Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Analysis of Influencing Factors of Postpartum Diastasis Recti Abdominis Based on Ultrasound Assessment

Hongqin Tu
Wuhan Children's Hospital
Xiaohong Yang
Wuhan Children's Hospital
Cong Yao
Wuhan Children's Hospital
Liangping Zhao
Wuhan Children's Hospital
Shubo Li
2596965146@qq.com

Wuhan Hospital of Traditional Chinese Medicine

Research Article

Keywords: Rectus abdominis diastasis, postpartum, ultrasound examination, influencing factors

Posted Date: July 3rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10045538/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Diastasis recti abdominis (DRA) impairs long-term maternal health, yet its etiology and independent risk factors are unclear, hindering prevention. This study systematically evaluates multifactorial influences—including sociodemographic features, physiological changes in pregnancy, and obstetric history—to inform evidence-based, individualized preventive strategies.

Methods

A cross-sectional analysis was conducted involving 2,379 postpartum women. DRA width was measured via high-frequency ultrasound at five standardized sites along the abdominal midline. Correlation analyses were performed, with statistical significance defined as $P < 0.05$.

Results

Age demonstrated an inverted V-shaped association with DRA width, with a distinct peak observed at the umbilical site (site 3) among women aged 35–40 years ($P < 0.05$). Both body mass index (BMI) and gestational weight gain (GWG) were strongly correlated with greater DRA severity ($P < 0.001$). Among obstetric characteristics, gravidity was positively associated with DRA ($P < 0.05$), while higher parity and cesarean delivery were significantly related to increased inter-rectus distance ($P < 0.001$). Neonatal birth weight exhibited a weak positive correlation (r range: 0.059–0.149; $P < 0.01$). Although higher educational attainment and twin pregnancy tended to be associated with wider DRA measurements, these differences did not reach statistical significance ($P > 0.05$). No significant association was observed between miscarriage history and DRA width ($P > 0.05$).

Conclusion

DRA is independently influenced by a range of maternal and obstetric factors. Age, BMI, GWG, gravidity, parity, mode of delivery, and neonatal birth weight emerged as significant determinants, offering valuable evidence for targeted prevention and individualized intervention strategies.

Introduction

Diastasis recti abdominis (DRA) is a frequently encountered postpartum condition defined by pathological widening of the inter-rectus distance at the linea alba. Physiologic changes during pregnancy—including uterine expansion and hormonal shifts—can cause excessive stretching of the linea alba, compromising its connective integrity and predisposing to DRA[1]. The overall prevalence of postpartum DRA has been reported to exceed 60% [2].Beyond contributing to cosmetic deformities—

including abdominal wall laxity and widening of the waist—DRA is strongly linked to chronic low back pain, pelvic floor dysfunction, and abdominal herniation. Such sequelae substantially compromise physical function and quality of life in postpartum women, underscoring DRA as a growing public health concern. High-frequency ultrasound, owing to its accuracy and repeatability, is now regarded as the reference standard for DRA evaluation, allowing precise measurement of the inter-rectus distance and detailed assessment of abdominal wall architecture.[3]. Although DRA imposes a substantial clinical burden, the determinants of its development and progression are yet to be fully elucidated. A range of factors—including maternal age, delivery mode, neonatal birth weight, and parity—have been proposed as potential risk factors; however, the existing evidence remains inconclusive. Many studies are further constrained by methodological limitations, such as modest sample sizes or dependence on subjective palpation techniques, thereby limiting the broader applicability of their findings.[4]. This highlights the necessity of using large sample sizes for standardized ultrasound assessments to evaluate the severity of DRA and identify independent influencing factors. Therefore, this study aims to explore the independent influencing factors of postpartum DRA formation through systematic ultrasound assessment, providing evidence-based support for clinical prevention and treatment.

1 Materials and Methods

1.1 Study Subjects This study included 2,379 postpartum women who underwent postpartum examinations at the Gynecology Outpatient Department of Wuhan Children's Hospital from January to December 2024.Inclusion criteria include: (1) Delivered in our hospital and received postpartum review; (2) Normal muscle tone;(3) Not received systematic rectus abdominis postpartum rehabilitation treatment. Exclusion criteria include: (1) History of abdominal and pelvic cavity surgery other than cesarean delivery; (2) Presence of other diseases that may lead to long-term increased intra-abdominal pressure (such as cough, constipation, etc.); (3)Recently taken any medications affecting muscle thickness; (4) Presence of congenital abdominal wall muscle or nerve defects.

1.2 Instruments and Methods The Jiangsu Furui Biological Stimulation Feedback Instrument (Model DS-D) was used,The full digital ultrasound diagnostic instrument (Model Crobe-5w) is equipped with 7.5 MHz and 10 MHz high-frequency probes, with a scanning depth of 40 mm and a gain setting of 80 dB. Standard guidance is provided for postpartum women to fill in basic information, including body height, weight, neonatal birth weight, delivery methods, and obstetric history. The puerpera is positioned supine, maintaining a relaxed state of the rectus abdominis (supine, knees bent, with both hands placed at the sides of the body). The examiner uses a high-frequency ultrasound probe, applies ultrasound coupling agent, and places it on the midline of the abdomen. Subsequently, the distance between the rectus abdominis is measured at five points: 4-5 cm above the umbilicus, 2-3 cm above the umbilicus, at the umbilicus, 2-3 cm below the umbilicus, and 4-5 cm below the umbilicus (Figure 1). Static images are collected immediately at the end of the postpartum woman's exhalation, freezing the frame, clicking on measurement, and distance, and then measuring the horizontal distance between the inner borders of the rectus abdominis, which is the inter-rectus distance (IRD) at that level.

