected in any two groups (all $P < 0.001$). Asymmetry in the paraspinal muscle (adjusted OR=1.5), LBP (adjusted OR=1.6), LPP in a previous pregnancy (adjusted OR=1.4), sick leave ≥ 90 days (adjusted OR=1.2), and heavy labor (adjusted OR=1.2) were risk factors for the unrecovered LPP during pregnancy.

Conclusions: Asymmetrical muscular compositions could lead to abnormal biomechanics for the segmental motions. One-lateral-directed physical training and stretching may help decrease the occurrence and severity of this condition.

Background

Lumbopelvic pain (LPP) during pregnancy occurs commonly, with a prevalence varying from 20–90%, mostly above 50% [1–3]. Because of such significant morbidity, this condition had to be generally considered a natural or trivial problem during pregnancy. Quite a few clinicians are helpless to give a “watch and wait” approach as the best solution for those women. However, severe LPP compromises daily routines such as running and even walking, work performance and incurs deterioration in the quality of life (QoL) [4, 5]. It is reported that over 80% of pregnant women experiencing LBP have limitations in daily activities and 30% of women suffering severe LPP have to confine to bed and sick leave from work [6, 7]. What's worse, for parts of women, LPP following the childbirth recedes slowly and incompletely, sustaining several years postpartum and even becoming a life-long condition. 51% of women with LPP continue suffering it one year after delivery [8], and 20% of women 3 years postpartum [9]. Ostgaard et al.

have reported that 15% of women experiencing LPP begin after childbearing [10]. The consequences of this high-incidence disease pushing those women to seek medical treatment for pain relief, producing economic burdens on individuals and health insurance. These intractable reactions could trigger perinatal depression and sleep disorders, which further threatens the infants' health except for mothers [11]. Hence, LPP should not be neglected during pregnancy due to enormous socioeconomic implications and significant influence on the physical and psychological quality of life for the women, their families, and society [12]. Oppositely, these problems are added to the demand for intensive research.

This disease is considered to be clinically complex, including low back pain (LBP) and pelvic girdle pain (PGP) [3, 7]. Pain around the symphysis pubis and sacroiliac joints is considered PGP, while LBP is frequently defined as pain between the 12th rib and the gluteal fold [7]. The incidence of PGP is relatively stable during the whole pregnancy, with nearly 10%. By contrast, LBP starts with a low rate in early pregnancy, then climbs and keeps a higher level, about 35% throughout pregnancy [13]. Apart from the frequency, PGP and LBP diminish differently after childbirth. PGP declines to 5% about 11 weeks postpartum, while LBP does not recede as expected and even could become worse [14].

Of note, generally, the intensity of both pains worsens as pregnancy progress. This condition is associated with the musculoskeletal system instead of urological or gynecological disorders. Unfortunately, the further pathogenesis and etiology of both LBP and PGP are undefined and multifactorial at present. Changes in posture during pregnancy, weight gain, a shift in the center of gravity, ligament laxity due to pregnancy-related hormones, fluid retention in connective tissue, and increased intra-abdominal pressure could contribute to the onset of LBP [5, 15–17]. Meanwhile, PGP is considered as a problem different from LBP during pregnancy. It has been demonstrated that these two pains should be distinguished due to different etiology and risk factors such as childbearing age, body mass index (BMI), heavy labor [13, 18].

Numerous studies have demonstrated that exercise, including deep and superficial lumbopelvic muscles, can help reduce the severity of LPP during pregnancy with an improvement in functional ability [19–23].

This means that paraspinal muscles are of importance to maintain and support the spine's functional stability, and their weakness participates in the occurrence of LPP [1]. Several clinical research has indicated that asymmetry in paraspinal muscles caused by the altered structure, such as atrophy and fat infiltration of the lumbar paraspinal and psoas muscle ipsilateral to the pain side, was observed in patients suffering chronic LPP [24–26]. Until now, little is known about whether the same conclusion can be generalized for the LPP in pregnant women. Considering the undefined etiology of this disease, the risk analysis for factors are significant. Therefore, this study's objective was to determine the asymmetry in the paraspinal muscle before pregnancy by measuring the digital image of magnetic resonance imaging (MRI) and evaluating its association with LPP during pregnancy. We hypothesized that asymmetry in lumbar paraspinal and psoas muscle might be used as a possible predictor for subsequent occurrence of pregnancy-related LPP.

