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Association between cardiometabolic index and postmenopausal stress urinary incontinence: a cross-sectional study from NHANES 2013 to 2018

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Abstract

Background Stress urinary incontinence (SUI) is a common condition affecting the genitourinary system in postmenopausal women. Obesity and dyslipidemia are recognized as significant factors that contribute to the onset of SUI. The cardiometabolic index (CMI), a reliable indicator of health risks associated with obesity, is crucial in assessing these risks. This study aims to investigate the relationship between CMI and the occurrence of SUI in postmenopausal women across the United States.

Methods This cross-sectional study employed data from the National Health and Nutrition Examination Survey (NHANES) conducted between 2013 and 2018, concentrating on postmenopausal women aged 40 years and above in the United States. Multiple regression models were utilized to evaluate the association between CMI and postmenopausal SUI, while controlling for pertinent confounding variables. Smooth curve fitting (SCF) techniques were utilized to evaluate the correlation between postmenopausal SUI incidence and CMI. To enhance the robustness of the findings, analyses of subgroups and assessments of interactions were performed.

Results 542 postmenopausal women participated in the study, with 237 of them indicating the presence of symptoms associated with stress urinary incontinence. The findings from the multiple regression analysis consistently demonstrated a positive correlation between CMI and SUI in all adjusted models. In particular, a one-unit increase in CMI correlated with a 63% greater probability of encountering postmenopausal SUI in fully adjusted models (OR = 1.63, 95% CI: 1.07–2.48). Additionally, a direct correlation was noted between CMI levels and the occurrence of SUI within this population. Subgroup analysis by the number of vaginal deliveries showed a significant interaction (P for interaction = 0.0471).

Conclusions The findings emphasize the importance of managing CMI levels to identify postmenopausal women at increased risk for SUI. This study confirms the strong predictive value of CMI for SUI in this population.

Keywords Stress urinary incontinence, Cardiometabolic index, Postmenopausal

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Background

Menopause represents a pivotal phase in the life trajectory of women, marked by profound hormonal and metabolic changes. These changes not only give rise to typical symptoms but also frequently result in mood disturbances, including restlessness. The underlying cause of these symptoms is the significant fluctuation in hormone levels, particularly the reduction in estrogen. This physiological transformation compromises daily comfort and increases the risk of chronic conditions, highlighting the broader health implications of menopause. Low estrogen levels may lead to an elevated susceptibility to cardiovascular conditions, such as palpitations, angina, and atherosclerotic heart disease. Additionally, abnormal lipid metabolism during menopause can contribute to obesity, hypertension, and type 2 diabetes. In the genitourinary system, urinary incontinence is closely linked to anatomical and functional changes in the lower reproductive tract that occur with menopause, with SUI being particularly common [1, 2]. Involuntary urinary leakage caused by increased abdominal pressure during activities is defined as SUI. The incidence of SUI in women ranges from 26–49% [3, 4].

Estrogen receptors are present in the muscles, fascia, ligaments, and connective tissues supporting the urogenital system. Consequently, the decline in estrogen levels following menopause causes degeneration of the pelvic floor muscles (PFM) and urethral supporting tissues. This impairs pelvic floor muscle relaxation and urethral sphincter function, negatively affecting lower urinary tract function and the urinary control mechanism [5]. Consequently, the risk of SUI increases in postmenopausal women. SUI has a detrimental impact on social activities, imposes a psychological burden, and substantially compromises the quality of life of female patients, creating substantial medical and economic burdens on both individuals and society [6–8].

The high prevalence of SUI among postmenopausal women is primarily attributed to the reduced protective effects of estrogen. However, the application of systemic menopausal hormone treatment for SUI remains controversial, with conflicting findings from epidemiological and clinical studies [9, 10]. A multi-ethnic longitudinal cohort study demonstrated that postmenopausal women experienced a twofold increase in the rate of weight gain during the first 2 years after menopause [11]. At this stage, the distribution of adipose tissue in women is influenced by endogenous sex hormones, potentially leading to central obesity [12]. Increased intra-abdominal pressure in obese postmenopausal women might be a key factor influencing the long-term development of urinary incontinence, thereby contributing to the elevated prevalence of SUI [13]. Central obesity, marked by visceral fat accumulation and increased lipolytic activity, leads to an excessive release of free fatty acids. This process is thought to contribute to hepatic insulin resistance and disturbances in systemic lipid metabolism, which may, in turn, impact the development of SUI [14].

The CMI integrates both anthropometric and biochemical markers to provide a broader insight into cardiometabolic health. In contrast to traditional metrics such as body mass index (BMI) and waist circumference (WC), CMI provides a stronger and more comprehensive evaluation [15]. CMI has become a reliable predictor of obesity risk and has gained significant attention in research. It has been widely applied in screening of diabetes and obesity and has been extensively discussed in studies on fatty liver, cardiovascular disease, depression, and gynecological conditions [16–20].

This study addresses an important gap in the existing literature by investigating the link between CMI and postmenopausal SUI. The findings provide compelling evidence linking lipid metabolism to the incidence of SUI, offering valuable insights that could inform early prevention approaches.

Methods

Study design

The NHANES represents a comprehensive, continuous survey of the population, orchestrated by the National Center for Health Statistics (NCHS), with the objective of assessing the health and nutritional status of individuals within the U.S. population. The analysis employed data from the NHANES database covering the period from 2013 to 2018, concentrating on postmenopausal women aged 40 and above who are experiencing SUI. The survey protocol underwent thorough examination and *was subsequently endorsed by* the NCHS Ethics Review Committee.

