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Original Article

Early pregnancy cardiometabolic index and its association with hypertensive disorder complicating pregnancy

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Abstract: Objective: To investigate the characteristics of early pregnancy cardiometabolic index in patients with hypertensive disorder complicating pregnancy (preeclampsia) and its correlation with the occurrence of different degrees of preeclampsia. Methods: This retrospective study enrolled 210 pregnant women with preeclampsia, who were registered and delivered at Beijing Haidian District Maternal and Child Health Hospital, as the preeclampsia group. Another 210 healthy pregnant women with similar gestational age during the same period were selected as the control group. Early pregnancy clinical data, including body mass index (BMI), blood pressure, waist circumference, triglyceride level, and cardiometabolic index, were compared between the two groups. The relationship between early pregnancy cardiometabolic index and the occurrence of preeclampsia was analyzed. Results: As the cardiometabolic index quartile increased, the proportion of preeclampsia patients showed a significant upward trend (trend Z=34.006, P<0.001). For each additional standard deviation (SD) unit of cardiometabolic index, the risk of preeclampsia increased by 24.245 times (95% CI: 8.359-70.321). After adjusting for age, weight, BMI, waist circumference, and gestational age, the risk of preeclampsia (SD units of cardiometabolic index) was 5.986 times higher (P<0.05). Conclusion: Early pregnancy cardiometabolic index is positively correlated with the occurrence of preeclampsia.

Keywords: Pregnancy, early, cardiometabolic index, hypertensive disorder complicating pregnancy, preeclampsia, relationship

Introduction

Hypertensive disorder complicating pregnancy (HDCP) is a condition characterized by the coexistence of pregnancy and elevated blood pressure, representing a major cause of adverse outcomes in pregnant women [1]. At present, the pathogenesis of HDCP remains unclear. Relevant studies have shown that extensive endothelial cell injury and dysfunction are closely related to this condition, with abnormal lipid metabolism contributing to vascular endothelial cell damage and disease development [2]. Preeclampsia, a significant subtype of HDCP, is characterized by new-onset hypertension and proteinuria after 20 weeks of gestation and is one of the leading causes of maternal and perinatal mortality [3]. In China, the incidence of preeclampsia is as high as 10.4% and continues to rise annually [4]. Therefore, identifying and managing risk factors for preeclampsia is critical.

Abnormal blood lipid profiles, especially elevated triglyceride (TG) and total cholesterol (TC) levels in early pregnancy have been identified as predictors of preeclampsia development [5]. The cardiometabolic index, introduced by Wakabayashi et al. in 2015 [6], incorporates clinically accessible parameters such as the waist-to-height ratio (WHtR), TG, and high-density lipoprotein cholesterol (HDL-C) [7], integrating abdominal obesity index and lipid-related factors, offering a comprehensive metric for cardiovascular risk. Previous studies have proved its predictive value for various diseases, including left ventricular geometry change [8], stroke [9], and diabetes [10], as well as its utility in assessing hypertension-related obesity burden [11].

However, few studies have reported on the relationship between the cardiometabolic index and hypertensive disorders complicating pregnancy (HDCP). A large-scale 2024 study [12]

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investigated cardiometabolic indicators and HDCP but didn't focus on urban populations in China, nor did it include quartile-trend analysis of the cardiometabolic index, linearity verification, or subgroup stratification. To address these gaps, we conducted a study in Haidian District, Beijing, to provide region-specific evidence for preeclampsia prevention. This study aims to explore the relationship between early pregnancy cardiometabolic index and preeclampsia, so as to provide insights to guide the prevention and management of hypertensive disorders during pregnancy and inform related public health strategies.

Materials and methods

Source and selection of study participants

This retrospective study included 210 pregnant women diagnosed with preeclampsia, who were registered and delivered at Beijing Haidian District Maternal and Child Health Hospital from April 2022 to March 2024, as the preeclampsia group. Another group of 210 healthy pregnant women with similar gestational age during the same period were selected as the control group.