Methods

2.1 Subjects

A total of 232 women (mean age \pm standard deviation [SD], 26.8 ± 6.3 years) were enrolled in a pre-pregnancy consultation clinic between Jan 1, 2017, and Dec 1, 2018. Exclusion criteria included: i) specific LPP with definite pathology such as lumbar disc herniation, spondylolisthesis, ankylosing spondylitis, infectious diseases, and tumor (N = 21); (ii) a history of spinal fracture, injuries, or back surgery (N = 9); (iii) other chronic diseases, such as hypertension and diabetes mellitus (N = 12); (iv) lumbar muscle training in the last six months (N = 6); (v) abnormal pregnancy such as placenta previa, ectopic pregnancy (N = 7) and (vi) lost to follow-up or incomplete data (N = 6). The duration of follow-up was limited to 24 months postpartum to reduce the possibility of other extraneous variables on the transition of LPP. Clinical data, including age, BMI, educational background, cesarean delivery, parity, sick leave, heavy labor, and the type of LPP, were collected. According to whether LPP during pregnancy, these women were divided into a case group or a control group. This prospective study was approved by the Institutional Review Board (IBR) of the author's hospital, and all volunteers offer a written consent to participate in this research.

Women experiencing LPP were referred to a multidisciplinary team, having an obstetrician, orthopaedist, acupuncturist, and physiotherapist. Arranged treatments, depending on a particular patient's condition, such as pain severity, gestational period [14], includes patient education, back-strengthening exercises, rest, physiotherapy, swimming, manipulation, and acupuncture.

2.2 Muscle measurements

Each subject was asked to follow a standardized clinical imaging protocol before the pregnancy. The image was acquired using a 3.0 T MRI scanner (Philips Achieva, Netherlands) with the repetition time (TR) of 2500 ms and echo time (TE) of 60 ms, a matrix of 332×266 , field-of-view of 200 mm, and a slice thickness of 5 mm. The quantitative analysis for the paraspinal muscles on the T2-weighted axial images was completed using Onis and ImageJ software (Wayne Rasband, National Institutes of Health, Bethesda, MD).

One of the authors, who was blinded to the participant's condition, segmented the area of muscles (multifidus, erector spinae, and psoas muscles) on the axial slice at mid-disc of L4–L5 and L5–S1 and then measured the cross-sectional area (CSA) of a particular muscle by outlining the innermost fascial border surrounding each muscle. Total muscle CSA (T-CSA) represents the sum of CSA of interested three muscles. The signal intensity can distinguish fat and muscle tissue in a different range. Based on this, functional CSA (F-CSA), represented by fat-free area, was evaluated quantitatively by excluding the signal of the deposits of intramuscular fat. Then, the ratio of F-CSA to T-CSA (F/T CSA) was calculated to determine the extent of fat infiltration of muscle degeneration. The above parameters were measured unilaterally (Fig. 1).

2.3 Measurement reliability

All measurements were performed by the same doctor. An intraclass correlation coefficient (ICC) was calculated to evaluate intratester reliability with repeated 10 times for all the images. The intra-rater ICC ranges from 0.92 to 0.98 for T-CSA and 0.90 to 0.98 for F-CSA. The intra-rater ICCs for the between-sides differences in CSA were 0.82 for erector spinae, 0.87 for multifidus, and 0.90 for psoas. The ICC for the between-sides difference in the F/T CSA was 0.87 for erector spinae, 0.90 for multifidus, and 0.93 for psoas.

2.4 Lumbopelvic pain (LPP) and its subtypes

Pregnancy-related LPP was defined as a pain from the lumbar spine or pelvis, lasting for one week or longer [14]. Meanwhile, the pain rating should be ≥ 3 using the self-reported scale of 0–10 (0 as no pain to 10 as the worst possible pain) through an interview or telephone call at any appointment during the whole pregnancy, as it is frequently considered as a disabling more or less [18]. This rating served as the primary outcome in this study.

LBP was defined as the pain located above the sacrum in the lumbar spine with a history of lumbar back pain before pregnancy, a limited motion in the lumbar spine, tenderness along with the erector spinae muscle, and negative results on the posterior pelvic pain provocation test (4P-test). PGP was defined as the pain located in the gluteal area with no history of lumbar back pain before pregnancy, relation to time- and weight-bearing, pain-free intervals, an unlimited motion in the lumbar spine, and positive results on the 4P-test [8].

2.5 Sample size

The sample size was 63 patients in each group to detect a mean difference in the pain rating of 0.5 with the SD of 0.25, $\alpha = 0.05$, and $1 - \beta = 0.9$, and additional compensation for a dropout rate of 20%.

