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Associations between maternal body composition in the second trimester and premature rupture of membranes: a retrospective study using hospital information system data

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Abstract

Background Maternal nutrition is associated with premature rupture of membranes (PROM), which affects 6.7–10.0% of term pregnancies and poses significant health challenges for both mothers and children. However, the relationship between body composition, a detailed reflection of maternal nutrition, and PROM remains under-explored.

Methods We conducted a retrospective correlational study using data from 38,610 obstetric cases (PROM = 9,857; non-PROM = 28,753) in the hospital information system of West China Second University Hospital. Multi-variable binary logistic regression was performed to investigate the relationships between key body composition indicators and PROM.

Results Advanced maternal age (OR:1.026, $P < 0.001$) and nulliparity (OR:1.402, $P < 0.001$) were associated with an increased risk of PROM, while longer gestational age (OR:0.864, $P < 0.001$) was linked to a lower risk. A higher waist-to-hip ratio was identified as a significant risk factor for PROM (OR:2.818, $P < 0.001$), whereas higher protein levels (OR:0.934, $P < 0.001$) and mineral content (OR:0.760, $P = 0.045$) were potential protective factors.

Conclusion Key body composition indicators, including a higher waist-to-hip ratio, lower protein levels, and lower mineral content, are associated with an increased risk of PROM. Additionally, advanced maternal age, shorter gestational age, and nulliparity are linked to a higher incidence of PROM. These findings provide valuable insights for early PROM risk screening and contribute to maternal and child health promotion. Future prospective, longitudinal, and causal studies are necessary to validate and further support these findings.

Keywords Body composition, Second trimester, PROM, Associations, Retrospective

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Introduction

Premature rupture of membranes (PROM) refers to the leaking of amniotic fluid before the onset of labor due to the detriment of fetal membranes [1]. It is classified based on gestational age: preterm PROM (PPROM) occurs before 37 weeks [2], while term PROM occurs after 37 weeks of pregnancy [3]. PROM is a common complication during mid to late pregnancy [1], with incidence ranging from 6.7 to 10.0% for term PROM [4, 5] and 1.6–3.0% for PPROM [4, 6]. A recent meta analysis highlights the significant maternal and neonatal complications associated with PROM [7]. These include premature birth, cesarean deliveries, oligohydramnios, chorioamnionitis, endometritis, placental abruption, and postpartum hemorrhage. PROM is associated with 86.3% of neonatal intensive care admissions, 66.5% of cases of respiratory distress syndrome, and 23.9% of neonatal mortality. Furthermore, these complications can have long-term negative impacts, persisting in approximately 30.0% of cases for 2 to 4 years of follow-up [7]. Prompt identification and management of PROM are therefore critical to reducing these risks and improving maternal and neonatal health outcomes, which remains a significant health challenge in the 21st century [8].

The etiology and mechanism of PROM remain incompletely understood, although several risk factors have been identified [9]. Maternal nutritional status has been a longstanding focus [10] and is attracting growing research interest due to it's potential role in inducing PROM [11, 12]. In this context, body composition analysis has gained prominence for its ability to measure key components such as fat mass, water content, muscle mass, and bone mass, offering health professionals a more detailed and comprehensive understanding of an individual's nutritional status [13].

Body composition changes significantly during pregnancy to meet nutritional demands. However, excessive changes in specific components, such as increased fat mass or waist-hip ratio, are linked to complications like gestational diabetes mellitus (GDM) and hypertensive disorders [14, 15], both of which are key contributors to PROM [16, 17]. Studies also suggest associations between PROM and maternal nutritional factors like metabolic conditions and lipid profile [18], gestational exposure to rare earth elements [19], and serum mineral levels [20]. Despite these findings, the majority body of literature has focused on general indicators like body mass index (BMI) [21] or isolated body composition components. Large-scale studies analyzing multi-component body composition data are lacking, limiting our ability to identify high-risk populations and implement effective monitoring and prevention strategies.

To address this gap, we conducted a retrospective correlational study using big data from the Hospital Information System (HIS) of West China Second University Hospital, a tertiary care center for women and children in Southwest China. This study aimed to explore the associations between maternal early-second trimester body composition and PROM. Our findings aim to improve screening and management strategies for PROM, contributing to the promotion of maternal and neonatal health.

Methods

Study design

This was a retrospective correlational study using data from the HIS database of West China Second University Hospital, Sichuan University, Chengdu, China.

Participants

Obstetric cases from the HIS database between January 2018 and December 2021 were extracted.