Inclusion criteria: (1) A clinical diagnosis of preeclampsia [13]; (2) Singleton pregnancy; (3) No recent use of drugs that could affect blood lipids. Exclusion criteria: (1) Presence of chronic hypertensive diseases, immune system diseases, or endocrine diseases; (2) Severe liver or kidney dysfunction; (3) Coexistence of malnutrition, diabetes, or heart disease. This study was reviewed and approved by the Medical Ethics Committee of Beijing Haidian District Maternal and Child Health Hospital.

Observed indicators

For all participants, indicator levels were measured during the first trimester, defined as before 14 weeks of gestation.

(1) Anthropometric indicators: Enrolled participants were instructed to wear light clothing and no shoes. Height was measured using a stadiometer (accuracy: 0.1 cm). Body weight was measured using a calibrated digital scale. Waist circumference was measured at the level of the umbilicus. Each of these anthropometric indicators (height, weight, and waist circumference) was measured twice, and the mean value was used for subsequent analysis.

(2) Blood lipid index: Fasting venous blood samples were collected in the morning after a 12-hour fast. Concentrations of total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were measured using an Abbott CI16200 biochemical and immunological analyzer and its matching reagents.

(3) Cardiometabolic index: The cardiometabolic index was calculated using the formula: cardiometabolic index = (TG/HDL-C) × WHtR [14], where WHtR was calculated as waist circumference (cm) divided by height (cm). Participants were divided into four groups based on the quartiles of their first-trimester cardiometabolic index.

(4) Body mass index (BMI): BMI = weight (kg) ÷ height $(m)^2$ [15].

(5) Blood pressure: Blood pressure was measured three times after a 5-minute rest period. The average value of the three measurements was used for statistical analysis.

(6) Detection of indicators: Peripheral blood routine indicators [white blood cell (WBC), neutrophil count, hematocrit, platelet (PLT)]: Venous blood samples were collected and anticoagulated with EDTA-K2. Detection was performed using an automated hematology analyzer (model: XN-9000, manufacturer: Sysmex Corporation, Kobe, Japan) following the manufacturer's standard operating procedures.

Liver and kidney function & metabolic indicators [(aspartate aminotransferase (AST), alanine aminotransferase (ALT), creatinine (Cr), uric acid (UA), chloride (Cl)]: Venous blood was collected without anticoagulation, centrifuged at 3000 r/min for 10 min to separate serum. Detection was conducted via an automated biochemical analyzer (model: Cobas 8000, manufacturer: Roche Diagnostics, Basel, Switzerland) using commercially available reagent kits (brand: Roche Diagnostics) with strict adherence to reagent and instrument operation protocols.

Statistical approach

Data were analyzed using SPSS 23.0 statistical software. Continuous variables with a normal distribution were expressed as mean ± standard deviation (SD) and compared using the independent samples t-test. Continuous vari-

Table 1. Comparison of baseline data between the two groups

Data	Preeclampsia group (n=210)	Control group (n=210)	$Z/t/\chi^2$	*P*
Age (year)	31 (7.00)	28 (5.25)	-5.932	<0.001
Height (cm)	160 (6)	160 (5)	-0.655	0.513
Weight (kg)	56.90 (11.00)	53.18±6.84	-5.062	<0.001
BMI (kg/m^2)	22.35 (3.73)	20.64±2.50	-6.173	<0.001
Waist circumference (cm)	79 (12)	75 (9)	-6.305	<0.001
Gestational age (week)	12 (2)	12 (1)	-2.203	0.028
Gravidities (times)	1.96±1.21	2.00 (1.00)	-0.567	0.570
Parity (times)			7.977	0.019
0	143 (68.10%)	129 (61.43%)		
1	57 (27.14%)	78 (37.14%)		
2	10 (4.76%)	3 (1.43%)		
History of cesarean section			36.995	<0.001
Have	34 (16.19%)	0 (0.00%)		
Not have	176 (83.81%)	210 (100.00%)		
History of abortion			3.044	0.081
Have	81 (38.57%)	64 (30.48%)		
Not have	129 (61.43%)	146 (69.52%)		
SBP (mmHg)	123.00 (15.00)	114.13±10.90	-7.038	<0.001
DBP (mmHg)	74.69±8.19	67.42±8.33	9.018	<0.001
Blood type			0.536	0.911
O-type	81 (38.57%)	84 (40.00%)		
A-type	65 (30.95%)	59 (28.10%)		
B-type	50 (23.81%)	54 (25.71%)		
AB-type	14 (6.67%)	13 (6.19%)		

BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure.

ables with a non-normal distribution were expressed as median (interquartile range, IQR) and compared using the Mann-Whitney U test. Categorical variables were presented as n (percentage, %) and compared using the chi-square test or Fisher's exact test, as appropriate. Logistic regression analysis was used to assess the independent association between cardiometabolic index and preeclampsia, with adjustment for potential confounding factors. Results were presented as odds ratios (ORs) with 95% confidence intervals (CIs). Linear trend tests across cardiometabolic index quartiles were performed using the chi-square test for trend. All statistical tests were two-tailed, with a significance level set at α=0.05.

Results

Baseline data

Compared with the control group, the preeclampsia group had significantly higher age, weight, BMI, waist circumference, gestational age, parity, cesarean section history, systolic blood pressure (SBP), and diastolic blood pressure (DBP) (all P<0.05), as shown in **Table 1**.

Laboratory index

In comparison with the control group, the preeclampsia group exhibited significantly higher levels of WBC, neutrophil count, hematocrit, PLT, AST, ALT, Cr, UA, and Cl (P<0.05), as shown in **Table 2**.

Blood lipid index and cardiometabolic index

The preeclampsia group demonstrated significantly higher TG, HDL-C, WHtR, and cardiometabolic index compared to the control group (P<0.05), as shown in **Table 3**.

Risk factors for preeclampsia

Binary logistic regression analysis was performed to identify risk factors for preeclampsia, with preeclampsia as the dependent variable

Table 2. Comparison of laboratory index between the two groups

Index	Preeclampsia group (n=210)	Control group (n=210)	$Z/t/\chi^2$	*P*
WBC ($\times10^9$/L)	9.15 (3.13)	8.81±1.92	-2.932	0.003
Neutrophil count ($\times10^9$/L)	6.64±1.84	6.06 (1.96)	-2.817	0.005
Lymphocyte count ($\times10^9$/L)	2.05 (0.77)	2.03 (0.69)	-0.536	0.592
Hemoglobin (g/L)	125.00(13.5)	123.42±8.79	-1.611	0.107
Hematokrit (%)	35.82±2.70	35.21±2.45	2.425	0.016
PLT ($\times10^9$/L)	231.49±53.67	213.12±41.20	3.934	<0.001
Albumin (g/L)	41.02±2.65	41.43±2.25	1.709	0.088
Total bilirubin (μmol/L)	10.10 (4.85)	10.75 (4.53)	-1.609	0.108
AST (U/L)	17 (7.65)	15 (5.00)	-5.304	<0.001
ALT (U/L)	16 (11.00)	11 (6.25)	-6.358	<0.001
Cr (μmol/L)	44.05±6.32	45.53±6.24	2.415	0.016
Urea (mmol/L)	3.0 (0.9)	2.9 (1.2)	-0.050	0.960
UA (μmol/L)	200.10±53.67	182.00 (54.25)	-3.101	0.002
FBG (mmol/L)	4.64±0.46	4.57 (0.52)	-1.575	0.115
Mg (mmol/L)	0.86 (0.09)	0.87 (0.08)	-1.651	0.099
Cl (mmol/L)	104 (3)	103 (3)	-2.213	0.027
TSH (mIU/L)	1.008 (1.23)	1.094 (1.13)	-1.124	0.261
Free thyroxine (ng/dL)	1.19 (0.23)	1.20 (0.19)	-0.653	0.514
Serum potassium (mmol/L)	4.06±0.28	4.06±0.30	<0.001	>0.999
Blood calcium (mmol/L)	2.31±0.11	2.31±0.10	<0.001	>0.999

WBC: white blood cell; PLT: platelet; AST: aspartate aminotransferase; ALT: alanine aminotransferase; Cr: creatinine; UA: uric acid; FBG: fasting blood glucose; Mg: magnesium; Cl: chloride; TSH: thyroid-stimulating hormone.