Study participants

The study initially included 29,400 participants. Of these, 3,844 postmenopausal women aged 40 or older were considered. Participants were excluded if they had missing data on SUI ($n = 16$), CMI ($n = 2{,}153$), a history of bilateral oophorectomy ($n = 352$), current estrogen use ($n = 308$), or missing covariates ($n = 473$). Following the exclusion process, the final sample included 542 participants. Statistical analysis ultimately yielded 542 participants (Fig. 1). Among these, 237 women were diagnosed with SUI, while 305 did not have the condition.

Study variables

Menopausal status was established through self-reports collected in the.

reproductive health questionnaire in the 2013–2018 NHANES database. Women aged over 40 were asked, " Have you had at least one menstrual period in the past

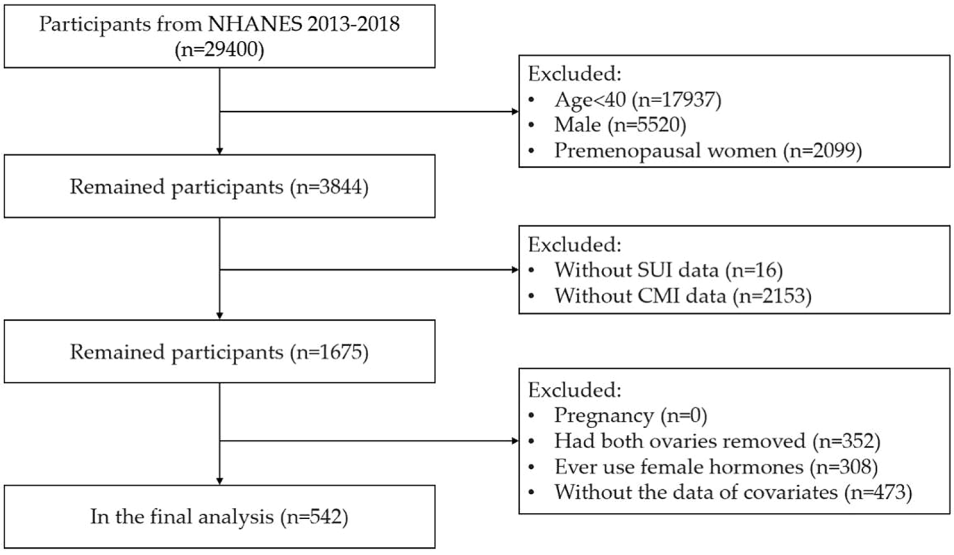

Fig. 1 Selection flowchart for participants

12 months? " For those who answered "no", a follow-up question was posed: " What is the reason you have not had a period in the past 12 months?" To ensure accurate classification, women with menstrual irregularities due to pregnancy, breastfeeding, or medical interventions were excluded. Postmenopausal status was assigned to women who had not experienced a menstrual period in the preceding 12 months, with amenorrhea attributed to either hysterectomy or menopause-related changes [21].

SUI is defined by the involuntary loss of urine during physical activities. The diagnostic criteria for SUI were derived from the NHANES database. A key diagnostic question, embedded in the structured "KIQ042" questionnaire, administered at the NHANES Mobile Examination Center, was central to identifying SUI. Specifically, participants were asked: "In the past 12 months, have you experienced any urinary leakage during activities such as coughing, lifting, or exercising?" Individuals who answered affirmatively were classified as having SUI.

The CMI was calculated: TG/HDL-c × waist-to-height ratio (WHtR) [22]. Triglycerides (TG) and high-density lipoprotein cholesterol (HDL-C) levels were derived from NHANES laboratory data (mg/dl), while WHtR was determined as the ratio of WC to height, both measured in centimeters (cm), based on body measurements recorded in the NHANES database.

Covariates

Key variables potentially influencing the relationship between CMI and postmenopausal SUI prevalence were identified through a review of existing research and clinical insights. These factors were derived from the NHANES questionnaires and examination datasets, including age, race (Mexican American, Non-Hispanic White, Other Hispanic, Non-Hispanic Black, Other Races), education level (< 9, 9–12, > 12), marital status (living with a partner/ living alone), poverty-to-income ratio (PIR: <1.30, 1.30–3.49, ≥ 3.50), alcohol consumption (yes/no), smoking status (never smoked, current smoker, former smoker), levels of vigorous and moderate physical activity (yes/no), number of vaginal deliveries (0, 1–2, 3–5, > 5), contraceptive use (yes/no), and medical history (diabetes, hypertension, hypercholesterolemia). Hypertension was identified through self-reported diagnoses, systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or the use of antihypertensive medications. Diabetes was diagnosed based on physician reports, fasting plasma glucose ≥ 126 mg/dL, HbA1c > 6.5%, or current use of antidiabetic medications [23]. Hypercholesterolemia was defined as total cholesterol (TC) ≥ 240 mg/dL, a physician's diagnosis, or taking lipid-lowering medications.

Statistical analysis

Continuous variables were represented as mean ± standard deviation (SD) or median, whereas categorical variables were displayed as frequencies and percentages. For continuous variables that do not follow a normal distribution (Shapiro-Wilk $p < 0.05$), the Kruskal-Wallis test was utilized, whereas one-way analysis of variance (ANOVA) was employed for data that adheres to a normal distribution. CMI values were systematically classified into quartiles using continuous measures, and trend analyses were performed to assess possible dose-response relationships. To evaluate the relationship between chronic musculoskeletal issues and stress urinary incontinence in postmenopausal women, three distinct multiple logistic regression models were utilized:

Model 1 (unadjusted), Model 2 (adjusted for sociodemographic variables such as race/ethnicity, marital status, and family poverty ratio), and Model 3 (fully adjusted for further variables, including alcohol consumption, smoking habits, levels of physical activity, hypertension, diabetes, hypercholesterolemia, number of vaginal deliveries, and contraceptive use). These models aimed to provide a comprehensive understanding of the association by controlling for potential confounders. SCF techniques were used to evaluate the linear relationships between CMI and SUI, and subgroup analyses were conducted to explore potential heterogeneity. Statistical significance was set at $p < 0.05$. All analyses were carried out using R software (version 4.2.1) and EmpowerStats (version 4.2).