2.6 Statistical analysis

We used SPSS version 22 (SPSS; Chicago, IL, USA) to perform all analyses. The mean and standard deviation was used to demonstrate variables, which have been tested to be normally distributed. The Chi-square test was performed to compare ordinal variables, and Student's t-test was for continuous variables. Then, Tukey's post hoc was used for pairwise comparison. Then patients were divided into asymmetry or symmetry in paraspinal muscle according to F-CSA/T-CSA. The cut-off value of F-CSA/ T-CSA was determined by the mean value. Logistic regression was performed to estimate the odds ratio (OR) and the associated 95% confidence interval (CI) to determine the risk factors for pregnancy-associated LPP. Multivariate logistic models were performed using stepwise elimination of variables of interest from univariate analysis after adjustment for confounding factors. The Pearson correlation coefficient was performed to test the relationship between asymmetry in F-CSA/ T-CSA and pain rating. The statistical significance and power analysis were P-values ≤ 0.05 and 0.8, respectively.

Results

171 subjects (mean age \pm SD, 27.4 \pm 5.8) were included in the final analysis according to the inclusion and exclusion criteria. 124 subjects (72.5%) (mean age \pm SD, 28.5 \pm 5.2) had the LPP during the pregnancy. Among them, 48 (38.7%) individuals had LBP, and 76 (61.3%) had PGP. After childbirth, 21 (43.8%) women failed to recovery from LBP, and 18 (23.7%) from PGP. Namely, a total of 39 (31.5%) women unrecovered from LPP.

76 women (44.4%) were determined as asymmetry in paraspinal muscle according to the definition in this methods section. Their demographic data and basic data were seen in Table 1.

Table 1

Comparisons about demographic data and basic data between asymmetry and symmetry in paraspinal muscle.

Variables	Asymmetry in paraspinal muscle (n = 76)	Symmetry in paraspinal muscle (n = 95)	P value
Age (Mean \pm SD) (years)	28.7 \pm 5.0	26.4 \pm 5.3	0.004*
BMI before pregnancy (Mean \pm SD) (kg/m ²)	24.3 \pm 2.6	26.2 \pm 1.8	\leq 0.001*
LPP during pregnancy (N, %)	63(82.9%)	61(64.2%)	0.011*
LBP during pregnancy (N, %)	27(35.5%)	19(20.0%)	0.036*
PGP during pregnancy (N, %)	36(47.4%)	40(42.1%)	0.594
LPP in a previous pregnancy (N, %)	31(40.8%)	23(24.2%)	0.031*
Side-to-side difference in F-CSA/T-CSA (cm ²)	1.5 \pm 0.6	0.8 \pm 0.3	\leq 0.001*
Smoking (N, %)	9(11.8%)	11(11.6%)	0.852
Alcohol user (N, %)	8(10.5%)	9(9.5%)	0.977
Educational Levels (\geq /Bachelor) (N, %)	45(59.2%)	51(53.7%)	0.570
Cesarean delivery (N, %)	12(15.8%)	16(16.8%)	0.982
Primigravida (N, %)	43(56.6%)	38 (40.0%)	0.045*
Sick leave \geq 90 days (N, %)	24(31.6%)	16(16.8%)	0.038*
Heavy labor (N, %)	30(39.5%)	17(17.9%)	0.003*
BMI = Body Mass Index, LPP = Lumbopelvic pain (LPP), LBP = Low back Pain, PGP = Pelvic Gridle Pain, T-CSA = total cross-sectional area, F-CSA = functional cross-sectional area.			

Comparisons about side-to-side parameters of the paraspinal muscles among groups

As shown in the Table 2, in the LBP group, all the mean T-CSA (18.2 ± 1.7 vs. 19.6 ± 1.6 , $p < 0.001$), F-CSA (15.5 ± 2.0 vs. 17.7 ± 1.7 , $p < 0.001$), and F-CSA/T-CSA (0.72 ± 0.07 vs. 0.84 ± 0.08 , $p < 0.001$) were decreased on the painful or more painful side compared with the no or less pain side. In the PGP group, the difference in mean T-CSA (18.7 ± 1.9 vs. 19.0 ± 1.8 , $p = 0.319$) between groups was no significant, while those in F-CSA (16.2 ± 1.6 vs. 17.0 ± 1.8 , $p = 0.004$) and F-CSA/T-CSA (0.81 ± 0.06 vs. 0.86 ± 0.07 , $p < 0.001$) on the painful or more painful side were decreased compared with the no or less pain side. However, in those without the LPP during pregnancy, there were no significant differences in the T-CSA (18.8 ± 1.6 vs. 19.2 ± 1.7 , $p = 0.243$), F-CSA (17.0 ± 2.0 vs. 17.3 ± 1.8 , $p = 0.447$), and F-CSA/T-CSA (0.83 ± 0.15 vs. 0.86 ± 0.12 , $p = 0.287$) between two sides (Fig. 1).