Table 3. Comparison of blood lipid index and cardiometabolic index between the two groups

Index	Preeclampsia group (n=210)	Control group (n=210)	$Z/t/\chi^2$	*P*
TC (mmol/L)	4.62±0.88	4.45 (0.97)	-1.175	0.240
TG (mmol/L)	1.56 (0.84)	1.30 (0.6)	-4.716	<0.001
HDL-C (mmol/L)	1.66±0.29	1.73±0.27	2.560	0.011
LDL-C (mmol/L)	2.230 (0.61)	2.435 (0.85)	-1.004	0.315
WHtR	0.500 (0.07)	0.465 (0.05)	-6.875	<0.001
Cardiometabolic index	0.470 (0.33)	0.335 (0.20)	-6.324	<0.001

TC, cholesterol; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; WHtR, waist-to-height ratio.

Table 4. Multivariate Logistic regression analysis of preeclampsia

Index	β	SE	OR	*P*
Age	0.259	0.047	1.295	<0.001
Parity				<0.001
Parity (1)	1.339	1.341	3.817	0.318
Parity (2)	-0.769	1.354	0.464	0.570
DBP	0.109	0.021	1.115	<0.001
PLT	0.007	0.003	1.007	0.036
Cr	-0.063	0.025	0.939	0.014
UA	0.008	0.003	1.008	0.023
Cl	0.143	0.070	1.154	0.042

DBP, diastolic blood pressure; PLT, platelet; Cr, creatinine; UA, uric acid; Cl, chloride.

(1=present, 0=absent) and variables with P< 0.05 in univariate analysis as independent variables. The results identified age, parity, DBP, PLT, Cr, UA, and Cl as independent risk factors for preeclampsia (**Table 4**).

Cardiometabolic index quartile distribution in preeclampsia patients

All participants were stratified into four groups based on the quartiles of their cardiometabolic index [16]: Q1 (cardiometabolic index ≤ 0.29), Q2 (0.29 < cardiometabolic index ≤ 0.38), Q3 (0.38 < cardiometabolic index ≤ 0.56), and Q4 (cardiometabolic index > 0.56). The prevalence

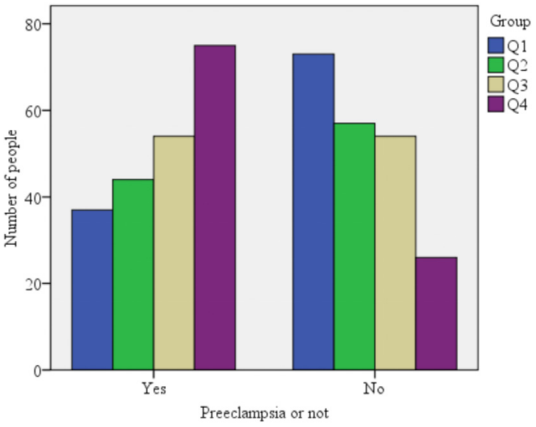

Figure 1. Cardiometabolic index quartile distribution in preeclampsia patients. *Note*: There were 37 preeclampsia patients in Q1 group, 44 in Q2 group, 54 in Q3 group, and 75 in Q4 group.

