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Association between cardiometabolic Index (CMI) and endometriosis: a cross-sectional study on NHANES

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Abstract

Background Endometriosis is intricately linked to metabolic health. The Cardiometabolic Index (CMI), a novel and readily accessible indicator, is utilized to evaluate metabolic status. This study seeks to investigate the potential correlation between CMI and endometriosis.

Methods Data from four consecutive survey cycles of the National Health and Nutrition Examination Survey (NHANES) conducted between 1999 and 2006 were utilized. This included adult females with self-reported diagnoses of endometriosis and complete information required for calculating the CMI. The calculation formula for CMI is Triglycerides(TG) / High-density lipoprotein cholesterol (HDL-C) × WHtR (WHtR = waist circumference / height). A multivariable logistic regression model was employed to investigate the linear association between CMI and endometriosis. Subgroup analyses were performed to explore potential influencing factors. Additionally, the linear relationship was validated using restricted cubic spline (RCS) curve plotting and threshold effect analysis.

Results This study, based on the National Health and Nutrition Examination Survey (NHANES), included a cohort of 2,224 adult women. The multivariable logistic regression analysis demonstrated that in the fully adjusted model, individuals with the highest CMI exhibited a 78% elevated likelihood of endometriosis compared to those with the lowest CMI (OR = 1.78; 95% CI, 1.02–3.11, $P < 0.05$). The subgroup analysis indicated that there were no significant interactions between CMI and specific subgroups (all interaction $P > 0.05$), except for the subgroup stratified by stroke status ($P < 0.05$). Additionally, the association between CMI and endometriosis was linear, with a 20% increase in the association for each unit increase in CMI when CMI > 0.67 (OR = 1.20; 95% CI, 1.05–1.37, $P < 0.01$).

Conclusion The study found that CMI levels are closely correlated with endometriosis, with this correlation increasing when the CMI exceeds 0.67. This finding implies that by regularly monitoring CMI levels, physicians may be able to screen women at risk for endometriosis at an earlier stage, thereby enabling the implementation of early interventions to slow the progression of the disease. To further validate these findings, larger-scale cohort studies are required to support the results of this research.

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Keywords Cardiometabolic Index, Endometriosis, Cross-sectional study, NHANES, Multivariate logic analysis

Introduction

Endometriosis is an estrogen-dependent condition defined by the presence of ectopic endometrial tissue beyond the confines of the uterine cavity. Key symptoms encompass dysmenorrhea, chronic pelvic pain, infertility, irregular menstrual cycles, dyspareunia, and rectal discomfort [1]. Currently, the prevalence of endometriosis in women of reproductive age is about 10%, and it is more common in developed countries [2]. Reports indicate that the incidence of chronic pelvic pain caused by endometriosis can reach 50–70%, and the incidence of infertility among women with endometriosis is 30–50% [3]. This severely impacts women's reproductive and physical health. Currently, the definitive diagnosis of endometriosis necessitates invasive hysteroscopy. Nonetheless, some patients, for economic and psychological reasons, exhibit reluctance towards undergoing invasive procedures despite presenting with similar symptoms. This reluctance may result in disease progression and subsequent infertility. Thus, investigating the relationship between easily accessible and convenient indices and endometriosis is of significant importance for the early diagnosis and treatment of endometriosis.

In recent years, the association between metabolic status and endometriosis has garnered significant attention. A retrospective analysis showed that triglyceride (TG) levels in endometriosis patients were positively correlated with the severity of endometriosis [4]. Prior research has suggested that women with endometriosis frequently demonstrate aberrant lipid profiles, including decreased High-density lipoprotein cholesterol (HDL-C) levels and elevated TG, total cholesterol (TC), and low-density lipoprotein levels [5–8]. Moreover, findings from a Mendelian randomization study indicated that elevated TG levels may contribute to gut microbiota dysbiosis, escalate inflammation, and enhance the susceptibility and advancement of endometriosis [9]. These studies suggest a close link between lipid metabolism disorders and endometriosis, making lipid profiles, which are readily accessible indicators and potentially effective biomarkers for endometriosis.

In clinical practice, the diagnosis of lipid metabolism disorders commonly involves the integration of anthropometric measurements and specific biochemical parameters. The Cardiometabolic Index (CMI) efficiently integrates obesity indicators such as waist-to-height ratio (WHtR) and the TG/HDL-C ratio, and has previously been utilized for the screening of diabetes and obesity [10]. Multiple studies have demonstrated that the CMI possesses predictive and diagnostic utility in evaluating conditions including fatty liver disease, hypertension, atherosclerosis, chronic kidney disease, and depression [11–15].

Currently, there is a lack of literature documenting the association between CMI and endometriosis association. This study suggested that there may be a correlation between CMI and endometriosis. Exploring the association between CMI levels and endometriosis association could aid in the prevention and treatment of endometriosis. CMI, which necessitates solely basic anthropometric measurements and lipid profiles, offers a more convenient means of disease assessment. Building upon this premise, the current study utilized the 1999–2006 NHANES dataset to undertake a cross-sectional analysis with the objective of exploring the potential association between CMI and endometriosis.