Inclusion and exclusion criteria

Our inclusion criteria were: cases with maternal age ≥ 18 years, singleton pregnancy, Han Chinese ethnicity, and pregnancies terminated between 28 and 42 weeks of gestation. Cases with the following situations were excluded: a history of diabetes or hypertension, any diagnosis of GDM, gestational hypertension, maternal infection, and cervical incompetence. Cases without records of body composition in early-second trimester were excluded as well.

Data extraction

Data extraction was performed in January 2022, including general obstetric information, PROM diagnosis, and body composition indicators.

General obstetric information

Five items related to obstetric history were extracted from the HIS database, including maternal age, gestational age at termination, gestational weight gain, nulliparity, and IVF treatment for the current pregnancy.

PROM diagnosis

The targeted hospital follows the guidelines issued by the Chinese Medical Association for diagnosing PROM [22], which classify PROM into PPROM and term PROM. After extracting the data, we manually combined the cases of PPROM and term PROM under the broader category of PROM.

Body composition indicators

We extracted 11 key body composition variables measured during the early-second trimester (13–15 weeks of gestation), including total body water (L), intracellular water (L), extracellular water (L), protein (Kg), mineral

(Kg), body fat mass (Kg), fat free mass (Kg), skeletal muscle mass (Kg), body mass index (BMI, kg/m²), basal metabolic rate (Kcal/day), and waist-to-hip ratio.

Body composition analysis at the targeted hospital is conducted between 13 and 15 weeks of gestation. Bioelectrical impedance analysis (BIA), a non-invasive, cost-effective, and reliable method for measuring body composition during pregnancy and the postpartum period [23], was used.

Data cleaning and quality check

We conducted the following steps to insure data quality. (1) Missing values: cases with missing data for any variables were removed. (2) Duplicated cases: duplicates were identified and removed by comparing patient IDs (unique identifiers for each case). (3) Outlier detection: outliers (e.g., gestational weight gain < 3 kg or > 35 kg) were identified and manually verified using HIS records. If no accurate data were found, the case was excluded. (4) Random validation: a random sample of 1,000 cases was checked for consistency with HIS records. If discrepancies were found, data extraction was repeated. (5) Variable coding: all variables were reviewed to ensure they were properly coded as numerical values.

Data analysis

We used SPSS software version 25.0 to analyze the data. Means and standard deviations (SD) were used to describe continuous variables, while frequencies and proportions were used to present categorical variables.

Univariable comparisons between cases diagnosed with PROM and those without were conducted using independent samples t-test for continuous variables and Chi-square tests for categorical variables. Variables with a *P* value of less than 0.1 in the univariable tests, along with clinically relevant variables regardless of statistical significance, were included in a multivariable binary logistic regression model to identify body composition indicators associated with PROM. Forward selection was employed for variable inclusion, and multicollinearity testing was conducted for the body composition variables. Additionally, subgroup analyses were conducted for PPROM and term PROM, considering gestational age at termination.

All tests were two-sided, and a *P* value of less than 0.05 was considered statistically significant.

Ethical consideration

This study was approved by the Medical Ethics Committee of West China Second University Hospital. All data were anonymized, with unique case IDs replacing personally identifiable information. No additional information beyond the extracted data was utilized in this study. Given the data extraction design and the absence of private or identifying information used or reported, consent to participate was not required by the Medical Ethics Committee of West China Second University Hospital.

Results

Descriptive statistics of the data

A total of 62,654 obstetric cases were identified in the HIS, with 54,867 meeting the inclusion criteria. Among these, 15,739 cases were excluded due to a pre-pregnancy history of diabetes or hypertension (659 cases), GDM or gestational hypertension (9,706 cases), maternal infection or cervical incompetence (156 cases), and missing body composition data (5,218 cases). Following quality checks on the remaining 39,128 eligible cases, 518 were removed for duplication (23 cases), missing values (208 cases), or outlier values (287 cases), resulting in a final sample size of 38,610. This included 9,857 cases diagnosed with PROM and 28,753 without. A detailed flowchart of case selection is presented in Fig. 1.

The average age of the included cases was 30.93 ± 3.39 years, with a mean gestational termination age of 38.42 ± 1.62 weeks and an average gestational weight gain of 13.24 ± 3.99 kg. Most cases (94.93%) did not receive IVF treatment for the current pregnancy, while nearly half (44.25%) were nulliparous.

