2026, 51(3) DOI:10.11817/j.issn.1672-7347.2026.250611

Risk factors and interaction analysis of severe diastasis recti abdominis within 6 months postpartum

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ABSTRACT

Objective: Severe diastasis recti abdominis (DRA) in the postpartum period may lead to long-term functional impairment in women. However, the independent effects and interactions of perinatal risk factors during the early postpartum recovery window have not been fully elucidated. This study aims to analyze the risk factors and interaction effects associated with severe postpartum DRA and to identify characteristics of high-risk populations.

Methods: This retrospective cohort study included postpartum women who underwent postpartum rehabilitation treatment at Hengyang Maternal and Child Health Hospital between January 2019 and August 2022, with a postpartum interval of 42 to 180 d. The inter-rectus distance was measured using palpation combined with caliper assessment. According to the inter-rectus distance, participants were divided into 4 groups: A severe DRA group (separation distance ⩾4 cm), a moderate DRA group (3.0 to 3.9 cm), a mild DRA group (2.0 to 2.9 cm), and a normal group (<2 cm). The moderate DRA, mild DRA, and normal groups were combined as the control group. Receiver operating characteristic (ROC) curve analysis was used to evaluate continuous variables and determine optimal cutoff values for stratification. The chi-square test was used to compare differences in influencing factors between the severe DRA group and the control group. Binary Logistic regression analysis was further performed to investigate the effects of various factors on severe DRA, and interaction analysis within the binary Logistic regression model was used to identify high-risk populations.

Results: A total of 525 postpartum women were ultimately included, including 112 in the severe DRA group, 257 in the moderate DRA group, 98 in the mild DRA group, and 58 in the normal group. The overall incidence of DRA was 89.0%, while the incidence of severe DRA was 21.3%. The diagnostic cutoff values for body mass index (BMI), neonatal birth weight, and gestational weight gain were 22.55 kg/m^2, 3 350 g, and 12.25 kg, respectively.

Date of reception: 2025-11-06
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Foundation item: This work was supported by the Natural Science Foundation of Hunan Province, China (2024JJ7069).
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Participants with BMI ≥22.55 kg/m^2, neonatal birth weight ≥3 350 g, gestational weight gain ≥12.25 kg, multiparity, cesarean delivery, or number of fetuses ≥2 had significantly higher incidences of severe DRA (all P<0.05). Binary Logistic regression analysis showed that neonatal birth weight ≥3 350 g, gestational weight gain ≥12.25 kg, cesarean delivery, and multiparity were independent risk factors for severe DRA (all P<0.05). The interaction among neonatal birth weight ≥3 350 g, multiparity, and cesarean delivery showed the strongest association with severe DRA (OR=7.10, 95% CI 3.43 to 14.71). When all 3 risk factors were present simultaneously, the incidence of severe DRA reached 61.76%.

Conclusion: Neonatal birth weight ≥3 350 g, gestational weight gain ≥12.25 kg, cesarean delivery, and multiparity are important independent risk factors for severe postpartum DRA, and significant synergistic amplification effects exist among these factors. This study clarified the characteristics of high-risk populations and may provide a basis for targeted early screening and intervention.

KEY WORDS diastasis recti abdominis; 6 months postpartum; risk factors; interaction effects; cesarean section; multiparity

产后6个月内重度腹直肌分离的危险因素及交互作用

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[摘 要] 目的：产后重度腹直肌分离(diastasis recti abdominis，DRA)可导致产妇远期功能障碍。然而，在产后早期恢复窗口期内，围产期危险因素的独立效应及其交互作用尚未得到充分阐明。本研究旨在分析产后重度DRA的危险因素及其交互作用，并识别高危人群特征。**方法：**本研究为回顾性队列研究，纳入2019年1月至2022年8月在衡阳市妇幼保健院接受产后康复治疗且产后时间为42~180 d的产妇。采用触诊联合卡尺测量腹直肌分离距离。根据腹直肌分离距离将所有参与者分为4组：重度DRA组(≥4 cm)、中度DRA组(3.0~3.9 cm)、轻度DRA组(2.0~2.9 cm)和正常组(<2 cm)。将中度DRA组、轻度DRA组和正常组合并为对照组。采用受试者操作特征(receiver operator characteristic，ROC)曲线分析评估连续变量，确定最佳截断值，并据此进行分层。采用卡方检验比较重度DRA组与对照组之间各影响因素的差异。进一步采用二元Logistic回归分析探讨各因素对DRA严重程度的影响，并利用二元Logistic回归中的交互作用分析识别高危人群。**结果：**最终共纳入525例产妇，其中重度DRA组、中度DRA组、轻度DRA组、正常组分别纳入112、257、98和58例。DRA的发生率为89%，重度DRA的发生率为21.3%。体重指数(body mass index，BMI)、新生儿出生体重及孕期体重增长的诊断截断值分别为22.55 kg/m²、3 350 g及12.25 kg。BMI≥22.55 kg/m^2、新生儿出生体重≥3 350 g、孕期体重增长≥12.25 kg、经产妇、剖宫产或胎儿数≥2的参与者，其重度DRA的发生率均显著增加(均P<0.05)。二元Logistic回归分析显示，新生儿出生体重≥3 350 g、孕期体重增长≥12.25 kg、剖宫产和经产妇是重度DRA的独立危险因素(均P<0.05)。新生儿出生体重≥3 350 g、经产妇与剖宫产三者之间的交互作用对重度DRA的影响最强(OR=7.10，95% CI 3.43~14.71)。当这3个危险因素同时存在时，重度DRA的发生率达到61.76%。**结论：**新生儿出生体重≥3 350 g、妊娠期体重增加≥12.25 kg、剖宫产及经产妇为产后重度DRA的重要独立危险因素，且各因素之间存在显著的协同放大效应。本研究明确了高危人群特征，可为实施针对性早期筛查与干预提供依据。