Results

Baseline characteristics of participants

The research encompassed a cohort of 542 postmenopausal women, presenting a mean age of 63.27 ± 9.95 years and a median CMI of 0.49 [0.31, 0.82]. The clinical characteristics of the participants were classified depending on the existence or non-existence of SUI (Table 1). Notable differences were identified between the two groups regarding ethnicity, marital status, diabetes, hypercholesterolemia, oral contraceptive use, and CMI (all $P < 0.05$). Notably, individuals with SUI had a significantly higher median CMI (0.58 [0.36, 0.93]) compared to those without SUI (0.44 [0.28, 0.73]).

Table 2 shows the baseline characteristics of the study, grouped by CMI quartile. Among the participants, 237 (43.73%) were diagnosed with SUI. The quartiles were defined as Q1 (0.06–0.31), Q2 (0.31–0.49), Q3 (0.49–0.82), and Q4 (0.82–3.45). A higher CMI was linked to a greater occurrence of SUI. Notably, the Q4 group, with the highest CMI, was more likely to be white, more educated, from low to middle-income households, living with a partner, drinking alcohol, never smoking, engaging in vigorous and moderate exercise, having diabetes, and having hypercholesterolemia or hypertension. This group also had 3 or more vaginal deliveries and used oral contraceptives.

Associations between CMI and SUI

Table 3 illustrates the outcomes of three adjustment models that include a range of covariates: Model 1 (OR = 2.02, 95% CI: 1.39–2.95); Model 2 (OR = 1.84, 95% CI: 1.23–2.73); and Model 3 (OR = 1.63, 95% CI: 1.07–2.48). In all models, a positive correlation between CMI and SUI was noted, suggesting a robust relationship where elevated CMI levels correspond to a greater incidence of SUI ($P < 0.05$). Notably, elevated CMI levels correlated with an increased probability of SUI manifestation. A dose-response relationship was observed, indicating an increase in SUI occurrence that was substantially linked to rising CMI levels (P for linear trend < 0.05), a trend that remained consistent across models with different levels of confounder adjustment. In Model 3, after comprehensive adjustment for covariates, the bottom quartile of CMI (Q1) was designated as the reference group. All other quartiles (Q2, Q3, Q4) demonstrated an increased prevalence of SUI, with the highest CMI quartile (Q4) revealing the most significant association (OR = 1.81, 95% CI: 1.01–3.23). The data indicate that a one-unit increase in CMI correlates with an 81% rise in the incidence of SUI within the Q4 group. The SCF analysis revealed a noteworthy significant association between CMI and SUI, as illustrated in Fig. 2. Furthermore, the analysis of threshold effects (Table 4) provided additional.

evidence for a linear correlation between CMI levels and the prevalence of SUI. The confirmation of the linear effect fit was observed ($P = 0.023$), further substantiated by the log-likelihood ratio test ($P = 0.447$).

Subgroup analysis

To assess the relationship stability between CMI and SUI among postmenopausal women, this study conducted stratified analyses across various subgroups (Fig. 3). The subgroup analysis identified a significant association where CMI was positively linked to SUI among this group (OR = 7.53, 95% CI: 2.01–28.24, $P < 0.05$), reinforcing the robustness of this association. The interaction analysis showed that the number of vaginal deliveries significantly influenced the significant positive relationship between CMI and SUI (P for interaction = 0.0471), with a stronger effect observed in women who.

had not experienced vaginal delivery. In addition, subgroup evaluations across various demographic and lifestyle factors further validated the dependability and consistency regarding the significant positive relationship between CMI and SUI. These factors included: Age (41–62), Race/ethnicity (Mexican American, Non-Hispanic White), Education Level (< 9, > 12), Marital status (Living with a partner, Living alone), Family poverty ratio, Alcohol use (Yes), Smoking status(never), Vigorous physical activity(no), Moderate physical activity, Hypertension, Diabetes(no), High cholesterol, Number of vaginal deliveries (0) and Birth control use. Notably, for individuals of the "Other Hispanic" ethnicity, an increase in CMI did not significantly elevate the occurrence of postmenopausal SUI.

Discussion

This research marks the inaugural cross-sectional examination of the association between CMI and postmenopausal SUI. The median CMI was significantly higher among SUI patients (0.58 [0.36, 0.93]) compared to non-SUI patients (0.44 [0.28, 0.73]). Furthermore, when CMI was grouped by quartile, the incidence of SUI in Q4

Table 1 Base characteristics of participants with and without SUI in the NHANES 2013–2018 cycles

