scientific reports

Check for updates

OPEN

Relationship between METS-IR and ABSI index and the prevalence of nocturia: a cross-sectional analysis from the 2005–2020 NHANES data

Fei Xue✉ & Yating Zhou

Nocturia, marked by frequent nighttime urination, significantly impacts quality of life. This study explores the association of METS-IR (Metabolic Score for Insulin Resistance) and ABSI (A Body Shape Index) with nocturia, using data from the National Health and Nutrition Examination Survey (NHANES). A cross-sectional analysis of NHANES data from 2005 to 2020 was performed. Multivariable logistic regression assessed the associations between METS-IR, ABSI, and nocturia, adjusting for demographic characteristics, chronic diseases, and lifestyle factors. Generalized additive models and smoothing splines were used to describe relationship dynamics. Among the 16,450 participants, both METS-IR (OR = 1.15, 95% CI: 1.11–1.20, $p < 0.0001$) and ABSI (OR = 1.14, 95% CI: 1.10–1.19, $p < 0.0001$) were significantly associated with nocturia based on z-scores. An incremental rise in the quartiles of METS-IR and ABSI was associated with a higher risk of nocturia. Specifically, compared to the lowest quartile (Q1), participants in the highest quartile (Q4) had an OR of 1.45 (95% CI: 1.30–1.61, $p < 0.0001$) for METS-IR and 1.38 (95% CI: 1.23–1.55, $p < 0.0001$) for ABSI. Subgroup analyses showed a stronger association between ABSI and nocturia among individuals living alone and those aged 20–38 years. Nonlinear modeling indicated a threshold effect for ABSI, with nocturia risk significantly increasing when ABSI exceeded 76.2. Higher METS-IR and ABSI indices are closely linked to a greater prevalence of nocturia, indicating that these indices can be valuable in clinical assessments for evaluating nocturia risk and supporting preventive strategies.

Keywords Nocturia, METS-IR, ABSI, NHANES, Insulin resistance, Abdominal obesity

Abbreviations

NHANES	National Health and Nutrition Examination Survey
OSA	Obstructive sleep apnea
MetS	Metabolic syndrome
HEC	Hyperinsulinemic-euglycemic clamp
METS	IR-metabolic score for insulin resistance
ABSI	A body shape index
BMI	Body mass index
WC	Waist circumference
HDL	High-density lipoprotein
FBG	Fasting blood glucose
TG	Triglycerides
PIR	Poverty income ratio
OAB	Overactive bladder
LUTS	Lower urinary tract symptoms
TNF	α-Tumor necrosis factor alpha
IL	6-Interleukin 6
GAM	Generalized additive models

Nocturia is a common urinary symptom characterized by frequent nighttime urination[1]. The Third National Health and Nutrition Examination Survey (NHANES) results show that in the US, the prevalence of nocturia

Kunshan Hospital of Traditional Chinese Medicine, 388 Zuchongzhi South Road, Kunshan City, Suzhou, Jiangsu, China. ✉email: 2090168460@qq.com

is 20.9% among women and 15.5% among men[2]. While a single nighttime void can define nocturia, two or more voids are associated with worse clinical outcomes[3]. Nocturia not only impacts quality of life due to sleep disruption but is also associated with various health issues, including increased risks of obstructive sleep apnea (OSA)[4], depression[5], falls and fractures[6], coronary heart disease[7], hypertension[8], and diabetes[9]. Data from NHANES III indicate a significant association between nocturia and all-cause mortality, suggesting that nocturia may signal more severe health risks[1].

A collection of metabolic disorders including hypertension, hyperglycemia, abnormal lipid levels, and abdominal obesity are collectively referred to as metabolic syndrome (MetS)[10]. The two primary features of MetS are central obesity and insulin resistance[11]. Insulin resistance refers to reduced sensitivity of the body to the action of insulin, leading to elevated blood glucose levels and further exacerbating insulin resistance, forming a vicious cycle[12]. Abdominal obesity, characterized by excessive fat accumulation around visceral organs, is closely associated with various metabolic diseases[13].

The hyperinsulinemic-euglycemic clamp (HEC) is widely regarded as the gold standard for assessing insulin sensitivity in peripheral tissues[14], as it directly measures insulin's ability to promote glucose uptake under controlled conditions[15]. However, due to its complexity, invasiveness, and time-consuming nature, HEC is rarely used in clinical practice and large-scale studies[16]. Therefore, simpler indices are often employed as alternatives. The metabolic score for insulin resistance (METS-IR) is a novel scoring system based on blood glucose, body weight, and lipid levels. It evaluates insulin resistance without the need for direct insulin measurement, offering convenience and cost-effectiveness. Studies have shown that METS-IR demonstrates greater sensitivity and accuracy in evaluating insulin sensitivity and predicting type 2 diabetes and cardiovascular events[17,18]. Meanwhile, the A Body Shape Index (ABSI) is a new obesity index based on WC[19]. Studies have shown that ABSI is closely associated with cardiovascular disease and metabolic syndrome, and can assess these risks independently of Body Mass Index (BMI)[20–24]. Compared to traditional obesity measures, ABSI provides a more accurate reflection of visceral fat distribution, offering more precise risk assessments for clinical use.

Studies suggest that nocturia and MetS may share similar pathophysiological mechanisms[25], including autonomic nervous system dysfunction[26], bladder ischemia caused by atherosclerosis[27], and the production of inflammatory mediators[28]. Numerous investigations have verified a noteworthy correlation between MetS and the higher occurrence of nocturia[29,30].

However, no research has yet explored the association between nocturia, ABSI, and METS-IR. Therefore, the purpose of this study is to determine whether METS-IR and ABSI are associated with nocturia. By analyzing data from the 2005–2020 NHANES, this study aims to provide a basis for risk stratification and personalized management of nocturia.

Methods

Study participants

To assess adults' and children's nutritional and health conditions in the United States, the NHANES is a nationally representative cross-sectional survey. The demographic, examination, laboratory, and questionnaire data from NHANES 2005–2020—which may be downloaded from the NHANES website at https://www.cdc.gov/nchs/nhanes/index.html—were integrated to create the study data. Out of 76,496 participants, 38,998 were excluded for not completing the urinary questionnaire, 20,352 were excluded due to missing data on fasting blood glucose (FBG), triglycerides (TG), total cholesterol (TC), BMI, or high-density lipoprotein (HDL), 320 were excluded for reporting benign prostatic hyperplasia, 51 were excluded for undergoing dialysis due to chronic kidney disease, and 325 were excluded for lacking waist circumference (WC) data. As shown in Fig. 1, a total of 16,450 participants were included in the study.