1.3 DRA diagnostic criteria DRA diagnostic criteria refer to expert consensus [5], dividing the affected areas of DRA into subxiphoid, upper abdomen, umbilical, below the umbilicus, and above the pubic symphysis. At any location at the umbilical ring, 3 cm above or 3 cm below the umbilical ring, if IRD >20 mm in the resting state, it is diagnosed as umbilical DRA. If IRD > 20 mm in the resting state at 5 cm above the umbilical ring, it is diagnosed as suprumbilical DRA, and if IRD > 20 mm in the resting state at 5 cm below the umbilical ring, it is diagnosed as infraumbilical DRA. Clinically, an IRD of 21-30 mm is generally considered mild DRA, 31-50 mm is moderate DRA, and >50 mm is severe DRA.

1.4 Statistical Methods This study used SPSS 22.0 software to conduct normality tests on continuous data. Data that conform to normal distribution are expressed as mean ± standard deviation (X ±s), while non-normally distributed data are represented by interquartile range (IQR), and categorical data are described using frequency (f). The correlation between indicators was assessed using Spearman correlation analysis. The differences between two groups of continuous variables were analyzed using the Mann-Whitney U test, and multiple group comparisons were performed using the Kruskal-Wallis test. Ordered logistic regression analysis was used to evaluate the impact of various indicators on DRA, with $P<0.05$ indicating statistical significance.

2 Results

2.1 General condition of the patient

A total of 2,379 postpartum women (median age: 35 years; all < 50 years) were enrolled. DRA severity was graded as none (0.55%, n = 13), mild (14.92%, n = 355), moderate (62.55%, n = 1,488), or severe (21.98%, n = 523); moderate separation predominated, while absent separation was exceedingly rare, and the substantial proportion (22%) with severe DRA underscores a high-risk subset warranting focused clinical attention. More than half (57%) of participants held a bachelor’s degree or higher, twin pregnancies accounted for 0.84% of the sample, 40.99% were multiparous (≥ second delivery), 18.79% reported a history of miscarriage, and 56.41% had undergone vaginal delivery. Pre-pregnancy body mass index (BMI) was stratified into underweight, normal, overweight, and obese categories. Gestational weight gain (GWG) was classified as insufficient, appropriate, or excessive according to pre-pregnancy BMI, with recommended total weight gain as follows: underweight (BMI < 18.5): 12.5–18.0 kg; normal (18.5–23.9): 11.5–16.0 kg; overweight (24.0–27.9): 7.5–11.5 kg; obese (≥ 28.0): 5.0–9.0 kg. Although 58.09% of women had a normal pre-pregnancy BMI and 28.63% were overweight, only 33.84% achieved GWG within the recommended range, and nearly half (49.60%) exceeded the guidelines(Table 1).

Table 1
Grouping by Frequency and Percentage in a Population with Diastasis Recti

Number of miscarriages (times)	Group	Frequency	Percentage
	0	1932	
	1	305	
	2	103	4.33
	>=3	39	1.64
Number of deliveries (times)	1	1774	74.57
	2	570	23.96
	>=3	35	1.47
Number of pregnancies (times)	1	1406	59.10
	2	558	23.46
	3	263	11.06
	4	114	4.79
	>=5	38	1.06
	Normal	1382	58.09
	Weight loss	137	5.76
BMI	Overweight	681	28.63
	Obesity	179	7.52
	Junior high school and below	143	6.01
Educational level	High school	196	8.24
	Vocational college	682	28.67
	Bachelor's degree	1085	45.61
	Master's degree or above	273	11.48
	~ 25	115	4.83
Age group	25–30	979	41.15
	30–35	987	41.49
	35–40	225	9.46
	40–50	73	3.07
	Normal	805	33.84

Weight gain (Kg)	Insufficient increase	394	16.56
	Increase excess	1180	49.60
	Single fetus	2359	99.16
Single and multiple pregnancies	Twin pregnancy	20	0.84
	Vaginal delivery	1342	56.41
Delivery method	Cesarean section	1037	43.59

2.2 Demographic and Social Factors

2.2.1 The research results of different age groups show that the width of rectus abdominis separation from site 1 to site 4 presents an inverted "V" shaped curve with increasing age($P < 0.001$). The separation width peaks in the 35–40 age group (with a peak of 4.17 cm at site 3), and then significantly decreases; the values in the 40–50 age group are the lowest. The differences between each site group are statistically significant ($P < 0.05$), indicating that age is an independent influencing factor for postpartum rectus abdominis separation. (Table 2).

Table 2
Effect of Age on Different Sites of the Rectus Abdominis

Indicator	**~ 25**	**25–30**	**30–35**	**35–40**	**40–50**	**P**
Part 1	2.88[2.3, 3.81]	3.01[2.39, 3.77]	3.05[2.34, 3.87]	3.17[2.46, 4.08]	2.48[1.86, 3.09]	< 0.001
Part 2	3.33[2.79, 4.1]	3.42[2.77, 4.17]	3.52[2.83, 4.3]	3.72[2.95, 4.49]	2.83[2.42, 3.4]	< 0.001
Part 3	3.79[3.21, 4.71]	3.92[3.22, 4.72]	4.01[3.33, 4.86]	4.17[3.4, 5.23]	3.24[2.83, 4.04]	< 0.001
Part 4	2.74[2.2, 3.62]	2.79[2.15, 3.59]	2.86[2.19, 3.67]	2.9[2.26, 3.78]	2.31[1.86, 2.96]	< 0.001
Part 5	2.08[1.46, 2.63]	2.01[1.51, 2.65]	2.06[1.56, 2.66]	2.03[1.43, 2.79]	1.63[1.32, 2.17]	0.013

2.2.2 This study simultaneously investigated the measurement of diastasis recti abdominis width in postpartum women with different educational backgrounds. The results showed that the width of diastasis recti abdominis tended to increase with higher education levels. Furthermore, the group with a master's degree or higher had a more severe diastasis recti abdominis width. The results suggested a potential lack of significant correlation between educational attainment and factors influencing DRA, although this difference did not reach statistical significance.(Table 3).