[关键词] 腹直肌分离；产后6个月；危险因素；交互作用；剖宫产；经产妇

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Diastasis recti abdominis (DRA) is a common condition during pregnancy and early postpartum, with reported incidences of 27% to 100% in the mid to late gestational period and 35% to 60% in the early postpartum period[1-3]. While mild DRA may resolve spontaneously, severe postpartum DRA has been associated with chronic low back pain, pelvic floor dysfunction, and reduced quality of life, imposing a substantial long-term burden on affected women[1]. Evidence[4-5] indicates that if DRA is not identified early, its adverse effects may persist for years postpartum, underscoring the clinical importance of early recognition of severe cases. Moreover, emerging studies[6-7] suggest that the postpartum period represents a critical window for abdominal wall recovery, during which timely screening and intervention may help prevent long-term functional impairment.

Accumulating evidence[8-10] suggests that the development and severity of DRA are influenced by multiple perinatal factors, including neonatal birth weight, gestational weight gain, mode of delivery, and parity. Recent observational and longitudinal studies[11-12] have identified cesarean section, higher parity, and increased fetal birth weight as important risk factors for DRA. However, most existing studies[13-15] have primarily examined these factors in isolation, and the potential interactions among perinatal risk factors in the progression to severe postpartum DRA remain poorly understood. This limitation hampers effective early risk stratification and targeted management during the early postpartum period.

This study aims to identify independent perinatal risk factors and explore their interactive effects on severe postpartum DRA during the early postpartum period. By systematically analyzing clinically accessible perinatal indicators, this study sought to improve early identification of women at high risk for severe DRA and to provide an evidence-based foundation for risk stratification and tiered management, ultimately contributing to the prevention of long-term functional impairment associated with severe postpartum DRA.

1 Participants and methods

1.1 Ethics statement

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the hospital (Ethics approval number: 2025100). Written informed consent was obtained from all participants prior to their inclusion in the study.

1.2 Participants

Parturients were included in this retrospective cohort study conducted at Hengyang Maternal and Child Health Hospital between January 2019 and August 2022. Inclusion criteria: 1) Parturients receiving rehabilitation treatment between 42 and 180 d postpartum; 2) normal cognitive function; 3) mental health; 4) voluntary cooperation in providing questionnaire information and conducting follow-up. Exclusion criteria: 1) Previous history of abdominal surgery, excluding cesarean section; 2) previous history of a chronic cough, diabetes mellitus, hypertension, or other diseases that affect abdominal muscle recovery and function; 3) previous history of abdominal wall cele or hernias.

According to the severity of DRA, all participants were divided into 4 groups: A severe DRA group, a moderate DRA group , a mild DRA group , and a normal group. Subsequently, the moderate DRA, mild DRA, and normal groups were merged into a single control group.

The sample size was estimated based on the number of potential risk factors included in the multivariable Logistic regression model. A total of 6 primary independent variables were planned for inclusion. The prevalence of severe DRA was anticipated to be 20%. According to the events per variable (EPV) principle, with each variable requiring at least 10 events, the minimum required sample size was 300. Additionally, power estimation for detecting an odds ratio of 2.0 (assuming a 2-sided significance level of α=0.05 and power of $1-\beta$=0.80) yielded a required sample size of approximately 450. To ensure the robustness and stability of the analyses, the target sample size was set at ⩾500.

1.3 Data collection and measurements

The demographic and clinical characteristics of all participants were recorded, including age, height, weight, body mass index (BMI), neonatal birth weight, gestational weight gain, educational level, occupation

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status, number of pregnancies, parity, lactation status, mode of delivery, and number of fetuses.

The primary outcome indicator was the separation distance of the rectus abdominis muscles. The diagnostic criteria for DRA were defined as follows[9, 12]: Severe DRA was classified as separation distance of the rectus abdominis muscles ≥4 cm, moderate DRA ranged from 3.0 to 3.9 cm, mild DRA ranged from 2.0 to 2.9 cm, and <2 cm indicated normality.

Measurement personnel for rectus abdominis muscles was a nurse practitioner with over 10 years of extensive professional experience in this field. The method used was palpation combined with caliper measurement[16-18]. The specific procedure was as follows: The parturient lay down in the supine position with knees flexed, exposing the abdominal skin. The nurse gently pressed on the patient's abdomen and instructed her to hold her breath. Then the nurse gently raised the head and shoulders to a height of approximately 10 cm above the bed surface. The nurse used her finger to measure the separation width of the rectus abdominis muscles at the umbilicus, 3 cm above the umbilicus, and 3 cm below the umbilicus[4]. Subsequently, the nurse employed a caliper to accurately measure the width between the fingers and selected the maximum value among these three locations as the separation distance of the rectus abdominis muscles. The measurement was performed by a trained nurse using a standardized protocol[11-12]: Finger placement was first used only to locate the maximal separation, after which the inter-recti distance was measured directly with a caliper positioned perpendicular to the linea alba at the identified point. During measurement, finger placement was maintained steadily, and the caliper reading was recorded immediately to minimize displacement. To ensure feasibility and measurement consistency, all assessments were performed by trained personnel following the same standardized procedure. In addition, operators received uniform training prior to data collection, and measurements were conducted in a consistent body position and breathing phase. These methodological clarifications were added to improve the transparency, reliability, and reproducibility of the measurement approach.