Characteristics	Total	Without SUI	With SUI	*P*-value
	N **= 542**	***N*** **= 305**	***N*** **= 237**	
Age(years), Mean ± SD	63.27 ± 9.95	63.07 ± 9.75	63.52 ± 10.22	0.604
Race/ethnicity, n (%)				0.001
Mexican American	83 (15.31)	40 (13.11)	43 (18.14)	
Other Hispanic	75 (13.84)	40 (13.11)	35 (14.77)	
Non-Hispanic White	158 (29.15)	75 (24.59)	83 (35.02)	
Non-Hispanic Black	123 (22.69)	85 (27.87)	38 (16.03)	
Other Races	103 (19.00)	65 (21.31)	38 (16.03)	
Education Level (year), n (%)				0.050
< 9	80 (14.76)	35 (11.48)	45 (18.99)	
9–12	83 (15.31)	48 (15.74)	35 (14.77)	
> 12	379 (69.93)	222 (72.79)	157 (66.24)	
Marital status, n (%)				0.032
Living with a partner	289 (53.32)	175 (57.38)	114 (48.10)	
Living alone	253 (46.68)	130 (42.62)	123 (51.90)	
Family poverty ratio, n (%)				0.418
< 1.3	176 (32.47)	92 (30.16)	84 (35.44)	
1.3–3.5	232 (42.80)	134 (43.93)	98 (41.35)	
≥ 3.5	134 (24.72)	79 (25.90)	55 (23.21)	
Alcohol use, n (%)				0.208
No	185 (34.13)	111 (36.39)	74 (31.22)	
Yes	357 (65.87)	194 (63.61)	163 (68.78)	
Smoking status, n (%)				0.140
Never	386 (71.22)	227 (74.43)	159 (67.09)	
Past	68 (12.55)	32 (10.49)	36 (15.19)	
Current	88 (16.24)	46 (15.08)	42 (17.72)	
Vigorous physical activity, n (%)				0.475
No	486 (89.67)	276 (90.49)	210 (88.61)	
Yes	56 (10.33)	29 (9.51)	27 (11.39)	
Moderate physical activity, n (%)				0.673
No	337 (62.18)	192 (62.95)	145 (61.18)	
Yes	205 (37.82)	113 (37.05)	92 (38.82)	
Hypertension, n (%)				0.380
No	206 (38.01)	111 (36.39)	95 (40.08)	
Yes	336 (61.99)	194 (63.61)	142 (59.92)	
Diabetes, n (%)				0.014
No	373 (68.82)	223 (73.11)	150 (63.29)	
Yes	169 (31.18)	82 (26.89)	87 (36.71)	
High cholesterol, n (%)				0.011
No	223 (41.14)	140 (45.90)	83 (35.02)	
Yes	319 (58.86)	165 (54.10)	154 (64.98)	
Number of vaginal deliveries, n (%)				0.052
0	74 (13.65)	52 (17.05)	22 (9.28)	
1–2	179 (33.03)	99 (32.46)	80 (33.76)	
3–5	236 (43.54)	123 (40.33)	113 (47.68)	
> 5	53 (9.78)	31 (10.16)	22 (9.28)	
Birth control pills taken, n (%)				0.021
No	208 (38.38)	130 (42.62)	78 (32.91)	
Yes	334 (61.62)	175 (57.38)	159 (67.09)	
CMI, median [IQR]	0.49 [0.31, 0.82]	0.44 [0.28, 0.73]	0.58 [0.36, 0.93]	< 0.001

Median [IQR] for skewed continuous variables (Shapiro-Wilk $p < 0.05$): P value by Kruskal-Wallis test; Mean ± SD for normally distributed variables: P value by one-way ANOVA; n (%) for categorical variables: P value by chi-square test