Table 2
Comparisons about side-to-side parameters of the paraspinal muscles among groups.

Variables	With LPP (n = 124)						Without LPP (n = 47)		
	LBP (n = 48)		P value	PGP (n = 76)		P value	Left side	Right side	P value
	Pain side	No pain side		Pain side	No pain side				
T-CSA (Mean \pm SD) (cm ²)	18.2 \pm 1.7	19.6 \pm 1.6	$\times 0.001^*$	18.7 \pm 1.9	19.0 \pm 1.8	0.319	18.8 \pm 1.6	19.2 \pm 1.7	0.243
F-CSA (Mean \pm SD) (cm ²)	15.5 \pm 2.0	17.7 \pm 1.7	$\times 0.001^*$	16.2 \pm 1.6	17.0 \pm 1.8	0.004*	17.0 \pm 2.0	17.3 \pm 1.8	0.447
F-CSA/T-CSA	0.72 \pm 0.07	0.84 \pm 0.08	$\times 0.001^*$	0.81 \pm 0.06	0.86 \pm 0.07	$\times 0.001^*$	0.83 \pm 0.15	0.86 \pm 0.12	0.287

P values from ANOVA and post hoc analysis. *indicates statistically significant. SD = Standard Deviation. BMI = Body Mass Index, LPP = Lumbopelvic pain. LBP = Low back Pain, PGP = Pelvic Girdle Pain, T-CSA = total cross-sectional area, F-CSA = functional cross-sectional area.

Comparisons about the ratio of F-CSA to T-CSA among groups

The ratio of F-CSA to T-CSA was significantly decreased in LBP than those in the PGP group and control group (0.03 ± 0.02 vs. 0.05 ± 0.03 vs. 0.12 ± 0.05 , all $P < 0.001$). Meanwhile, significant differences were detected in any two groups (Fig. 2).

Logistic regression analysis for the unrecovered LPP after the pregnancy

After adjusting for the remaining covariates, asymmetry in paraspinal muscle (adjusted OR = 1.5; 95% CI: 1.4–1.6; $P < 0.01$), LBP (adjusted OR = 1.6; 95% CI: 1.5–1.7; $P < 0.01$), LPP in previous pregnancy (adjusted OR = 1.4; 95% CI: 1.3–1.5; $P < 0.01$), sick leave ≥ 90 days (adjusted OR = 1.2; 95% CI: 1.1–1.3; $P < 0.05$) and heavy labor (adjusted OR = 1.2; 95% CI: 1.1–1.3; $P < 0.05$), were risk factors for the

unrecovered LPP during pregnancy. The rest of the variables, including sick leave, BMI \geq 28, smoking, alcohol user, educational levels, cesarean delivery, and primigravida (all $P \geq 0.05$), failed to be found to predict the development of LPP after adjusting for the remaining covariates (Table 3).

Table 3
Logistic regression analysis for the unrecovered LPP during pregnancy

Variables	Unrecovered LPP (n = 242)			
	OR	P value	Adjusted OR#	P value
Asymmetry in paraspinal muscle	1.8 (1.7–1.9)	< 0.01*	1.5 (1.4–1.6)	< 0.01*
LBP types				
No LBP (ref.)				
LBP	2.0 (1.9–2.1)	< 0.01*	1.6 (1.5–1.7)	< 0.01*
PGP	1.5 (1.4–1.6)		1.2 (1.1–1.3)	
BMI \geq 28	1.6 (1.5–1.7)		1.2 (1.1–1.3)	
LPP in previous pregnancy	1.7 (1.6–1.8)	< 0.01*	1.4(1.3–1.5)	< 0.01*
Smoking	1.3 (1.2–1.4)		1.1(1.0-1.2)	
Alcohol user	1.4 (1.3–1.6)		1.2 (1.1–1.3)	
Educational Levels \geq high school/university	1.2 (1.1–1.3)		1.0 (0.9–1.1)	
Cesarean delivery	1.3 (1.2–1.4)		1.0 (0.9–1.1)	
Primigravida	1.4 (1.3–1.5)		1.1 (1.0-1.2)	
Sick leave \geq 90 days	1.5 (1.4–1.6)	< 0.05*	1.2 (1.1–1.3)	< 0.05*
Heavy labor	1.6 (1.5–1.7)	< 0.05*	1.2 (1.1–1.3)	< 0.05*
*indicates statistically significant. # fully adjusted by confounding factors. Odds ratios, as well as 95% CI, were showed. OR = Odds Ratios, LBP = Low Back Pain, LP = Lumbar Pain, PPP = Posterior Pelvic Pain, CP = Combined Pain, BMI = Body Mass Index.				

