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Associations between metabolic score for visceral fat and urinary incontinence among US adult women: a population-based cross-sectional study

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Abstract

Background This study aimed to elucidate the association between metabolic score for visceral fat (METS-VF) and urinary incontinence (UI) prevalence among adult women in the US.

Methods Using data from the National Health and Nutrition Examination Survey (NHANES, 2007–2016), the study conducted a cross-sectional analysis of 4,190 adult women aged ≥ 20 years. The investigation evaluated the relationship between METS-VF and the prevalence and severity of three types of UI: stress urinary incontinence (SUI), urgency urinary incontinence (UUI), and mixed urinary incontinence (MUI). Weighted multivariable logistic regression models and restricted cubic splines (RCS) were employed to assess these associations. Subgroup analyses and interaction tests were performed to explore potential modifying factors.

Results METS-VF was positively associated with the prevalence of SUI, UUI, and moderate to severe UI in the fully adjusted model. After categorizing METS-VF into quartiles, higher METS-VF quartiles were linked to increased susceptibility to all UI types, with a notable positive correlation observed for moderate and severe UI. RCS analysis revealed a nonlinear dose-response relationship between METS-VF and both UUI and MUI. Subgroup analyses and interaction tests suggested that age, ethnicity, and vaginal delivery times may influence the positive association between METS-VF and SUI.

Conclusion METS-VF was positively associated with UI prevalence (SUI, UUI) and moderate to severe UI. These findings underscore the importance of visceral fat assessment in identifying individuals at risk for UI, offering novel insights for prevention and management strategies. METS-VF may serve as a practical tool for early risk stratification and personalized clinical interventions.

Keywords METS-VF, Urinary incontinence, NHANES, Cross-sectional study

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Introduction

Urinary incontinence (UI) is characterized by the involuntary leakage of urine and is a prevalent urogenital disorder predominantly affecting women [1]. According to global statistics, the incidence of UI among women has been rising steadily, with current estimates ranging from 25 to 45% [2]. As the global population ages, the prevalence of UI and other pelvic floor disorders, such as pelvic organ prolapse and fecal incontinence, is anticipated to increase. In the US, the number of women affected by UI is projected to increase from 18.3 million in 2010 to approximately 28.4 million by 2050, reflecting the growing public health impact of this condition [3]. UI is classified based on its symptoms into stress urinary incontinence (SUI), urgency urinary incontinence (UUI), and mixed urinary incontinence (MUI) [1]. UI represents a significant public health concern, profoundly affecting the quality of life for many individuals. Major risk factors for UI include obesity, diabetes, hypertension, smoking, and advancing age [4, 5]. Early identification and management of these risk factors are crucial, as they can help reduce the incidence of UI and its associated complications, ultimately improving patients' mental health and overall quality of life.

Obesity has evolved into a prevalent global health disorder, affecting a substantial number of individuals worldwide. According to the World Health Organization (WHO), an estimated 2.5 billion adults aged 18 and older were classified as overweight in 2022, including 890 million individuals affected by obesity [6]. This equates to 43% of the adult population (43% of men and 44% of women) being classified as overweight [6]. Notably, the percentage of healthcare expenditures in the United States allocated to the treatment of adult obesity-related conditions increased from 6.1% in 2001 to 7.9% in 2015, representing a growth of 29% [7]. Numerous studies have established a correlation between obesity and the exacerbation of UI. Liang and Long et al. found a significant association between weight gain and the increased incidence of UI [8, 9]. Both general obesity and central obesity are recognized risk factors for UI, as excess weight contributes to a pro-inflammatory state and increased intra-abdominal pressure, which may weaken the pelvic floor muscles and exacerbate UI symptoms [10, 11]. Studies have shown that overweight or obese women experience a reduction in the frequency of UI episodes following weight loss [12]. However, most previous investigations concerning the correlation between obesity and UI have predominantly relied on BMI as the principal indicator of obesity. This approach was contentious, as research indicated that individuals with high visceral fat content face a greater risk of cardiovascular-related issues, irrespective of whether their BMI is classified as normal or elevated [13]. Therefore, relying solely on BMI for assessing obesity is inadequate, and considering central obesity offers a more comprehensive understanding of obesity-related health issues. Although waist circumference (WC) is widely recognized by researchers and clinicians for its convenience and accuracy in assessing abdominal obesity, it is important to note that the height and BMI of participants may influence the precision of WC measurements [14]. Consequently, there is an urgent need to develop a novel assessment metric for visceral fat accumulation that does not depend on BMI or WC. Bello-Chavolla et al. proposed a new obesity index termed the metabolic score for visceral fat (METS-VF) [15]. Compared to various alternative indicators of fat accumulation, this indicator demonstrates enhanced efficacy in assessing obesity, particularly visceral obesity, and in effectively evaluating cardiovascular metabolic risk [15]. Given the shared risk factors between cardiovascular disease and UI [16], there is reason to hypothesize a potential association between METS-VF and UI.

Recent studies have demonstrated the effectiveness of the METS-VF in assessing a variety of diseases [15, 17]. However, the accuracy of utilizing METS-VF as an evaluative metric for UI necessitated further investigation. This study employed data from the National Health and Nutrition Examination Survey (NHANES) to conduct a cross-sectional analysis, marking the first exploration of the relationship between METS-VF and UI among adult women in the US. The purpose of this study was to fill knowledge gaps in this area from previous studies. Elucidating this association may help clarify the metabolic mechanisms underlying UI and provide a novel, practical tool for early risk stratification and prevention strategies at the public health level.

Methods

Study cohort

The NHANES represents a significant initiative of the National Center for Health Statistics (NCHS) aimed at assessing the health and nutritional status of both adults and children in the US. This comprehensive survey encompasses household interviews and systematic medical evaluations conducted at mobile examination centers, which include physical assessments and laboratory tests. Detailed information regarding the NHANES methodology and datasets can be accessed via the official Centers for Disease Control and Prevention (CDC) portal (https://www.cdc.gov/nchs/nhanes/index.htm). Since all information about the NHANES program is publicly available, approval from a medical ethics committee is not required. All NHANES research protocols have received ethical approval from the NCHS Institutional Review Board, and participants provided written informed consent prior to the commencement of data collection.