Regarding body composition, the mean total body water, intracellular water, and extracellular water were 28.10 ± 2.67 L, 17.24 ± 1.67 L, and 10.86 ± 1.02 L, respectively. Protein and mineral contents averaged 7.45 ± 0.72 kg and 2.82 ± 0.27 kg, respectively, while body fat mass, fat-free mass, and skeletal muscle mass were 17.71 ± 4.44 kg, 38.37 ± 3.65 kg, and 20.49 ± 2.18 kg. The average BMI was 21.83 ± 2.52 kg/m^2, the basal metabolic rate averaged 1198.87 ± 78.75 kcal/day, and the waist-to-hip ratio was 0.86 ± 0.04. Detailed descriptive statistics for each group are presented in Table 1.

Univariable analysis of cases with and without PROM

Univariable analysis revealed significant differences between cases with and without PROM (Table 1). Cases with PROM were generally older (31.11 ± 3.83 vs. 30.86 ± 3.23 years, P<0.001), had shorter gestational age at termination (38.11 ± 1.76 vs. 38.53 ± 1.55 weeks, P<0.001), lower gestational weight gain (13.13 ± 3.94 vs. 13.28 ± 4.00 Kg, P = 0.001), and were more likely to be nulliparous (48.88% vs. 42.66%, P<0.001).

Most body composition indicators were significantly lower in cases with PROM compared to those without, including total body water (28.03 ± 2.84 vs. 28.13 ± 2.61 L, P = 0.001), intracellular water (17.20 ± 1.78 vs. 17.26 ± 1.63 L, P = 0.002), extracellular water (10.83 ± 1.08 vs. 10.87 ± 1.00 L, P = 0.001), protein (7.43 ± 0.77 vs. 7.46 ± 0.70 Kg, P = 0.001), mineral (2.81 ± 0.29 vs. 2.82 ± 0.27 Kg, P = 0.001), fat free mass (38.27 ± 3.87 vs. 38.41 ± 3.56 Kg, P = 0.001), skeletal muscle mass