Outcome ascertainment

The exposure variables in this study were the ABSI index and the METS-IR index. The METS-IR formula is: $\text{METS-IR} = \text{Ln}[(2 \times \text{FBG (mg/dL)}) + \text{TG (mg/dL)}] \times \text{BMI (kg/m}^2) / [\text{Ln(HDL (mg/dL))}]$[31]. The ABSI formula is: $\text{ABSI} = \text{WC (cm)} / [\text{BMI(kg/m}^2)^{(2/3)} \times \text{height (cm)}^{(1/2)}] \times 1000$ [19]. FBG and TG were measured using enzymatic techniques on an automated biochemical analyzer. The "Body Measurements" component of the examination data contains information on weight, height, and WC. The measurements of weight, height, and WC followed NHANES protocol: Weight: Measured using a Toledo electronic scale (in kilograms), with participants dressed only in undergarments and disposable paper gowns. Height: Measured using a fixed stadiometer, with participants standing upright, heels together, and head aligned with the Frankfurt horizontal plane. WC: Measured at the uppermost edge of the iliac crest using a tape measure, ensuring the tape is snug but not compressing the skin. BMI was calculated as weight (kg) divided by height (m) squared.

Nocturia assessment

Nocturia was assessed through a questionnaire asking participants, "How many times a night, from the time you went to bed until you got up in the morning, did you usually get up to urinate during the last thirty days?" The response options ranged from 0 to 5 or more times per night. Participants reporting two or more nightly urinations were classified as having nocturia[8].

Covariate assessment

The multivariable models included ABSI and other confounders potentially affecting the relationship between nocturia and METS-IR, as informed by previous research. These covariates include age, gender, racial background, education level, poverty income ratio (PIR), and marital status, cholesterol levels, smoking, alcohol consumption, diabetes, coronary heart disease, and depression. Education levels were categorized into three groups: less than high school, high school or equivalent, and college degree or higher. Marital status was categorized as living

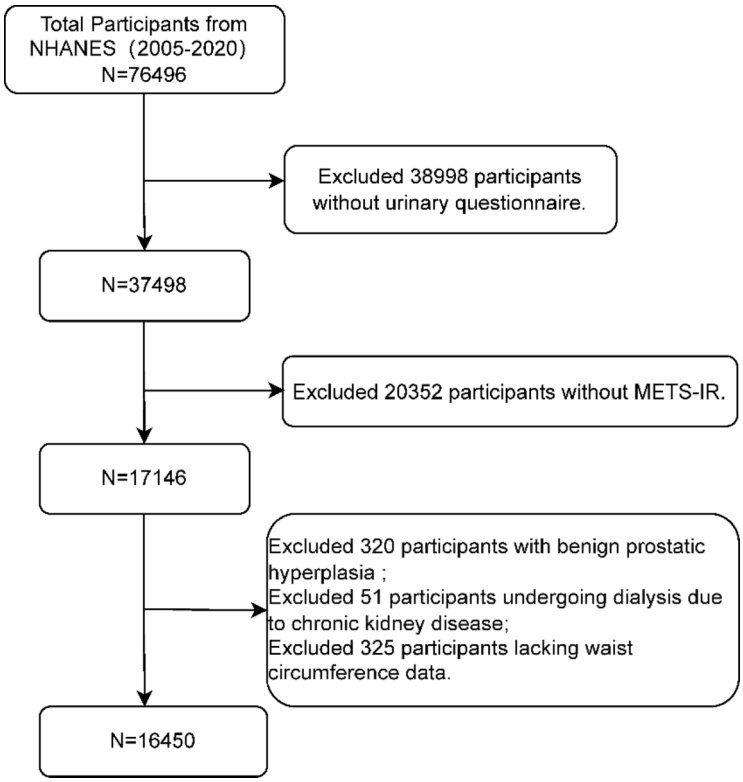

Fig. 1. Flow chart showing the NHANES 2005–2020 participants' selection.

with a partner or living alone. PIR, the ratio of a family's income to the poverty threshold, was used to classify participants into two income categories: low income (PIR ≤ 1.3) and non-poor income (PIR > 1.3)[32].

Medical history information was collected through household interviews and laboratory measurements. Participants were considered hypertensive if they had been previously diagnosed or were currently on antihypertensive medication. Diabetes was characterized as having received a prior diagnosis of the disease or as being on medication to reduce glucose levels. Individuals previously diagnosed with hyperlipidemia or currently using lipid-lowering medication were defined as having hyperlipidemia. Participants were classed as having coronary heart disease if they indicated in the "yes" category when asked if they had been informed of their condition by a medical expert. Never smoked was defined as having smoked fewer than 100 cigarettes in one's lifetime, while Ever smoked was defined as having smoked at least 100 cigarettes. Low alcohol consumption referred to having fewer than 12 alcoholic drinks in the past year, and High alcohol consumption was defined as having consumed 12 or more alcoholic drinks within the past year. The nine-item Patient Health Questionnaire was used to gauge the severity of depression (PHQ-9)[33], with a score of ≥ 5 considered indicative of mild depression.

Statistical analysis

In this study, we standardized METS-IR, ABSI, BMI, and WC variables into z-scores to facilitate comparisons. For the combined period of 2005–2020, we calculated the weights separately for 2005–2016 and 2017–2020, using the variables WTMEC2YR and WTMEC2PRP. The specific calculation methods are as follows: For participants from 2005 to 2016, weights were calculated as WTMEC2YR/7.625, while for 2017–2020, the calculation was WTMEC2PRP × 1.625/7.625. More information can be found on https://wwwn.cdc.gov/nchs/nhanes/analyticguidelines.aspx.

Data presentation

Categorical variables were expressed as counts and percentages (%), while METS-IR, ABSI, BMI, and WC variables were presented as means ± standard deviation or medians (interquartile ranges) based on z-scores. Differences in continuous variables were analyzed using weighted linear regression models, and differences in categorical variables were tested using weighted chi-square tests.

Regression analysis

We used weighted logistic regression to examine the association between METS-IR, ABSI, BMI, WC, and nocturia, presenting odds ratios (ORs) and 95% confidence intervals (CIs) for each model. All indices were standardized as z-scores. Model 1 adjusted for demographic factors such as sex, age, and race. Model 2 further adjusted for lifestyle factors including smoking, alcohol consumption, education, income, and marital status.

Model 3 added adjustments for health-related factors, including cholesterol levels, hypertension, cardiovascular disease, diabetes, and depression.