Abbreviation: SUI Stress urinary incontinence, CMI, cardiometabolic index

Table 2 Basic characteristics of participants by CMI among postmenopausal women

CMI	Total	Q1	Q2	Q3	Q4	*P*-value
	N **= 542**	**(0.06–0.31)**	**(0.31–0.49)**	**(0.49–0.82)**	**(0.82–3.45)**	
		N **= 136**	***N*** **= 135**	***N*** **= 135**	***N*** **= 136**	
Age(years), Mean ± SD	63.27 ± 9.95	64.51 ± 9.50	63.40 ± 9.77	63.87 ± 10.64	61.29 ± 9.67	0.044
Race/ethnicity, n (%)						< 0.001
Mexican American	83 (15.31%)	9 (6.62%)	18 (13.33%)	31 (22.96%)	25 (18.38%)	
Other Hispanic	75 (13.84%)	12 (8.82%)	17 (12.59%)	20 (14.81%)	26 (19.12%)	
Non-Hispanic White	158 (29.15%)	38 (27.94%)	43 (31.85%)	31 (22.96%)	46 (33.82%)	
Non-Hispanic Black	123 (22.69%)	40 (29.41%)	33 (24.44%)	29 (21.48%)	21 (15.44%)	
Other Races	103 (19.00%)	37 (27.21%)	24 (17.78%)	24 (17.78%)	18 (13.24%)	
Education Level (year), n (%)						0.043
< 9	80 (14.76%)	15 (11.03%)	13 (9.63%)	25 (18.52%)	27 (19.85%)	
9–12	83 (15.31%)	16 (11.76%)	22 (16.30%)	19 (14.07%)	26 (19.12%)	
> 12	379 (69.93%)	105 (77.21%)	100 (74.07%)	91 (67.41%)	83 (61.03%)	
Marital status, n (%)						0.774
Living with a partner	289 (53.32%)	68 (50.00%)	71 (52.59%)	74 (54.81%)	76 (55.88%)	
Living alone	253 (46.68%)	68 (50.00%)	64 (47.41%)	61 (45.19%)	60 (44.12%)	
Family poverty ratio, n (%)						0.008
< 1.3	176 (32.47%)	28 (20.59%)	45 (33.33%)	46 (34.07%)	57 (41.91%)	
1.3–3.5	232 (42.80%)	63 (46.32%)	55 (40.74%)	61 (45.19%)	53 (38.97%)	
≥ 3.5	134 (24.72%)	45 (33.09%)	35 (25.93%)	28 (20.74%)	26 (19.12%)	
Alcohol use, n (%)						0.157
No	185 (34.13%)	57 (41.91%)	45 (33.33%)	42 (31.11%)	41 (30.15%)	
Yes	357 (65.87%)	79 (58.09%)	90 (66.67%)	93 (68.89%)	95 (69.85%)	
Smoking status, n (%)						0.020
Never	386 (71.22%)	113 (83.09%)	91 (67.41%)	93 (68.89%)	89 (65.44%)	
Past	68 (12.55%)	9 (6.62%)	19 (14.07%)	22 (16.30%)	18 (13.24%)	
Current	88 (16.24%)	14 (10.29%)	25 (18.52%)	20 (14.81%)	29 (21.32%)	
Vigorous physical activity, n (%)						0.270
No	486 (89.67%)	116 (85.29%)	123 (91.11%)	122 (90.37%)	125 (91.91%)	
Yes	56 (10.33%)	20 (14.71%)	12 (8.89%)	13 (9.63%)	11 (8.09%)	
Moderate physical activity, n (%)						0.066
No	337 (62.18%)	73 (53.68%)	82 (60.74%)	90 (66.67%)	92 (67.65%)	
Yes	205 (37.82%)	63 (46.32%)	53 (39.26%)	45 (33.33%)	44 (32.35%)	
Hypertension, n (%)						0.109
No	206 (38.01%)	59 (43.38%)	52 (38.52%)	40 (29.63%)	55 (40.44%)	
Yes	336 (61.99%)	77 (56.62%)	83 (61.48%)	95 (70.37%)	81 (59.56%)	
Diabetes, n (%)						< 0.001
No	373 (68.82%)	118 (86.76%)	100 (74.07%)	89 (65.93%)	66 (48.53%)	
Yes	169 (31.18%)	18 (13.24%)	35 (25.93%)	46 (34.07%)	70 (51.47%)	
High cholesterol, n (%)						< 0.001
No	223 (41.14%)	78 (57.35%)	58 (42.96%)	55 (40.74%)	32 (23.53%)	
Yes	319 (58.86%)	58 (42.65%)	77 (57.04%)	80 (59.26%)	104 (76.47%)	
Number of vaginal deliveries, n (%)						0.606
0	74 (13.65%)	25 (18.38%)	18 (13.33%)	11 (8.15%)	20 (14.71%)	
1–2	179 (33.03%)	44 (32.35%)	44 (32.59%)	48 (35.56%)	43 (31.62%)	
3–5	236 (43.54%)	57 (41.91%)	60 (44.44%)	60 (44.44%)	59 (43.38%)	
> 5	53 (9.78%)	10 (7.35%)	13 (9.63%)	16 (11.85%)	14 (10.29%)	
Birth control pills taken, n (%)						0.238
No	208 (38.38%)	61 (44.85%)	45 (33.33%)	53 (39.26%)	49 (36.03%)	
Yes	334 (61.62%)	75 (55.15%)	90 (66.67%)	82 (60.74%)	87 (63.97%)	
SUI, n (%)						0.002

Table 2 (continued)

CMI	Total	Q1	Q2	Q3	Q4	*P*-value
	N **= 542**	**(0.06–0.31)**	**(0.31–0.49)**	**(0.49–0.82)**	**(0.82–3.45)**	
		N **= 136**	***N*** **= 135**	***N*** **= 135**	***N*** **= 136**	
No	305 (56.27%)	92 (67.65%)	79 (58.52%)	73 (54.07%)	61 (44.85%)	
Yes	237 (43.73%)	44 (32.35%)	56 (41.48%)	62 (45.93%)	75 (55.15%)	

Mean ± SD for normally distributed variables: P value by one-way ANOVA; n (%) for categorical variables: P value by chi-square test

Abbreviation: SUI Stress urinary incontinence, CMI, cardiometabolic index

Table 3 Associations between CMI and stress urinary incontinence

SUI	Model 1		Model 2		Model 3	
	OR (95% CI)	***P*-value**	**OR (95% CI)**	***P*-value**	**OR (95% CI)**	***P*-value**
CMI	2.02 (1.39, 2.95)	0.0002	1.84 (1.23, 2.73)	0.0027	1.63 (1.07, 2.48)	0.0225
Categories						
Q1	Reference		Reference		Reference	
Q2	1.48 (0.90, 2.43)	0.1202	1.43 (0.86, 2.39)	0.1682	1.24 (0.73, 2.12)	0.4278
Q3	1.78 (1.08, 2.91)	0.0226	1.69 (1.01, 2.83)	0.0463	1.36 (0.78, 2.35)	0.2802
Q4	2.57 (1.57, 4.21)	0.0002	2.29 (1.36, 3.87)	0.0020	1.81 (1.01, 3.23)	0.0457
P for trend	< 0.001		0.002		0.047	

OR: odds ratio, 95%CI: 95% confidence interval

Model 1: unadjusted

Model 2: adjusted for age, race/ethnicity, Education Level, Marital status AND Family poverty ratio

Model 3: adjusted for all variables, including age, race/ethnicity, Education Level, Marital status, Family poverty ratio, Alcohol use, Smoking status, Vigorous physical activity, Moderate physical activity, Hypertension, Diabetes, High cholesterol, Number of vaginal deliveries, Birth control pills taken