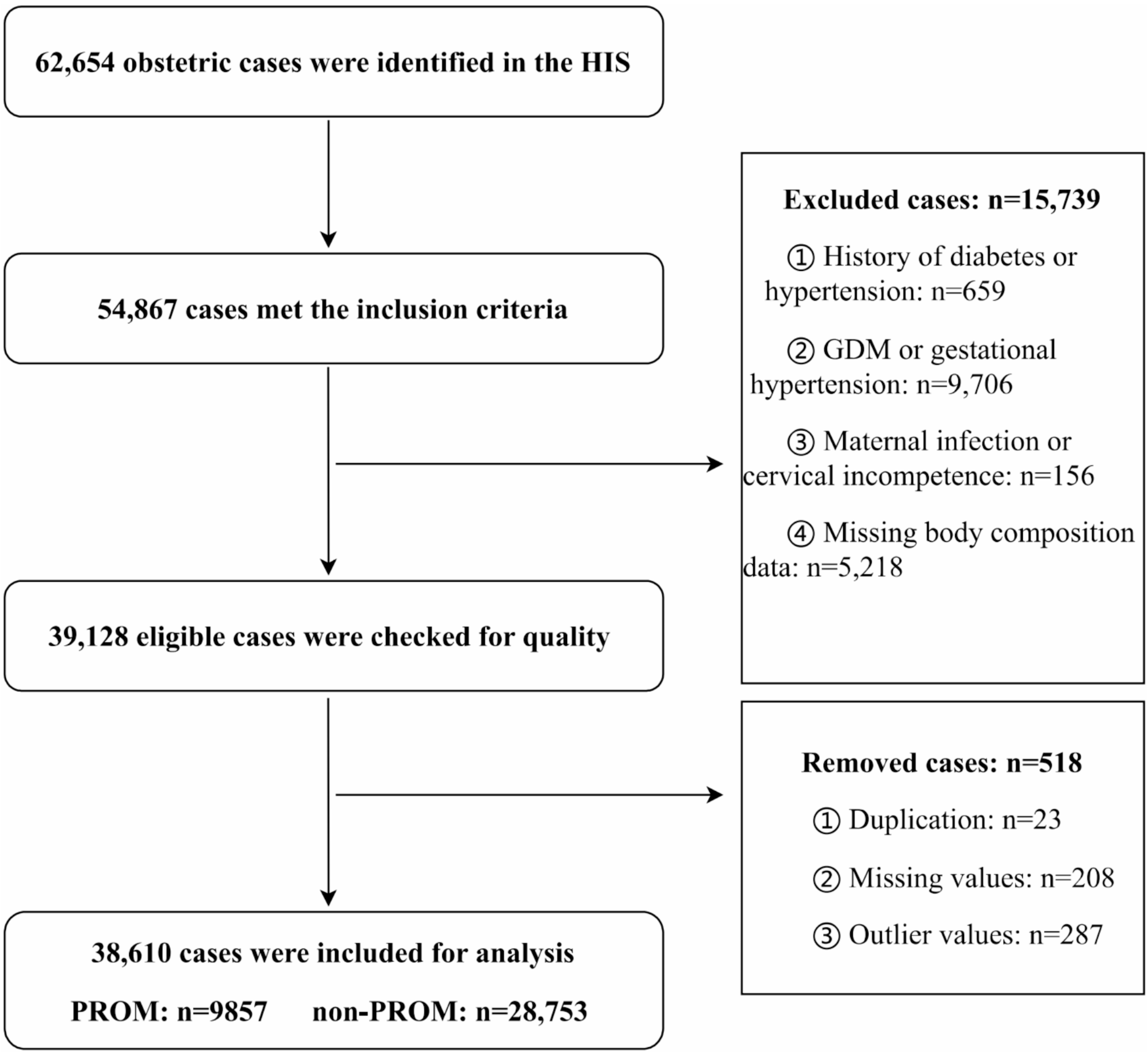

Fig. 1 Flow chart of case selection

(20.43 ± 2.32 vs. 20.51 ± 2.13 Kg, $P = 0.002$), and basal metabolic rate (1196.66 ± 83.61 vs. 1199.62 ± 77.00 Kcal/day, $P = 0.001$). Waist-to-hip ratio was higher in cases with PROM (0.86 ± 0.04 vs. 0.85 ± 0.04, $P = 0.029$). However, body fat mass (17.74 ± 4.60 vs. 17.70 ± 4.39 Kg, $P = 0.493$) and BMI (21.82 ± 2.61 vs. 21.84 ± 2.49 kg/m^2, $P = 0.661$) did not differ significantly between the groups.

Associations between body composition indicators and PROM

All variables with a *P* value below 0.1 in the univariable analyses were included in the multivariable binary logistic regression model, with PROM diagnosis as the dependent variable. Body fat mass and BMI were also included due to their clinical relevance, regardless of their univariable results. Variables such as intracellular water, extracellular water, body fat mass, and skeletal muscle mass were excluded to address multicollinearity concerns.

As summarized is Table 2, older maternal age was associated with a higher risk of PROM (OR: 1.026, $P<0.001$). Conversely, longer gestational age at termination was linked to a reduced risk of PROM (OR: 0.864, $P<0.001$). Nulliparous cases had approximately 1.4 times the risk of PROM compared to multiparous cases (OR: 1.402, $P<0.001$). A higher basal metabolic rate appeared to be a protective factor against PROM (OR: 0.999, $P<0.001$), while a lager waist-to-hip ratio was identified as a significant risk factor (OR: 2.818, $P = 0.001$).

Table 1 Basic information and body composition indicators of participants

Variables	Total (*N* = 38610)	PROM (*n* = 9857)	Non-PROM (*n* = 28753)	*P* (95%CI)
Maternal age (years)	30.93 ± 3.39	31.11 ± 3.83	30.86 ± 3.23	<0.001 (−0.319,−0.164)
Gestational age at termination (weeks)	38.42 ± 1.62	38.11 ± 1.76	38.53 ± 1.55	<0.001 (0.377,0.451)
Gestational weight gain (Kg)	13.24 ± 3.99	13.13 ± 3.94	13.28 ± 4.00	0.001 (0.060,0.242)
Nulliparity				<0.001 (0.743, 0.815)
No	21,527 (55.75)	5039 (51.12)	16,488 (57.34)	
Yes	17,083 (44.25)	4818 (48.88)	12,265 (42.66)	
IVF treatment				0.149 (0.972, 1.202)
No	36,651 (94.93)	9384 (95.20)	27,267 (94.83)	
Yes	1959 (5.07)	473 (4.80)	1468 (5.17)	
Total body water (L)	28.10 ± 2.67	28.03 ± 2.84	28.13 ± 2.61	0.001 (0.039,0.161)
Intracellular water (L)	17.24 ± 1.67	17.20 ± 1.78	17.26 ± 1.63	0.002 (0.023,0.099)
Extracellular water (L)	10.86 ± 1.02	10.83 ± 1.08	10.87 ± 1.00	0.001 (0.016,0.062)
Protein (Kg)	7.45 ± 0.72	7.43 ± 0.77	7.46 ± 0.70	0.001 (0.010,0.043)
Mineral (Kg)	2.82 ± 0.27	2.81 ± 0.29	2.82 ± 0.27	0.001 (0.004,0.017)
Body fat mass (Kg)	17.71 ± 4.44	17.74 ± 4.60	17.70 ± 4.39	0.493 (−0.137,0.066)
Fat free mass (Kg)	38.37 ± 3.65	38.27 ± 3.87	38.41 ± 3.56	0.001 (0.054,0.220)
Skeletal muscle mass (Kg)	20.49 ± 2.18	20.43 ± 2.32	20.51 ± 2.13	0.002 (0.031,0.130)
Body mass index (kg/m²)	21.83 ± 2.52	21.82 ± 2.61	21.84 ± 2.49	0.661 (−0.045,0.071)
Basal metabolic rate (Kcal/day)	1198.87 ± 78.75	1196.66 ± 83.61	1199.62 ± 77.00	0.001 (1.164,4.766)
Waist-to-hip ratio	0.86 ± 0.04	0.86 ± 0.04	0.85 ± 0.04	0.029 (−0.002,−0.001)

