International Journal of Women's Health

Dovepress
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ORIGINAL RESEARCH

Linking Lipid Profile to Stress Urinary Incontinence in US Women: A National Cross-Sectional Study

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Objective: Stress urinary incontinence (SUI) is a common pelvic floor disorder in women, yet the role of lipid metabolism in its occurrence remains unclear. This study investigated the association between lipid parameters and SUI in women.
Methods: This study analyzed data from the 2005–2018 National Health and Nutrition Examination Survey (NHANES), including 7,892 women. SUI was identified via questionnaire, and lipid levels were measured using standardized laboratory methods. Weighted multivariable logistic regression examined the association between lipid levels and SUI, while restricted cubic splines (RCS) assessed potential nonlinear relationships. Subgroup analyses explored effect modifications.
Results: Higher remnant cholesterol (RC), total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) were significantly associated with increased SUI risk ($P < 0.05$), with a significant positive trend (P for trend < 0.05). RCS analysis indicated a linear relationship between RC and SUI, while TC and LDL-C showed nonlinear associations with inflection points at 4.97 and 2.85 mmol/L, respectively. High-density lipoprotein cholesterol (HDL-C) exhibited a U-shaped relationship, with the lowest SUI risk at 1.47 mmol/L. Subgroup analyses showed stronger associations for RC in women <65 years and those without hypertension, while TC and LDL-C had a greater impact in women without hypertension or oral contraceptive use.
Conclusion: Elevated RC, TC, and LDL-C may increase SUI risk, while both low and high HDL-C levels may also contribute. These findings highlight the role of lipid metabolism in SUI and support early screening and metabolic intervention strategies.
Keywords: stress urinary incontinence, remnant cholesterol, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, NHANES

Introduction

Stress urinary incontinence (SUI) is one of the most common pelvic floor disorders in women, characterized by involuntary urine leakage during activities that increase abdominal pressure, such as coughing, sneezing, or exercising.[1] Epidemiological studies indicate that 34–53% of women may experience SUI at some point in their lives, with the prevalence increasing with age, childbirth history, and obesity.[2,3] While SUI is not life-threatening, it can significantly impair quality of life, affecting social activities, mental health, and increasing the risk of anxiety and depression. However, the pathophysiology of SUI remains poorly understood, particularly the role of metabolic factors, which are still insufficiently studied.

From an anatomical perspective, the pelvic floor consists of striated muscles and connective tissue, forming a structural support system essential for maintaining bladder stability and continence. SUI often results from functional or structural impairment of this system.[4] Recently, increasing attention has been directed toward the role of metabolic disturbances in the pathogenesis of SUI. Obesity, insulin resistance, and chronic inflammation have been identified as metabolic-related risk factors potentially involved in its development.[2,5,6] Among these, obesity not only increases the mechanical load on the pelvic floor but may also alter the local metabolic milieu and impair neuromuscular function,

Received: 26 February 2025
Accepted: 11 May 2025
Published: 3 June 2025

leading to reduced continence capacity.[7,8] Within this context, disordered lipid metabolism—a central component of metabolic dysfunction—has been increasingly implicated in SUI. It may affect the structural and functional integrity of pelvic tissues through systemic inflammation and oxidative stress.[9,10] In particular, chronic low-grade inflammation has been shown to accelerate extracellular matrix degradation and abnormal collagen metabolism, thereby compromising the urethral sphincter and pelvic support structures.[11]

Although lipid metabolism disorders are recognized contributors to cardiovascular disease, diabetes, and neurodegenerative conditions,[12–14] their relationship with stress urinary incontinence (SUI) remains largely underexplored. Limited evidence suggests that total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) may be associated with SUI risk.[15] However, few studies have systematically investigated these associations. No research to date has specifically examined the role of remnant cholesterol (RC). Moreover, potential differences across population subgroups remain largely unaddressed. RC, a component of triglyceride-rich lipoprotein remnants, is considered an independent atherogenic factor and may impair tissue repair through inflammatory and oxidative mechanisms.[16,17] Nevertheless, whether RC is associated with SUI and how different lipid components contribute to SUI risk across diverse populations have yet to be thoroughly investigated.