The nurses strictly followed the operating procedures for measurement and accurately entered the relevant information. Finally, 2 nurses meticulously examined the measurement data to ensure its accuracy and integrity.

1.4 Statistical analysis

Statistical analysis was conducted using SPSS 30.0 software. Continuous data that followed a normal distribution were described as mean±standard deviation, while categorical data were expressed as percentages (%). Continuous variables were assessed using receiver operating characteristic (ROC) curve analysis and stratified based on diagnostic cut-off values. The chi-square test was used to compare differences between the severe DRA group and the control group.

Binary Logistic regression analysis was conducted to further investigate the impact of factors on the severity of DRA. The variables were categorized as follows: BMI ≥22.55 kg/m² (yes=C, no=C0); neonatal birth weight ≥3 350 g (yes=D, no=D0); gestational weight gain ≥12.25 kg (yes=E, no=E0); cesarean section (yes=F, no=F0); multipara (yes=G, no=G0); number of fetuses ≥2 (yes=H, no=H0). The interaction term in binary Logistic regression analysis was used to identify high-risk groups. Statistical significance was determined with a threshold of $P<0.05$.

2 Results

2.1 Demographic and clinical characteristics of the participants

A total of 544 parturients were initially recruited for this study. After excluding 11 with incomplete or erroneous data, 7 with comorbidities (e. g., chronic cough, diabetes mellitus, or hypertension), and 1 with a history of abdominal surgery, 525 parturients were finally enrolled, meeting the predetermined sample size requirement.

Based on the DRA grouping criteria, there were 112 participants in the severe group, 257 in the moderate group, 98 in the mild group, and 58 in the normal group (Figure 1).

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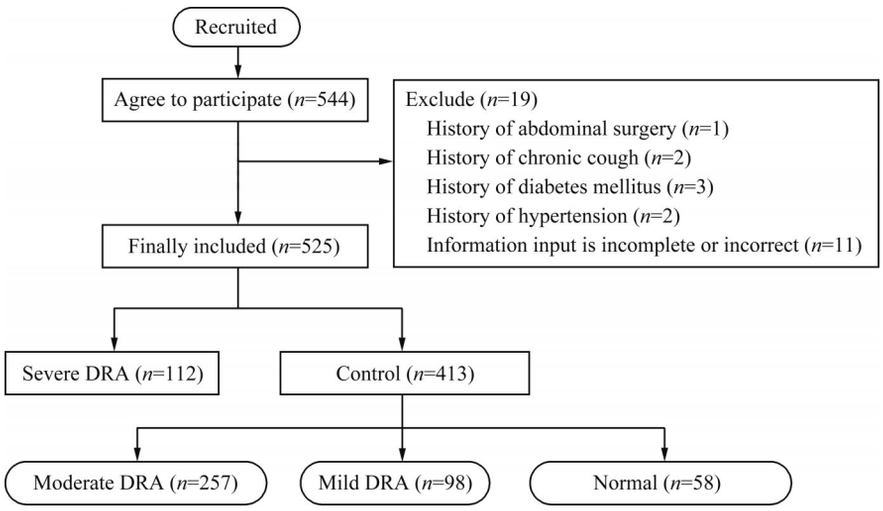


Figure 1 Flowchart of study participant enrollment

In the 525 participants, the incidence of DRA was 88.9%, and the incidence of severe DRA was 21.3%. The participants had an age of (30.5±4.2) years, and a BMI of (22.50±3.22) kg/m^2; their babies had a birth weight of (3 305.1±592.3) g. Additionally, the participants had a gestational weight gain of (14.2±5.0) kg. Seventy-two percent had a higher level of education, and 76.0% were engaged in non-manual work. Among them, 56.0% had their first pregnancy, and 73.3% underwent vaginal delivery. The breast feeding rate was 78.7% (Table 1).

2.2 ROC curve analysis of clinical data

The continuous variables, including age, height, weight, BMI, neonatal birth weight, and gestational weight gain, were utilized to construct ROC curves (Figure 2). The area under the curve (AUC) values for the 6 variables all exceeded 0.5 (Table 2). The Youden index was calculated from the ROC curve based on sensitivity and specificity at each cut-off point, and the diagnostic cut-off value corresponding to the maximum Youden index was determined. BMI corresponded to a diagnostic cut-off of 22.55 kg/m^2; neonatal birth weight corresponded to a diagnostic cut-off of 3 350 g; gestational weight gain corresponded to a diagnostic cut-off of 12.25 kg. Age, height, and weight did not have specific diagnostic cut-offs (Table 2).

Table 1 Demographic and clinical characteristics of 525 participants

Variables	Values
Age/years	30.5±4.2
Height/cm	160.0±4.7
Weight/kg	57.8±8.9
BMI/(kg·m^{-2})	22.50±3.22
Neonatal birth weight/g	3 305.1±592.3
Gestational weight gain/kg	14.2±5.0
Severe DRA/[No.(%)]	112(21.3)
Moderate DRA/[No.(%)]	257(49.0)
Mild DRA/[No.(%)]	98(18.7)
Normal/[No.(%)]	58(11.0)
Educational level/[No.(%)]	
Primary school, high school, or other	147(28.0)
College/University	378(72.0)
Occupational status/[No.(%)]	
Non-manual work	399(76.0)
Manual work	126(24.0)
Number of pregnancies/[No.(%)]	
1	294(56.0)
2	198(37.7)
≥3	33(6.3)
Breast feeding/[No.(%)]	
Yes	413(78.7)
No	112(21.3)
Mode of delivery/[No.(%)]	
Cesarean section	140(26.7)
Vaginal delivery	385(73.3)
Number of fetuses/[No.(%)]	
≥2	7(1.3)
1	518(98.7)

BMI: Body mass index; DRA: Diastasis recti abdominis.