Sensitivity and interaction analyses

To assess potential interactions and confounding factors, we conducted sensitivity analyses by stratifying for demographic factors and metabolic syndrome status. We used the likelihood ratio test to evaluate interactions and applied generalized additive models (GAM) to assess the dose-response relationships between METS-IR, ABSI, BMI, WC, and nocturia. When nonlinearity was observed, we used smooth curve fitting to determine if independent variables should be split into intervals. We then applied segmented regression to fit separate lines to each interval, using the likelihood ratio test to compare the segmented model with a linear model to determine the presence of thresholds.

Model comparison and AIC analysis

In order to compare model fit, we calculated the Akaike Information Criterion (AIC) for each model. A lower AIC score indicates a better trade-off between model complexity and accuracy and a better model fit.

R software (http://www.R-project.org) and Empower (http://www.empowerstats.com) were used for all data analysis in this research. When $p < 0.05$, statistical significance was established.

Results

Baseline characteristics

16,450 persons with an average age of 49.39 years were enrolled in the study; 48.38% of them were men. Compared to the non-nocturia group, individuals with nocturia were older on average (56.07 vs. 46.21), had higher HDL levels (52.00 vs. 51.00), higher TG levels (106.00 vs. 99.00), lower LDL levels (108.00 vs. 111.00), higher BMI (30.48 ± 7.40 vs. 28.61 ± 6.55), higher WC (103.19 ± 16.89 vs. 97.79 ± 15.94),higher METS-IR (45.55 ± 13.33 vs. 42.48 ± 12.13), and higher ABSI (82.82 ± 5.04 vs. 81.10 ± 4.75). Additionally, the prevalence of hypertension, hyperlipidemia, diabetes, coronary heart disease, and depressive disorders was notably greater in the nocturia group, with higher rates of alcohol and tobacco use (details are provided in Table 1).

Associations of METS-IR and ABSI with the prevalence of nocturia

Table 2 shows that after adjusting for all covariates, both METS-IR and ABSI, as continuous variables, are significantly associated with nocturia in Model 3. The OR for METS-IR is 1.15 (95% CI: 1.11–1.20, $p < 0.0001$), and for ABSI, the OR is 1.14 (95% CI: 1.10–1.19, $p < 0.0001$). In the quartile analysis, compared to the lowest quartile (Q1), the highest quartile (Q4) of METS-IR has an OR of 1.45 (95% CI: 1.30–1.61, $p < 0.0001$), and for ABSI, the OR for Q4 compared to Q1 is 1.38 (95% CI: 1.23–1.55, $p < 0.0001$). In Supplementary Table 1, we also analyzed the relationship between BMI, WC, and nocturia. After adjusting for all covariates, both BMI and WC were significantly associated with nocturia. In Model 3, compared to the Q1, Q4 of BMI is 1.43 (95% CI: 1.29–1.59, $p = 0.0001$), and for WC, the OR for Q4 compared to Q1 is 1.54 (95% CI: 1.39–1.72, $p < 0.0001$). To compare model performance, we calculated the Akaike Information Criterion (AIC) for each model. The AIC values were as follows: METS-IR (20476.24), BMI (20427.33), WC (20302.44), and ABSI (20244.15) (see Supplementary Table 2).

Subgroup analysis

We performed subgroup analyses based on gender, age, education level, race, income, marital status, and metabolic syndrome status (see Fig. 2). After adjusting for other covariates, the results showed that the associations between METS-IR, ABSI, and nocturia were consistent across most subgroups. However, marital status and age significantly modified the relationship between ABSI and nocturia. Specifically, the association was stronger in participants who were living alone and in the younger age group (20–38 years) (P for interaction = 0.0010 and 0.0097). Other demographic factors, such as gender and race, did not significantly influence these associations. Additionally, the analysis presented in Supplementary Fig. 1 demonstrated that the associations between BMI, WC, and nocturia were relatively consistent across various subgroups.

Dose-response relationship

The dose-response analysis showed that METS-IR z-score was linearly associated with the prevalence of nocturia (non-linearity $p = 0.490$, Fig. 3a), while the ABSI z-score exhibited a non-linear relationship (non-linearity $p = 0.015$, Fig. 3b). For the BMI z-score, a linear relationship was observed (non-linearity $p = 0.511$, Fig. 3c), whereas WC z-score demonstrated a non-linear association (non-linearity $p = 0.029$, Fig. 3d).

Threshold effect analysis identified the inflection point for ABSI at 76.2. When ABSI was below 76.2, nocturia prevalence showed no significant change (OR = 0.88, 95% CI: 0.74–1.04, $p = 0.1409$). However, when ABSI exceeded 76.2, the prevalence of nocturia became significantly higher (OR = 1.19, 95% CI: 1.13–1.25, $p < 0.0001$). Similarly, for WC, nocturia prevalence did not significantly change when WC was below 93.77 (OR = 1.04, 95% CI: 0.93–1.17, $p = 0.4558$), but it became significantly higher when WC was above this threshold (OR = 1.23, 95% CI: 1.06–1.42, $p = 0.0049$). (See Supplementary Table 3)

Discussion

This study is the first to reveal the association between METS-IR and ABSI indices with the prevalence of nocturia. Through multivariable logistic regression analysis, we found a significant positive correlation between higher METS-IR and ABSI indices and nocturia prevalence. Subgroup analyses and interaction tests showed that this association remained consistent across most demographic subgroups, except for marital status and age