Table 3
Impact of Educational Level on Different Parts of the Rectus Abdominis Muscle

Indicator	Junior high school and below	High school	Vocational college	Bachelor's degree	Master's degree or above	P
Part 1	2.95[2.26, 3.58]	2.92[2.28, 3.83]	3.05[2.43, 3.78]	3.01[2.31, 3.85]	3.1[2.41, 4]	0.370
Part 2	3.35[2.7, 4.34]	3.34[2.74, 4.2]	3.51[2.82, 4.23]	3.44[2.77, 4.23]	3.59[2.87, 4.33]	0.474
Part 3	3.87[3.07, 4.86]	3.99[3.21, 4.72]	3.96[3.29, 4.81]	3.94[3.25, 4.8]	4.04[3.35, 4.96]	0.497
Part 4	2.66[2.13, 3.39]	2.71[2.17, 3.53]	2.87[2.2, 3.62]	2.81[2.15, 3.65]	2.88[2.2, 3.79]	0.218
Part 5	1.99[1.51, 2.57]	2.01[1.54, 2.58]	2.06[1.55, 2.69]	2.03[1.47, 2.66]	2.03[1.56, 2.67]	0.678

2.3 Physiological Factors

This study uses multi-site ultrasound measurements and inter-group analysis methods to explore the effects of postpartum BMI and GWG on postpartum DRA. BMI is divided into four groups: underweight, normal, overweight, and obese, while GWG is divided into three groups: insufficient gain, normal gain, and excessive gain. The comparison of DRA width at five sites of mothers grouped by BMI classification shows that DRA width increases sequentially with higher BMI (underweight < normal < overweight < obese).At the umbilical region (site 3), the RA width in the obesity group increased by 0.52 cm compared to the normal group (an increase of 14%). The differences between groups at each site were statistically significant ($P < 0.001$), as shown in Table 4. For GWG and DRA width, a consistent trend of "insufficient increase < normal increase ≈ excessive increase" was observed. In comparison to the umbilical DRA width, it can be seen that the excessive GWG group had a width increase of 0.35 cm compared to the insufficient GWG group, and the differences between all site groups were highly statistically significant ($P < 0.001$), as shown in Table 5. The results confirm that BMI and GWG are independent quantitative influencing factors of postpartum RA.

Table 4
The effects of different BMI on various regions of the rectus abdominis.

Indicator	Normal	Weight loss	Overweight	Obesity	P
Part 1	2.93[2.3, 3.68]	2.78[2.26, 3.59]	3.21[2.51, 4.05]	3.36[2.62, 4.21]	< 0.001
Part 2	3.35[2.69, 4.07]	3.16[2.55, 3.96]	3.69[2.94, 4.52]	3.79[3.11, 4.61]	< 0.001
Part 3	3.84[3.15, 4.62]	3.78[3.05, 4.47]	4.2[3.45, 5.18]	4.36[3.66, 5.4]	< 0.001
Part 4	2.69[2.1, 3.48]	2.75[2.03, 3.25]	2.93[2.3, 3.78]	3.17[2.45, 3.97]	< 0.001
Part 5	1.96[1.47, 2.57]	1.85[1.35, 2.45]	2.14[1.64, 2.81]	2.29[1.83, 3.23]	< 0.001

Table 5
Effects of GWG during Various Pregnancy Stages on Specific Regions of the Rectus Abdominis

Indicator	Normal	Insufficient increase	Increase excess	P
Part 1	3.10[2.37, 3.86]	2.71[2.19, 3.4]	3.11[2.41, 3.88]	< 0.001
Part 2	3.46[2.79, 4.22]	3.19[2.61, 3.95]	3.55[2.86, 4.35]	< 0.001
Part 3	3.94[3.24, 4.66]	3.72[3.05, 4.48]	4.07[3.35, 5.01]	< 0.001
Part 4	2.79[2.18, 3.56]	2.64[2.01, 3.4]	2.90[2.23, 3.75]	< 0.001
Part 5	2.01[1.48, 2.62]	1.89[1.41, 2.44]	2.10[1.59, 2.75]	< 0.001

2.4 Pregnancy-related factors

2.4.1 This cross-sectional study simultaneously assessed the association between gravidity and DRA width, and the results showed a significant impact relationship. With the increase in the number of deliveries, the separation width at all five anatomical sites showed an upward trend($P < 0.05$). Specifically, the separation widths at umbilical Sites 2 and 3 exhibited a marked increasing trend, whereas the width at Site 4 demonstrated a slight reduction or stabilization ($P < 0.001$). (Table 6.)

Table 6
Effects of Pregnancy Frequency on Different Regions of the Rectus Abdominis Muscle

Indicator	1	2	3	4	>=5	P
Part 1	2.96[2.32, 3.70]	3.15[2.38, 4.06]	3.16[2.52, 4.15]	2.96[2.39, 3.99]	3.05[2.73, 3.75]	0.001
Part 2	3.38[2.74, 4.08]	3.58[2.85, 4.43]	3.71[2.85, 4.58]	3.45[2.81, 4.36]	3.73[3.17, 4.50]	< 0.001
Part 3	3.88[3.21, 4.69]	4.07[3.31, 4.98]	4.19[3.30, 5.18]	3.99[3.32, 4.72]	4.06[3.51, 5.30]	< 0.001
Part 4	2.74[2.12, 3.52]	2.97[2.23, 3.84]	3.01[2.27, 3.88]	2.61[2.11, 3.49]	2.94[2.41, 3.71]	< 0.001
Part 5	2.00[1.50, 2.61]	2.07[1.56, 2.81]	2.09[1.52, 2.87]	2.01[1.52, 2.60]	2.38[1.90, 2.87]	0.023

2.4.2 Parity was found to be significantly and positively associated with the severity ofDRA. Inter-rectus distances at all measurement sites increased consistently with increasing parity, with inter-group differences reaching statistical significance ($P < 0.001$). The umbilical site (site 3) displayed the most pronounced separation. While site 4 showed more modest differences, a progressive widening was still evident; site 5, though least affected, also exhibited a detectable deteriorating trend (Table 7).