Table 2 Associations between body composition variables and PROM

Variables in the model	β	SE	*P*	OR	95%CI
Maternal age (years)	0.026	0.004	<0.001	1.026	1.019,1.033
Gestational age at termination (weeks)	−0.146	0.007	<0.001	0.864	0.852,0.875
Nulliparity (yes)	0.338	0.024	<0.001	1.402	1.337,1.471
Basal metabolic rate (Kcal/day)	−0.001	0.000	<0.001	0.999	0.998,0.999
Waist-to-hip ratio	1.036	0.316	0.001	2.818	1.516,5.236

Subgroup analyses

To account for the influence of gestational age at termination, subgroup analyses were performed. A total of 3,268 cases (8.46%) with gestational age of less than 37 weeks were classified as preterm termination cases (PPROM: 1,216; non-PPROM: 2,052). The remaining 35,342 cases (91.54%) with gestational age of 37 weeks or over were classified as term termination cases (term PROM: 8,641; non-term PROM: 26,701). Descriptive statistics and univariable analyses for these subgroups were presented in Supplementary Table 1.

In addition to generally obstetric variables such as maternal age, gestational age at termination, and nulliparity, body composition indicators identified in the subgroup multivariable analyses included waist-to-hip ratio, protein, and mineral content. A larger waist-to-hip ratio was significantly associated with both PPROM (OR: 7.214, $p = 0.034$) and term PROM (OR: 2.456, $P = 0.008$). Conversely, higher protein and mineral content were found to be protective factors. For term PROM, the OR for protein content was 0.934 ($P<0.001$), while for PPROM, the OR for mineral content was 0.760 ($P = 0.045$) (Table 3).

Table 3 Body composition indicators for PROM (subgroup analyses)

Variables in the model	β	SE	*P*	OR	95%CI
Term PROM					
Maternal age (years)	0.014	0.004	<0.001	1.014	1.007,1.022
Gestational age at termination (weeks)	−0.289	0.014	<0.001	0.749	0.729,0.770
Nulliparity (yes)	0.339	0.026	<0.001	1.404	1.332,1.474
Protein (Kg)	−0.068	0.019	<0.001	0.934	0.900,0.970
Waist-to-hip ratio	0.898	0.338	0.008	2.456	1.276,4.760
PPROM					
Maternal age (years)	0.072	0.010	<0.001	1.075	1.054,1.097
Nulliparity (yes)	0.434	0.076	<0.001	1.544	1.330, 1.792
Mineral (Kg)	−0.275	0.137	0.045	0.760	0.580,0.994
Waist-to-hip ratio	1.976	0.931	0.034	7.214	1.163,44.768

Discussion

This is the first study from Mainland China to investigate the associations between body composition indicators and PROM. Our findings reveal that maternal body composition in the early-second trimester is significantly associated with the occurrence of PROM. Body composition indicators, including maternal waist-to-hip ratio, protein and mineral content, and basal metabolic rate, and critical obstetric variables, were identified as significant influential factors of PROM. The large sample size and detailed subgroup analyses enhance the clinical relevance of our findings, addressing a research gap in the relationship between body composition and pregnancy outcomes. These results provide valuable insights for promoting maternal and child health.