This study incorporated data from five consecutive NHANES cycles spanning from 2007 to 2016. Initially, a total of 50,588 subjects were recruited for the survey. Exclusion criteria were applied to individuals under the age of 20, males, those who reported pregnancy at the time of the survey, those lacking METS-VF data, individuals without responses to the UI questionnaire, and those missing relevant covariate data. Following the application of these exclusion criteria, a total of 4,190 data-complete adult female respondents were included in the cross-sectional analysis (Fig. 1).

Assessment of metabolic score for visceral fat

This study employed the METS-VF as the primary exposure variable. METS-VF integrated the metabolic score for insulin resistance (METS-IR), waist-to-height ratio (WHtR), age, and sex [18]. In this study, METS-VF was derived utilizing the following equation: METS-VF = 4.466 + 0.011[(Ln (METS-IR)) ^{3}] + 3.329[(Ln

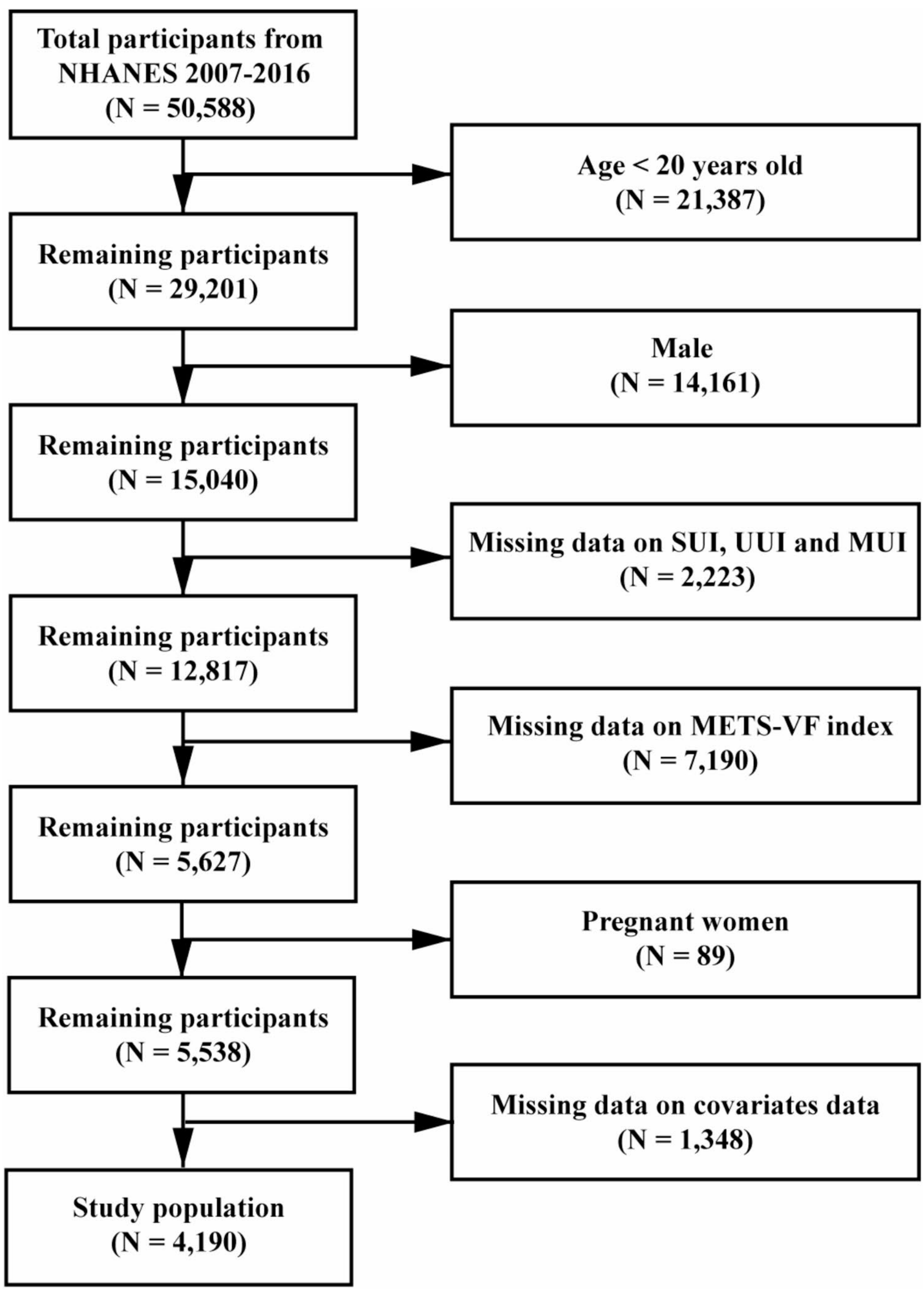

Fig. 1 The flowchart of the study

(WHtR)) ^{3}] + 0.319(Sex) + 0.594(Ln (Age)), wherein the variable for sex is encoded as "male" = 1 and "female" = 0. Gender was set at 0 for this study because male participants were not included. The metabolic insulin resistance score (METS-IR) was computed using the formula: METS-IR = Ln [(2 × fasting glucose) + (fasting triglycerides)] × BMI / [Ln (high-density lipoprotein cholesterol)]. Furthermore, WHtR was assessed according to the equation WHtR = WC / height.

Assessment of SUI, UUI and MUI

This study utilized questionnaire data from the NHANES database, specifically focusing on two items related to "Kidney Conditions" to assess the occurrence of UI (KIQ042 and KIQ044). Participants who responded affirmatively to the question, "During the past 12 months, have you leaked urine or lost control due to activities such as coughing, lifting, or exercising, even if it was a small amount?" were classified as having SUI. Conversely, individuals who answered "yes" to the query, "During the past 12 months, have you leaked urine or lost control due to an urgency or pressure to urinate, even if it was a small amount, and were unable to reach the toilet in time?" were categorized as experiencing UUI. Furthermore, participants who responded affirmatively to both questions were classified as having MUI. The severity index of UI was assessed using two-item Incontinence Severity Index from the kidney condition questionnaire [19]. The index was calculated by multiplying the responses to the questions on the frequency (less than once per month, a few times a month, a few times a week, or every day and/or night) and amount of urinary leakage (drops, splashes, or more), resulting in a score ranging from 1 to 8. Based on this score, the severity of UI is categorized as follows: "slight" (severity score = 1–2), "moderate" (severity score = 3–4), or "severe" (severity score = 6–8) [19].