Based on this background, this study utilized data from the 2005–2018 National Health and Nutrition Examination Survey (NHANES) to evaluate the associations between lipid parameters (RC, TC, LDL-C, and HDL-C) and SUI in women, their linear relationships, and variations across different subgroups. The findings of this study will help clarify the relationship between lipid metabolism and SUI and provide new scientific evidence for early screening, prevention, and metabolically-based intervention strategies for SUI.

Materials and Methods

Data Source

This study utilized data from the NHANES, a nationally representative program conducted by the National Center for Health Statistics (NCHS) using a complex, multistage probability sampling design. NHANES collects health and nutrition-related information through household interviews, physical examinations, and laboratory tests, covering demographic characteristics, medical history, health behaviors, and biomarker measurements. All laboratory analyses were conducted at the Centers for Disease Control and Prevention (CDC) Environmental Health Laboratory under strict quality control protocols. The NHANES study protocols were approved by the NCHS Institutional Review Board, and all participants provided written informed consent. This study utilized publicly available NHANES data from 2005–2018 and selected eligible participants based on predefined criteria.

Study Population

This study analyzed NHANES data from 2005–2018, initially including 70,190 participants. Males (n = 34,709) were excluded, leaving 35,481 women for further selection. Participants were subsequently excluded due to missing SUI assessment data (n = 17,965), TC (n = 862), and LDL-C (n = 8,762), while no HDL-C data were missing. A total of 7,892 women met the final inclusion criteria (Figure 1). Additionally, all remaining participants had complete survey weights, requiring no further exclusions.

SUI Assessment

SUI was identified based on self-reported questionnaire responses. Participants were asked whether they experienced urine leakage during coughing, sneezing, laughing, or physical activity. Those who answered “yes” were classified as having SUI, while others were categorized as non-SUI. This method has been widely used in epidemiological studies to estimate the prevalence of urinary incontinence.[3]

Lipid Measurements

Lipid parameters included RC, TC, LDL-C, and HDL-C, all measured in mmol/L. RC was calculated as RC = TC – (HDL-C) – (LDL-C).[18]

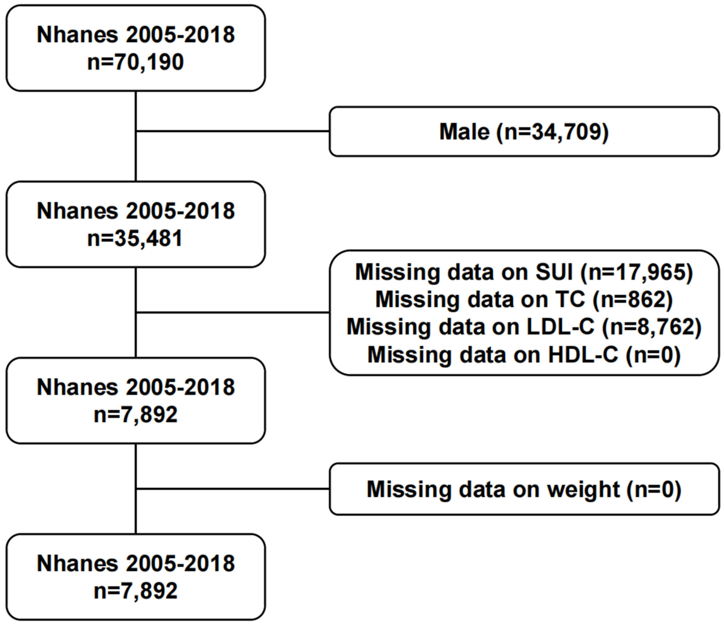

Figure 1 Flowchart of the Study Population Selection.

Covariates

Based on prior studies,[19] covariates included age (<65 / ≥65 years), race/ethnicity (White, Black, Mexican American, Other), poverty-to-income ratio (PIR), body mass index (BMI <25 / ≥25 kg/m²), education level (less than high school, high school, more than high school), smoking status (yes/no), alcohol use (yes/no), self-reported hypertension, self-reported diabetes, vaginal delivery history (yes/no), and oral contraceptive use (yes/no).