Methods

Study population

This study employed data from four consecutive survey cycles conducted between 1999 and 2006, including all NHANES database records with reported endometriosis. The National Health and Nutrition Examination Survey (NHANES) is a nationally representative cross-sectional study conducted by the National Center for Health Statistics (NCHS) with a focus on assessing the health and nutritional status of the United States population. It covers a broad spectrum of topics, ranging from demographic data, socioeconomic indicators, dietary patterns, to various health parameters, and employs rigorous methodologies for data collection, including medical and dental evaluations, physiological assessments, and laboratory analyses carried out by skilled healthcare professionals. The primary objective of the survey is to elucidate the prevalence and determinants of key health issues in the U.S. population and furnish evidence-based support for public health policy decisions. For more detailed information, kindly refer to the official website at https://www.cdc.gov/nchs/nhanes/index.htm.

This study encompassed all participants from the 1999 to 2006 period, amounting to a total of 2,224 individuals. The participants included in this analysis possessed comprehensive demographic information, standard anthropometric measurements, lipid profiles, as well as details regarding reproductive and medical conditions. The exclusion criteria were as follows: (1) age < 18 years; (2) male; (3) lack of endometriosis diagnosis or data for calculating CMI; (4) missing covariate data, including marry, estrogen/progestin use, contraceptive use, pregnancy, alcohol consumption, smoking, BMI, Poverty Income Ratio (PIR), diabetes, coronary heart disease,

angina, stroke, and heart attack status. The flowchart of this process is shown in Fig. 1.

Exposure variable: CMI

The CMI is computed utilizing the waist-to-height ratio and lipid profile of the participants. The formula is as follows: CMI = TG/HDL-C × WHtR. WHtR = waist circumference/height [16].

Outcome variable: Endometriosis

In the NHANES study, data regarding endometriosis was collected from participants' health questionnaires, specifically relying on their answer to the inquiry, "Have you ever been diagnosed with Endometriosis by a healthcare provider?" An affirmative answer classified the individual as an endometriosis patient. While establishing the primary study outcome using questionnaire responses may introduce some level of uncertainty, the absence of direct diagnostic evidence like hysteroscopy or ultrasound in the NHANES dataset presents challenges in accurately identifying Endometriosis cases. Nonetheless, prior research has validated the feasibility and acceptance of utilizing questionnaires to ascertain the presence of Endometriosis in NHANES participants [17–20].

Covariates

To demonstrate the independent association between CMI and endometriosis, adjusted for potential covariates that might influence the association between CMI and endometriosis based on clinical relevance, including sociodemographic factors, reproductive status, medication use, and health conditions. The sociodemographic and lifestyle-related variables included in the analysis encompassed age (years), race (Mexican, American/Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Other race), marital status (Married, Unmarried), education level (Less than 9th grade, 9–11th grade, High school, Some college, College graduate), pregnancy status, Poverty Income Ratio (PIR), smoking status (categorized as no for participants who smoked < 100 cigarettes in their lifetime and yes for participants who smoked > 100 cigarettes in their lifetime), and alcohol consumption (categorized as no for participants who consumed < 12 alcoholic beverages in the past 12 months and yes for participants who consumed at least 12 alcoholic beverages in the past 12 months). Medication utilization and reproductive status variables comprised contraceptive usage, estrogen/progestin therapy, and age at menarche, with information collected from the NHANES Questionnaire Data.

Body mass index (BMI, kg/m^2), height, waist circumference, diabetes, stroke, coronary artery disease, angina, myocardial infarction, triglyceride (TG) levels, and directly measured high-density lipoprotein cholesterol (HDL-C) were all regarded as critical indicators of individual health status. Height, waist circumference, and BMI were objectively assessed by trained professionals at the Mobile Examination Center (MEC), with BMI computed as the individual's weight (kg) divided by the square of their height (m^2). Cholesterol levels were determined through serum samples sent to the University of Minnesota for specialized processing and analysis, following detailed protocols outlined in the NHANES Laboratory Procedures Manual. Information regarding diabetes, coronary heart disease, angina, stroke, and myocardial infarction was self-reported by participants via questionnaires.

Statistical analysis

To accommodate the intricate design elements of the NHANES survey, including oversampling techniques for specific populations, managing non-response, and stratified adjustments according to U.S. Census data, a sophisticated weighting mechanism is implemented to uphold the representativeness and precision of the data. In this study, pertinent sampling weights were applied throughout all statistical analyses. The fundamental characteristics of the survey participants were stratified into two groups based on the presence or absence of endometriosis. Continuous measurement data were expressed as mean ± standard deviation, whereas categorical variables were depicted as percentages to provide a comprehensive overview of each group's characteristics. Analysis of variance (ANOVA) and weighted chi-square tests were conducted to assess discrepancies in baseline continuous and categorical variables, respectively.