Table 7
Effects of Delivery Frequency on Different Regions of the Rectus Abdominis Muscle

Indicator	1	2	>=3	P
Part 1	2.96[2.31, 3.69]	3.29[2.53, 4.2]	3.41[2.23, 4.79]	< 0.001
Part 2	3.37[2.73, 4.09]	3.76[3.02, 4.66]	3.75[2.67, 4.8]	< 0.001
Part 3	3.87[3.2, 4.67]	4.27[3.49, 5.23]	4.15[3.25, 5.27]	< 0.001
Part 4	2.73[2.13, 3.52]	3.07[2.34, 3.99]	2.84[2.17, 3.66]	< 0.001
Part 5	1.99[1.5,2.6]	2.14[1.59, 2.97]	2.18[1.68, 2.79]	< 0.001

2.4.3 This study found that the mode of delivery has an impact on the degree of postpartum DRA, with the DRA width at all sites in the Cesarean delivery group being greater than that in the Natural labor group, with the most significant increase observed in the upper abdomen (sites 1–3). The differences between all groups were statistically significant (P < 0.001). It can be seen that the mode of delivery is an independent influencing factor for postpartum diastasis recti, and Cesarean delivery is associated with a more severe degree of separation. (Table 8).

Table 8
Effects of delivery method on different regions of the rectus abdominis muscle

Indicator	Vaginal delivery	Cesarean section	P
Part 1	2.88[2.22, 3.61]	3.28[2.55, 4.03]	< 0.001
Part 2	3.30[2.62, 4.01]	3.71[3.01, 4.51]	< 0.001
Part 3	3.78[3.10, 4.54]	4.18[3.49, 5.16]	< 0.001
Part 4	2.62[2.05, 3.39]	3.04[2.34, 3.87]	< 0.001
Part 5	1.92[1.41, 2.49]	2.18[1.68, 2.91]	< 0.001

2.4.4 In the study, compared with the singleton pregnancy group, the DRA width in the twin pregnancy group was generally larger, but there was no statistical difference. In addition, twin pregnancy had a more significant impact on the separation of the rectus abdominis in the mid-abdominal region (location 2–4) (Table 9).

Table 9
Effects of singleton and twin pregnancies on different regions of the rectus abdominis muscle

Indicator	Single fetus	Twin pregnancy	P
Part 1	3.02[2.36, 3.83]	3.4[2.48, 4.13]	0.357
Part 2	3.47[2.79, 4.24]	3.94[3.21, 5.01]	0.071
Part 3	3.96[3.25, 4.81]	4.66[3.72, 5.3]	0.076
Part 4	2.81[2.17, 3.62]	3.20[2.34, 4.31]	0.140
Part 5	2.02[1.52, 2.66]	2.22[1.71, 3.55]	0.147

2.4.5 The study found that the body weight of newborns has a weak positive correlation with the postpartum DRA width at all sites (r value: 0.059–0.149; P < 0.005). Among them, the correlation at the umbilical region (site 3) is the strongest (r = 0.149). Although the clinical effect size is limited, the umbilical region is relatively significantly influenced by fetal volume (Table 10).

Table 10
Effects of neonatal body weight on different regions of the rectus abdominis muscle

	Indicator	Part 1	Part 2	Part 3	Part 4	Part 5
Neonatal	r	0.098	0.101	0.149	0.096	0.059
weight	p	< 0.001	< 0.001	< 0.001	< 0.001	0.004

2.4.6 The study compared the effect of the number of miscarriages on the width of diastasis recti in the postpartum period. The differences were not statistically significant. The results showed that there were no statistically significant differences in the width of diastasis recti among the groups with 0, 1, 2, and ≥ 3 miscarriages at all five measurement sites (P > 0.05)(Table 11)

Table 11
Effects of Abortion Frequency on Different Regions of the Rectus Abdominis Muscle

Indicator	0	1	2	>=3	P
Part 1	3.01[2.34, 3.81]	3.16[2.45, 4.02]	2.94[2.25, 3.79]	2.95[2.48, 3.66]	0.339
Part 2	3.45[2.78, 4.22]	3.63[2.80, 4.34]	3.54[2.85, 4.39]	3.40[2.88, 4.21]	0.207
Part 3	3.95[3.23, 4.79]	4.11[3.35, 4.99]	4.06[3.15, 4.80]	3.72[3.43, 5.08]	0.137
Part 4	2.80[2.16, 3.64]	3.01[2.22, 3.66]	2.70[2.12, 3.54]	2.61[2.08, 3.18]	0.395
Part 5	2.03[1.53, 2.66]	2.07[1.51, 2.62]	2.02[1.43, 2.59]	1.98[1.47, 2.85]	0.994

3 Discussion

Diastasis recti abdominis is one of the most common complications associated with pregnancy-related abdominal wall adaptation, with an incidence rate as high as 60–70%[6]. Diagnosis of diastasis recti typically involves palpation, computed tomography (CT), or magnetic resonance imaging (MRI). Palpation offers simplicity, though its reliability may be limited by abdominal adiposity and examiner skill. CT presents concerns regarding radiation exposure, whereas MRI avoids radiation but incurs higher costs. In clinical practice, MRI is generally restricted to preoperative assessment in complex presentations—such as suspected malignancy or patients with a history of multiple abdominal operations—and is therefore not recommended for routine screening purposes.[7].In this study, high-frequency ultrasound was used to conduct a standardized, multi-point quantitative evaluation of DRA. The method provides precise measurements of the inter-rectus distance at rest while permitting dynamic assessment of linea alba morphology during maneuvers that alter intra-abdominal pressure. High-frequency ultrasound, due to its objective, non-invasive, precise, and repeatable characteristics, demonstrates significant clinical diagnostic value in DRA research[8]. A five-point measurement protocol was adopted, evaluating the inter-rectus distance at the following locations: 4–5 cm above the umbilicus, 2–3 cm above the umbilicus, at the umbilicus, 2–3 cm below the umbilicus, and 4–5 cm below the umbilicus. This multi-site design advances beyond the conventional single-point umbilical assessment, systematically delineating a gradient in the distribution of DRA along the midline. The model offers a refined framework for interpreting regional biomechanical function: the upper abdominal segments (sites 1–2) are principally influenced by the structural constraint of the costal margin; the umbilical region (site 3) acts as a focal zone for intra-abdominal pressure transmission; and the lower abdominal segments (sites 4–5) are closely linked to integrated pelvic and abdominal wall dynamics. Analysis of contributing factors further elucidated DRA risk profiles and underscored the complexity of their interactions. Importantly, the effect of each factor was found to be site-specific, varying according to the anatomical level measured.