Statistical Analysis

All analyses accounted for NHANES survey weights to ensure national representativeness. Weighted t-tests were used for continuous variables and weighted chi-square tests for categorical variables. Weighted logistic regression models were employed to examine the association between lipid parameters and SUI, estimating odds ratios (ORs) and 95% confidence intervals (CIs). Four models were constructed: Model 1 (unadjusted), Model 2 (adjusted for age, race, PIR, BMI, and education level), Model 3 (further adjusted for smoking, alcohol consumption, diabetes, hypertension, and vaginal delivery), and Model 4 (additionally adjusted for oral contraceptive use). Restricted cubic spline (RCS) models were applied to assess potential nonlinear relationships and identify threshold effects between lipid levels and SUI risk. Subgroup analyses were conducted to examine effect modifications across different characteristics, with interaction terms included to test for statistical significance. Statistical analyses were performed using R, with a two-tailed $P < 0.05$ considered statistically significant.

Results

Baseline Characteristics

Table 1 presents the baseline characteristics of the study population, comparing individuals with and without SUI. No significant difference in the PIR was observed between the groups ($P = 0.36$). The prevalence of SUI was higher among individuals aged ≥65 years ($P < 0.001$), with a greater proportion having BMI ≥25 kg/m² ($P < 0.001$). Significant differences were noted in racial distribution ($P < 0.001$), with a lower proportion of Black individuals and a higher proportion of White individuals in the SUI group. Regarding education, women with SUI were less likely to have received higher education ($P = 0.002$). Smoking prevalence was significantly higher in the SUI group ($P < 0.001$), whereas alcohol consumption did not differ significantly between groups ($P = 0.13$). Hypertension ($P < 0.001$) and diabetes ($P < 0.001$) were more common among individuals with SUI. Additionally, oral contraceptive use was

Table 1 Comparison of Baseline Traits Between SUI and Non-SUI Groups

	No SUI (n=4,568)	SUI (n=3,324)	P value
PIR	2.93(0.04)	2.89(0.05)	0.36
Age			**< 0.001**
<65	3586(81.87)	2388(75.24)	
≥65	982(18.13)	936(24.76)	
BMI			**< 0.001**
<25	1362(33.13)	560(18.85)	
≥25	3206(66.87)	2764(81.15)	
Race			**< 0.001**
Black	1130(13.88)	504(7.84)	
Mexican	661(7.58)	590(8.00)	
Other	985(13.64)	643(11.63)	
White	1792(64.90)	1587(72.53)	
Education			**0.002**
Above High School	2592(63.68)	1715(59.91)	
High School	1004(22.73)	733(23.16)	
Less High School	972(13.59)	876(16.93)	
Smoking			**< 0.001**
No	3032(63.83)	2003(57.41)	
Yes	1536(36.17)	1321(42.59)	
Alcohol Use			0.13
No	983(16.05)	661(14.59)	
Yes	3585(83.95)	2663(85.41)	
Hypertension			**< 0.001**
No	3106(72.27)	1840(58.81)	
Yes	1462(27.73)	1484(41.19)	
Diabetes			**< 0.001**
No	4110(93.15)	2805(87.37)	
Yes	458(6.85)	519(12.63)	
Oral Contraceptive			**< 0.001**
No	3893(80.94)	3054(88.58)	
Yes	675(19.06)	270(11.42)	
RC	0.54(0.01)	0.62(0.01)	**< 0.001**
TC	5.02(0.02)	5.15(0.03)	**< 0.001**
LDL-C	2.91(0.02)	3.01(0.02)	**< 0.001**
HDL-C	1.57(0.01)	1.52(0.01)	**< 0.001**

Notes: Means presented as weighted mean (SE). Bolded P values indicate statistical significance (P < 0.05).
Abbreviations: PIR, Poverty-to-Income Ratio; BMI, Body Mass Index; SUI, Stress Urinary Incontinence; RC, Remnant Cholesterol; TC, Total Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; HDL-C, High-Density Lipoprotein Cholesterol.

significantly lower in the SUI group (P < 0.001). Regarding lipid parameters, RC, TC, and LDL-C levels were significantly higher in the SUI group (P < 0.001), while HDL-C levels were lower (P < 0.001).