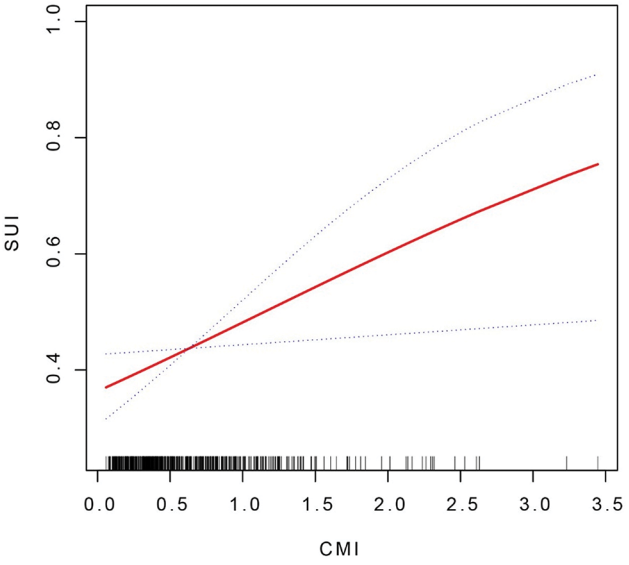

Fig. 2 The association between CMI and postmenopausal SUI

group (55.15%) was higher than that in Q1 group. Key confounding variables were identified through an extensive review of existing literature and clinical insights, with suitable adjustments implemented for these factors across different models. The results of multiple logistic regression analysis showed that CMI was positively correlated with SUI: model 1 (OR = 2.02, 95%CI: 1.39–2.95); Model 2 (OR = 1.84, 95%CI: 1.23–2.73); Model 3 (OR = 1.63, 95%CI: 1.07–2.48). In Model 3 after comprehensive adjustment for covariates, the highest quartile

Table 4 Threshold effect analysis of CMI on SUI using a linear regression model

Threshold effect analysis	SUI	
CMI	**OR (95% CI)**	***P*-value**
Fitting by a standard linear model	1.63 (1.07, 2.48)	0.023
Fitting by two-piecewise linear model		
The inflection point of CMI (K)	0.27	
CMI < K	0.25 (0.00, 31.89)	0.573
CMI > K	1.73 (1.10, 2.71)	0.017
P for log-likelihood ratio	0.447	

OR: odds ratio, 95%CI: 95% confidence interval adjusted for all variables

of CMI (Q4) showed the most significant association (OR = 1.81, 95%CI: 1.01–3.23). The results demonstrated a significant positive relationship between CMI and the prevalence of SUI, suggesting that elevated levels of CMI correspond to an increased likelihood of developing SUI. The analyses of SCF and threshold effects both indicated a linear correlation between CMI and the prevalence of SUI. The linear effect fit was statistically significant ($P = 0.023$), further validated by additional statistical tests. This relationship's strength was additionally reinforced through subgroup analyses and interaction assessments. In the subgroup analysis, it was observed that the frequency of vaginal deliveries influenced the relationship between CMI and SUI, indicating a variation in impact based on the number of vaginal deliveries. The correlation between CMI and SUI was particularly evident in females who had not experienced vaginal delivery (OR = 7.53, 95% CI: 2.01–28.24, $P < 0.05$). The findings