Linear regression analysis between paraspinal asymmetry and pain ratings

In patients with LBP, the level of paraspinal asymmetry, represented by the difference in F/T-CSA, was positively correlated with pain scores ($r = 0.52$, $p < 0.01$). However, no statistically significant correlation between pain scores and paraspinal asymmetry was found in PGP ($r = 0.42$, $p \geq 0.05$).

Discussion

This study investigated the asymmetry in the paraspinal muscle before pregnancy by measuring the T-CSA, F-CSA, and F/T CSA of multifidus, erector spinae, and psoas muscles on the digital image of MRI and evaluated its association with LPP during pregnancy. The measurement repeatability for these parameters was good, meaning that the present assessments were reliable. Due to the lack of research about the asymmetry in the paraspinal muscle in pregnant women, we have to compare our results with other similar studies that focused on this condition in other population, such as non-specific LBP [24], chronic LBP [25, 28], lumbar disc pathology [27] and acute LBP [28]. In general, our results are consistent with these studies that there is a reduction of CSA, especially F-CSA, in the paraspinal muscles of the pain in unilateral LBP or more pain in the bilateral side. Although similar results about this data, there were seemingly totally different explanations for pregnant populations and non-pregnant populations.

The mechanism behind the occurrence of muscular asymmetry is complex and remains unclear at present. First, a decreased CSA of the paraspinal muscles in LBP, whether specific or non-specific, might arise from the disuse atrophy from the pain stimulation [26–28]. Second, the authors assumed that this phenomenon might also result from an inhibition along a long-loop reflex to protect the pain side's impaired muscles, whether acute or chronic [28]. Third, another research suggested that the side-related reduction in the paraspinal muscle could be associated with the degenerative changes of the lumbar discs and radiculopathy [29, 30]. Namely, nerve root irritation or compression could occur and lead to denervation of the muscle by the nerve root or dorsal ramus injury [31].

However, the prospective study where the CSA of the muscles was measured on the MRI scans before pregnancy revealed that pregnancy-related LPP might be closely associated with a reduction in stability due to the asymmetry in paraspinal muscles. Exactly why it is not known for the asymmetry, it could be caused by either pathological or non-pathological factors such as an imbalance in bilateral muscles around the spine from poor sitting posture. At this stage, the symptoms could be mild or not appear, which does not interfere with daily life. However, the physically adaptive changes, including abdominal and pelvic muscles stretch, uterus expansion, and increased joint laxity, such as the sacroiliac joint and symphysis pubis, significantly affect the spinal biomechanics [32, 33]. Under such a condition, the morphological change of the paraspinal muscle, which serves as one of the most important stabilizers [27, 28], could magnify the lumbar instability, and consequently, clinical manifestations as LPP and muscular atrophy appear. There could be a pathologically vicious cycle where the pain leads to muscle spasm and meanwhile inhibits the stabilizing muscles on the painful side, compensatory hypertrophy could occur on the non-painful side [27], and these changes further aggravate the imbalance of the paraspinal muscles, making the forces more vulnerable to atrophy.

Our results showed that significant side-to-side differences were found in F-CSA and the ratio of F-CSA to T-CSA, but not in T-CSA. Although parts of individuals have superior T-CSA of the paraspinal muscles, increased fatty infiltration and less muscular composition exist. This can be reflected more accurately by the lower F-CSA, especially F-CSA/T-CSA. Currently, the etiology of muscular fat filtration is far from clear [28]. Previous research has suggested it is likely multifactorial, such as altered differentiation of the fibroblasts after paraspinal muscle inflammation, age-related degeneration, and trauma [34]. More

muscular contents and less fat naturally have stronger stability for the spine, even when a pregnancy happens. However, the present findings that F-CSA/T-CSA was significantly decreased in LBP and PGP than those in the control group further added that asymmetrical muscular compositions could bring out the symptomatic LPP during the pregnancy.