A multivariate logistic regression model was utilized to explore the association between CMI and endometriosis, with three models: Model 1 (unadjusted), Model 2 (adjusted for age and race), and Model 3 (adjusted for all covariates). After adjusting for covariates, a smoothed curve fitting analysis was conducted. A threshold effect analysis model was applied to investigate the relationship and identify inflection points between CMI and endometriosis. Finally, subgroup analysis was carried out to stratify the population based on different criteria, such as age, race, marriage, education level, PIR, BMI, smoking, alcohol consumption, pregnancy, contraceptive use, estrogen/progesterone use, coronary heart disease, angina, heart attack, stroke and diabetes. Interaction terms were incorporated to evaluate heterogeneity among subgroups. All statistical analyses were conducted using R (version 4.2.1) and EmpowerStats (version 2.0). A significance level of $P < 0.05$ was employed to determine statistical significance.

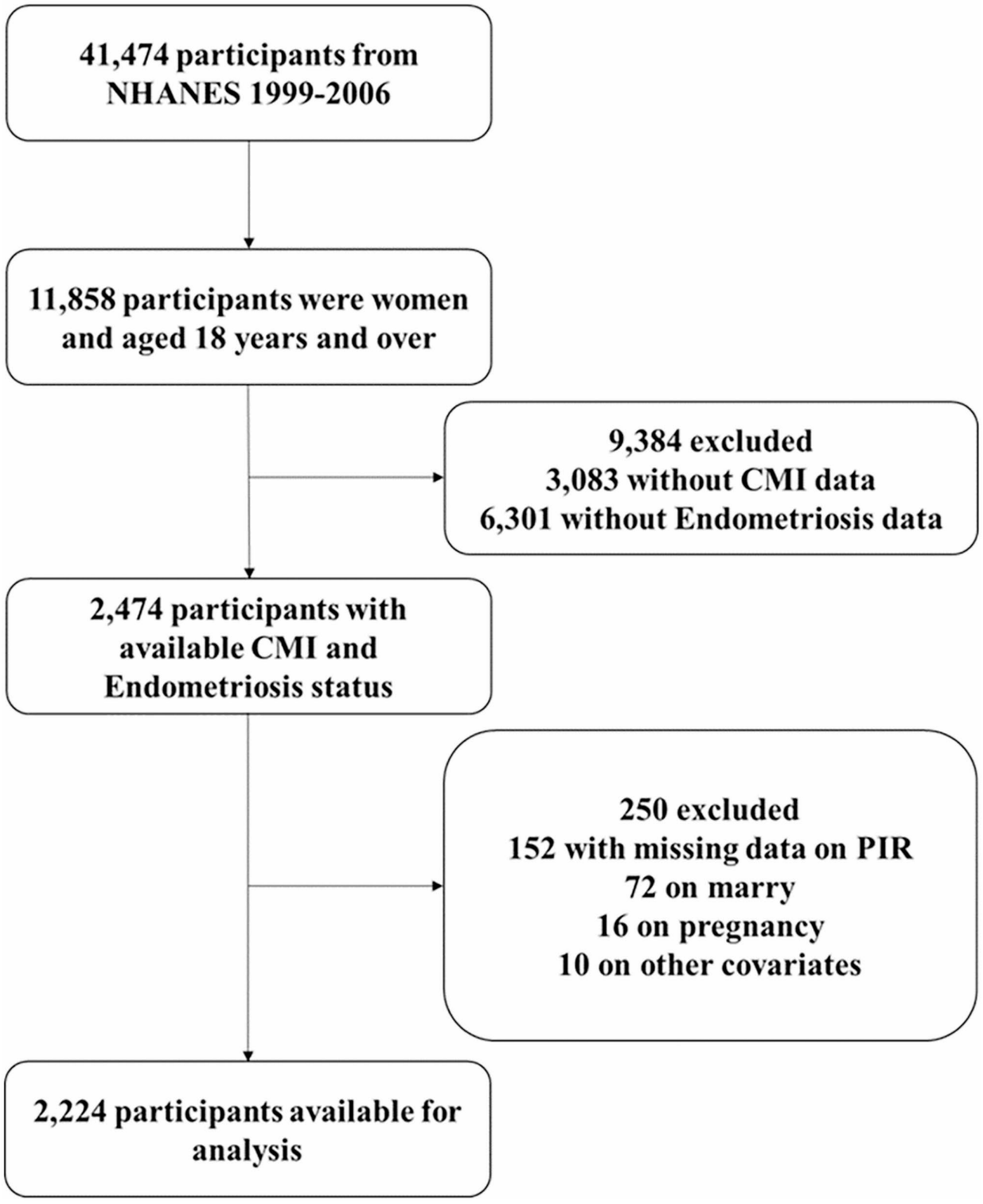

Fig. 1 Diagram of participant enrollment process

Results

Baseline characteristics of the population

In accordance with the established inclusion and exclusion criteria, a total of 2,224 adult women were enrolled in this research study. The mean age of the participants was 35.72±9.93 years, with 22.35% identified as Mexican American, 48.61% as Non-Hispanic White, 20.23% as Non-Hispanic Black, 4.36% as other Hispanic, and 4.45% representing other ethnicities. The average BMI and waist circumference for the cohort were 28.8±7.23 kg/m² and 94.58±16.12 cm, respectively.