Covariates

In the present investigation, we considered a range of covariates that may influence the association between METS-VF and UI. These covariates included age, race, marital status, education level, BMI, poverty income ratio (PIR), smoking status, alcohol consumption, physical activity, diabetes, hypertension, stroke, congestive heart failure, coronary heart disease, chronic bronchitis, hyperlipidemia, depression, prior hysterectomy and vaginal delivery times. Age was categorized into three groups: 20–44 years, 45–64 years, and ≥ 65 years. Race was classified as Mexican American, non-Hispanic White, non-Hispanic Black, other Hispanic, and other ethnicities. The PIR was stratified into three categories: < 1.30, 1.30–3.49, and ≥ 3.50. BMI was classified as < 25 kg/m², 25–30 kg/m², and > 30 kg/m². Education level was categorized into three groups: less than high school, high school or GED, and college or higher. Marital status was classified as married, living with a partner, or living alone. Smoking status was categorized as never smoked, former smoker, or current smoker. Alcohol consumption was divided into drinkers and non-drinkers. Physical activity was defined as engaging in at least 10 min of moderate-intensity recreational activity per week. Pre-existing conditions such as chronic bronchitis, stroke, congestive heart failure, and coronary heart disease were identified based on participants' self-reports in the questionnaire regarding their previous diagnoses. Alcohol consumption was defined as drinking at least 12 standard alcoholic beverages within the past year. Diabetes was defined by an HbA1c level > 6.5%, fasting blood glucose ≥ 7.0 mmol/L, random blood glucose ≥ 11.1 mmol/L, 2-hour oral glucose tolerance test (OGTT) blood glucose ≥ 11.1 mmol/L, current use of insulin or diabetes medications, or self-reported diagnosis. The diagnostic criteria for hypertension were established as a systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg, diagnosed by a healthcare professional, or current use of antihypertensive medications. Depressive symptoms were evaluated using the Patient Health Questionnaire-9 (PHQ-9). Based on prior research, a score of 10 or higher was used to identify individuals with clinically significant depression [20]. Hyperlipidemia was defined as low-density lipoprotein cholesterol (LDL-C) ≥ 130 mg/dL, total cholesterol (TC) ≥ 200 mg/dL, triglycerides (TGs) ≥ 150 mg/dL, or high-density lipoprotein cholesterol (HDL-C) ≤ 50 mg/dL in females and ≤ 40 mg/dL in males [21]. Prior hysterectomy was defined as a "yes" or "no" response to the question: "Have you ever had a hysterectomy, which is a surgical procedure to remove your uterus or womb?" The number of vaginal deliveries was categorized into three groups: 0 times, 1–2 times, and ≥ 3 times [22].

Statistical analysis

The statistical analyses conducted in this study adhered to the guidelines provided by the CDC and incorporated sampling weights from the NHANES to address the complexities inherent in a multistage cluster sampling design. Continuous variables are expressed as means ± standard deviation (SD), while categorical variables are reported using unweighted counts and weighted percentages. The Chi-square test was employed for categorical variables, and the Mann-Whitney U test was utilized for continuous variables. Three distinct models were established in the multivariable logistic regression analysis to evaluate the association between METS-VF and the prevalence of UI. In addition, we examined the relationship between METS-VF and different severity levels of UI. Model 1 was unadjusted for any variables, while Model 2 adjusted for age, race, marital status, educational level, BMI, PIR, smoking and drinking status. Model 3 further adjusted for physical activity, diabetes, hypertension, stroke, coronary heart disease, congestive heart failure, chronic bronchitis, hyperlipidemia, depression, prior hysterectomy and vaginal delivery times, building upon the adjustments made in Model 2. Furthermore, METS-VF was categorized into quartiles (Q1-Q4) based on continuous variables, enabling a trend analysis to ascertain its potential association with UI. To assess the relationship between obesity measures and UI severity, we analyzed the distribution of BMI and WC across UI severity subgroups and examined trends in the proportion of low, medium, and high levels of BMI and WC groups with increasing UI severity. This study explored the potential dose-response relationship between METS-VF and UI using restricted cubic spline (RCS) curves, based on the Model 3. Subgroup analyses and interaction tests were conducted for categorical covariates, including age, race, PIR, BMI, educational level, marital status, smoking and drinking behaviors, physical activity, hypertension, diabetes, stroke, coronary heart disease, congestive heart failure, chronic bronchitis, hyperlipidemia, depression, prior hysterectomy and vaginal delivery times. All statistical analyses were performed using R software version 4.3.1, with a significance threshold set at a P-value < 0.05.

Results

Characteristics of participants at baseline

The initial demographic and clinical characteristics of the study subjects were presented in Table 1, classified according to the quartiles of METS-VF. A total of 4,190 non-pregnant women aged 20 years or older were included in the study, representing a weighted population of 34,227,924 individuals. The mean age of the participants was 51.40 ± 15.80 years. Among the participants, 48% self-reported experiencing SUI, 31% reported UUI, and 19% reported MUI. The designated quartiles for METS-VF were Q1 (3.90–6.40), Q2 (6.40–6.89), Q3 (6.89–7.25), and Q4 (7.25–8.01). Notably, the significant increase in the prevalence of UI (SUI, UUI, and MUI) was associated with higher METS-VF categories. Furthermore, individuals in the highest quartile of METS-VF were more likely to be older, have lower PIR, higher BMI, identify as non-Hispanic White, possess higher educational levels, live alone, consume alcohol, exhibit elevated blood pressure, engage in lower levels of physical activity, have hyperlipidemia, and report more vaginal deliveries compared to those in the lowest quartile.