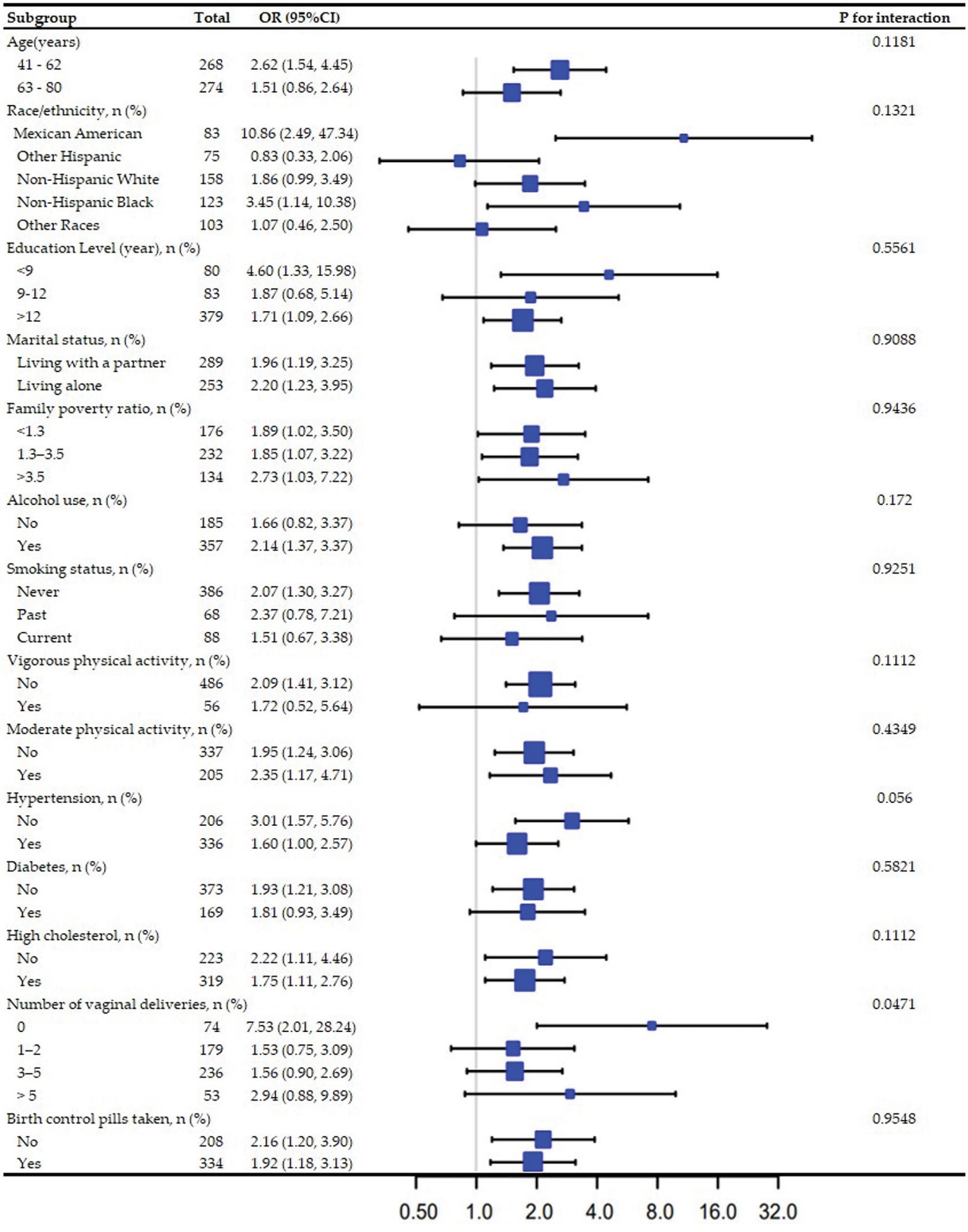

Fig. 3 The association between CMI and postmenopausal SUI

indicate that CMI may function as a standalone predictor for evaluating SUI in postmenopausal women, providing considerable utility for regular monitoring and clinical assessment. Furthermore, CMI can be a valuable tool for identifying individuals at higher risk for SUI, thus enabling earlier intervention and tailored treatment strategies.

Obesity is an escalating global public health concern, affecting approximately 42% of American adults [24]. Postmenopausal women are particularly vulnerable to central obesity and abnormal lipid metabolism due to decreased estrogen levels, relative androgen excess, and changes in lipid profiles [25, 26]. Traditional obesity studies have primarily relied on BMI, which does not effectively differentiate adipose tissue distribution or detect abdominal obesity. To address these limitations, WC and WHtR have emerged as more effective indicators for assessing central obesity [27]. TG and HDL-C levels are essential factors influencing insulin secretion. The TG/HDL-C ratio is commonly utilized for the assessment of lipid metabolism disorders and is a key predictor of insulin resistance and cardiovascular disease [28]. CMI is a novel assessment method that combines anthropometric measurements (WHtR) with lipid profile parameters (TG and HDL-C). This composite measure provides a comprehensive and reliable reflection of visceral fat distribution and lipid health, making it an important early predictor of obesity and metabolic abnormalities associated with dyslipidemia [15, 29]. Current investigations reveal a notable relationship connecting CMI with diverse health conditions, including cardiovascular diseases, urinary system disorders, reproductive system issues, mental health concerns, and metabolic syndrome [17, 18, 19, 30, 31, 32]. Nonetheless, the link between CMI and postmenopausal SUI remains insufficiently explored and has not been extensively addressed in existing literature.

The accumulation of abdominal fat and dyslipidemia in postmenopausal women with SUI have prompted academic discussions [12, 33]. A cross-sectional survey involving 10,000 women reported that central obesity indicators such as WHtR were positively correlated with the severity of SUI [27]. The findings regarding the relationship between CMI and postmenopausal SUI are consistent with this conclusion. This correlation may be explained by the following factors: First, obesity affects the female genitourinary system and is an independent risk factor for female SUI [34]. Obesity leads to metabolic disturbances and insulin resistance, which can lead to detrimental effects on the pelvic floor's (PF) neural and vascular structures, potentially resulting in urinary control dysfunction [35]. In postmenopausal women, central obesity increases intra-abdominal pressure over an extended period, which can cause irreversible weakening of the PFM and connective tissues. This deterioration reduces the support provided to the urinary tract and bladder neck, thereby exacerbating the risk of urinary incontinence [36]. Excessive abdominal pressure also generates additional strain on the bladder [37]. These changes lower the threshold for urinary incontinence, making it more likely to occur even with mild intra-abdominal pressure from normal physical activity. Second, dyslipidemia is a common feature of obesity. Long-term exposure to dyslipidemia impairs metabolic and epigenetic changes triggered by muscle-derived stem cells, challenging pelvic floor function in women [38, 39]. Abnormal lipid metabolism-driven metabolic syndrome has been strongly associated with SUI in women [40], highlighting the central role of dysregulated lipid metabolism in SUI pathophysiology. In addition, systemic chronic inflammation linked to adipose tissue accumulation can worsen lipid and glucose metabolism, leading to increased lipid deposition in pelvic tissues and a heightened risk of SUI [41]. Intra-abdominal pressure is a form of mechanical stress. Excessive mechanical stress causes reactive oxygen species (ROS) to accumulate in tissues, resulting in lipid damage and oxidative stress (OS) [42]. OS is another critical pathological condition induced by obesity, and elevated CMI levels are often observed alongside OS in obese individuals. OS is closely associated with apoptosis, resulting in continuous loss of muscle cells in the urethral sphincter and its supporting system, weakened contractile function, and impaired urinary control, contributing to the development of SUI [43, 44]. The extracellular matrix (ECM), which is mainly composed of collagen, elastin, proteoglycans, and glycosaminoglycans, is secreted by fibroblasts and epithelial cells. It is widely present in pelvic floor supporting tissues, playing a vital role in mechanical support [45]. Obesity-induced damage and remodeling of the ECM contribute to pelvic floor tissue relaxation [46]. Additionally, reduced estrogen levels are another important factor contributing to the onset and progression of SUI.