Association Between Lipid Levels and SUI: Weighted Multivariable Logistic Regression

Table 2 summarizes the association between lipid indices and SUI based on weighted multivariable logistic regression analysis. RC was positively associated with SUI across all models (P < 0.05), with the highest quartile (Q4) showing an OR of 1.34 (95% CI: 1.10–1.65, P = 0.01) in Model 4. TC remained positively associated with SUI, with an OR of 1.28

Table 2 Regression Analysis of Lipid Indices and SUI Risk

Exposure	OR (95% CI) P value			
	Model 1	**Model 2**	**Model 3**	**Model 4**
RC	2.37(1.91,2.92) **<0.001**	1.58(1.25,1.98) **<0.001**	1.39(1.10,1.76) **0.01**	1.49(1.17,1.90) **0.001**
Q1	Reference	Reference	Reference	Reference
Q2	1.11(0.93,1.33) 0.23	0.96(0.80,1.15) 0.63	0.90(0.75,1.07) 0.23	0.89(0.75,1.07) 0.22
Q3	1.56(1.31,1.87) **<0.001**	1.19(0.98,1.44) 0.07	1.10(0.91,1.33) 0.31	1.12(0.92,1.35) 0.26
Q4	2.10(1.75,2.53) **<0.001**	1.45(1.18,1.77) **<0.001**	1.28(1.05,1.57) **0.02**	1.34(1.10,1.65) **0.01**
P for trend	**<0.001**	**<0.001**	**0.003**	**<0.001**
TC	1.12(1.05,1.19) **<0.001**	1.10(1.03,1.18) **0.005**	1.10(1.03,1.18) **0.01**	1.10(1.03,1.18) **0.01**
Q1	Reference	Reference	Reference	Reference
Q2	1.05(0.89,1.24) 0.56	1.02(0.86,1.20) 0.84	1.03(0.87,1.23) 0.70	1.04(0.87,1.24) 0.69
Q3	1.41(1.20,1.67) **<0.001**	1.35(1.13,1.61) **<0.001**	1.37(1.13,1.65) **0.001**	1.38(1.14,1.66) **0.001**
Q4	1.34(1.12,1.61) **0.002**	1.28(1.05,1.56) **0.01**	1.27(1.04,1.56) **0.02**	1.28(1.04,1.57) **0.02**
P for trend	**<0.001**	**0.002**	**0.003**	**0.003**
LDL-C	1.12(1.05,1.20) **<0.001**	1.09(1.02,1.17) **0.01**	1.10(1.02,1.18) **0.01**	1.08(1.01,1.17) **0.03**
Q1	Reference	Reference	Reference	Reference
Q2	1.11(0.92,1.33) 0.27	1.09(0.90,1.32) 0.36	1.13(0.94,1.37) 0.20	1.12(0.93,1.36) 0.23
Q3	1.43(1.21,1.69) **<0.001**	1.34(1.12,1.59) **0.001**	1.38(1.15,1.66) **<0.001**	1.36(1.13,1.63) **0.001**
Q4	1.32(1.12,1.57) **0.001**	1.23(1.03,1.48) **0.02**	1.27(1.05,1.53) **0.02**	1.24(1.03,1.50) **0.03**
P for trend	**<0.001**	**0.005**	**0.004**	**0.008**
HDL-C	0.74(0.63,0.86) **<0.001**	0.97(0.83,1.13) 0.71	1.00(0.86,1.17) 0.97	1.03(0.89,1.20) 0.69
Q1	Reference	Reference	Reference	Reference
Q2	0.94(0.78,1.14) 0.54	1.06(0.87,1.28) 0.56	1.08(0.88,1.31) 0.46	1.08(0.89,1.32) 0.42
Q3	0.70(0.59,0.84) **<0.001**	0.87(0.72,1.05) 0.14	0.89(0.74,1.07) 0.23	0.90(0.75,1.08) 0.24
Q4	0.69(0.59,0.81) **<0.001**	0.94(0.78,1.13) 0.50	0.98(0.81,1.17) 0.80	1.00(0.83,1.20) 1.00
P for trend	**<0.001**	0.19	0.39	0.53

Notes: Model 1 is the unadjusted model. Model 2 is adjusted for age, race, PIR, BMI, and education. Model 3 further includes smoking, alcohol use, diabetes, hypertension, and vaginal delivery. Model 4 additionally adjusts for oral contraceptive use. Bolded P values indicate statistical significance (P < 0.05).

Abbreviations: OR, odds ratio; CI, confidence interval.