Evaluation of METS-VF and UI risk via multivariate logistic regression and dose-response analysis

In the fully adjusted models, METS-VF showed statistically significant positive associations with the prevalence of SUI (OR = 1.72, 95% CI: 1.31–2.26) and UUI (OR = 1.37, 95% CI: 1.02–1.85) (Table 2, and 3). Conversely, the association between METS-VF and MUI did not reach statistical significance (OR = 1.30, 95% CI: 0.89–1.88) (Table 4). To further substantiate these findings, we analyzed the METS-VF variable by dividing it into quartiles (Q1–Q4) (Tables 2, 3 and 4). In both Model 1 and Model 2, individuals in the highest quartile (Q4) exhibited a significantly higher likelihood of experiencing any type of UI compared to those in the lowest quartile (Q1): Model 1 (SUI: OR = 2.51, 95% CI: 2.07–3.05; UUI: OR = 4.29, 95% CI: 3.39–5.43; MUI: OR = 3.95, 95% CI: 2.88–5.42); Model 2 (SUI: OR = 1.91, 95% CI: 1.21–3.00; UUI: OR = 1.85, 95% CI: 1.15–2.97; MUI: OR = 2.05, 95% CI: 1.16–3.61). In Model 3, which adjusted for all covariates, a significant positive correlation was observed between METS-VF and the prevalence of SUI, UUI and MUI (SUI: OR = 1.77, 95% CI: 1.11–2.84; UUI: OR = 1.65, 95% CI: 1.01–2.67; MUI: OR = 1.97, 95% CI: 1.15–3.38) (Tables 2, 3 and 4). Furthermore, the RCS model indicated a significant linear dose-response relationship between the increment of METS-VF and the increased risk of SUI (P-nonlinear = 0.4972), whereas a significant non-linear dose-response relationship was found between METS-VF and both UUI and MUI (P-nonlinear < 0.05), as illustrated in Fig. 2.

Table S1 presents the association between METS-VF and different severity levels of UI. After adjusting for all potential covariates, higher METS-VF were significantly positively correlated with the prevalence of both moderate UI (OR = 4.36, 95% CI: 2.31–8.22) and severe UI (OR = 4.37, 95% CI: 1.22–15.7), but not for slight UI (OR = 1.43, 95% CI: 0.99–2.09). When analyzing METS-VF in quartiles, a positive association persisted for METS-VF quartiles (Q2-Q4) with moderate UI (OR = 3.31, 95% CI: 1.57–6.96; OR = 3.71, 95% CI: 1.80–7.65; OR = 5.10, 95% CI: 2.16-12.0, respectively). In addition, the METS-VF quartiles (Q3 and Q4) was positively correlated with severe UI (OR = 4,43, 95% CI: 1.75–11.2; OR = 8.87, 95% CI: 2.60–30.3, respectively). And the trend test was statistically significant in moderate and severe UI (*P* for trend < 0.05).

BMI, WC and severity of UI associations

Figure S1-S2 and Table S2-S3 showed that BMI and WC gradually increased with increasing severity of UI. According to the severity of UI, we observed significant differences in BMI and WC between subgroups. As shown in Figure S3-S4, as the severity of UI increased, the proportion of the low-level BMI and WC group gradually decreased, while the proportion of the high-level BMI and WC group gradually increased.

Table 1 Baseline population characteristics based on METS-VF quartile (NHANES 2007–2016)

Characteristic	Overall (N = 4,190)	Q1 (3.90–6.40) (N = 936)	Q2 (6.40–6.89) (N = 976)	Q3 (6.89–7.25) (N = 1,087)	Q4 (7.25–8.01) (N = 1,191)	P-value
Age (years)	51.40 (15.80)	42.08 (13.98)	50.53 (15.05)	54.58 (15.43)	60.73 (12.27)	< 0.001
PIR	2.89 (1.65)	3.12 (1.68)	2.97 (1.64)	2.77 (1.66)	2.65 (1.55)	< 0.001
BMI (kg/m^2)	29.36 (7.21)	22.65 (2.73)	27.34 (3.54)	31.66 (4.91)	37.76 (6.85)	< 0.001
Age group, n (%)						< 0.001
20–44 years	1,388 (33%)	640 (57%)	396 (34%)	265 (27%)	87 (8.6%)	
45–64 years	1,548 (40%)	278 (32%)	393 (42%)	419 (41%)	458 (46%)	
>=65 years	1,254 (27%)	130 (11%)	258 (24%)	363 (32%)	503 (45%)	
PIR group, n (%)						< 0.001
<1.30	1,458 (24%)	332 (22%)	339 (22%)	385 (25%)	402 (25%)	
1.30–3.49	1,591 (37%)	356 (32%)	400 (38%)	397 (37%)	438 (42%)	
≥3.50	1,141 (39%)	360 (46%)	308 (40%)	265 (37%)	208 (33%)	
BMI group (kg/m^2), n (%)						< 0.001
<25	1,159 (30%)	813 (80%)	282 (26%)	63 (4.9%)	1 (0.2%)	
25–30	1,280 (30%)	226 (19%)	529 (54%)	424 (38%)	101 (8.3%)	
>30	1,751 (39%)	9 (0.5%)	236 (21%)	560 (57%)	946 (91%)	
Race, n (%)						< 0.001
Non-Hispanic White	1,876 (70%)	507 (72%)	467 (70%)	430 (68%)	472 (72%)	
Non-Hispanic Black	849 (11%)	162 (8.3%)	212 (11%)	229 (13%)	246 (13%)	
Mexican American	641 (7.5%)	119 (6.2%)	161 (7.7%)	193 (9.1%)	168 (7.0%)	
Other Hispanic	473 (5.1%)	107 (5.4%)	117 (5.1%)	129 (5.5%)	120 (4.6%)	
Other/multiracial	351 (6.0%)	153 (8.6%)	90 (6.6%)	66 (4.6%)	42 (3.5%)	
Educational level, n (%)						< 0.001
College or above	2,181 (60%)	669 (70%)	577 (62%)	494 (56%)	441 (50%)	
High school or GED	945 (23%)	206 (19%)	225 (22%)	265 (26%)	249 (27%)	
Less than high school	1,064 (17%)	173 (11%)	245 (16%)	288 (18%)	358 (23%)	
Marital status, n (%)						< 0.001
Living alone	1,750 (34%)	362 (26%)	388 (33%)	454 (35%)	546 (43%)	
Living with a partner	290 (6.5%)	99 (8.9%)	87 (6.7%)	65 (5.9%)	39 (4.1%)	
Married	2,150 (60%)	587 (65%)	572 (61%)	528 (59%)	463 (53%)	
Smoking status, n (%)						< 0.001
Current smoker	778 (19%)	227 (21%)	213 (22%)	190 (17%)	148 (14%)	
Former smoker	863 (24%)	164 (19%)	196 (23%)	216 (24%)	287 (30%)	
Never smoker	2,549 (58%)	657 (60%)	638 (55%)	641 (59%)	613 (56%)	
Drinking status, n (%)						< 0.001
yes	2,545 (69%)	727 (76%)	680 (73%)	598 (64%)	540 (59%)	
no	1,645 (31%)	321 (24%)	367 (27%)	449 (36%)	508 (41%)	
Physical activity, n (%)						< 0.001
yes	1,812 (49%)	578 (61%)	494 (55%)	429 (43%)	311 (32%)	
no	2,378 (51%)	470 (39%)	553 (45%)	618 (57%)	737 (68%)	
Hypertension, n (%)						< 0.001
yes	1,918 (42%)	186 (15%)	386 (35%)	578 (53%)	768 (71%)	
no	2,272 (58%)	862 (85%)	661 (65%)	469 (47%)	280 (29%)	
Diabetes, n (%)						< 0.001
yes	900 (17%)	36 (2.7%)	125 (8.6%)	254 (20%)	485 (43%)	
no	3,290 (83%)	1,012 (97%)	922 (91%)	793 (80%)	563 (57%)	
Stroke, n (%)						< 0.001
yes	179 (3.7%)	17 (1.5%)	35 (3.2%)	48 (3.8%)	79 (6.9%)	
no	4,011 (96%)	1,031 (98%)	1,012 (97%)	999 (96%)	969 (93%)	
Chronic bronchitis, n (%)						< 0.001
yes	331 (8.2%)	48 (4.4%)	70 (7.6%)	83 (9.5%)	130 (12%)	
no	3,859 (92%)	1,000 (96%)	977 (92%)	964 (91%)	918 (88%)	
CHD, n (%)						< 0.001