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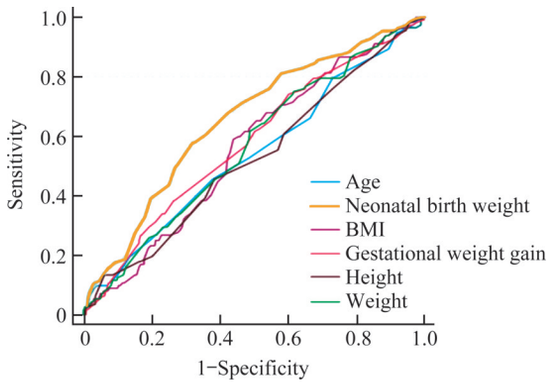


Figure 2 ROC curves for age, height, weight, BMI, neonatal birth weight, and gestational weight gain

ROC: Receiver operating characteristic; BMI: Body mass index.

2.3 Factors influencing the occurrence of severe DRA

Educational level, occupational status, and breast feeding did not exhibit statistically significant differences between the severe DRA group and the control group (all P>0.05, Table 2). Participants with BMI ≥22.55 kg/m^2, neonatal birth weight ≥3 350 g, gestational weight gain ≥12.25 kg, multipara, cesarean section, or number of fetuses ≥2 had a significantly higher incidence of severe DRA (all P<0.05, Table 3).

Table 2 ROC curve analysis of clinical data from 525 participants

Variables	AUC	Youden index	Diagnosis cut-off
Age/years	0.540	0.08	—
Height/cm	0.525	0.07	—
Weight/kg	0.565	0.14	—
BMI/(kg·m^{-2})	0.559	0.15	22.55
Neonatal birth weight/g	0.655	0.26	3 350
Gestational weight gain/kg	0.579	0.14	12.25

—: No specific diagnosis cut-offs. ROC: Receiver operating characteristic; AUC: Area under the curve.

Table 3 Comparison of the influencing factors between the severe DRA and control groups

Variables	Severe DRA (n=112)	Control (n=413)	χ^2	P
BMI≥22.55 kg/m^2/[No.(%)]			8.067	0.010
Yes	66(58.9)	181(43.6)		
No	46(41.1)	232(56.2)		
Gestational weight gain≥12.25 kg/[No.(%)]			7.475	0.001
Yes	83(74.1)	248(60.0)		
No	29(25.9)	165(40.0)		
Neonatal birth weight≥3 350 g/[No.(%)]			24.513	0.001
Yes	65(58.0)	134(32.4)		
No	47(42.0)	279(67.6)		
Educational level/[No.(%)]			0.392	0.530
Primary school, high school, or other	34(30.4)	113(27.4)		
College/University	78(69.6)	300(72.6)		
Occupational status/[No.(%)]			0.220	0.660
Non-manual work	87(77.7)	312(75.5)		
Manual work	25(22.3)	101(24.5)		
Multipara/[No.(%)]			12.877	0.001
Yes	66(58.9)	165(40.0)		
No	46(41.1)	248(60.0)		
Breast feeding/[No.(%)]			0.653	0.420
Yes	85(75.9)	328(79.4)		
No	27(24.1)	85(20.6)		

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Table 3 (to be continued)

Variables	Severe DRA (*n*=112)	Control (*n*=413)	χ^2	*P*
Mode of delivery/[No.(%)]			19.084	0.001
Cesarean section	48(42.9)	92(22.3)		
Vaginal delivery	64(57.1)	321(77.7)		
Number of fetuses/[No.(%)]			9.603	0.010
≥2	5(4.5)	2(0.5)		
1	107(95.5)	411(99.5)		

Results of binary Logistic regression analysis showed that neonatal birth weight ≥3 350 g, gestational weight gain ≥12.25 kg, cesarean section, and multipara were all identified as independent risk factors for severe DRA (all *P*<0.05, Table 4).

Analysis of the interaction in the binary Logistic regression model revealed that, compared with the reference group (D0*F0*G0), participants who met all 3 conditions (D*F*G) had a 7.10-fold increased probability of severe DRA, with an incidence of 61.76%. Specifically, when neonatal birth weight was ≥ 3 350 g, multiparas who opted for a cesarean section were at the highest risk for severe DRA. Overall, when these independent risk factors coexisted, the risk of developing severe DRA increased substantially (Table 5).

Table 4 Binary Logistic regression analysis on independent risk factors for severe DRA

Variables	*n*	Severe DRA	Control	Incidence/%	*OR*	95% *CI*	*P*
C	247	66	181	26.72	1.488	0.942 to 2.301	0.094
D	199	65	134	32.66	2.257	1.436 to 3.552	<0.001
E	331	83	248	25.08	1.670	1.023 to 2.736	0.042
F	140	48	92	34.29	2.227	1.391 to 3.568	<0.001
G	231	66	165	28.57	1.823	1.162 to 2.861	0.009
H	7	5	2	71.43	2.202	0.336 to 12.262	0.368

The variables were categorized as follows: BMI ≥22.55 kg/m² (yes=C, no=C0); neonatal birth weight ≥3 350 g (yes=D, no=D0); gestational weight gain ≥12.25 kg (yes=E, no=E0); cesarean section (yes=F, no=F0); multipara (yes=G, no=G0); number of fetuses ≥2 (yes=H, no=H0).