When it comes to the regression of LPP after the childbirth, logistic regression analysis revealed that LBP (adjusted OR = 1.6), LPP in a previous pregnancy (adjusted OR = 1.4), sick leave \geq 90 days (adjusted OR = 1.2), and heavy labor (adjusted OR = 1.2), our findings were consistent with several previous studies [7–10, 12, 35]. Among these factors, LPP types, LBP or PGP, were considered as a primary reason for the substantially different regression. LBP does not regress as expected, whereas PGP usually diminishes about week 11 postpartum [14]. Our results showed asymmetry in F-CSA/T-CSA is a risk for the unrecovered LPP 2 years after the childbirth (adjusted OR = 1.5). OR values in LPP types and asymmetry in paraspinal muscle could reveal similar strengths of the association between this condition and exposures in the case-control study. Another analysis showed that the level of paraspinal asymmetry, represented by the difference in F-CSA/T-CSA, was positively correlated with pain scores, in LBP, instead of PGP [28]. This further confirmed the conclusions in previous studies that LBP and PGP arise from different mechanisms, despite it is not completely clear. Therefore, it is worthy of being postulated that asymmetrical muscles played various parts in the occurrence and development of these two types of pains.

There are several implications for the present findings. First, the present results may push forward the recognition of the mechanism for this disease. Asymmetrical muscular compositions could lead to abnormal biomechanics for the segmental motions. It is hard to say that a minor change in pathological morphology could not be magnified to incur the appearance of symptoms when a growing uterus happens. However, a biomechanical experiment in a further study is needed to know the whole clear picture behind these conditions. Besides, higher F-CSA/T-CSA, representing an increase in muscular deposition and reduction in fat infiltration, have better muscular contractility to stabilize the spine and thus make these women less likely to experience pain and segmental instability during the pregnancy. Based on this phenomenon, it is seemingly necessary for orthopedics or obstetricians to arrange women who have a high risk for developing severe LPP and unsatisfactory regression after childbirth, such as LPP in a previous pregnancy, heavy labor, and depression [10, 13, 35], with MRI scan to screen for asymmetrical muscles. Therefore, morphological parameters, mostly describing the muscle's contents, could be used for predicting the occurrence and development of pregnancy-associated with LPP. It might be helpful for those women to have the one-lateral-directed physical training and stretching to decrease the occurrence and severity of this condition.

Several limitations exist in our study. First, signal intensity was not measured, so that intramuscular fat filtration was neglected due to the applied methodology. However, the quantitative measurements on other parameters have provided adequate reliability and precision to find the differences between groups instead of qualitative evaluations. Second, a total of three muscles was compared as the whole instead of a particular muscle and that at each segment. Multifidus is reported as the primary respondents to the

pains or pathology among previous studies' paraspinal muscles [26–28]. Confirming these results needs further study, and it would reveal more detailed information about the mechanism of pregnancy-related LPP. Third, considering the small sample, we had to control the number of variables in the logistic analysis. This selection bias could decrease the reliability of the present results.

Conclusion

The ratio of F-CSA to T-CSA was significantly decreased in LBP than those in the PGP group and control group. Asymmetry in the paraspinal muscle (adjusted OR = 1.5), LBP (adjusted OR = 1.6), LPP in a previous pregnancy (adjusted OR = 1.4), sick leave \geq 90 days (adjusted OR = 1.2), and heavy labor (adjusted OR = 1.2) were risk factors for the unrecovered LPP during pregnancy. These findings may push forward the recognition of the mechanism for this disease. Asymmetrical muscular compositions could lead to abnormal biomechanics for the segmental motions. For those women, it might be helpful to have the one-lateral-directed physical training and stretching to decrease the occurrence and severity of this condition.

Abbreviations

LPP	Lumbopelvic pain
LBP	Low back pain
PGP	Posterior girdle pain
SD	Standard deviation
T-CSA	Total muscle CSA
F-CSA	Functional CSA
F/T CSA	The ratio of F-CSA to T-CSA
OR	Odds ratio
QoL	Quality of life
BMI	Body mass index
MRI	Magnetic resonance imaging
IBR	Institutional Review Board
CSA	Cross-sectional area
ICC	Intraclass correlation coefficient
CI	Confidence interval

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of the China-Japan Friendship Hospital. The study was performed under Helsinki's ethical principle. To preserve confidentiality, we coded each patient and removed their original identifications. Written informed consent was based on the hospital consent policy at the time of admission or clinic visit, in which patients consented to the analysis of their medical records. Our team acquired administrative permissions to access the data used in this research.