3.1 Demographic and Social Factors

This study utilized multi-site ultrasonography and trend analysis to examine the influence of age and educational attainment on the severity of postpartum DRA. While existing literature [9]commonly reports a positive correlation between age and DRA severity—attributed to age-related declines in muscle mass and density—the rectus abdominis, as a key abdominal muscle group, may serve as a sentinel for sarcopenia and metabolic disturbances. Nonetheless, stratified investigations targeting women over 35 years remain sparse, with particularly limited data on advanced maternal age [10]. Age-stratified analysis across the reproductive continuum revealed an inverted V-shaped association between age and DRA width, peaking in the 35–40 year stratum. This nonlinear pattern may reflect a metabolic inflection in collagen homeostasis during this decade. Fibroblast activity declines substantially, impairing the synthesis of both type I collagen—the predominant structural isoform—and type III collagen, which is critical for fascial elasticity. As the primary fibrous bridge between the rectus abdominis muscles, the linea alba is particularly vulnerable to such shifts; diminished collagen production and elastic compromise likely underpin the progressive loss of tensile strength in the abdominal midlinee[11]

Interestingly, DRA width regressed in participants older than 40 years. This observation may reflect, in part, the modest sample size of this subgroup or residual confounding by parity and BMI. Nonetheless, our findings are consistent with a prior cross-sectional analysis of 644 women undergoing abdominal computed tomography, in which age-stratified DRA prevalence declined progressively: 50.9% among those < 45 years, 24.6% among those 45–59 years, and 22.7% among those ≥ 60 years[12]. While accumulating evidence positions age as a protective factor for DRA, the regression observed in the older cohort of the current study warrants further investigation.

Although no statistically significant relationship was identified between educational level and the severity of diastasis recti abdominis (DRA), a positive trend emerged: DRA width increased with advancing education, most notably among women with a master's degree or higher. This pattern runs counter to the well-established health sociology principle that higher education typically confers better health outcomes. It may instead reflect distinct reproductive-related behaviors among highly educated Chinese women, such as delayed childbearing, extended occupational sitting, and the dual burden of childcare and professional responsibilities[13]. The underlying mechanisms may include: the decrease in muscle elasticity due to aging; the disruption of biomechanical balance in the abdominal core muscle group caused by prolonged sitting; and chronic stress leading to changes in hormone levels and mechanical stress, which in turn affect the repair process of abdominal connective tissue. Prolonged sitting causes long-term contraction of the abdominal core muscle group, obstructing local blood circulation, which then triggers micro ischemia and oxidative stress reactions in muscle tissue. These changes accelerate the degradation of muscle proteins, especially the atrophy of fast-twitch muscle fibers. As a result, both muscle endurance and strength are affected. During pregnancy, the abdominal wall tissue is stretched and thinned, and during the recovery period, the function of the core muscle group becomes imbalanced, further exacerbating the separation of the rectus abdominis [14].Several mechanistic pathways may explain this association. First, delayed childbearing coincides with age-related loss of connective tissue elasticity, undermining abdominal wall structural integrity. Second, prolonged sitting maintains the core musculature in a state of sustained contraction, compromising local perfusion and triggering micro-ischemia and oxidative stress. These insults accelerate muscle protein catabolism and fast-twitch fiber atrophy [14]. Chronic stress further impedes DRA recovery via dual neuroendocrine and biomechanical routes.It stimulates the hypothalamic-pituitary-adrenal (HPA) axis, raising cortisol levels, suppressing fibroblast function, and activating matrix metalloproteinases (MMPs), thereby promoting collagen breakdown and diminishing tissue repair capacity [15]Concurrently, stress-driven aberrant breathing patterns—chiefly thoracic breathing—and anxiety-induced muscle tension provoke recurrent spikes in intra-abdominal pressure, worsening DRA and delaying abdominal wall healing [16]. Pregnancy itself thins and stretches the abdominal wall, and postpartum core muscle imbalance perpetuates DRA severity.

Notably, while highly educated postpartum women show higher DRA detection rates, a distinction between true prevalence and detection rate warrants attention. This group exhibits greater adherence to postnatal follow-up, and variations in education and health literacy may lead to differential recognition of

occult disease. Future investigations should incorporate social stratification frameworks to better delineate the complex interplay between educational attainment and DRA