All clinical characteristics of the participants are listed in Table 1, where endometriosis is used as a stratifying variable to divide the population into Non-endometriosis and endometriosis groups. This study demonstrates notable variances in demographic and baseline clinical features between participants with and without endometriosis. Compared to participants without endometriosis, those with endometriosis were older, more likely to be Non-Hispanic White, married, drink alcohol, smoke, and have higher education levels and PIR. Notably, compared to Non-endometriosis subjects, endometriosis subjects had higher usage of estrogen/progestin and contraceptives, as well as higher TG levels. Furthermore, individuals with endometriosis exhibited elevated prevalence rates of coronary heart disease, angina, stroke, and myocardial infarction compared to Non-endometriosis subjects (Table 1).

Association between CMI and endometriosis

The findings suggest that a higher CMI is correlated with an elevated probability of endometriosis prevalence (Table 2). In Model 1, which did not adjust for any covariates, the odds ratio (OR=1.15; 95%CI, 1.03,1.27, $P<0.001$). Model 2 adjusted for age and race, the odds ratio (OR=1.17; 95%CI, 1.05,1.30, $P<0.001$). Model 3, which additionally controlled for marriage, education level, PIR, smoking, alcohol consumption, pregnancy, contraceptive use, estrogen/progesterone use, coronary heart disease, angina, heart attack, stroke and diabetes, revealed a significant correlation (OR=1.22;95%CI, 1.07,1.38, $P<0.001$). Each unit increase in CMI is associated with a 22% increase in the risk of endometriosis.

In the sensitivity analysis utilizing CMI as a categorical variable (Quartiles), individuals in the highest CMI category exhibited a 78% elevated association of endometriosis compared to those with the lowest CMI (OR=1.78;95%CI, 1.02–3.11, $P<0.05$). (Table 2)

RCS curve plotting and threshold effect analysis

To enhance understanding of the association between CMI and endometriosis, that performed RCS curve plotting and threshold effect analysis (Fig. 2; Table 3). The results indicated no threshold effect between CMI and endometriosis, showing a linear relationship (P for overall<0.01, P for nonlinear and Log likelihood ratio tests>0.05). When CMI>0.67, the association between CMI and endometriosis gradually increased 20% (OR=1.20; 95% CI, 1.05, 1.37, $P<0.01$).

Subgroup analyses

In order to assess the consistency of the relationship between CMI and endometriosis across different subgroups, this study conducted subgroup analyses. The interaction tests revealed no statistically significant variations in the association between CMI and endometriosis across various subgroups (Fig. 3), indicating that variables including race (Mexican American/Other Hispanic/Non-Hispanic White/Non-Hispanic Black/Other race), age, education level (less than high school/high school/more than high school), Poverty Income Ratio (PIR), marital status (married/unmarried), contraceptive use (yes/no), estrogen/progestin use (yes/no), pregnancy (yes/no), diabetes (yes/no), coronary heart disease (yes/no), angina (yes/no), stroke (yes/no), heart attack (yes/no), alcohol consumption, and smoking status (yes/no) did not have a significant impact on this positive association (all interaction $P>0.05$). Nevertheless, a significant interaction was observed within the stroke subgroup ($P<0.05$), signifying that the association between CMI and endometriosis remains consistent across subgroups, demonstrating a high level of stability and reliability.

Discussion

In this cross-sectional study involving 2,224 participants, a novel correlation between CMI levels and the presence of endometriosis was identified for the first time. The findings revealed a linear association between CMI and endometriosis, regardless of whether CMI was assessed as a continuous or categorical variable. Following smoothed curve fitting and threshold effect analysis, it was discovered that when CMI exceeds 0.67, CMI emerges as an independent factor contributing to an elevated association with endometriosis, with higher CMI levels positively linked to the presence of endometriosis. This discovery validates and enhances the original hypothesis of the study, emphasizing the intricate involvement of CMI in endometriosis and offering valuable insights into the role of lipid metabolism processes in the development of endometriosis.