(95% CI: 1.04–1.57, P = 0.02) for Q4 in Model 4. LDL-C also exhibited a consistent positive association, with an OR of 1.24 (95% CI: 1.03–1.50, P = 0.03) for Q4 in Model 4. HDL-C showed a significant negative association in the unadjusted model (P < 0.001), but the association was no longer significant after adjusting for confounders (Models 2–4, P > 0.05). Trend analysis confirmed significant dose-response relationships for RC, TC, and LDL-C (P for trend < 0.05), while no significant trend was observed for HDL-C (P for trend = 0.53).

Nonlinear Relationships Between Lipid Indices and SUI Risk

RCS analysis was conducted to assess the nonlinear associations between lipid parameters and SUI risk (Figure 2). RC exhibited a linear positive association with SUI (P for overall < 0.001, P for nonlinear = 0.55). TC demonstrated a nonlinear association (P for overall < 0.001, P for nonlinear = 0.03), with an inflection point at 4.97 mmol/L, beyond which the risk increase plateaued. Similarly, LDL-C displayed a nonlinear relationship (P for overall < 0.001, P for nonlinear = 0.01), with a threshold at 2.85 mmol/L; below this level, SUI risk increased with LDL-C, but above this point, the risk remained stable HDL-C exhibited a U-shaped relationship with SUI (P for overall = 0.01, P for nonlinear = 0.004), with the lowest SUI risk observed around 1.47 mmol/L, suggesting that both excessively high and low HDL-C levels may elevate SUI risk.

Subgroup Analysis of Lipid Parameters and SUI Risk

Subgroup analyses were conducted to evaluate potential effect modifications by different population characteristics (Figure 3). RC remained significantly associated with SUI across multiple subgroups, with significant interactions