Table 5 Interaction effects of neonatal birth weight, gestational weight gain, cesarean section, and multiparity on the risk of severe DRA

Variables	*n*	Severe DRA	Control	Incidence/%	*OR*	95% *CI*	*P*
D*G	107	42	65	39.25	3.209	2.021 to 5.119	<0.001
F*G	71	32	39	45.07	3.841	2.270 to 6.491	<0.001
D*F	64	32	32	50.00	4.760	2.759 to 8.221	<0.001
D*E*F	46	24	22	52.17	4.848	2.601 to 9.038	<0.001
D*F*G	34	21	13	61.76	7.102	3.431 to 14.707	<0.001

3 Discussion

As the fetus grows, the pregnant woman's abdomen gradually expands, and the 2 sides of the rectus abdominis muscles gradually separate to accommodate the growing uterus. Fei, et al[8] observed

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that cesarean section and multiple deliveries constituted risk factors for DRA. Kaufmann, et al[19] noted that advanced age and obesity were identified as risk factors for DRA. Other studies[20-21] have identified obesity, weight gain at advanced maternal age, multiparity, multiple pregnancies, and neonatal birth weight as risk factors associated with DRA. We conducted further in-depth research based on these. Our findings showed that neonatal birth weight ≥3 350 g, gestational weight gain ≥12.25 kg, multipara, and cesarean section were independent risk factors for severe DRA. Moreover, we also found that when these independent risk factors coexisted, the risk of developing severe DRA increased substantially. In particular, the co-existence of neonatal birth weight ≥3 350 g, cesarean section, and multipara had the most obvious impact on the severe DRA. The core contribution of this study lies in revealing the synergistic amplification effect of multiple risk factors. This finding deepens the understanding of the pathogenesis of DRA and advances the identification of high-risk populations from "having any single risk factor" to the more precise level of "concurrent multiple risk factors". The risk factors identified in this study hold clear clinical significance.

Parturients with a neonatal birth weight ≥3 350 g exhibited a higher likelihood of experiencing severe DRA. The maternal abdominal circumference positively correlates with neonatal birth weight, indicating a direct relationship between the 2 variables. The larger the neonatal birth weight, the greater the maternal abdominal circumference. Consequently, the abdominal muscles undergo excessive stretching, while the weight of the fetus directly compresses them, thereby increasing susceptibility to severe DRA[15, 21].

Women who gained ≥12.25 kg of gestational weight were more likely to have severe DRA. Pregnant women are prone to excessive nutrient supplementation during gestation, which can result in a relative increase in their body fat and potentially lead to muscle loss[22]. Furthermore, the accumulation of superior mesenteric adipose tissue within the abdominal cavity may lead to an elevation of abdominal pressure, rendering individuals more susceptible to developing DRA[20]. The rapid weight gain of pregnant women can also lead to excessive neonatal birth weight. The greater the weight of pregnant women, the larger their abdominal circumference, and the greater the direct mechanical force, resulting in a higher susceptibility to overstretching of the abdominal muscles[23]. Consequently, this can lead to more pronounced DRA.

Parturients opting for cesarean section exhibited a higher propensity for severe DRA. During cesarean section, conventional blunt separation of the anterior rectus sheath and passive stretching of the rectus abdominis muscles on both sides can lead to damage to the rectus abdominis muscle fibers[23]. In addition, postoperative wound exudation can result in adhesion, posing challenges to the complete restoration of normal anatomical structure and affecting both the distance and thickness of the rectus abdominis muscles[24]. Therefore, the risk of severe DRA is higher.

Multiparity is one of the independent risk factors for severe DRA. Some parturients may experience incomplete postpartum recovery, and the interpregnancy interval is relatively short[25]. A second or subsequent delivery exacerbates the initial rectus abdominis separation, resulting in further injury and an increased likelihood of severe DRA[21, 26].

Previous studies[26-27] employed univariate analysis to examine the association between the occurrence of DRA and neonatal birth weight. Several studies[26-27] have identified neonatal birth weight as a significant risk factor for DRA, with reported weights of (3 370±470) g or (3 276±457) g. However, no detailed stratified analysis was conducted on neonatal birth weight; only overall mean values were reported. Our findings indicated that neonatal birth weight is an independent risk factor for severe DRA. Based on ROC curve analysis, the specific diagnostic cut-off value for neonatal birth weight was calculated. The incidence of severe DRA was higher in neonates with a birth weight ≥3 350 g compared to those with a birth weight <3 350 g.

The findings of this study demonstrated that multiparas who underwent cesarean section and had a neonate with birth weight ≥3 350 g were at the highest risk of severe DRA. Preventing the coexistence of these 3 risk factors is a key primary prevention strategy for severe DRA. We analyzed the potential mechanisms by which these 3 risk factors jointly contribute to severe DRA. First, the greater the neonatal birth weight, the larger the maternal abdominal circumference, which leads to overstretching of the abdominal muscles and

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subsequent weakening of the rectus abdominis muscles. Second, cesarean section causes damage to the rectus abdominis muscle fibers. Third, due to lack of appropriate intervention, some parturients may not fully recover and become pregnant again, thereby increasing the likelihood of rectus abdominis separation and severe DRA.