Consent to publish

Consent for publication was obtained for the patient in Figure 1.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to restrictions associated with the anonymity of participants but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no further competing interests.

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No funding was obtained for this study.

Authors' contributions

TM and GL participated in concept development, data generation, quality control of the data, data analysis and interpretation, and writing of the manuscript. GL and TM were responsible for the data analysis and participated in the interpretation and presentation of the data. GL, MH and YP provided input into the data interpretation. GL, YP, and TM were involved in the concept development, quality control of the data, and data analysis and interpretation of the manuscript. All authors have read and approved the final version of the submitted manuscript.

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Figures

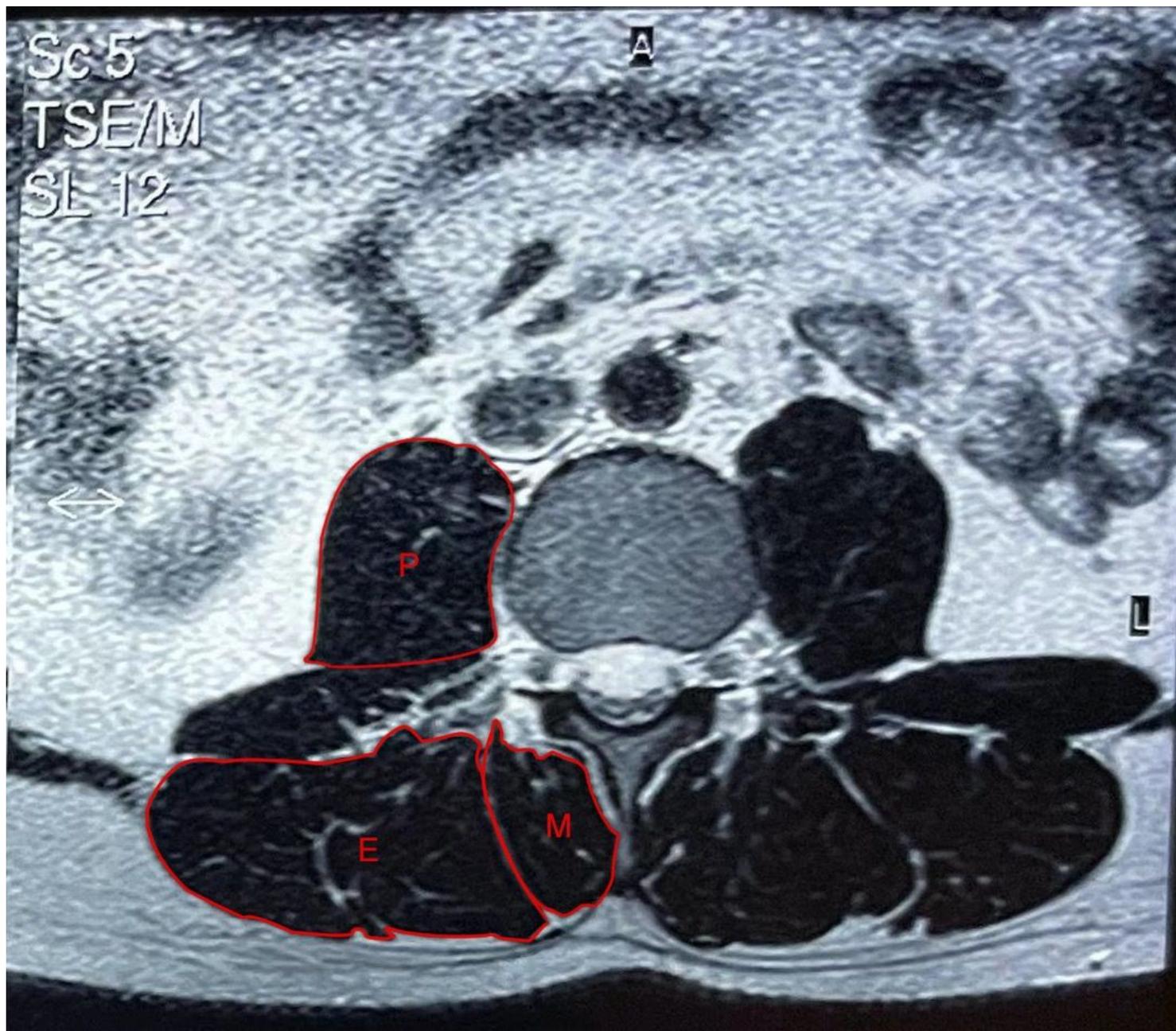


Figure 1

Erector spinae, multifidus, and psoas muscles were segmented separately on right and left sides on T2-weighted axial images.