3.2 Analysis of the multi-pathway mechanism of physiological factors

This study identified strong correlations between BMI, gestational GWG, and the severity of DRA, highlighting a synergistic interplay between metabolic factors and mechanical load in DRA pathogenesis. Biomechanically, obesity and excessive GWG not only mechanically stretch the linea alba via elevated intra-abdominal pressure but also shift the trunk's center of gravity, leading to compensatory lumbar lordosis and heightened abdominal wall shear stress—both of which exacerbate DRA[17]. At the molecular level, adipose-derived pro-inflammatory cytokines (e.g., TNF-α, IL-6) may activate extracellular matrix-degrading enzymes through the NF-κB pathway, resulting in disorganized and fragmented collagen fibers, compromised linea alba integrity, and diminished tensile strength[18].This aligns with findings from international studies reporting significantly lower collagen content in the supra-umbilical linea alba of obese individuals compared to age-matched non-obese controls[19]. Although an early investigation with limited sample size found no significant differences in pre-pregnancy BMI, GWG, or abdominal circumference between women with and without DRA[20]. our large-scale data revealed that the statistically significant difference in DRA width between excessive and insufficient GWG groups warrants clinically nuanced interpretation—specifically, one that accounts for pre-pregnancy BMI. These findings underscore the need for BMI-stratified GWG targets and the urgent development of a GWG-DRA dose–response curve tailored to Chinese populations.Moreover, fat distribution patterns—particularly the visceral-to-subcutaneous fat ratio—may offer superior predictive value for DRA risk compared to overall adiposity, a hypothesis requiring validation using advanced imaging techniques such as CT or MRI. Future research should also investigate sociobehavioral determinants of GWG adherence and rigorously assess the efficacy of structured weight management interventions in improving pregnancy outcomes and mitigating postpartum DRA, thereby informing evidence-based updates to clinical guidelines and public health policies.

3.3 Biomechanical and histological mechanisms related to pregnancy factors

Conventional obstetric determinants—namely parity, mode of delivery, neonatal birth weight, and multiple gestation—are widely recognized as direct contributors to DRA and have been the subject of extensive investigation. Although accumulating evidence suggests that higher parity, cesarean delivery, increased neonatal birth weight, and multifetal pregnancy are associated with elevated DRA risk, robust, large-scale evidence remains scarce[21]. The current study identified a distinct dose–response relationship between parity and DRA severity, reinforcing the notion of cumulative gestational insult to the abdominal wall. Increasing parity was accompanied by progressive disorganization of collagen fibers and heightened elastic fiber fragmentation within the linea alba.

With respect to delivery mode, cesarean section is consistently reported to confer greater DRA aggravation than vaginal delivery. Prior work has demonstrated more pronounced fascial remodeling in women delivered by cesarean section relative to those delivering vaginally [22]. One of the reasons for the differences in delivery methods may be that the cesarean section technique creates scar tissue, primarily affecting the fascia. The abdominal muscles and thoracolumbar fascia, along with the abdominal fascia, form a continuous structure, and the integrity of the fascia ensures the high coordination of these abdominal muscle groups[23]. Second, in addition to direct injury to the rectus abdominis muscle, cesarean section may exert site-specific effects on the mid-to-upper abdomen. The surgical incision frequently compromises the dense periumbilical network of perforating branches of the inferior epigastric artery and their accompanying nerves, precipitating localized ischemia and hypoxia. This microvascular and neural insult impairs collagen synthesis and reparative capacity within the rectus sheath, while aberrant innervation may precipitate muscle atrophy and functional decline. Moreover, the influence of cesarean section may be modulated by procedural history; primary and repeat cesarean deliveries may confer distinct patterns of abdominal wall compromise, a possibility warranting exploration in adequately powered subgroup analyses.

Twin gestation, elevated neonatal birth weight, increased uterine height, and enlarged abdominal circumference have been identified as risk factors for postpartum DRA [24]. Excess fetal weight or twin pregnancy substantially increases uterine height and abdominal girth, imposing sustained, supraphysiologic tensile forces on the abdominal wall. This chronic overstretch elongates and thins the linea alba, disrupts its microarchitecture, and exacerbates DRA[25]. In twin pregnancies, the uterus assumes a transversely oval configuration, generating focal stress concentrations and mechanical overload in the periumbilical zone. Such regional strain provokes excessive rectus abdominis stretching —particularly affecting the mid-abdomen—and underscores the contribution of uterine geometry to DRA pathogenesis. Although twin pregnancies demonstrated greater DRA widths than singletons, this difference lacked statistical significance, likely reflecting the earlier delivery typical of multifetal gestations. Clinically, these findings advocate for closer surveillance of fetal abdominal circumference and positioning, and support the construction of integrated prediction models that incorporate these anthropometric indices.

A history of miscarriage exhibited no significant association with DRA severity, possibly owing to the minimal abdominal wall load imposed during early pregnancy. Notably, the type of pregnancy loss warrants differentiation, as early spontaneous abortion and mid-trimester termination may exert disparate, dose-dependent biomechanical effects. Moreover, women with recurrent miscarriage often demonstrate enhanced health vigilance, including rigorous preconception preparation and postpartum rehabilitation—behaviors that may partially mitigate mechanical injury.

Conclusion

Diastasis recti abdominis (DRA) represents a fundamental disruption of the structural and functional integrity of the abdominal core. Its etiology is multifactorial, encompassing anatomical, hormonal, and

biomechanical contributors. Despite its clinical significance, large-scale, multifactorial investigations into DRA remain limited.This cross-sectional study of 2,379 postpartum women employed standardized multi-site ultrasonography to objectively quantify DRA severity and identify associated factors. Key findings revealed a nonlinear, inverted V-shaped relationship between age and DRA severity, with a distinct peak in the 35–40 year stratum. Educational attainment demonstrated a positive but statistically non-significant association with DRA severity. Higher BMI, excessive gestational weight gain, increased parity and gravidity, and cesarean delivery were each consistently linked to greater DRA severity. Neonatal birth weight exhibited only a weak positive correlation, whereas twin pregnancy and miscarriage history showed no appreciable effect.These findings carry important clinical implications. They underscore the necessity of targeted antenatal surveillance and postpartum intervention—particularly in mitigating risk factors such as advanced maternal age, excessive weight gain, high parity, and cesarean sections performed without clear medical indication. A biopsychosocial framework is advocated to holistically reduce DRA burden. By illuminating previously underexplored dimensions—notably the nonlinear age trajectory and the role of sociodemographic factors—this study advances the translation of epidemiological insights into actionable clinical strategies. The resultant risk profile contributes to a personalized prevention paradigm.