In recent years, there has been a significant focus among researchers on the relationship between abnormal metabolic features and endometriosis. In this study, CMI, serving as an indicator of lipid metabolism characteristics assessed through lipid profiles, demonstrated a robust correlation with the presence of endometriosis. Various pieces of evidence can elucidate the strong connection observed between CMI and endometriosis. Initially,

Table 1 Weighted comparison in basic characteristics

Characteristics	Overall	Endometriosis		*P*-value
		Without	With	
	n = 2224	*n* = 2051	*n* = 173	
Age, years	35.72 ± 9.93	35.35 ± 9.96	40.05 ± 8.57	< 0.01
Race(%)				< 0.01
Mexican American	497 (22.35)	488 (23.79)	9(5.20)	
Other Hispanic	97 (4.36)	92 (4.49)	5(2.89)	
Non-Hispanic White	1078 (48.61)	959 (46.76)	122(70.52)	
Non-Hispanic Black	450 (20.23)	419 (20.43)	31(17.92)	
Other Race	99 (4.45)	93 (4.53)	6 (3.47)	
Marry(%)				< 0.01
Married	1279 (57.51)	1170 (57.05)	109(63.01)	
Unmarried	945 (42.49)	881 (42.95)	64(36.99)	
Education level(%)				< 0.01
Less than 9th	180 (8.09)	178 (8.68)	2(1.16)	
9–11th	326 (14.66)	308 (15.02)	18(10.40)	
High school	481 (21.63)	436 (21.26)	45(26.01)	
Some college	742 (33.36)	677 (33.01)	65(37.57)	
College graduate	495 (22.26)	452 (22.04)	43(24.86)	
PIR	2.72 ± 1.66	2.68 ± 1.65	3.12 ± 1.67	< 0.01
Pregnancy(%)				< 0.01
Yes	432 (19.42)	414 (20.19)	18(10.40)	
No	1792 (80.58)	1637 (79.81)	155(89.60)	
Drinking(%)				0.04
Yes	1378 (61.96)	1260 (61.43)	118(68.21)	
No	846 (38.04)	791 (38.57)	55(31.79)	
Waistline, cm	94.58 ± 16.12	94.48 ± 16.15	95.74 ± 15.65	0.25
BMI, kg/m^2	28.8 ± 7.23	28.77 ± 7.25	29.25 ± 6.91	0.24
Age at first menstruation, years	12.62 ± 1.72	12.64 ± 1.71	12.43 ± 1.82	0.09
Coronary heart disease(%)				0.20
Yes	11 (0.49)	9 (0.44)	2(1.16)	
No	2213 (99.51)	2042 (99.56)	171(98.84)	
Angina(%)				< 0.01
Yes	13 (0.58)	9 (0.44)	4(2.31)	
No	2211 (99.42)	2042 (99.56)	169(97.69)	
Heart attack(%)				< 0.01
Yes	21 (0.94)	16 (0.78)	5(2.89)	
No	2203 (99.06)	2035 (99.22)	168(97.11)	
Stroke(%)				< 0.01
Yes	27 (1.21)	19 (0.93)	8(4.62)	
No	2197 (98.79)	2032 (99.07)	165(95.38)	
Smoking(%)				< 0.01
Yes	857 (38.53)	767 (37.40)	90(52.02)	
No	1367 (61.47)	1284 (62.60)	83(47.98)	
Diabetes(%)				0.68
Yes	104 (4.68)	97 (4.73)	7(4.05)	
No	2120 (95.32)	1954 (95.27)	166(95.95)	
Contraceptive(%)				< 0.001
Yes	1736 (78.06)	1581 (77.08)	155(89.60)	
No	488 (21.94)	470 (22.92)	18(10.94)	
Estrogen(%)				< 0.001
Yes	283 (12.72)	218 (10.63)	65(37.57)	
No	1941 (87.28)	1833 (89.37)	108(62.43)	
TG(%)				0.34

Table 1 (continued)

Characteristics	Overall	Endometriosis		*P*-value
		Without	With	
	n = 2224	*n* = 2051	*n* = 173	
≤ 72 mg/dL	556 (25)	521 (25.40)	35 (20.23)	
73–106 mg/dL	548 (24.64)	506 (24.67)	42 (24.28)	
107–159 mg/dL	557 (25.04)	513 (25.01)	44 (25.43)	
> 159 mg/dL	563 (25.31)	511 (24.91)	52 (30.06)	
CMI(%)				0.34
≤ 0.63	556 (25)	522 (25.45)	34 (19.65)	
0.64–1.10	556 (25)	513 (25.01)	43 (24.86)	
1.11–1.96	556 (25)	509 (24.82)	47 (27.17)	
> 1.96	556 (25)	507 (24.72)	49 (28.32)	
HDL(mg/dL)	58.15 ± 16.32	58.19 ± 16.27	57.56 ± 16.91	0.45

Mean ± SD for continuous variables:

P value was calculated by weighted linear regression model

% for categorical variables: *P* value was calculated by weighted chi-square test

Table 2 Association between CMI and endometriosis

	Continuous	Q1	Q2	Q3	Q4
Model 1 OR (95% CI)	1.15(1.03,1.27)	1	1.29(0.81,2.05)	1.38(0.87,2.19)	1.51(0.96,2.38)
Model 2 OR (95% CI)	1.17(1.05,1.30)	1	1.32(0.82,2.13)	1.58(0.99,2.53)	1.72(1.08,2.73)
Model 3 OR (95% CI)	1.22(1.07,1.38)	1	1.28(0.78,2.10)	1.60(0.95,2.68)	1.78(1.02,3.11)