Table 1 (continued)

Characteristic	Overall (*N* = 4,190)	Q1 (3.90–6.40) (*N* = 936)	Q2 (6.40–6.89) (*N* = 976)	Q3 (6.89–7.25) (*N* = 1,087)	Q4 (7.25–8.01) (*N* = 1,191)	*P*-value
yes	133 (2.9%)	10 (0.7%)	34 (3.4%)	25 (2.0%)	64 (6.0%)	
no	4,057 (97%)	1,038 (99%)	1,013 (97%)	1,022 (98%)	984 (94%)	
CHF, n (%)						< 0.001
yes	135 (2.8%)	17 (1.0%)	23 (2.4%)	20 (1.6%)	75 (6.6%)	
no	4,055 (97%)	1,031 (99%)	1,024 (98%)	1,027 (98%)	973 (93%)	
Hyperlipidemia, n (%)						< 0.001
yes	2,906 (70%)	522 (49%)	741 (72%)	801 (78%)	842 (84%)	
no	1,284 (30%)	526 (51%)	306 (28%)	246 (22%)	206 (16%)	
Depression, n (%)						< 0.001
yes	489 (10.0%)	100 (7.9%)	94 (7.9%)	122 (10%)	173 (15%)	
no	3,701 (90%)	948 (92%)	953 (92%)	925 (90%)	875 (85%)	
Prior hysterectomy, n (%)						< 0.001
yes	1,059 (26%)	120 (11%)	231 (26%)	304 (29%)	404 (40%)	
no	3,131 (74%)	928 (89%)	816 (74%)	743 (71%)	644 (60%)	
Vaginal delivery times, n (%)						< 0.001
0	782 (20%)	230 (23%)	217 (21%)	173 (18%)	162 (18%)	
1–2	1,807 (48%)	545 (54%)	466 (51%)	418 (45%)	378 (40%)	
>=3	1,601 (32%)	273 (23%)	364 (28%)	456 (37%)	508 (42%)	
SUI, n (%)						< 0.001
yes	1,899 (48%)	353 (38%)	430 (44%)	517 (52%)	599 (61%)	
no	2,291 (52%)	695 (62%)	617 (56%)	530 (48%)	449 (39%)	
UUI, n (%)						< 0.001
yes	1,342 (31%)	185 (18%)	260 (24%)	378 (37%)	519 (48%)	
no	2,848 (69%)	863 (82%)	787 (76%)	669 (63%)	529 (52%)	
MUI, n (%)						< 0.001
yes	809 (19%)	100 (10.0%)	151 (14%)	229 (23%)	329 (31%)	
no	3,381 (81%)	948 (90%)	896 (86%)	818 (77%)	719 (69%)	

Continuous variables are expressed as mean (standard deviation); Categorical variables are expressed as n unweighted (weighted %). PIR, poverty income ratio; BMI, body mass index; CHF, congestive heart-failure; CHD, coronary heart disease; METS-VF, metabolic score for visceral fat; SUI, stress urinary incontinence; UUI, urgency urinary incontinence; MUI, mixed urinary incontinence

Table 2 The association between METS-VF and SUI

	Model 1		**Model 2**		**Model 3**	
	OR (95%CI)	***P***	**OR (95%CI)**	***P***	**OR (95%CI)**	***P***
METS-VF	1.77 (1.55, 2.01)	< 0.001	1.72 (1.32, 2.25)	< 0.001	1.72 (1.31, 2.26)	< 0.001
METS-VF quartiles						
Q1 (3.90–6.40)	1 (Ref.)		1 (Ref.)		1 (Ref.)	
Q2 (6.40–6.89)	1.34 (1.05, 1.71)	0.021	1.23 (0.89, 1.68)	0.200	1.24 (0.90, 1.71)	0.200
Q3 (6.89–7.25)	1.82 (1.45, 2.29)	< 0.001	1.53 (1.10, 2.13)	0.013	1.51 (1.07, 2.11)	0.019
Q4 (7.25–8.01)	2.51 (2.07, 3.05)	< 0.001	1.91 (1.21, 3.00)	0.006	1.77 (1.11, 2.84)	0.019
***P*for trend**		< 0.001		0.004		0.020