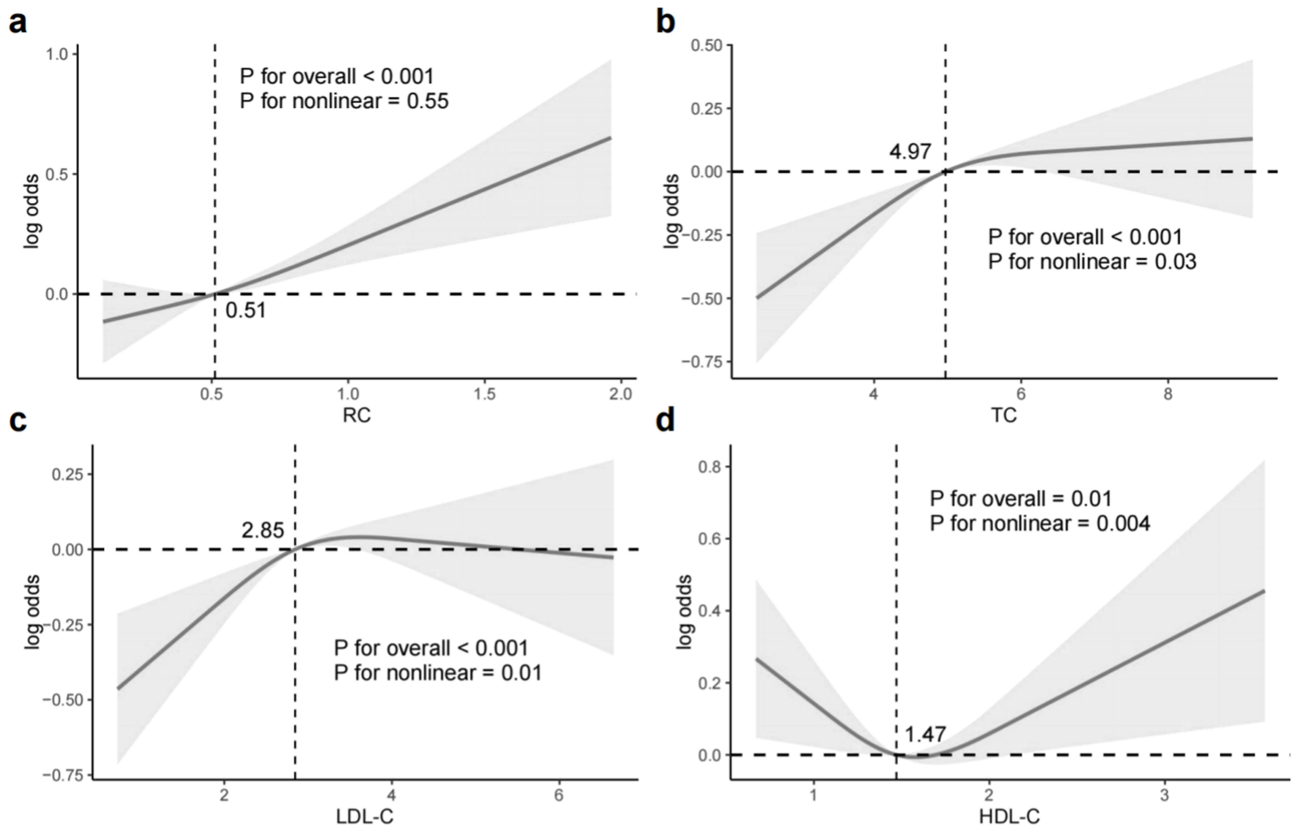

Figure 2 Restricted Cubic Spline Analysis of the Association Between Lipid Indices and SUI. (**a**) RC; (**b**) TC; (**c**) LDL-C; (**d**) HDL-C.

observed for age and hypertension status (P for interaction < 0.05). Stronger associations were found in women aged <65 years and those without hypertension. TC and LDL-C showed significant interactions with hypertension and oral contraceptive use (P for interaction < 0.05), with higher SUI risk observed in women without hypertension and those who had never used oral contraceptives. No significant interactions were detected for other characteristics. HDL-C was inversely associated with SUI, but a significant interaction was only observed in the age-stratified analysis (P for interaction < 0.001), where its protective effect was evident only in women aged <65 years.

Discussion

This study, based on NHANES 2005–2018 data, systematically evaluated the association between lipid metabolism (RC, TC, LDL-C, and HDL-C) and stress urinary incontinence (SUI) in women, examining potential nonlinear relationships and subgroup differences. The findings indicate that elevated RC, TC, and LDL-C levels are associated with a higher risk of SUI, while HDL-C exhibits a U-shaped relationship, where both excessively high and low levels may increase risk. Additionally, interactions were observed for age, hypertension status, and oral contraceptive use, providing new epidemiological evidence for the potential involvement of lipid metabolism abnormalities in SUI development.

Previous studies have suggested a link between metabolic syndrome and SUI.[20] A Mendelian randomization (MR) study by Xiang et al further reported that higher TC, LDL-C, and HDL-C levels were associated with increased SUI risk,[15] aligning with our findings. Their study also found a stronger effect in overweight/obese women, whereas no such interaction was observed in our analysis, possibly due to population differences. Notably, their study did not include RC, while our study fills this gap by demonstrating an independent association between RC and SUI. RC has recently been recognized as a lipid metabolism risk factor distinct from LDL-C and is linked to atherosclerosis, inflammation, and metabolic dysfunction. In our study, elevated RC remained significantly associated with SUI after multivariable adjustments, suggesting an independent role in its development. While the underlying mechanisms remain unclear, existing evidence suggests that RC may contribute to microvascular dysfunction through chronic inflammation and