Several limitations warrant consideration. The cross-sectional design precludes causal inferences, and the single-center recruitment may constrain generalizability, particularly given regional diversity in perinatal practices and physique across China. Longitudinal cohort studies commencing in early pregnancy are urgently needed to characterize the temporal progression of abdominal wall changes. Such research will be pivotal in shifting DRA prevention and treatment from an empiric toward a precision-based model of care.

Abbreviations

DRA
Diastasis recti abdominis
BMI
Both body mass index
GWG
gestational weight gain
IRD
inter-rectus distance
CT
computed tomography
MRI
magnetic resonance imaging
HPA
hypothalamic-pituitary-adrenal
MMPs

matrix metalloproteinases
TNF-α
Tumor Necrosis Factor-α
IL-6
Interleukin-6
NF-κB
Nuclear Factor-kappa B

Declarations

Ethics approval and consent to participate

This study was reviewed and approved by the Ethics Committee of Wuhan Children's Hospital (Approval No. 2026R027-E01) and conducted in accordance with the Declaration of Helsinki. The requirement for individual written informed consent was waived by the Ethics Committee, as this is a retrospective study using fully anonymized clinical data — all data were de-identified prior to analysis, precluding any linkage to individual patients. This waiver decision, made by the Ethics Committee in the exercise of its institutional review authorities, is in accordance with Article 39 of the Measures for Ethical Review of Biomedical Research Involving Human Subjects (National Health Commission of the People's Republic of China, 2016; Order No. 11), which allows ethics committees to approve the waiver of informed consent for research using data where participants cannot be retraced and the study does not involve personal privacy or commercial interests. It is also consistent with the Measures for Ethical Review of Life Science and Medical Research Involving Human Subjects (National Health Commission of the People's Republic of China, 2023; Document No. NHC-SE-2023-4), which permits the use of anonymized information data in research without compromising participant privacy, thereby supporting the waiver of informed consent for such studies.

Consent for publication

Not Applicable. No identifiable images or personal/clinical details that could compromise participant anonymity are presented in this manuscript.

Competing interests

Hongqin Tu, Xiaohong Yang, Cong Yao, Liangping Zhao and Shubo Li declare that they have no conflict of interest.

Funding

This work was supported by the National Key R&D Program of China (Grant No. 2023YFC2706003).

Author Contribution

Hongqin Tu and Xiaohong Yang conceived and designed the study. Hongqin Tu filtered and downloaded data. Cong Yao analyzed the data. Hongqin Tu and Xiaohong Yang wrote the original draft of the manuscript.Liangping Zhao and Shubo Li revised the manuscript. All authors have read and approved the final manuscript.

Acknowledgement

The authors would like to acknowledge Wuhan Children's Hospital for providing the clinical data and research infrastructure.

Data Availability

Available from the corresponding author upon reasonable request, with permission from the Wuhan Children's Hospital Ethics Committee / Medical Records Department.

References

1. Cavalli M, Aiolfi A, Bruni PG, et al. Prevalence and risk factors for diastasis recti abdominis: a review and proposal of a new anatomical variation. Hernia. 2021;25(4):883–90.
2. perstad JB, Tennfjord MK, Hilde G, et al. Diastasis recti abdominis during pregnancy and 12 months after childbirth: prevalence,risk factors and report of lumbopelvic pain. Br J Sports Med. 2016;50(17):1092–6.
3. Tung RC, Towfigh S. Diagnostic techniques for diastasis recti. Hernia. 2021;25(4):915–9.
4. Wu L, Gu Y, Gu Y, Wang Y, et al. Diastasis recti abdominis inadult women based on abdominal computed tomography imaging: Preva lence, risk factors and its impact on life. J Clin Nurs. 2021 Feb;30(3–4):518–27.
5. Fan Jian YZ, Hui YLX, et al. Expert consensus on the diagnosis and treatment of rectus abdominis diastasis after childbirth. J Practical Clin Med. 2023;27(04):1–14.
6. Du Y, Huang M, Wang S, et al. Diastasis recti abdominis: A comprehensive review. Hernia. 2025;29(1):222. 10.1007/s10029-025-03417-5. Published 2025 Jul 7.
7. Guoyong F, Qiucheng L, Gan Y, et al. Clinical analysis of laparoscopic retroperitoneal repair of diastasis recti abdominis in 17 cases[J]. Chin J Practical Surg. 2023;43(07):803–6.
8. Wang Liang H, Jun, Wang X, Na. Quantitative assessment of postpartum diastasis recti abdominis using high-frequency ultrasound and shear wave elastography[J]. J Clin Ultrasound Med. 2023;25(01):44–8.