Variables	Total ($n = 16450$)	Nocturia		P
		No ($n = 11147$)	Yes ($n = 5303$)	
Age (years)	49.39 ± 17.57	46.21 ± 17.01	56.07 ± 16.84	< 0.001
METS-IR	43.47 ± 12.61	42.48 ± 12.13	45.55 ± 13.33	< 0.001
ABSI	81.66 ± 4.91	81.10 ± 4.75	82.82 ± 5.04	< 0.001
BMI (kg/m^2)	29.21 ± 6.89	28.61 ± 6.55	30.48 ± 7.40	< 0.001
WC (cm)	99.53 ± 16.45	97.79 ± 15.94	103.19 ± 16.89	< 0.001
HDL (mg/dl)	52.00 (42.00, 63.00)	51.00 (42.00, 62.00)	52.00 (43.00, 64.00)	0.008
TG (mg/dl)	101.00 (69.00, 150.00)	99.00 (68.00, 147.00)	106.00 (72.00, 156.00)	< 0.001
LDL (mg/dl)	110.00 (88.00, 135.00)	111.00 (89.00, 136.00)	108.00 (86.00, 134.00)	< 0.001
TC (mg/dl)	188.00 (163.00, 217.00)	189.00 (163.00, 217.00)	188.00 (161.00, 217.00)	0.341
Cr (mg/dl)	0.84 (0.70, 1.00)	0.84 (0.71, 0.99)	0.83 (0.70, 1.01)	0.182
BUN (mg/dl)	5.40 (4.40, 6.40)	5.40 (4.50, 6.30)	5.40 (4.40, 6.50)	0.07
Gender (%)				< 0.001
Male	7959 (48.38)	5691 (51.05)	2268 (42.77)	
Female	8491 (51.62)	5456 (48.95)	3035 (57.23)	
Education level (%)				< 0.001
Less than high school graduate	3927 (23.87)	2269 (20.36)	1658 (31.27)	
High school graduate or GED	3800 (23.10)	2452 (22.00)	1348 (25.42)	
Some college or above	8723 (53.03)	6426 (57.65)	2297 (43.32)	
Race (%)				< 0.001
Mexican American	2561 (15.57)	1736 (15.57)	825 (15.56)	
Non-Hispanic white	1681 (10.22)	1118 (10.03)	563 (10.62)	
Non-Hispanic black	6987 (42.47)	4970 (44.59)	2017 (38.04)	
Other Hispanic	3418 (20.78)	1973 (17.70)	1445 (27.25)	
Other race/ethnicity	1803 (10.96)	1350 (12.11)	453 (8.54)	
Marital status (%)				< 0.001
Married/Living with a partner	6543 (39.78)	4237 (38.01)	2306 (43.48)	
Living alone	9907 (60.22)	6910 (61.99)	2997 (56.52)	
Income level (%)				< 0.001
Low income	10,413 (63.30)	7422 (66.58)	2991 (56.40)	
Non-low income	6037 (36.70)	3725 (33.42)	2312 (43.60)	
Alcohol consumption (%)				< 0.001
Low	6583 (40.02)	4119 (36.95)	2464 (46.46)	
High	9867 (59.98)	7028 (63.05)	2839 (53.54)	
Smoking status (%)				< 0.001
Never smoked	9046 (54.99)	6304 (56.55)	2742 (51.71)	
Ever smoked	7404 (45.01)	4843 (43.45)	2561 (48.29)	
Hypertension (%)				< 0.001
No	10,482 (63.72)	7849 (70.41)	2633 (49.65)	
Yes	5968 (36.28)	3298 (29.59)	2670 (50.35)	
Hyperlipidemia (%)				< 0.001
No	10,461 (63.59)	7501 (67.29)	2960 (55.82)	
Yes	5989 (36.41)	3646 (32.71)	2343 (44.18)	
Diabetes mellitus (%)				< 0.001
No	14,235 (86.53)	10,071 (90.35)	4164 (78.52)	
Yes	2215 (13.47)	1076 (9.65)	1139 (21.48)	
Coronary heart disease (%)				< 0.001
No	15,812 (96.12)	10,836 (97.21)	4976 (93.83)	
Yes	638 (3.88)	311 (2.79)	327 (6.17)	
Depressive disorder (%)				< 0.001
No	12,460 (75.74)	9016 (80.88)	3444 (64.94)	
Yes	3990 (24.26)	2131 (19.12)	1859 (35.06)	
METS-IR quantile (%)				< 0.001
Q1 (17.14–34.37)	4113 (25.00)	3089 (27.71)	1024 (19.31)	
Q2 (34.37–41.56)	4112 (25.00)	2817 (25.27)	1295 (24.42)	

Continued

Variables	Total ($n = 16450$)	Nocturia		P
		No ($n = 11147$)	Yes ($n = 5303$)	
Q3 (41.56–50.22)	4112 (25.00)	2758 (24.74)	1354 (25.53)	
Q4 (50.22- 129.57)	4113 (25.00)	2483 (22.28)	1630 (30.74)	
ABSI quantile (%)				< 0.001
Q1 (60.03–78.38)	4113 (25.00)	3122 (28.01)	991 (18.69)	
Q2 (78.38–81.60)	4112 (25.00)	2981 (26.74)	1131 (21.33)	
Q3 (81.60–84.90)	4112 (25.00)	2742 (24.60)	1370 (25.83)	
Q4 (84.49- 111.47)	4113 (25.00)	2302 (20.65)	1811 (34.15)	
BMI quantile, n(%)				< 0.001
Q1 (13.40–24.40)	4076 (24.78)	3038 (27.25)	1038 (19.57)	
Q2 (24.40- 28.08)	4148 (25.22)	2914 (26.14)	1234 (23.27)	
Q3 (28.08–32.64)	4112 (25.00)	2743 (24.61)	1369 (25.82)	
Q4 (32.64- 82.00)	4114 (25.01)	2452 (22.00)	1662 (31.34)	
WC quantile, n(%)				< 0.001
Q1 (56.2–87.90)	4092 (24.88)	3114 (27.94)	978 (18.44)	
Q2 (87.90–98.20)	4123 (25.06)	2955 (26.51)	1168 (22.03)	
Q3 (98.20- 109.10)	4110 (24.98)	2696 (24.19)	1414 (26.66)	
Q4 (109.10–178.00)	4125 (25.08)	2382 (21.37)	1743 (32.87)	

Table 1. Baseline characteristics of Nocturia in adults aged 20 years and older. Percentages for categorical variables are calculated based on the frequency of observations in the sample. *BMI* body mass index, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *TG* triglycerides,*TC* total cholesterol, *Cr* serum creatinine, *BUN* blood urea nitrogen, *WC* waist circumference.

Variables	Model 1	Model 2	Model 3
METS-IR	1.27 (1.22, 1.31) < 0.0001	1.25 (1.21, 1.29) < 0.0001	1.15 (1.11, 1.20) < 0.0001
ABSI	1.22 (1.17, 1.27) < 0.0001	1.18 (1.13, 1.22) < 0.0001	1.14 (1.10, 1.19) < 0.0001
METS-IR quartile			
Q1 (Z < -0.722)	Reference	Reference	Reference
Q2 (-0.722 ≤ Z < -0.152)	1.22 (1.10, 1.35) 0.0001	1.22 (1.10, 1.35) 0.0002	1.16 (1.05, 1.29) 0.0054
Q3 (-0.152 ≤ Z < 0.536)	1.27 (1.15, 1.41) < 0.0001	1.26 (1.14, 1.40) < 0.0001	1.14 (1.02, 1.26) 0.0194
Q4 (Z ≥ 0.536)	1.86 (1.68, 2.05) < 0.0001	1.79 (1.62, 1.98) < 0.0001	1.45 (1.30, 1.61) < 0.0001
ABSI			
Q1 (Z < -0.667)	Reference	Reference	Reference
Q2 (-0.667 ≤ Z < -0.012)	1.10 (0.99, 1.23) 0.0663	1.08 (0.97, 1.20) 0.1606	1.05 (0.94, 1.17) 0.4053
Q3 (-0.012 ≤ Z < 0.659)	1.26 (1.13, 1.40) < 0.0001	1.21 (1.08, 1.34) 0.0006	1.15 (1.03, 1.28) 0.0127
Q4 (Z ≥ 0.659)	1.63 (1.46, 1.82) < 0.0001	1.49 (1.33, 1.67) < 0.0001	1.38 (1.23, 1.55) < 0.0001