Logistic regression was used. Model 1 unadjusted. Model 2 adjusted for age, race, marital status, education level, body mass index, poverty income ratio, smoking and drinking. Model 3 adjusted for age, race, marital status, education level, body mass index, poverty income ratio, smoking, drinking, physical activity, diabetes, hypertension, stroke, congestive heart-failure, coronary heart disease, chronic bronchitis, hyperlipidemia, depression, prior hysterectomy and vaginal delivery times. METS-VF, metabolic score for visceral fat; SUI, stress urinary incontinence; OR, odds ratio; CI, confidence interval

Subgroup and interaction analysis

The present study also conducted subgroup analyses and interaction tests to evaluate the robustness of the associations between METS-VF and UI across different demographic and clinical strata. The stratifying factors included age, race, educational level, marital status, PIR, BMI, physical activity, smoking status, hypertension, diabetes, stroke, congestive heart failure, coronary artery disease, chronic bronchitis, hyperlipidemia, depression, prior hysterectomy and vaginal delivery times. Notably, it was found that age, race and vaginal delivery times influenced the relationship between METS-VF and SUI (P for interaction < 0.05), with a more pronounced association observed among participants aged 20–44 years, from other racial backgrounds, and who did not have a vaginal

Table 3 The association between METS-VF and UUI

	Model 1		Model 2		Model 3	
	OR (95%CI)	***P***	**OR (95%CI)**	***P***	**OR (95%CI)**	***P***
METS-VF	2.52 (2.13, 2.97)	< 0.001	1.44 (1.07, 1.95)	0.017	1.37 (1.02, 1.85)	0.039
METS-VF quartiles						
Q1 (3.90–6.40)	1 (Ref.)		1 (Ref.)		1 (Ref.)	
Q2 (6.40–6.89)	1.49 (1.15, 1.94)	0.003	1.05 (0.76, 1.45)	0.800	1.06 (0.75, 1.48)	0.700
Q3 (6.89–7.25)	2.60 (1.98, 3.41)	< 0.001	1.53 (1.06, 2.21)	0.023	1.48 (1.01, 2.18)	0.044
Q4 (7.25–8.01)	4.29 (3.39, 5.43)	< 0.001	1.85 (1.15, 2.97)	0.011	1.65 (1.01, 2.67)	0.045
***P*for trend**		< 0.001		0.002		0.019

Logistic regression was used. Model 1 unadjusted. Model 2 adjusted for age, race, marital status, education level, body mass index, poverty income ratio, smoking and drinking. Model 3 adjusted for age, race, marital status, education level, body mass index, poverty income ratio, smoking, drinking, physical activity, diabetes, hypertension, stroke, congestive heart-failure, coronary heart disease, chronic bronchitis, hyperlipidemia, depression, prior hysterectomy and vaginal delivery times. METS-VF, metabolic score for visceral fat; SUI, stress urinary incontinence; OR, odds ratio; CI, confidence interval

Table 4 The association between METS-VF and MUI

	Model 1		Model 2		Model 3	
	OR (95%CI)	***P***	**OR (95%CI)**	***P***	**OR (95%CI)**	***P***
METS-VF	2.39 (1.90, 3.02)	< 0.001	1.43 (0.96, 2.12)	0.079	1.30 (0.89, 1.88)	0.200
METS-VF quartiles						
Q1 (3.90–6.40)	1 (Ref.)		1 (Ref.)		1 (Ref.)	
Q2 (6.40–6.89)	1.48 (1.07, 2.03)	0.017	1.14 (0.79, 1.64)	0.500	1.21 (0.85, 1.72)	0.300
Q3 (6.89–7.25)	2.78 (1.99, 3.87)	< 0.001	1.84 (1.19, 2.85)	0.007	1.97 (1.25, 3.11)	0.004
Q4 (7.25–8.01)	3.95 (2.88, 5.42)	< 0.001	2.05 (1.16, 3.61)	0.014	1.97 (1.15, 3.38)	0.014
***P*for trend**		< 0.001		0.006		0.039

Logistic regression was used. Model 1 unadjusted. Model 2 adjusted for age, race, marital status, education level, body mass index, poverty income ratio, smoking and drinking. Model 3 adjusted for age, race, marital status, education level, body mass index, poverty income ratio, smoking, drinking, physical activity, diabetes, hypertension, stroke, congestive heart-failure, coronary heart disease, chronic bronchitis, hyperlipidemia, depression, prior hysterectomy and vaginal delivery times. METS-VF, metabolic score for visceral fat; SUI, stress urinary incontinence; OR, odds ratio; CI, confidence interval

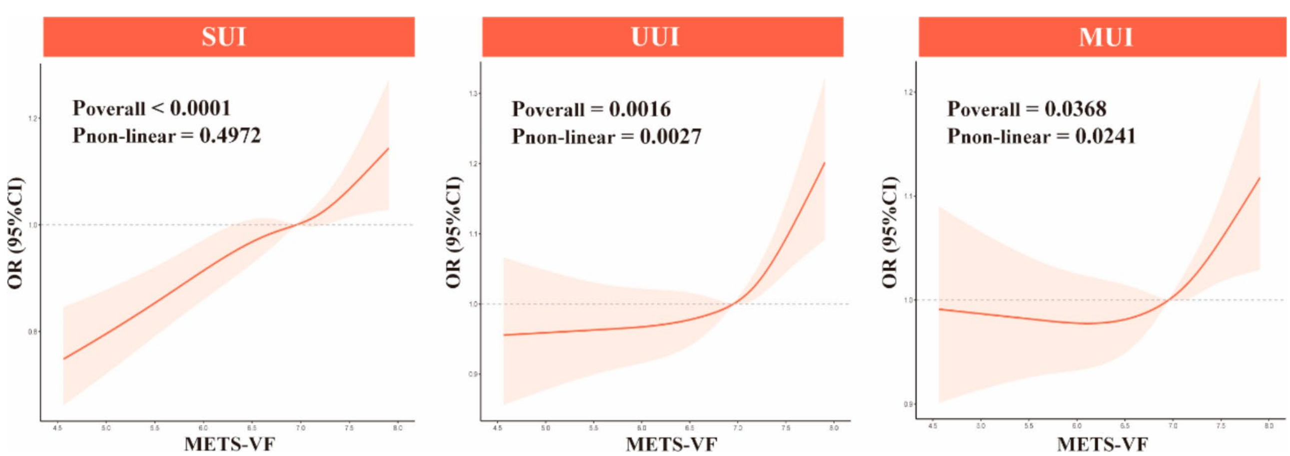

Fig. 2 Restricted cubic spline model of the association between METS-VF and UI (SUI, UUI and MUI)