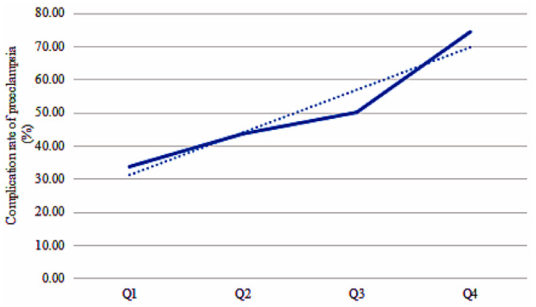

Figure 2. Trends in the proportion of preeclampsia and the quartile of cardiometabolic index. *Note*: With the increase of cardiometabolic index quartile, the proportion of preeclampsia patients showed an increasing trend (trend $P<0.05$).

of preeclampsia in each group was as follows: Q1, 33.64% (37/110); Q2, 43.56% (44/101); Q3, 50.00% (54/108); and Q4, 74.26% (75/101) (**Figure 1**).

The prevalence of preeclampsia showed a significant upward linear trend with increasing cardiometabolic index quartiles (trend $\chi^2=34.006$, $P<0.001$). This finding indicates a positive association between the cardiometabolic index and preeclampsia risk (**Figure 2**).

Logistic regression analysis of cardiometabolic index and preeclampsia

Binary logistic regression analysis was further performed to evaluate the association between the cardiometabolic index and preeclampsia, with the results presented in **Table 5**. In the unadjusted model (Model 1), each 1-standard deviation (SD) increase in the cardiometabolic index was associated with a 24.245-fold higher risk of preeclampsia (OR=24.245, 95% CI: 8.359-70.321). After adjusting for age, weight, BMI, waist circumference, and gestational age, the risk of preeclampsia per SD increase in the cardiometabolic index was 5.986 times higher ($P<0.05$).

Regarding cardiometabolic index quartiles, with the Q1 group as the reference, the risk of preeclampsia in the Q2 group was 0.411 times that of the reference group (95% CI: 0.198-0.855, $P=0.017$), indicating a lower risk. The risk in the Q3 group was 0.620 times (95% CI: 0.307-1.253, $P=0.183$) and in the Q4 group was 0.533 times (95% CI: 0.272-1.041, $P=0.065$) that of the reference group, with the Q3 and Q4 groups showing no statistically significant risk difference in risk compared to the reference group. To assess the linear relationship between cardiometabolic index and preeclampsia, a smooth curve fitting analysis was performed, revealing a significant linear relationship ($P<0.05$).

Stratification analysis

Stratified analyses were further conducted by predefined covariates (known preeclampsia risk factors, including age, BMI, and parity) to validate the robustness of the associations identified by the logistic regression model. All stratified analyses were adjusted for the same set of confounders (age, weight, BMI, waist circumference, and gestational age) as in the main model. As shown in **Table 6**, the risk of preeclampsia increased with higher cardiometabolic index across all subgroups, confirming the consistency of this association.

Discussion

Preeclampsia is an idiopathic disorder specific to pregnancy, accounting for approximately 4% of all pregnancies, and can affect multiple organ systems [17]. It is a major contributor to adverse maternal and perinatal outcomes. Although its pathogenesis remains incompletely elucidated, clinical evidence strongly supports vascular endothelial injury as a central mediator of its development [18]. Given that preeclampsia risk is associated with elevated TG and TC, and considering that the cardiometabolic index combines abdominal obesity

Table 5. Logistic regression analysis of cardiometabolic index and preeclampsia

Item	n	Unadjusted OR (95% CI)	*P*	Model OR (95% CI)	*P*
Cardiometabolic index (SD increment)		24.245 (8.359, 70.321)	<0.001	5.986 (1.713, 20.917)	0.005
Cardiometabolic index grouping					
Q1 group	110	1			0.105
Q2 group	101	0.176 (0.097, 0.319)	<0.001	0.411 (0.198, 0.855)	0.017
Q3 group	108	0.268 (0.148, 0.485)	<0.001	0.620 (0.307, 1.253)	0.183
Q4 group	101	0.347 (0.193, 0.622)	<0.001	0.533 (0.272, 1.041)	0.065
P for trend			<0.001		<0.001

SD, standard deviation; OR, odds ratio; CI, confidence interval.