In clinical practice, decisions regarding cesarean section should strictly comply with established surgical indications and evidence-based clinical guidelines, with careful avoidance of non-medically indicated procedures. Particular caution is warranted when considering cesarean delivery for multiparous women with an estimated fetal weight ⩾3 350 g, as the combined effects of fetal macrosomia, repeated pregnancies, and abdominal wall stretching may increase the risk of postpartum abdominal wall dysfunction[26]. Therefore, individualized risk-benefit assessment and shared decision-making between clinicians and patients are essential to optimize maternal outcomes.

Awareness of severe DRA among pregnant and postpartum women should be strengthened through targeted education and health promotion initiatives during antenatal care and postpartum follow-up. Healthcare providers should emphasize the potential functional consequences of untreated DRA, including impaired core stability, lower back pain, and reduced quality of life. Furthermore, early postpartum screening, timely diagnosis, and stratified management strategies should be implemented to facilitate early intervention and prevent progression to severe DRA.

For women identified as high risk based on the identified factors, as well as for those with mild to moderate DRA, non-surgical rehabilitation strategies should be prioritized under professional supervision. These may include neuromuscular electrical stimulation therapy, manual techniques, and individualized exercise programs focusing on deep core muscles—particularly the transversus abdominis—as well as coordinated pelvic floor muscle training[28]. Such interventions may help restore abdominal wall integrity, improve functional outcomes, and reduce symptom burden.

In cases of severe DRA accompanied by significant functional impairment or persistent symptoms that are refractory to conservative management, referral to a multidisciplinary team—including obstetricians, rehabilitation specialists, and surgeons—should be considered for comprehensive evaluation. For carefully selected patients, surgical intervention may represent a viable option to improve anatomical restoration and functional recovery[29]. Overall, the implementation of a structured, risk-stratified prevention and management framework may contribute to improved postpartum care and reduced long-term morbidity associated with severe DRA.

One major strength of the present study is that diagnostic cut-off values for significant independent risk factors were determined using ROC curve analysis. While previous studies have established that these factors are associated with the occurrence of DRA, the specific conditions under which they exert an effect and the magnitude of their impact remain unclear. Our findings address this gap by quantitatively defining clinically relevant thresholds. In addition, we demonstrated the combined effects of multiple risk factors on the development of severe DRA when they coexist. This approach enables the identification of populations at high risk for severe DRA and may serve as an effective strategy for primary prevention.

Several limitations of this study should also be acknowledged. First, maternal data were collected exclusively during the postpartum period between 42 and 180 d, and information regarding pre-delivery rectus abdominis separation was not available for analysis. Second, the assessment method combining palpation and caliper measurement involves a degree of subjectivity; however, all measurements were performed by a single experienced specialist to minimize inter-observer variability. Third, participants were recruited solely from the rehabilitation department of a single center, which may have introduced selection bias and potentially led to an overestimation of the prevalence of severe DRA. Therefore, caution is warranted when generalizing these findings to broader populations. Fourth, although sensitivity analyses were conducted, several diagnostic cut-off values were derived from the present dataset and require validation in external cohorts. Finally, the relatively small sample sizes in subgroup interaction analyses resulted in wide confidence intervals for the estimated odds ratios.

Future research will focus on developing a predictive model based on the identified risk factors to

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more accurately identify women at high risk for severe DRA. In addition, large-scale and multicenter studies conducted across different regions will be necessary to enhance the external validity of these findings and to provide stronger evidence for clinical application.

In conclusion, neonatal birth weight ≥3 350 g, gestational weight gain ≥12.25 kg, cesarean section, and multiparity were identified as significant independent risk factors for severe DRA. Notably, the combined effect of neonatal birth weight ≥3 350 g, multiparity, and cesarean section had the greatest impact on the occurrence of severe DRA. These findings provide clinically relevant evidence for the early identification and targeted intervention of populations at high risk for severe DRA and may facilitate the development of predictive models for risk stratification and screening.

Acknowledgements: The authors sincerely thank all participants for their involvement in this study, as well as the clinicians and nursing staff who contributed to data collection and coordination.

Contributions: SHAN Hongjie Study conception, design, and interpretation, participant identification, recruitment, and phenotyping, data statistical analysis, and manuscript drafting; XIAO Min Participant identification, recruitment, and phenotyping and data statistical analysis; CHEN Chao Participant identification, recruitment, and phenotyping; GAO Hong Study conception, design, and interpretation, participant identification, recruitment, and phenotyping, and manuscript drafting. All authors have substantively revised the manuscript and approved the submitted version.

Conflict of interest: The authors declare that they have no conflicts of interest to disclose.

References

[1] Cardaillac C, Vieillefosse S, Oppenheimer A, et al. Diastasis of the rectus abdominis muscles in postpartum: Concordance of patient and clinician evaluations, prevalence, associated pelvic floor symptoms and quality of life[J]. Eur J Obstet Gynecol Reprod Biol, 2020, 252: 228-232. https://doi.org/10.1016/j.ejogrb.2020.06.038.

[2] da Mota PGF, Pascoal AGBA, Carita AIAD, et al. Prevalence and risk factors of diastasis recti abdominis from late pregnancy to 6 months postpartum, and relationship with lumbo-pelvic pain[J]. Man Ther, 2015, 20(1): 200-205. https://doi.org/10.1016/j.math.2014.09.002.