Model 1: no covariates were adjusted. Model 2: age and race were adjusted. Model 3: age, race, marriage, education level, PIR, smoking, alcohol consumption, pregnancy, contraceptive use, estrogen/progesterone use, coronary heart disease, angina, heart attack, stroke and diabetes

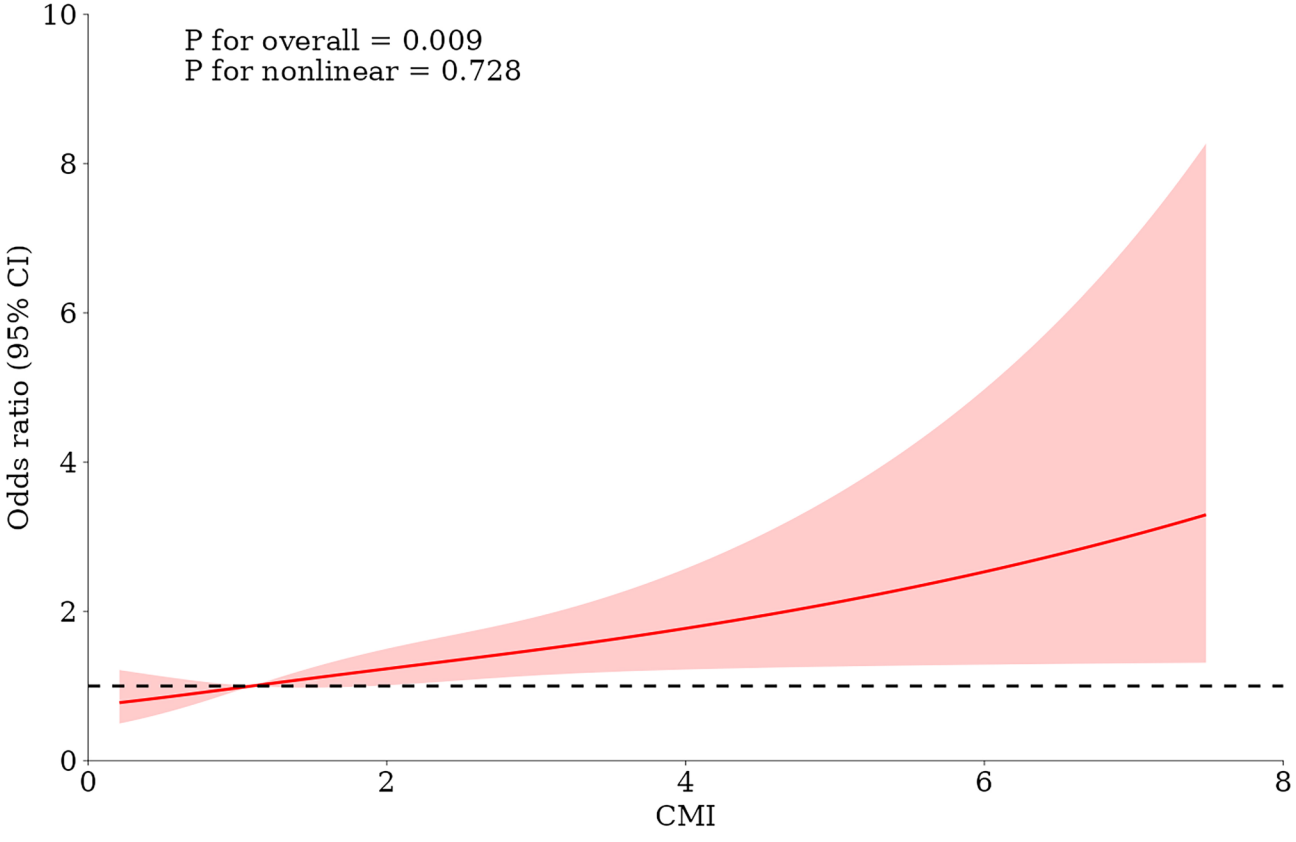

Fig. 2 The association between CMI and Endometriosis

Table 3 Analysis of threshold effect

CMI	Adjusted OR (95% CI), *P* value
Model 1	
A straight-line effect	1.22 (1.07, 1.38) < 0.01
Model 2	
Fold points (K)	0.67
CMI < 0.67	2.71 (0.45, 16.35) 0.28
CMI > 0.67	1.20 (1.05, 1.37) < 0.01
Effect size difference of 2 versus 1	0.44 (0.07, 2.75) 0.38
Equation predicted values at break points	-2.54 (-2.76, -2.31)
Log likelihood ratio tests	0.37