9. Yang SL, Li WR, Rui ZQ, et al. Evaluation of factors affecting the distance of rectus abdominis in women of childbearing age with no history of pregnancy[J]. Chin J Med Imaging. 2022;30(05):490–3.
10. Li Ling CJ, Hui O, Li, Ping, et al. Analysis of related risk factors for postpartum diastasis recti abdominis[J]. J Sun Yat-sen Univ (Medical Sci Edition). 2021;42(05):790–5.
11. Li YR, Chang S, Bin LZ et al. The role of different types of collagen in skin aging and its research progress[J/OL]. J Bioeng, 1–16 [2025-11-30].
12. Wu L, Gu Y, Gu Y, et al. Diastasis recti abdominis in adult w omen based on abdominal computed tomography imaging: Prevalence, risk factors and its impact on life. J Clin Nurs. 2021;30(3–4):518–27.
13. Qing Shisong. The Improvement of Women's Education and the Change of Fertility Behavior: A Study Based on the Perspective of Spousal Matching [J]. Sociol Res. 2024;39(02):179–202.
14. Wu Guangyan Z, Ran W, Lu, et al. The Effect of Core Muscle Control Training on Postpartum Rectus Abdominis Diastasis [J]. Chin J Rehabilitation Theory Pract. 2023;29(08):948–53.
15. Wu Yefeng L, Daohong G, Zhiwei. The Expression of Serum TIMP-1 and MMP-8 in Elderly Type III Inguinal Hernia and Its Relationship with Postoperative Stress Response [J]. Chin J Geriatr. 2024;44(20):4945–8.
16. Huang Danping Z, Jing G, Yixuan, et al. The Effect of Core Muscle Training on the Treatment of Postpartum Rectus Abdominis Diastasis: A Meta-analysis [J]. Chin J Evidence-Based Med. 2023;23(09):1026–32.
17. Ormsbee MJ, Prado CM, Ilich JZ, et al. Osteosarcopenic obesit y: the role of bone, muscle, and fat on health. J Cachexia Sarcop enia Muscle. 2014;5(3):183–92.
18. Dai Hao L, Zihao C. Analysis of the association between NHHR and phenotypic age acceleration and the mediating role of BMI based on the NHANES database[J]. Chin J Aesthetic Med. 2025;34(11):5–10.
19. Grossi JV, Nicola FF, Zepeda IA, et al. LINEA ALBA COLLAGEN A SSESSMENT IN MORBIDLY OBESE PATIENTS. Arq Bras Cir Dig. 2016;29(Suppl 1):8–11. Su ppl.
20. Fernandes da Mota PG, Pascoal AG, Carita AI, et al. Prevalenc e and risk factors of diastasis recti abdominis from late pregnan cy to 6 months postpartum, and relationship with lumbo-pelvic pai n. Man Ther. 2015;20(1):200–5.
21. Nanna W, Li W, Lu, et al. Ultrasonic evaluation of the inter-rectus distance in multiparous women and analysis of influencing factors[J]. Practical J Obstet Gynecol. 2025;41(01):71–6.
22. Fan C, Guidolin D, Ragazzo S, Fede C, Pirri C, Gaudreault N, Porzionato A, Macchi V, De Caro R, Stecco C. Effects of Cesarean Section and Vaginal Delivery on Abdominal Muscles and Fasciae. Me dicina (Kaunas). 2020;56(6):260.
23. Fan C, Fede C, Gaudreault N, Porzionato A et al. Anatomical and functional relationships between external abdominal oblique m uscle and posterior layer of thoracolumbar fascia. Clin Anat. 201 8 Oct;31(7):1092–8.

24. Cai Liuyun D, Xinru L, Yanxu, et al. Ultrasound assessment of rectus abdominis diastasis and associated factors in primiparas at 6 weeks postpartum[J]. Chin J Med Imaging. 2021;29(11):1134–8.
25. Zhang Mingzhu N, Minchang L, Feifei, et al. Preliminary study on high-frequency ultrasound evaluation of rectus abdominis diastasis types in postpartum women[J]. Chin J Clin Med Imaging. 2022;33(03):201–5.

Figures

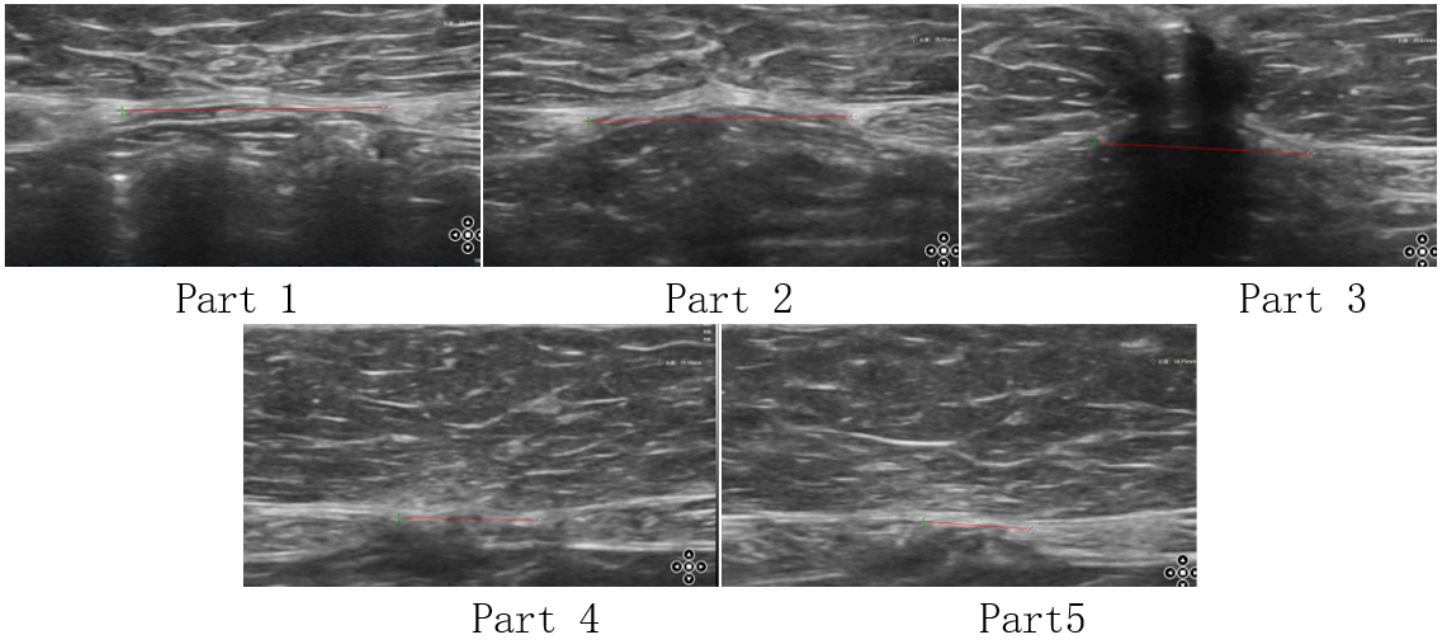


Figure 1

Ultrasound Measurement IRD