Table 2. Weighted relationship between Z-score of METS-IR, ABSI, and nocturia. ORs, 95% CIs, and p-values are used to display the data. Both METS-IR and ABSI are presented as Z-scores (standardized values) for continuous variables and quartiles. Model 1: adjusted for gender, race, age; Model 2: further adjusted for income, marital status, education level, smoking status and alcohol consumption; Model 3: further adjusted for cholesterol, hypertension, cardiovascular disease, diabetes, and depression based on Model 2.

groups, which exhibited significant differences. Further smoothing curve analysis indicated a linear association between METS-IR and nocturia, whereas ABSI showed a non-linear relationship, with a threshold at 76.2. AIC analysis demonstrated that the ABSI model provided the best fit. BMI and WC were also significantly associated with nocturia. Quartile analysis revealed that higher BMI and WC were linked to greater nocturia risk. However, compared to BMI and WC, METS-IR and ABSI indices appeared to offer advantages in evaluating metabolic health and nocturia risk.

METS-IR is a composite index that evaluates insulin resistance by integrating fasting glucose, TG, HDL-C, and BMI, without relying on fasting insulin levels[17]. METS-IR offers a simpler and more cost-effective way to assess metabolic health, particularly excelling in predicting diseases related to metabolic syndrome[34,35]. Previous studies, such as those by Rohrmann et al., have shown that men with metabolic syndrome are at higher risk of nocturia and incomplete bladder emptying[36]. Additionally, insulin resistance has been linked to overactive bladder (OAB), with MetS-associated OAB potentially representing a distinct subtype[25].

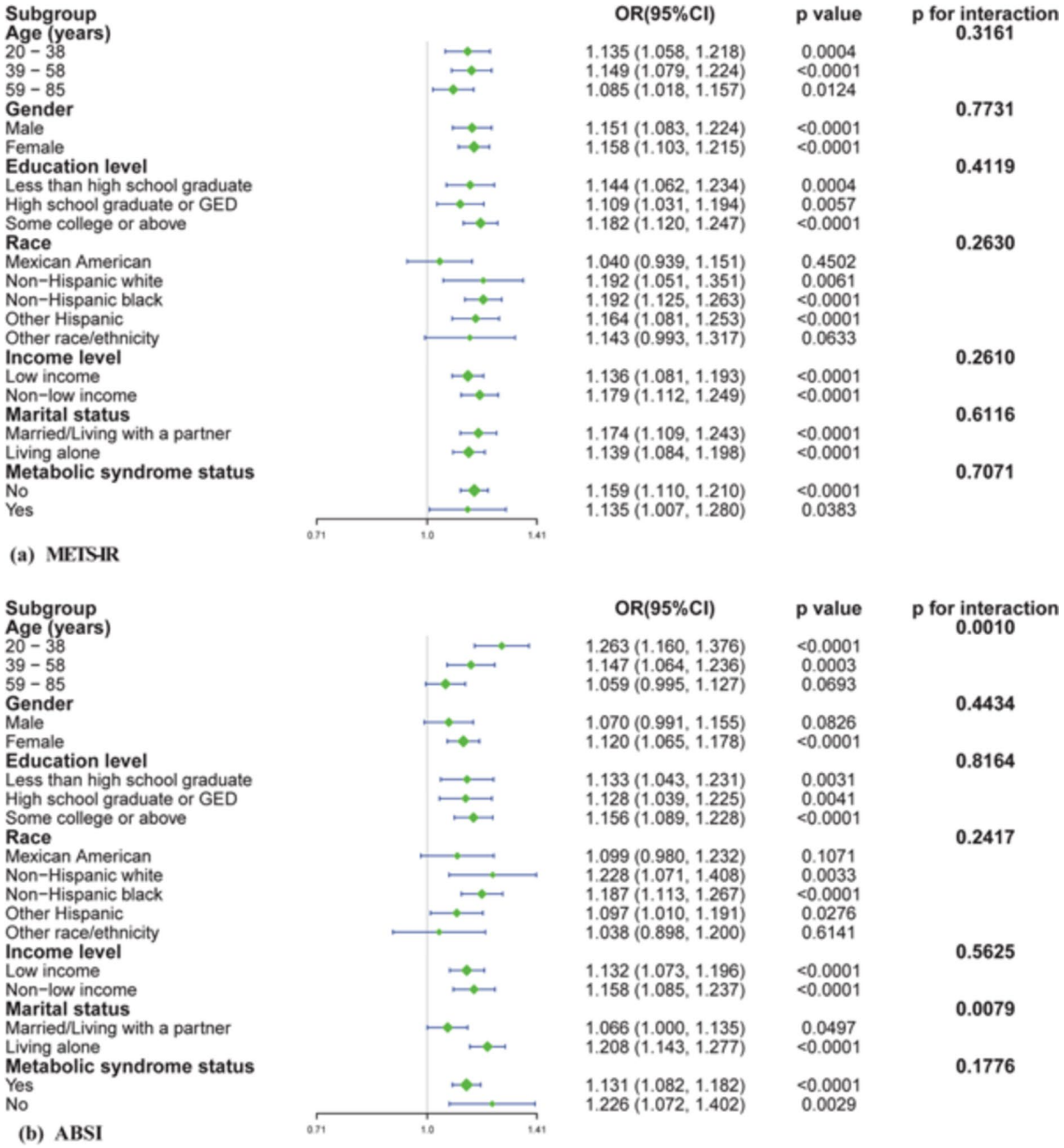

Fig. 2. Subgroup analysis of the relationship between the prevalence of nocturia and METS-IR (**a**), and ABSI (**b**). Adjusted for gender, race, age, income, marital status, education level, cholesterol, hypertension, cardiovascular disease, diabetes, smoking status, alcohol consumption, and depression, except for the stratified factor itself.