multiple metabolomic investigations have highlighted that individuals with endometriosis exhibit compromised sphingolipid metabolism [21, 22], indicating underlying lipid metabolic irregularities. Furthermore, dyslipidemia is frequently accompanied by persistent inflammation [23], and ongoing chronic inflammation can potentially impact estrogen regulation and endometrial receptivity in females [24, 25], consequently fostering the onset and progression of endometriosis. Second, dyslipidemia and abdominal obesity commonly contribute to insulin resistance and oxidative stress, which could collaboratively influence endometrial stromal cells, thereby stimulating the advancement of endometriosis [26]. Consequently, aberrant metabolic features may collectively mediate the relationship between the occurrence and progression of endometriosis. Considering the significant correlation between CMI and endometriosis, it is imperative in clinical practice to evaluate women with elevated CMI levels and undertake timely assessments and effective interventions to mitigate this association for the prevention and management of endometriosis.

This study demonstrates a substantial correlation between elevated CMI levels and the presence of endometriosis. Even following adjustments for various potential confounders, the link between CMI and endometriosis persists significantly. This implies that obesity and dyslipidemia are intricately intertwined with the presence of endometriosis. The subgroup analysis findings reveal a notable interaction between CMI and endometriosis in the stroke (yes/no) subgroup. This outcome indicates that the influence of CMI on endometriosis could be more pronounced in individuals with a history of stroke. Indeed, numerous prior studies have established connections among stroke, CMI, and endometriosis. Numerous prospective cohort studies have highlighted an increased risk of stroke in individuals with laparoscopically confirmed endometriosis compared to the general population [27, 28]. Mendelian randomization and meta-analysis studies have additionally proposed that endometriosis could independently serve as a risk factor for stroke [29, 30], aligning with previous findings. The subgroup analysis outcomes of this study indicate that heightened CMI levels in stroke patients may potentially intensify the association with endometriosis. Additionally, individuals with a history of stroke often present with compromised metabolic and cardiovascular health conditions [31], which can contribute to the development of metabolic abnormalities and inflammatory responses [32, 33], potentially influencing the connection between CMI and endometriosis. Metabolic disorders and inflammation themselves can heighten the association with endometriosis. Therefore, stroke represents a significant covariate that impacts the correlation between CMI and endometriosis and should be taken into account when utilizing CMI as an indicator for assessing the association with endometriosis. Future animal studies and larger cohort investigations are warranted to further elucidate the intricate relationship and potential biological mechanisms linking stroke, CMI, and endometriosis.

Furthermore, previous studies mainly focused on the associations between dietary intake, environmental exposure, inflammation, and endometriosis [34–36]. This study, however, assesses a range of indicators of lipid metabolism characteristics integrated into CMI, offering a more comprehensive and straightforward evaluation method. Additionally, this research showcases through subgroup analysis that stroke is a significant influencing factor for both CMI and endometriosis, an aspect that is rarely mentioned in existing cross-sectional studies. Other studies seem to lack detailed exploration on the metabolic nexus between stroke and endometriosis, whereas this study provides preliminary evidence in this regard. Therefore, it is crucial to emphasize and manage metabolic status in the prevention and early intervention of endometriosis.

Study strengths and limitations

This study employed cross-sectional data analysis of American women from the NHANES database. Previous research has not explored the correlation between CMI and the presence of endometriosis, making this study the pioneering investigation to identify CMI as a plausible predictor for endometriosis. Utilizing multivariate logistic regression analysis and subgroup analysis, this study aimed to clarify the association between CMI and endometriosis, as well as confirm the reliability of the findings. These outcomes hold substantial importance for the advancement of strategies concerning the prevention and early intervention for endometriosis. Nevertheless, it is important to acknowledge that a limitation of cross-sectional studies collect data at a single point in time, this study cannot determine whether CMI precedes endometriosis or vice versa. The results may be influenced by this temporal relationship uncertainty and thus require cautious interpretation. In dynamic social settings or