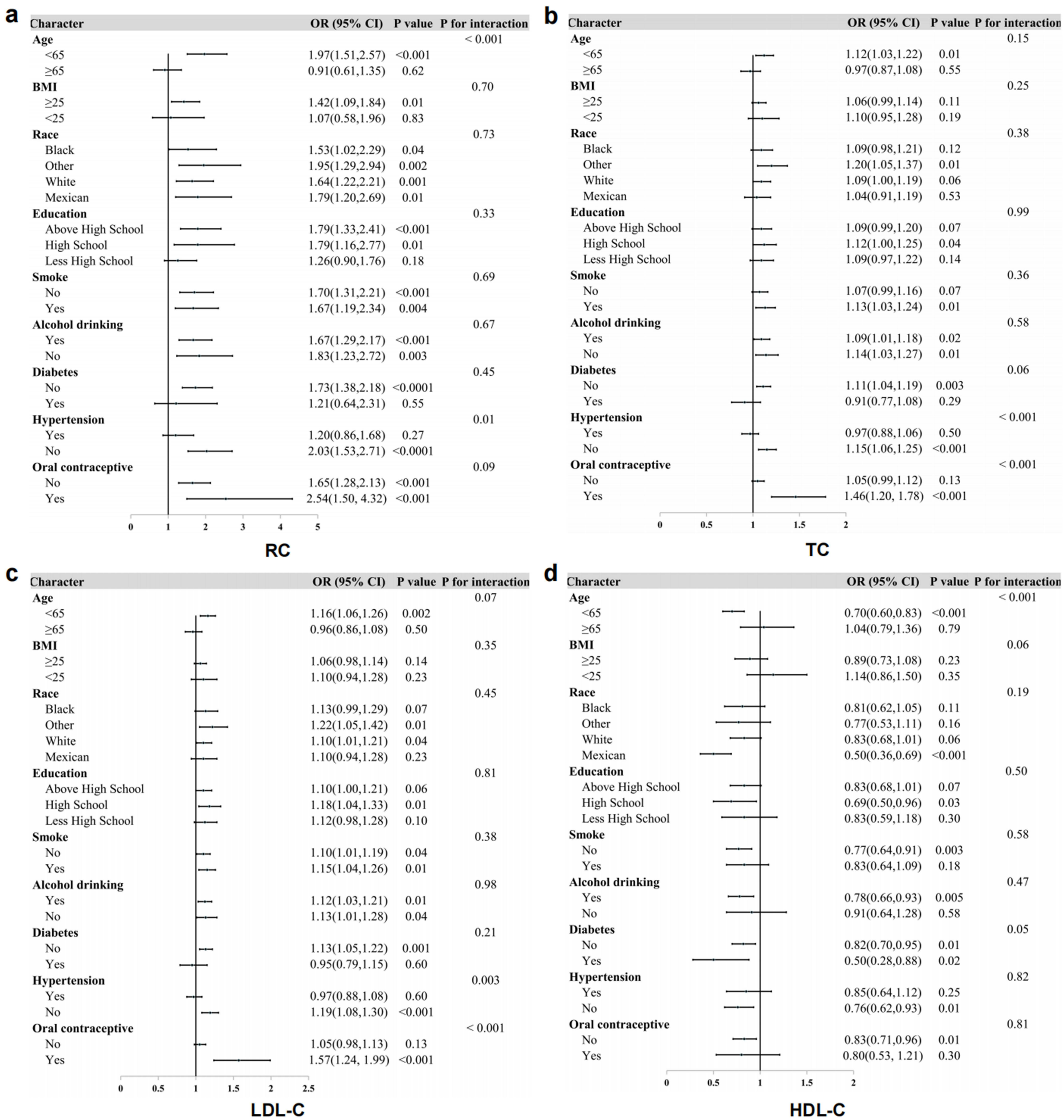

Figure 3 Forest Plot of the Association Between Lipid Indices and SUI Across Different Subgroups. (**a**) RC; (**b**) TC; (**c**) LDL-C; (**d**) HDL-C.

oxidative stress which could impair pelvic floor tissue perfusion and repair capacity, thereby affecting pelvic stability.[21–23]

RCS analysis further revealed potential nonlinear relationships between lipid parameters and SUI risk, with TC and LDL-C demonstrating threshold effects. Specifically, SUI risk plateaued at TC levels above 4.97 mmol/L and LDL-C levels above 2.85 mmol/L. This trend is consistent with previous cardiovascular studies that have reported LDL-C threshold effects in atherosclerosis progression,[24] suggesting that lipid-related pathophysiological changes in SUI may also reach a saturation point. Additionally, while previous studies support a positive association between HDL-C and SUI risk, our RCS analysis suggests a U-shaped relationship, where both excessively low and high HDL-C levels may contribute to increased risk. This may be related to alterations in HDL particle function, which have been shown to exhibit differential effects under various metabolic conditions.[25] While HDL-C is traditionally considered anti-inflammatory and protective for vascular function, recent studies have linked excessively high HDL-C levels to increased all-cause mortality,[26,27] suggesting that its effects may vary in different pathological states. However, the specific impact of elevated HDL-C on SUI remains inconclusive and warrants further investigation to determine the optimal HDL-C range for pelvic floor health.