This study successfully integrated the characteristics of visceral obesity and dyslipidemia, demonstrating that more severe lipid metabolism disorders in postmenopausal women correlate with a higher incidence of SUI. Subgroup analyses emphasized a significant association of elevated CMI levels with higher SUI prevalence within this population. This finding aligns with another study examining the relationship between lipid metabolism and SUI prevalence in women [47]. It is also supported by a recent study on CMI in women, which highlights the triglyceride glucose index as a mediator [48]. However, this study specifically focused on urinary health issues in postmenopausal women. A 4-year longitudinal study of urinary incontinence in 24,985 Chinese adult women supports the findings [49]. Combining the results of SCF

and subgroup analysis, this study observed that the prevalence of SUI in postmenopausal women increased significantly as CMI rose. This positive association remained robust across most subgroups. Of particular note was the strong association shown between CMI levels and the incidence of postmenopausal SUI within the vaginal delivery subgroup. Urinary incontinence in women is significantly influenced by fertility, which is a key risk factor. As pregnancy progresses, the uterus expands in both volume and weight, exerting prolonged pressure of the bladder and pelvic floor support structures. During vaginal delivery, the muscles surrounding the vagina and tissues such as the perineal body become overstretched. In the second stage of labor, nearby nerve fibers experience prolonged compression and hypoxia. Following pelvic nerve injury, the denervated internal urethral sphincter atrophies, impairing its contractile function and preventing it from closing the urethra before bladder pressure increases [50]. Obese women may experience a higher rate of instrumental delivery, prolonged labor, and a greater incidence of urinary incontinence [51]. Some women require instrument-assisted delivery or episiotomy to avoid potential perineal laceration during childbirth. These factors increase the risk of damage to PF nerves (PFN), blood vessels, and muscles, compromising the overall support function of the pelvic floor. Long-term physical overload also results in high urethral mobility. When intra-abdominal pressure increases, the closed urethra moves downward, leading to a lower urethral pressure compared to bladder pressure, which causes urine leakage. The number of deliveries is linked to the incidence and severity of SUI [52]. In comparison to cesarean deliveries, women who have undergone vaginal births experience a higher incidence of SUI [53]. The findings underscore the significance of considering reproductive factors, such as the number of vaginal deliveries, in the context of obesity, dyslipidemia, and the development of SUI in postmenopausal women. Therefore, targeting postmenopausal women at high CMI levels, especially those with a history of multiple vaginal deliveries, strengthening health assessments and early interventions could help reduce SUI risk in high-risk groups. CMI could serve as an effective early screening tool to identify individuals at high risk, enabling proactive preventive measures. For patient groups that show limited response to conventional therapies, developing new treatments or enhancing existing ones based on CMI may offer improved outcomes. The findings of this study suggest that longitudinal research should be conducted to more thoroughly understand how CMI changes over time and its influence on the progression of SUI. Additionally, future studies incorporating a broader range of participants—including various age groups, ethnicities, and geographic locations—are essential to validate the generalizability of these findings. In summary, the findings underscore the clinical importance of monitoring CMI in postmenopausal women with SUI. CMI should be considered a key metric for assessing and managing SUI risk in this population.

The study had several strengths. First, participant data were sourced from the NHANES database, ensuring that the sample accurately reflects the U.S. population. Second, this study adjusted for covariates related to exposure and outcomes, which increases the generalizability of the results. This adjustment also provides preliminary support for future clinical and basic research on the influence of CMI on postmenopausal SUI. However, there are limitations. Since the NHANES data are cross-sectional, this study cannot determine temporal sequences or make causal inferences. Cohort studies would be necessary to explore these aspects in more detail. Additionally, although this study controlled for major covariates identified in previous studies, the NHANES database lacked data on several established SUI risk factors, including pelvic surgery history, pelvic organ prolapse, chronic constipation, and specific medication use (particularly antidepressants and diuretics). Therefore, the study cannot fully eliminate all potential confounding factors. Given these limitations, further investigation into the association between CMI and postmenopausal SUI, as well as the underlying mechanisms, is recommended. Longitudinal studies and more comprehensive data collection are essential to address the current limitations and provide a clearer understanding of this relationship.

Conclusions

These findings suggest a potential link between elevated CMI levels and a higher rate of SUI in postmenopausal women. This emphasizes the importance of managing CMI to identify postmenopausal women at risk for SUI and highlights its potential role in preventing metabolic and urinary health issues in women. For postmenopausal women with high CMI, it is crucial to strengthen the evaluation of pelvic floor muscle function. Given that several components of CMI (such as waist circumference and blood lipid levels) are modifiable, lifestyle interventions targeting metabolic health—such as weight management and pelvic floor muscle training—may serve as promising non-invasive strategies to reduce the risk of SUI among these women.

Abbreviations

SUI	Stress urinary incontinence
CMI	Cardiometabolic index
NHANES	National Health and Nutrition Examination Survey
WC	Waist circumference
BMI	Body mass index
WHtR	Waist-to-height ratio
TG	Triglycerides
HDL-C	high-density lipoprotein cholesterol

OR	Odds ratio
CI	Confidential interval
PIR	Income-to-Poverty ratio
ROS	reactive oxygen species
ECM	Extracellular matrix

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions
TY designed the research. TY and YH collected, analyzed the data and drafted the manuscript. HC revised the manuscript. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The NCHS Ethics Review Committee completed the approval of the survey protocol, and in-formed consent was obtained from all participants. Since this cross-sectional study used publicly available data, it was exempt from additional ethical review.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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