[3] Kamel DM, Yousif AM. Neuromuscular electrical stimulation and strength recovery of postnatal diastasis recti abdominis muscles[J]. Ann Rehabil Med, 2017, 41(3): 465-474. https://doi.org/10.5535/arm.2017.41.3.465.

[4] Reinpold W, Köckerling F, Bittner R, et al. Classification of rectus diastasis: a proposal by the German hernia society (DHG) and the international endohernia society (IEHS) [J]. Front Surg, 2019, 6:1. https://doi.org/10.3389/fsurg.2019.00001.

[5] Köhler G, Fischer I, Kaltenböck R, et al. Minimal invasive *Linea* Alba reconstruction for the treatment of umbilical and epigastric hernias with coexisting rectus abdominis diastasis[J]. J Laparoendosc Adv Surg Tech A, 2018, 28(10): 1223-1228. https://doi.org/10.1089/lap.2018.0018.

[6] 吴丽, 顾艳, 谷雨, 等. 基于腹部CT成像的成年女性腹直肌分离: 患病率、危险因素及其对生活的影响[J]. 临床护理杂志, 2021, 30(3/4): 518-527. http://doi.org/10.1111/jocn.15568.
WU Li, GU Yan, GU Yu, et al. Diastasis recti abdominis in adult women based on abdominal computed tomography imaging: Prevalence, risk factors and its impact on life[J]. Journal of Clinical Nursing, 2021, 30(3/4): 518-527. http://doi.org/10.1111/jocn.15568.

[7] Benjamin DR, Frawley HC, Shields N, et al. Relationship between diastasis of the rectus abdominis muscle (DRAM) and musculoskeletal dysfunctions, pain and quality of life: a systematic review[J]. Physiotherapy, 2019, 105(1): 24-34. https://doi.org/10.1016/j.physio.2018.07.002.

[8] Fei H, Liu Y, Li MX, et al. The relationship of severity in diastasis recti abdominis and pelvic floor dysfunction: a retrospective cohort study[J]. BMC Womens Health, 2021, 21 (1): 68. https://doi.org/10.1186/s12905-021-01194-8.

[9] Sperstad 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[J]. Br J Sports Med, 2016, 50(17): 1092-1096. https://doi.org/10.1136/bjsports-2016-096065.

[10] Bø K, Hilde G, Tennfjord MK, et al. Pelvic floor muscle function, pelvic floor dysfunction and diastasis recti abdominis: Prospective cohort study[J]. Neurourol Urodyn, 2017, 36(3): 716-721. https://doi.org/10.1002/nau.23005.

[11] 孙秀丽, 李环, 苏园园, 等. 产后腹直肌分离诊断与治疗的专家共识[J]. 中国妇产科临床杂志, 2021, 22(2): 220-221. https://doi.org/10.13390/j.issn.1672-1861.2021.02.043.
SUN Xiuli, LI Huan, SU Yuanyuan, et al. Expert consensus on the diagnosis and treatment of postpartum diastasis recti abdominis[J]. Chinese Journal of Clinical Obstetrics and Gynecology, 2021, 22(2): 220-221. https://doi.org/10.13390/j.issn.1672-1861.2021.02.043.

[12] 范健, 虞志艳, 李晓辉, 等. 产后腹直肌分离诊疗专家共识[J]. 实用临床医药杂志, 2023, 27(4): 1-14. https://doi.org/10.7619/jcmp.20230017.

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FAN Jian, YU Zhiyan, LI Xiaohui, et al. Expert consensus on diagnosis and treatment of postpartum diastasis recti abdominis [J]. Journal of Clinical Medicine in Practice, 2023, 27(4): 1-14. https://doi.org/10.7619/jcmp.20230017.

[13] Akram J, Matzen SH. Rectus abdominis diastasis[J]. J Plast Surg Hand Surg, 2014, 48(3): 163-169. https://doi.org/10.3109/2000656x.2013.859145.

[14] Beer GM, Schuster A, Seifert B, et al. The normal width of the linea alba in nulliparous women[J]. Clin Anat, 2009, 22(6): 706-711. https://doi.org/10.1002/ca.20836.

[15] Hills NF, Graham RB, McLean L. Comparison of trunk muscle function between women with and without diastasis recti abdominis at 1 year postpartum[J]. Phys Ther, 2018, 98(10): 891-901. https://doi.org/10.1093/ptj/pzy083.

[16] Keshwani N, Mathur S, McLean L. Relationship between interrectus distance and symptom severity in women with diastasis recti abdominis in the early postpartum period[J]. Phys Ther, 2018, 98(3): 182-190. https://doi.org/10.1093/ptj/pzx117.

[17] Benjamin DR, Frawley HC, Shields N, et al. Establishing measurement properties in the assessment of inter-recti distance of the abdominal muscles in a postnatal women[J]. Musculoskelet Sci Pract, 2020, 49: 102202. https://doi.org/10.1016/j.msksp.2020.102202.

[18] Wang Q, Yu XJ, Chen GM, et al. Does diastasis recti abdominis weaken pelvic floor function? A cross-sectional study[J]. Int Urogynecol J, 2020, 31(2): 277-283. https://doi.org/10.1007/s00192-019-04005-9.

[19] Kaufmann RL, Reiner CS, Dietz UA, et al. Normal width of the linea alba, prevalence, and risk factors for diastasis recti abdominis in adults, a cross-sectional study[J]. Hernia, 2022, 26(2): 609-618. https://doi.org/10.1007/s10029-021-02493-7.