Table 6. Subgroup analysis of cardiometabolic index in preeclampsia

Item		OR	95% CI	*P*
Age	≥35 year	0.748	0.003, 210.154	0.920
	<35 year	7.728	2.071, 28.839	0.002
BMI	>24 kg/m^2	7.738	0.738, 81.131	0.088
	≤24 kg/m^2	6.404	1.422, 28.845	0.016
Parity	≥1 time	2.071	0.276, 15.559	0.479
	<1 time	12.774	2.421, 67.405	0.003

BMI, body mass index; OR, odds ratio; CI, confidence interval.

(assessed via WHtR) and lipid-related parameters, we hypothesized that the early pregnancy cardiometabolic index may be associated with an increased risk of preeclampsia.

In our study, women with preeclampsia exhibited significantly older age, higher levels of weight, BMI, waist circumference, gestational age, parity, prior cesarean section history, SBP, DBP, WBC count, neutrophil count, hematocrit, PLT count, AST, ALT, Cr, UA, CI, TG, and cardiometabolic index compared to healthy pregnant women. Conversely, HDL-C was significantly lower in the preeclampsia group. By definition, preeclampsia is diagnosed in pregnant individuals with new-onset hypertension after 20 weeks of gestation. Previous studies have identified several common risk factors for preeclampsia, including advanced maternal age (≥35 years), excessive gestational weight gain, parity, pre-pregnancy BMI ≥28 kg/m^2 (obesity), elevated Cr levels, and increased mean arterial pressure [19]. Notably, distinct from prior research, the present study further demonstrated that the cardiometabolic index differed significantly between the preeclampsia and control groups. These results suggest that cardiometabolic index may also contribute to the development of preeclampsia. Further studies revealed an independent association between the cardiometabolic index and preeclampsia prevalence, with a positive correlation observed. These results indicated that cardiometabolic index could be used as an effective indicator for early monitoring of preeclampsia, potentially improving awareness and control rates of preeclampsia in pregnant women. A cross-sectional study found that serum TG content was significantly higher in hypertensive patients than that in non-hypertensive individuals [20]. The possible reason is that pregnant women with higher TG level and lower HDL-C level may face a higher risk of dyslipidemia, which could impair placental function, promote damage and apoptosis of placental vascular cells, and contribute to preeclampsia [21]. Under normal physiological conditions, pregnancy induces adaptive changes in lipid metabolism; however, abnormal lipid metabolism can stimulate vascular smooth muscle cell proliferation, promoting vasoconstriction. This in turn leads to the accumulation of lipids in the vascular intima, further exacerbating vascular endothelial cell damage and inducing maternal arterial spasm [22]. Arteriospasm is a major pathological feature of preeclampsia [23]. Reducing abdominal obesity in pregnant women could also reduce the incidence of weight catch-up during the neonatal period and lower the risk of metabolic syndrome in children [24]. Studies had pointed out that maternal obesity is closely related to preeclampsia [25]. Yang et al. [26] showed that obesity is a risk factor for preeclampsia, suggesting the role of lifestyle and health factors. Preeclampsia is widely recognized as an inflammatory disorder of pregnancy [27]. Obese pregnant individuals face an elevated risk of preeclampsia, potentially due to impaired placental develop-

ment resulting from disrupted metabolic homeostasis [28]. Inflammatory cytokines secreted by maternal adipose tissue, along with circulating cholesterol, are associated with systemic inflammation, hypertension, and other adverse outcomes associated with preeclampsia [29].

Strengths and limitations

This study shows that the cardiometabolic index can be used to predict the risk of preeclampsia, providing a valuable foundation for the health promotion, prevention, and control of preeclampsia. Additionally, stratified analyses of potential confounding factors were performed to minimize bias in the study results. However, this study has several limitations. First, this study identifies an association between the cardiometabolic index and preeclampsia, but does not establish a causal relationship. Second, being a single-center study with a limited sample size, the results may not be generalizable to pregnant populations in other regions. Therefore, future research should focus on multi-center studies to enhance the external validity of these findings and further validate the results.

Conclusions

Early pregnancy cardiometabolic index is positively associated with the risk of preeclampsia.

Disclosure of conflict of interest

None.

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