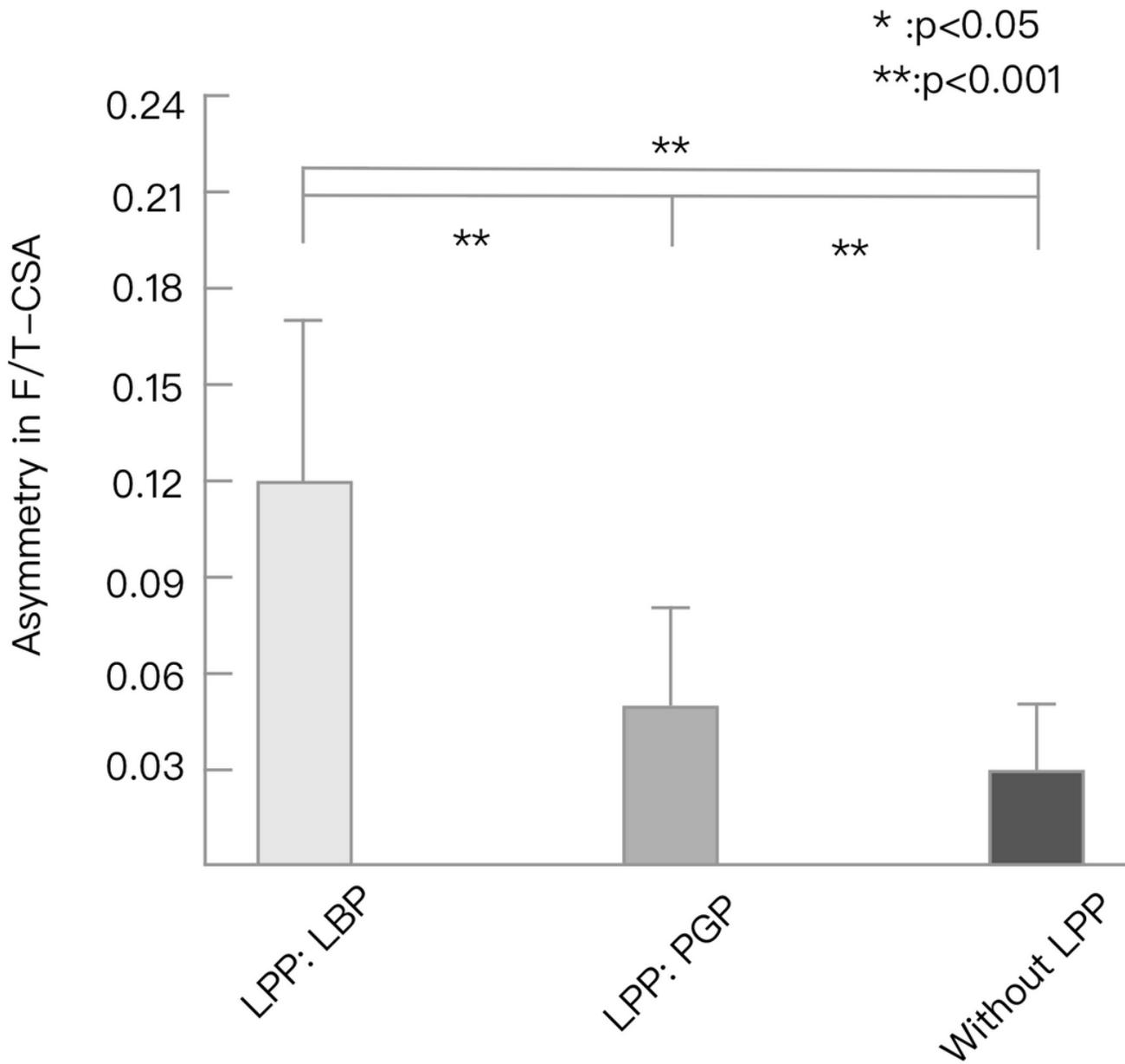


Figure 2

The percentage of different depression status in control group and case subgroups.

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