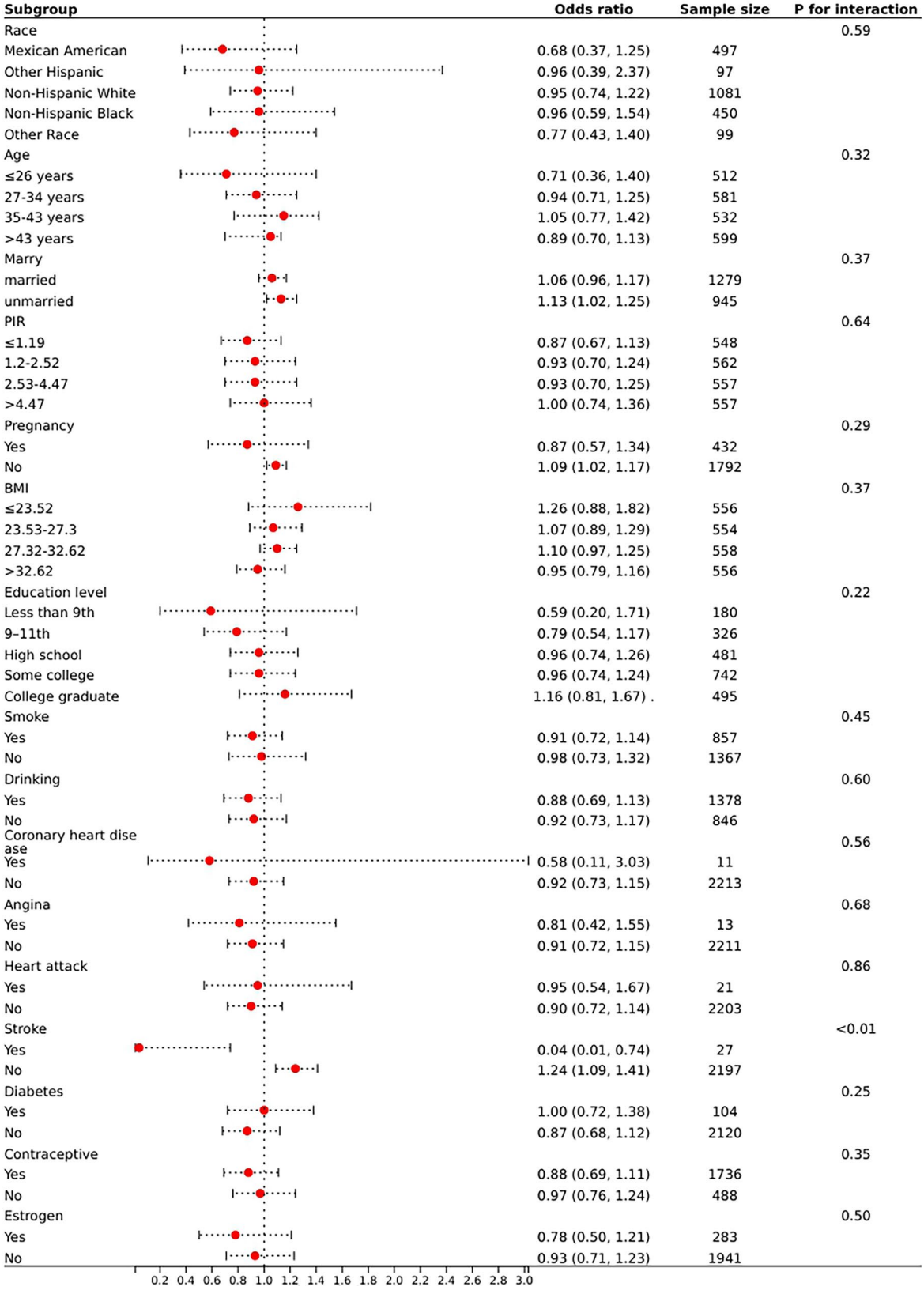

Fig. 3 Subgroup analysis for the association between CMI and Endometriosis

with evolving population dynamics, the data obtained from such studies may influence the research outcomes. Furthermore, due to the limitations in the included population, the relatively small sample sizes in certain subgroups (such as coronary heart disease, stroke, and heart attack) may restrict the statistical power of subgroup analysis and interaction tests. This can potentially affect the results of the regression analysis, increasing the instability of the findings. Hence, for a more in-depth examination of the relationship between CMI and endometriosis, future research endeavors should concentrate on extensive cohort studies that monitor the fluctuating trends of CMI longitudinally and explore its potential temporal correlation with the inception and progression of endometriosis. This approach would bolster the credibility of causal interpretations. Furthermore, forthcoming investigations should delve into the intricate biological mechanisms governing the interplay between CMI and endometriosis. This may involve experimental inquiries or clinical trials to meticulously dissect the pathways and fundamental principles of their interaction. These comprehensive investigations not only advance comprehension of this intricate association but also hold promise for introducing innovative approaches and strategies for the prevention and management of endometriosis and its associated complications. By tackling these challenges and opportunities, it is envisaged that forthcoming research will offer more thorough and profound insights, fostering significant advancements in the exploration of the relationship between CMI and endometriosis.

Conclusion

The study found that CMI levels are closely correlated with endometriosis, with this correlation increasing when the CMI exceeds 0.67. This finding implies that by regularly monitoring CMI levels, physicians may be able to screen women at risk for endometriosis at an earlier stage, thereby enabling the implementation of early interventions to slow the progression of the disease. To further validate these findings, larger-scale cohort studies are required to support the results of this research.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12944-024-02314-7.

Supplementary Material 1

Supplementary Material 2

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Author contributions

WJM: Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Writing - Review & Editing. WBY: Formal Analysis, Validation, Investigation, Data curation. LT: Methodology, Formal Analysis. SJY: Formal Analysis, Investigation. GXM: Writing - Review & Editing, Funding Acquisition. ZTC: Funding Acquisition, Project Management. CHF: Supervision, Writing - Review Editing.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

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