ABSI was developed to address the limitations of BMI and provides a better assessment of visceral fat distribution and related health risks[37,38]. Unlike BMI, which only measures body weight, ABSI combines WC, height, and weight, offering a more precise evaluation of abdominal obesity and its impact on health[39]. The association between abdominal obesity and nocturia has been well-documented in several studies, with a cross-sectional study showing that adults with abdominal obesity are more prone to moderate-to-severe lower urinary tract symptoms (LUTS)[40]. Abdominal obesity is also an independent risk factor for OAB and LUTS in women[41,42]. and is associated with increases in BMI and metabolic syndrome[43,44]. This is consistent with our study conclusions.

Insulin resistance and abdominal obesity often interact and share common mechanisms that may increase the risk of nocturia[45]. Insulin resistance may impair renal sodium and water reabsorption, leading to greater nighttime urine volume[46]. Abdominal obesity increases intravesical pressure, reducing bladder capacity, particularly at night[44]. Additionally, chronic low-grade inflammation, as indicated by higher levels of markers

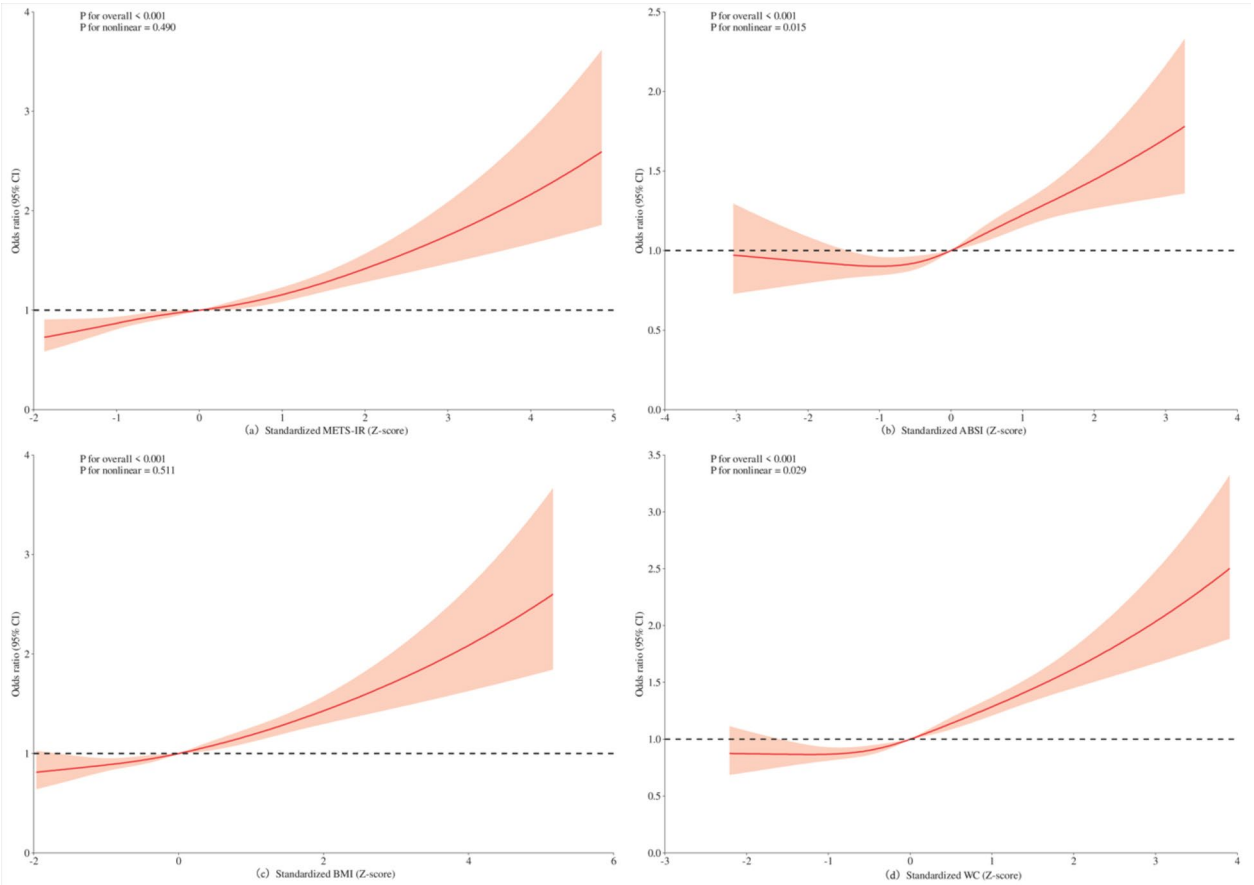

Fig. 3. GAM smooth curve fitting analysis evaluating the relationship between METS-IR (**a**), ABSI (**b**), BMI (**c**), WC (**d**) and the prevalence of nocturia. The red solid line represents the probability of nocturia, and the red shaded area indicates the 95% CI curve.

such as TNF-α and IL-6, can exacerbate bladder nerve dysfunction, contributing to a higher risk of nocturia[47]. Hormonal shifts, particularly in antidiuretic hormone (ADH) regulation, may also play a role in the greater occurrence of nocturia[48].

In our subgroup analysis, the association between ABSI and nocturia was more pronounced among younger individuals (aged 20–38) and those living alone. The higher metabolic rate in younger individuals may amplify the impact of abdominal fat distribution on health outcomes, including nocturia[49]. Additionally, unhealthy lifestyle behaviors, such as sedentary habits and poor dietary choices, are more prevalent in younger populations and may further exacerbate the relationship between ABSI and nocturia[50]. For individuals living alone, the lack of social support and greater psychological stress may contribute to a higher risk risk of nocturia[51,52]. Their irregular lifestyle, including less structured eating and exercise patterns, could heighten the health risks associated with abdominal obesity[53,54]. These combined factors may explain the stronger association observed between ABSI and nocturia in these subgroups.

This study, based on the large sample dataset from NHANES, ensures the representativeness and generalizability of the study sample. The large sample size provides higher statistical power, reducing the influence of random errors. Additionally, we used METS-IR and ABSI, two comprehensive metabolic indicators, which more holistically reflect individuals' metabolic health and body shape characteristics compared to traditional single indicators like BMI. By adjusting for multiple potential confounders in the multivariable models, we improved the reliability and scientific validity of the results. The application of stratified analysis allowed us to explore the relationships between metabolic indices and nocturia across different demographic subgroups, revealing potential heterogeneity and providing a basis for personalized intervention measures.