[20] 陈小红, 徐永敏. 产后腹直肌分离发生的影响因素[J]. 吉林医学, 2022, 43(9): 2362-2364. https://doi.org/10.3969/j.issn.1004-0412.2022.09.015.
CHEN Xiaohong, XU Yongmin. The influencing factors of rectus abdominis muscle separation after delivery[J]. Jilin Medical Journal, 2022, 43(9): 2362-2364. https://doi.org/10.3969/j.issn.1004-0412.2022.09.015.

[21] 刘雅莉, 赵琼蕊, 李娟, 等. 中国育龄期妇女产后腹直肌分离发生率meta分析[J]. 中国公共卫生, 2020, 36(10): 1507-1509. https://doi.org/10.11847/zgggws1129890.
LIU Yali, ZHAO Qiongrui, LI Juan, et al. Incidence of postpartum diastasis recti abdominis in Chinese childbearing women—a meta analysis[J]. Chinese Journal of Public Health, 2020, 36(10): 1507-1509. https://doi.org/10.11847/zgggws1129890.

[22] 徐小琼, 柏青, 邵明琨, 等. 孕妇孕期膳食营养指导对孕妇营养补充及母婴影响的研究[J]. 中国卫生标准管理, 2019, 15(8): 35-38. https://doi.org/10.3969/j.issn.1674-9316.2024.08.009.
XU Xiaoqiong, BAI Qing, SHAO Mingkun, et al. Effects of dietary nutrition guidance during pregnancy on maternal nutritional supplementation and maternal-infant outcomes[J]. Chinese Journal of Health Standards Management, 2019, 15(8): 35-38. https://doi.org/10.3969/j.issn.1674-9316.2024.08.009.

[23] 王青, 于晓杰, 杨欣, 等. 产后腹直肌分离发生的影响因素研究[J]. 现代妇产科进展, 2019, 28(12): 913-916. https://doi.org/10.13283/j.cnki.xdfckjz.2019.12.006.
WANG Qing, YU Xiaojie, YANG Xin, et al. Risk factors for diastasis recti abdominis after delivery[J]. Progress in Obstetrics and Gynecology, 2019, 28(12): 913-916. https://doi.org/10.13283/j.cnki.xdfckjz.2019.12.006.

[24] 李玲, 崔金晖, 欧阳丽萍, 等. 产后腹直肌分离的相关危险因素分析[J]. 中山大学学报. 医学科学版, 2021, 42(5): 790-795. https://doi.org/10.13471/j.cnki.j.sun.yat-sen.univ(med.sci).2021.519.
LI Ling, CUI Jinhui, OUYANG Liping, et al. Risk factors analysis of diastasis recti abdominis during postpartum[J]. Journal of Sun Yat-sen University (Medical Sciences), 2021, 42(5): 790-795. https://doi.org/10.13471/j.cnki.j.sun.yat-sen.univ(med.sci).2021.0519.

[25] 郑新烈, 陈潇宇, 涂素华, 等. 产后女性腹直肌分离危险因素的Meta分析[J]. 全科护理, 2022, 20(27): 3754-3758. http://dx.chinadoi.cn/10.12104/j.issn.1674-4748.2022.27.003.
ZHENG Xinlie, CHEN Xiaoyu, TU Suhua, et al. Meta-analysis of risk factors for separation of rectus abdominalis in postpartum women[J]. Journal of General Nursing, 2022, 20(27): 3754-3758. http://dx.chinadoi.cn/10.12104/j.issn.1674-4748.2022.27.003.

[26] 焦子珊, 邱金花, 王娜娜, 等. 489例产后腹直肌分离产妇患病现状及影响因素分析[J]. 护理学报, 2021, 28(20): 7-10. https://doi.org/10.16460/j.issn1008-9969.2021.20.007.
JIAO Zishan, QIU Jinhua, WANG Nana, et al. Current status of postpartum diastasis recti abdominis and its influence factors: a 489-case study[J]. Journal of Nursing (China), 2021, 28(20): 7-10. https://doi.org/10.16460/j.issn1008-9969.2021.20.007.

[27] 贾晓慧. 产后腹直肌分离的超声评估及影响因素的探讨[D]. 太原: 山西医科大学, 2022. https://doi.org/10.27288/d.cnki.gsxyu.2022.000325.
JIA Xiaohui. Ultrasonic evaluation of diastasis recti abdominis in postpartum women and risk factors[D]. Taiyuan: Shanxi Medical University, 2022. http://doi.org/10.27288/d.cnki.gsxyu.2022.000325.

[28] 廖柏丹, 柳元娥, 林立平, 等. 电针配合推拿手法治疗产后腹直肌分离症的疗效观察[J]. 实用中西医结合临床, 2018, 18(7): 85-86. https://doi.org/10.13638/j.issn.1671-4040.2018.07.044.
LIAO Baidan, LIU Yuan'e, LIN Liping, et al. Observation on therapeutic effect of electroacupuncture combined with massage on postpartum rectus abdominis separation[J]. Practical Clinical Journal of Integrated Traditional Chinese and Western Medicine, 2018, 18(7): 85-86. https://doi.org/10.13638/j.issn.1671-4040.2018.07.044.

[29] Fukano M, Tsukahara Y, Takei S, et al. Recovery of abdominal muscle thickness and contractile function in women after childbirth[J]. Int J Environ Res Public Health, 2021, 18(4): 2130. https://doi.org/10.3390/ijerph18042130.

(Edited by GUO Zheng)

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