delivery (Figure S5). Additionally, interaction tests indicated that none of the stratifying variables substantially altered the positive correlation between METS-VF and UUI and MUI, thereby confirming the consistency across all examined cohorts (all P for interaction > 0.05; Figure S6-S7).

Discussion

In this study involving 4,190 female US adults, we investigated the relationship between the METS-VF and three types of UI, namely SUI, UUI, and MUI. The findings from this large cross-sectional study indicated that higher METS-VF scores were significantly positively correlated with the presence of SUI and UUI after adjusting for all potential covariates. And higher METS-VF were significantly positively correlated with the prevalence of both moderate UI and severe UI. Upon categorizing

METS-VF into quartile groups, a strong association was observed in Model 3 between higher quartiles of METS-VF (Q3-Q4) and susceptibility to SUI, UUI and MUI. Moreover, higher METS-VF quartiles were positively associated with moderate and severe UI. This study also found that the severity of UI increased significantly with increasing BMI and WC levels. RCS analysis further demonstrated a significant non-linear dose-response relationship between METS-VF and both UUI and MUI, whereas a notable linear dose-response relationship was found between METS-VF and SUI. Subgroup analyses revealed that individuals aged 20–44 years, from other racial backgrounds, and without a history of vaginal delivery exhibited a more pronounced susceptibility to SUI, underscoring the potential age, race-specific and vaginal delivery times effects of METS-VF on SUI.

This study pioneeringly investigated the correlation between METS-VF and three types of UI. Although previous research has not documented a connection between METS-VF and UI, the relationship between obesity and UI has been extensively explored. Research identified obesity as an independent risk factor correlated with the prevalence and incidence of UI [11]. Furthermore, a cross-sectional study highlighted a significant association between increased BMI and trunk fat percentage and the prevalence and severity of UI in women [23]. Elbaset et al. found that visceral fat tissue, independent of BMI, was linked to a heightened risk of SUI [24]. A cross-sectional study involving 9,709 adult women in the US demonstrated that visceral obesity was associated with an increased risk of SUI [25]. Additionally, a retrospective study of 182 adult women in Japan revealed that excessive accumulation of visceral fat was independently related to bladder overactivity in females [26]. While our findings align with previous studies demonstrating the association between obesity and UI [11, 23], as well as the role of visceral fat in SUI risk [24, 25], there are some discrepancies worth noting. For instance, our study found a stronger association between METS-VF and SUI in younger women (aged 20–44), whereas other studies have reported a higher prevalence of UI in older populations [1, 27]. This discrepancy may be attributed to differences in study populations, measurement methods, or the inclusion of additional confounders in our analysis. Notably, traditional metrics for assessing individual overweight and obesity have primarily centered on BMI. However, research indicated that BMI predominantly evaluated overall adiposity and may not adequately differentiate between lean body mass and fat mass, nor the types of fat distribution, such as visceral and subcutaneous fat [28, 29]. Relying solely on BMI to assess the prevalence of obesity may impede future interventions aimed at preventing and controlling UI. In contrast, METS-VF, as a novel composite metric, incorporates insulin resistance (IR), fat distribution (e.g., WHtR), age, and sex, providing a more effective assessment of obesity, particularly visceral obesity, compared to BMI [30].

Based on existing research, several potential physiological mechanisms have been proposed to explain the relationship between obesity, visceral fat, and UI. Firstly, studies indicated that excess body weight and the accumulation of visceral fat could lead to increased intra-abdominal pressure, which subsequently raised bladder pressure [10, 11]. This resulted in abnormal contractions of the detrusor muscle, causing overactive bladder and ultimately leading to UI [10, 11]. Secondly, obesity may facilitate the onset of UI through the pathway of IR. Research conducted by Nazzal et al. has shown that diabetes significantly increased the likelihood of developing UI, with further investigations linking this condition to IR [31]. IR can lead to increased levels of oxidative stress-induced cellular damage, which is associated with oxidative injury within the urethral sphincter [32]. Moreover, IR can disturb lipid metabolism, resulting in elevated TGs and LDL-C, while concurrently lowering HDL-C levels [33]. This dysregulation can culminate in the accumulation of atherosclerotic deposits in the bladder wall, leading to ischemia of the bladder [33]. The increased levels of oxidative stress, combined with diminished bladder blood flow, may result in neurofunctional disturbances of the bladder, neuronal fiber damage, and detrusor cell injury, thereby altering lower urinary tract function and ultimately leading to urgent urination [34]. Additionally, IR plays a role in promoting inflammatory activation, contributing to elevated levels of inflammatory cytokines such as Tumor Necrosis Factor-alpha (TNF-α) and interleukin 6 (IL-6) [35, 36]. A study found that the inflammatory cytokine TNF-α inhibits the myogenic differentiation of human urethral sphincter cells, thereby heightening the risk of SUI [37]. Finally, obesity may contribute to the occurrence of UI by altering collagen metabolism. Research has shown that individuals with obesity are more susceptible to oxidative stress, which can enhance the degradation of collagen in pelvic muscle fibroblasts [10, 38, 39]. The pelvic muscles, including the levator ani muscle group, pelvic fascia, and supporting ligaments, play a crucial role in maintaining urinary control. When these structures become weakened, the urethra fails to generate adequate pressure to counteract the increasing pressure within the bladder, leading to the manifestation of UI [10, 38, 40].