We found that older maternal age and nulliparity were associated with a higher risk of PROM, while longer gestational age at termination was linked to a reduced risk of PROM. These findings align with exist literature. Studies both in China and internationally have reported that advanced maternal age contributes to the incidence of PROM [24, 25]. A 5-year cohort study demonstrated that nulliparity is associated with 2.52-fold increased risk of PROM [26]. Additionally, a community-based cohort study involving 10,171 pregnant women in China found that the combination of advanced maternal age and nulliparity resulted in a 6.84-fold increased risk of developing PROM [27]. PROM often leads to the discharge of the amniotic fluid and the onset of labor [28], which explains the shorter gestational age observed in PROM cases.

Our findings identified several key body composition indicators associated with PROM. Higher levels of protein, mineral content, and basal metabolic rate emerged as potential protective factors against PROM, whereas a higher waist-to-hip ratio is found as an important risk factor. Published literature provides theoretical support for these findings. The waist-to-hip ratio is a critical marker of central obesity [29], which typically indicates increased fat accumulation in the central body region. This condition is often associated with lower basal metabolic rates [30], leading to gestational hypertension [31] and inflammatory responses [32] in pregnant women, both of which are contributors to PROM, either directly or indirectly. Additionally, a previous case-control study reported that lower hemoglobin levels are linked to higher risk of PROM [33], consistent with our findings. This relationship may be further supported by animal models demonstrating that low protein levels contribute to inflammation [34], a significant risk factor for PROM. A recent case-control study also found that lower maternal serum zinc levels are associated with a higher risk of PROM [20]. This aligns with our findings, as higher mineral content appears to act as a protective factor against PROM.

Taken together, our findings highlight the essential role of precision nutrition management during pregnancy for early screening and potential prevention of PROM. Early nutrition assessments, particularly body composition analysis, should be conducted to identify women at higher risk, including those with elevated waist-to-hip ratios, lower protein levels, and reduced mineral content. Additionally, pregnant women with advanced maternal age, shorter gestational age, and nulliparity should be closely monitored due to their increased vulnerability to PROM. Our findings also suggest that maintaining optimal levels of protein, minerals, and waist-to-hip ratios is crucial for reducing the risk of PROM.

Our study has several limitations. First, as a retrospective study using data from the HIS, the generalizability of our findings is limited, underscoring the need for future prospective studies. Second, we relied on body composition information from the early-second trimester. Given the significant changes in body composition throughout pregnancy, future longitudinal studies focusing on the later stages of pregnancy are warranted to refine our findings. Third, in the multivariable analysis for PROM (Table 2), the OR for basal metabolic rate was very close to 1, and in the analysis for PPROM, the 95% CI for the waist-to-hip ratio was extremely wide (Table 3). This highlights the need for caution when drawing conclusions about these two variables. Last, other factors, such as education level, dietary habits, and physical activity, which may significantly influence PROM, should be considered in future research.

Conclusion

Maternal body composition indicators in the early-second trimester, including a higher waist-to-hip ratio, lower protein levels, lower mineral content, and lower basal metabolic rate, are associated with an increased risk of PROM. Additionally, advanced maternal age, shorter gestational age, and nulliparity are linked to a higher incidence of PROM. These findings provide valuable insights for early screening of PROM risk and contribute to promoting maternal and child health. Future prospective, longitudinal, and causal studies are needed to validate and further support these findings.

Abbreviations

BIA	Bioelectrical impedance analysis
BMI	Body mass index
GDM	Gestational diabetes mellitus
HIS	Hospital information system
PPROM	Preterm premature rupture of membranes
PROM	Premature rupture of membranes

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-025-07334-4.

Supplementary Material 1

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Author contributions

Shujuan Liao conceptualized the study, performed and verified data analyses, drafted the initial manuscript, revised subsequent drafts, prepared the figures and tables, and reviewed and approved the final version. Anqi Xiong verified raw data, conducted data cleaning and analyses. Siqi Xiong verified raw data and prepared the figures and tables. Yan Zuo had access to the raw data and revised the manuscript drafts. Yan Wang had access to the raw data and revised the manuscript drafts. Biru Luo conceptualized the study, accessed the raw data, revised the drafts, and reviewed and approved the final manuscript.

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Data availability
Data used in this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval
This study was approved by the Medical Ethics Committee of West China Second University Hospital. All data were anonymized, with unique case IDs replacing personally identifiable information. No additional information beyond the extracted data was utilized in this study. Given the data extraction design and the absence of private or identifying information used or reported, consent to participate was not required by the Medical Ethics Committee of West China Second University Hospital.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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