However, this study has several limitations. First, the cross-sectional design restricts us from establishing causality, leaving the possibility of reverse causation[55]. While we observed an association between nocturia and both METS-IR and ABSI, we cannot determine if nocturia causes these metabolic issues or is a result of them. Future research should adopt longitudinal designs to clarify these relationships. Nevertheless, it is unlikely that nocturia would lead to insulin resistance or abdominal obesity, as these are typically the causes rather than the outcomes of nocturia.Second, the diagnosis of nocturia relies on self-reports, which may introduce recall bias and inaccuracies. Furthermore, despite adjusting for many confounding factors, unmeasured variables such as dietary habits, sleep quality[56], and psychological stress might still affect the results. Lastly, this study uses data primarily from the U.S. population, so further validation is required for other racial and regional groups.

The findings of this study emphasize the importance of considering METS-IR and ABSI as evaluation tools for metabolic health in the clinical prevention and intervention of nocturia. This suggests that healthcare professionals should comprehensively consider these metabolic indices when assessing the risk of nocturia in patients. Given the close relationship between nocturia, abdominal obesity, and insulin resistance, actively intervening in these metabolic issues can not only improve patients' overall health but also effectively prevent the occurrence of nocturia.

Conclusion

This study demonstrates a significant association between METS-IR and ABSI indices and the prevalence of nocturia. METS-IR index showed a linear positive correlation with the prevalence of nocturia, whereas ABSI index exhibited a nonlinear relationship. Our findings underscore the need to consider these metabolic indices in the clinical prevention and intervention of nocturia.

Data availability

The data used in this study were derived from the National Health and Nutrition Examination Survey (NHANES) 2005-2020 datasets, which are publicly available and can be accessed through the NHANES website at https://www.cdc.gov/nchs/nhanes/index.htm. The NHANES datasets include comprehensive demographic, examination, laboratory, and questionnaire data. All data supporting the findings of this study are available from the corresponding author upon reasonable request.

Received: 28 May 2024; Accepted: 28 November 2024
Published online: 02 December 2024

References

1. Haylen, B. T. et al. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction. *Neurourol. Urodyn. Off. J. Int. Cont. Soc.* **29**, 4–20 (2010).
2. Kupelian, V. et al. Association of nocturia and mortality: results from the Third National Health and Nutrition Examination Survey. *J. Urol.* **185**, 571–577 (2011).
3. Dutoglu, E. et al. Nocturia and its clinical implications in older women. *Arch. Gerontol. Geriatr.* **85**, 103917 (2019).
4. Zhou, J., Xia, S., Li, T. & Liu, R. Association between obstructive sleep apnea syndrome and nocturia: a meta-analysis. *Sleep. Breath.* **24**, 1293–1298 (2020).
5. Johnson, T. V. et al. Nocturia associated with depressive symptoms. *Urology* **77**, 183–186 (2011).
6. Stewart, R. B., Moore, M. T., May, F. E., Marks, R. G. & Hale, W. E. Nocturia: a risk factor for falls in the elderly. *J. Am. Geriatr. Soc.* **40**, 1217–1220 (1992).
7. Lightner, D. J. et al. Nocturia is associated with an increased risk of coronary heart disease and death. *BJU Int.* **110**, 848 (2012).
8. Chen, J. et al. Relationship between nocturia and hypertension: findings from the NHANES 2005–2016. *Front. Cardiovasc. Med.* **10** (2023).
9. Fu, Z., Wang, F., Dang, X. & Zhou, T. The association between diabetes and nocturia: a systematic review and meta-analysis. *Front. Public Health* **10**, 924488 (2022).
10. Radu, F. et al. The link between NAFLD and metabolic syndrome. *Diagnostics* **13**, 614 (2023).
11. Emanuela, F. et al. Inflammation as a link between obesity and metabolic syndrome. *J. Nutr. Metab.* **2012** (2012).
12. Mikhail, N. The metabolic syndrome: insulin resistance. *Curr. Hypertens. Rep.* **11**, 156–158 (2009).
13. Li, G. et al. The feasibility of two anthropometric indices to identify metabolic syndrome, insulin resistance and inflammatory factors in obese and overweight adults. *Nutrition* **57**, 194–201 (2019).
14. Davidson, M. B. et al. Comment on: Tam defining insulin resistance from hyperinsulinemic-euglycemic clamps. Diabetes Care 2012; 35: 1605–1610. *Diabetes Care* 36, e10-e10 (2013).
15. Kim, J. K. Hyperinsulinemic–euglycemic clamp to assess insulin sensitivity in vivo. *Type 2 Diabetes: Methods Protocols*, 221–238 (2009).
16. Rebelos, E. & Honka, M. J. PREDIM index: a useful tool for the application of the euglycemic hyperinsulinemic clamp. *J. Endocrinol. Investig.* **44**, 631–634 (2021).
17. Bello-Chavolla, O. Y. et al. METS-IR, a novel score to evaluate insulin sensitivity, is predictive of visceral adiposity and incident type 2 diabetes. *Eur. J. Endocrinol.* **178**, 533–544 (2018).
18. Pan, L. et al. Predictive values of metabolic score for insulin resistance on risk of major adverse cardiovascular events and comparison with other insulin resistance indices among Chinese with and without diabetes mellitus: results from the 4 C cohort study. *J. Diabetes Investig.* **14**, 961–972 (2023).
19. Krakauer, N. Y. & Krakauer, J. C. A new body shape index predicts mortality hazard independently of body mass index. *PloS One* **7**, e39504 (2012).
20. Aoki, K. C. & Mayrovitz, H. N. Utility of a body shape index parameter in predicting cardiovascular disease risks. *Cureus* **14** (2022).
21. Bertoli, S. et al. Association of body shape index (ABSI) with cardio-metabolic risk factors: a cross-sectional study of 6081 caucasian adults. *PloS One* **12**, e0185013 (2017).
22. Leone, A. et al. Evaluation of different adiposity indices and association with metabolic syndrome risk in obese children: is there a winner? *Int. J. Mol. Sci.* **21**, 4083 (2020).
23. Ikeue, K., Kusakabe, T., Yamakage, H., Ishii, K. & Satoh-Asahara, N. A body shape index is useful for BMI-independently identifying Japanese patients with obesity at high risk of cardiovascular disease. *Nutr. Metab. Cardiovasc. Dis.* **34**, 387–394 (2024).
24. Kajikawa, M. et al. A body shape index as a simple anthropometric marker of abdominal obesity and risk of Cardiovascular events. *J. Clin. Endocrinol. Metab.*, dgae282 (2024).
25. Hsu, L. N., Hu, J. C., Chen, P. Y., Lee, W. C. & Chuang, Y. C. Metabolic syndrome and overactive bladder syndrome may share common pathophysiologies. *Biomedicines* **10**, 1957 (2022).
26. Kasturi, S., Russell, S. & McVary, K. T. Metabolic syndrome and lower urinary tract symptoms secondary to benign prostatic hyperplasia. *Curr. Prostate Rep.* **4**, 127–131 (2006).
27. AZADZOI, K. M., TARCAN, T., SIROKY, M. B. & KOZLOWSKI, R., KRANE, R. J. & Overactivity and structural changes in the chronically ischemic bladder. *J. Urol.* **162**, 1768–1778 (1999).
28. Bhide, A. A., Cartwright, R., Khullar, V. & Digesu, G. A. biomarkers in overactive bladder. *Int. Urogynecol. J.* **24**, 1065–1072 (2013).
29. Kupelian, V. *Vol. 188 2041–2042* (Wolters Kluwer Philadelphia, 2012).
30. Wu, M. Y. et al. Risks of nocturia in patients with chronic kidney disease—do the metabolic syndrome and its components matter? *J. Urol.* **188**, 2269–2273 (2012).