It was noteworthy that subgroup analyses revealed a more significant correlation between METS-VF and SUI among women aged 20–44. This finding aligns with previous study, which has shown that women between the ages of 25 and 49 have the highest rate of SUI symptoms, with a relative decrease with age thereafter [27]. This phenomenon may be attributed to the higher activity levels typically exhibited by younger women, who engaged in various sports, potentially leading to fatigue of the pelvic floor muscles [41, 42]. Such fatigue could impair the urethra's ability to generate sufficient pressure, thereby contributing to the incidence of SUI [41, 42]. Additionally, pregnancy may represent a significant risk factor for SUI in women, likely due to physiological weight gain during gestation, which increased pressure on the pelvic floor muscles and bladder [43]. The findings also underscored the influence of ethnicity on the association between METS-VF and UI. This variability may be attributed to differences in genetic diversity, environmental factors, and lifestyle among various ethnic groups, warranting further investigation to elucidate the mechanisms driving this phenomenon. Further analyses showed a significant difference in the association between METS-VF and SUI based on the number of vaginal deliveries. Specifically, the association was more pronounced in women without vaginal deliveries compared to those with single or multiple deliveries. This finding suggested that METS-VF may play a more critical role in elevating SUI risk among women who have not experienced vaginal delivery. A potential explanation for this observation was that women without vaginal deliveries may have relatively intact pelvic floor muscles, making obesity-induced increases in intra-abdominal pressure a predominant factor in SUI development. In contrast, among women with multiple deliveries, preexisting pelvic floor weakness may already contribute significantly to SUI risk, thereby attenuating the additional impact of obesity. These results highlighted the importance of considering individual characteristics, such as obstetric history, when assessing SUI risk, and underscored the variability in the association between METS-VF and SUI across different physiological states and populations.

The findings have important clinical and public health implications, particularly for the prevention and management of UI in high-risk populations. For example, the strong association between METS-VF and UI suggests that interventions targeting visceral obesity and metabolic health (e.g., weight loss programs, dietary modifications, and physical activity) may be effective in reducing UI risk. This is especially relevant for older adults, who are more likely to experience frailty and metabolic dysfunction. Additionally, the identification of age- and race-specific risk patterns highlights the need for tailored interventions. For instance, younger women with high METS-VF scores may benefit from early screening and pelvic floor muscle training, while older adults may require more comprehensive management of metabolic comorbidities. These findings underscore the importance of integrating metabolic health assessments into routine clinical practice for UI prevention. Furthermore, these strategies have the potential to improve urinary health and reduce healthcare costs associated with incontinence management.

Strengths and limitations

The notable advantage of this study lay in its pioneering cross-sectional exploration of the correlation between METS-VF and UI. Furthermore, leveraging data from the NHANES, this research aimed to enhance the applicability of its findings to the broader US population through a nationally representative sample. Additionally, we conducted analyses across various types of variables and adjusted for covariates to ensure the robustness of our results. Finally, subgroup analyses further enabled a more precise evaluation of the relationship between METS-VF and UI.

However, this study was not without limitations. Firstly, due to the cross-sectional design, we were unable to ascertain the causal relationship between METS-VF and UI. Future research should employ a prospective cohort design to elucidate the causality between these variables. Secondly, given that this study was conducted within the US population, the conclusions may not be generalizable to other populations due to potential environmental, genetic, and racial differences. Thirdly, the inherent limitations of the NHANES database, particularly regarding the self-reported nature of the UI questionnaire and the symptoms and medical information related to the three types of UI gathered through interviews, may be subject to recall bias. Lastly, the lack of data on relevant voiding dysfunction in the dataset (e.g., incomplete emptying or urinary hesitance) limited our understanding of the impact of these factors on the relationship between METS-VF and UI. Future studies should focus on more comprehensive datasets to more fully assess and understand UI.

Conclusion

In conclusion, this study revealed a positive correlation between METS-VF and UI in adult women in the US, a relationship that remained significant even after adjusting for multiple covariates. Notably, METS-VF was also significantly positively correlated with moderate and severe UI. This study demonstrated that BMI and WC increased progressively with UI severity. Consequently, we speculated that METS-VF may represent a novel and valuable clinical indicator for the assessment of UI. Further prospective studies and randomized controlled trials were needed to corroborate our findings. Additionally, the potential mechanisms through which METS-VF may influence UI warrant further investigation.

Abbreviations

METS-VF	Metabolic score for visceral fat
UI	Urinary incontinence
SUI	Stress urinary incontinence

UUI	Urgency urinary incontinence
MUI	Mixed urinary incontinence
WHO	World Health Organization
NHANES	National Health and Nutrition Examination Survey
NCHS	National Center for Health Statistics
CDC	Centers for Disease Control and Prevention
WC	Waist circumference
BMI	Body mass index
PIR	Poverty income ratio
METS-IR	Metabolic score for insulin resistance
WHtR	Waist-to-height ratio
LDL-C	Low-density lipoprotein cholesterol
HDL-C	High-density lipoprotein cholesterol
TGs	Triglycerides
TC	Total cholesterol
OGTT	Oral glucose tolerance test
PHQ-9	Patient Health Questionnaire-9
NCEP	National Cholesterol Education Program
IR	Insulin resistance
TNF-α	Tumor Necrosis Factor-alpha
IL-6	Interleukin 6
RCS	Restricted cubic spline
OR	Odds ratios
CI	Confidence interval
SD	Standard deviation

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-21966-3 .

Supplementary Material 1

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Author contributions

CY and WH conceptualized the project, developed the methodology, and curated the data; CY, WH, and YL contributed to software development; YL, WH, and GC conducted validation; CY, WH, YL, GC and SD prepared the original draft of the manuscript; CY and KL also reviewed and edited the manuscript; WH, GC and SD worked on visualization. All authors have read and agreed to the published version of the manuscript.

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Data availability

The datasets used in this study can be accessed through NHANES at https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Ethics approval and consent to participate

The research involving human participants underwent review and approval by the NHANES, sanctioned by the National Center for Health Statistics Research Ethics Review Board. All participants provided informed consent before participation.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

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