Subgroup analysis provided additional insights into population-specific variations in lipid-SUI associations. RC showed a stronger association with SUI in women under 65 years, whereas this relationship weakened in those aged ≥65 years, potentially due to age-related differences in pelvic tissue structure and metabolic responses. Younger women may have better pelvic floor integrity, making their tissues more responsive to metabolic disturbances, whereas in older women, SUI may be predominantly driven by postmenopausal hormonal changes and sarcopenia. Additionally, RC, TC, and LDL-C were more strongly associated with SUI in women without hypertension. Given that hypertensive individuals typically exhibit elevated TC and LDL-C levels, lipid-related SUI risk in this group may be overshadowed by hypertension itself.[28,29] Furthermore, TC and LDL-C were more strongly linked to SUI in women who had never used oral contraceptives. Since oral contraceptives are known to influence lipid metabolism by increasing TG and LDL-C levels, their modifying effects on lipid-SUI associations require further exploration.[30,31]

The strengths of this study include the use of a large, nationally representative NHANES dataset, ensuring broad generalizability. Weighted analysis and multivariable adjustments were performed to minimize confounding bias. Additionally, this study is the first to systematically assess the relationship between RC and SUI in women, with RCS models enhancing the evaluation of nonlinear associations. However, several limitations should be acknowledged. First, the cross-sectional nature of NHANES prevents causal inference, necessitating future validation through prospective cohort studies. Second, SUI diagnosis relied on self-reported data, which may introduce information bias; integrating objective assessments such as urodynamic testing could improve accuracy. Lastly, other metabolic markers potentially influencing SUI were not included in the analysis, highlighting the need for future multi-omics research to further elucidate the metabolic mechanisms underlying SUI. Taken together, these findings highlight the need for longitudinal cohort studies and mechanistic research to confirm causality, further clarify biological pathways, and explore potential targets for preventive or therapeutic interventions.

Conclusions

Elevated levels of RC, TC, and LDL-C were significantly associated with an increased risk of SUI, while HDL-C exhibited a U-shaped relationship. Age, hypertension status, and oral contraceptive use may modify these associations. These findings underscore the potential role of lipid metabolism in the development of SUI. However, due to the cross-sectional nature of this study and reliance on self-reported SUI data, causal inferences cannot be drawn. Further prospective studies and mechanistic investigations are warranted to validate these associations and inform future preventive or therapeutic strategies.

Abbreviations

SUI, Stress urinary incontinence; RC, Remnant cholesterol; TC, Total cholesterol; LDL-C, Low-density lipoprotein cholesterol; HDL-C, High-density lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey; NCHS, National Center for Health Statistics; CDC, Centers for Disease Control and Prevention; PIR, Poverty-to-income ratio; BMI, Body mass index; OR, Odds ratio; CI, Confidence interval; RCS, Restricted cubic spline; MR, Mendelian randomization.

Data Sharing Statement

The data analyzed in this study are publicly available through the NHANES database, maintained by the Centers for Disease Control and Prevention (CDC). The dataset can be accessed at https://www.cdc.gov/nchs/nhanes/index.htm.

Ethics Approval and Consent to Participate

This study was based on publicly available, de-identified data from the NHANES, which is conducted by the National Center for Health Statistics (NCHS). The NHANES protocol was reviewed and approved by the NCHS Ethics Review Board, and all participants provided written informed consent prior to participation. The approval details are publicly accessible via the official CDC website (https://www.cdc.gov/nchs/nhanes/about/erb.html), and a printable version of the ethical approval has been provided as Supplementary File 1. As this study involved only secondary analysis of anonymized data, no additional ethical approval was required. In accordance with Article 32, Items 1 and 2, of the *Measures for Ethical Review of Life Science and Medical Research Involving Human Subjects* (effective February 18, 2023, China), research using publicly accessible and anonymized databases is exempt from review by local institutional ethics committees. This exemption has been confirmed by the Medical Ethics Committee of the Eighth Affiliated Hospital of Southern Medical University (The First People's Hospital of Shunde Foshan).

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study was funded by the National Natural Science Foundation of China (82471659), the Guangdong Provincial Administration of Traditional Chinese Medicine (20251376), the Beijing Science and Technology Innovation Medical Development Foundation (KC2023-JX-0186-RZ102), and Shunde Hospital, Southern Medical University (SRSP2023021, SRSP2024014).

Disclosure

The authors declare no competing interests in this work.

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