31. Su, W. et al. METS-IR, a novel score to evaluate insulin sensitivity, is associated with the urinary albumin–creatinine ratio in Chinese adults: a cross-sectional REACTION study (2021).
32. Ogden, C. L. Prevalence of obesity among youths by household income and education level of head of household—United States 2011–2014. *MMWR Morb. Mortal. Wkly Rep.* 67 (2018).
33. Kroenke, K., Spitzer, R. L. & Williams, J. B. The PHQ-9: validity of a brief depression severity measure. *J. Gen. Intern. Med.* **16**, 606–613 (2001).
34. Whaley-Connell, A. & Sowers, J. R. Insulin resistance in kidney disease: is there a distinct role separate from that of diabetes or obesity. *Cardiorenal Med.* **8**, 41–49 (2017).
35. Ma, X. et al. METS-IR, a Novel simple insulin Resistance Index, is Associated with NAFLD in patients with type 2 diabetes Mellitus. *Diabetes Metab. Syndrome Obes.*, 3481–3490 (2024).
36. Rohrmann, S., Smit, E., Giovannucci, E. & Platz, E. Association between markers of the metabolic syndrome and lower urinary tract symptoms in the Third National Health and Nutrition Examination Survey (NHANES III). *Int. J. Obes.* **29**, 310–316 (2005).
37. Després, J. P. & Lemieux, I. Abdominal obesity and metabolic syndrome. *Nature* **444**, 881–887 (2006).
38. Christakoudi, S. et al. A body shape index (ABSI) achieves better mortality risk stratification than alternative indices of abdominal obesity: results from a large European cohort. *Sci. Rep.* **10**, 14541 (2020).
39. Gomez-Peralta, F. et al. Relationship between a body shape index (ABSI) and body composition in obese patients with type 2 diabetes. *Diabetol. Metab. Syndr.* **10**, 1–8 (2018).
40. Laven, B. A. et al. Birth weight, abdominal obesity and the risk of lower urinary tract symptoms in a population based study of Swedish men. *J. Urol.* **179**, 1891–1896 (2008).
41. Bunn, F. et al. Is there a link between overactive bladder and the metabolic syndrome in women? A systematic review of observational studies. *Int. J. Clin. Pract.* **69**, 199–217 (2015).
42. Zacche, M., Giarenis, I., Thiagamoorthy, G., Robinson, D. & Cardozo, L. Is there an association between aspects of the metabolic syndrome and overactive bladder? A prospective cohort study in women with lower urinary tract symptoms. *Eur. J. Obstet. Gynecol. Reprod. Biol.* **217**, 1–5 (2017).
43. Markland, A. D. et al. Characterizing the spectrum of bladder health and lower urinary tract symptoms (LUTS) among women: results from the CARDIA study. *Urology* **158**, 88–94 (2021).
44. Otsubo, A. et al. Excessive accumulation of visceral fat is associated with lower urinary symptoms including overactive bladder in female patients. *Int. J. Urol.* **28**, 397–403 (2021).
45. Jiang, K. et al. Association between visceral adiposity index and insulin resistance: a cross-sectional study based on US adults. *Front. Endocrinol.* **13**, 921067 (2022).
46. Yang, W. et al. The metabolic score for insulin resistance (METS-IR) predicts cardiovascular disease and its subtypes in patients with hypertension and obstructive sleep apnea. *Clin. Epidemiol.*, 177–189 (2023).
47. Rutten, E. P. et al. Abdominal fat mass contributes to the systemic inflammation in chronic obstructive pulmonary disease. *Clin. Nutr.* **29**, 756–760 (2010).
48. Li, R. et al. Uric acid metabolic disorders in Pituitary-Target Gland Axis. *Diabetes Metab. Syndrome Obes.*, 661–673 (2024).
49. Seidell, J. C. & Visscher, T. L. Body weight and weight change and their health implications for the elderly. *Eur. J. Clin. Nutr.* **54**, S33–S39 (2000).
50. Kemmler, W., Bebenek, M., Stengel, S., Kohl, M. & Bauer, J. Increases of cardiometabolic risk in young adults. Impact of exercise reductions during the college years. *Br. J. Med. Med. Res.* **8**, 485–494 (2015).
51. Denning, E. et al. Social support and social strain as predictors of depressive symptom trajectories following a marital transition. *Innov. Aging.* **5**, 1015–1015 (2021).
52. Anderson, D. J. et al. Lower urinary tract symptoms in depression: a review. *Health Psychol. Res.* 11 (2023).
53. Yamamoto, R. et al. Living alone and prediction of weight gain and overweight/obesity in university students: a retrospective cohort study. *J. Am. Coll. Health* **71**, 1417–1426 (2023).
54. Otto, C. M. Heartbeat: is cardiovascular health affected by marital status, living alone or loneliness? *Heart* **106**, 243–245 (2020).
55. Wang, C. et al. Association between the triglyceride glucose index and obstructive sleep apnea and its symptoms: results from the NHANES. *Lipids Health Dis.* **23**, 133 (2024).
56. Chang, C. J. et al. Correlates of nocturia and relationships of nocturia with sleep quality and glycemic control in women with type 2 diabetes. *J. Nurs. Scholarsh.* **49**, 400–410 (2017).

Author contributions

XF conducted the data analysis, tabulation, and graphing, authored the manuscript, and evaluated the analysis results. ZYT provided methodological and conceptual advice. Both authors read and approved the final manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The study was approved by the NCHS Ethics Review Board.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-024-81721-3.

Correspondence and requests for materials should be addressed to F.X.