



Association of Sarcopenia and Urinary Incontinence in Adult Women Aged Less Than 60 years

Fan Zhang ^{1,2}, Wenjian Li ^{3,4}

¹Department of Endocrinology, Changzhou Third People's Hospital, Changzhou, Jiangsu, People's Republic of China; ²Department of Clinical Nutrition, Changzhou Third People's Hospital, Changzhou, Jiangsu, People's Republic of China; ³Department of Urology, Changzhou Third People's Hospital, Changzhou, Jiangsu, People's Republic of China; ⁴Changzhou Clinical College, Xuzhou Medical University, Changzhou, Jiangsu, People's Republic of China

Correspondence: Wenjian Li, Department of Urology, Changzhou Third People's Hospital, 300 Lanling North Road, Changzhou, Jiangsu, People's Republic of China, 213001, Tel +86 0519 82009011, Email bolite@163.com

Purpose: This study aimed to explore the association between sarcopenia and urinary incontinence in adult women younger than 60 and provide insights into their pathophysiological mechanisms.

Patients and Methods: The study included 4,553 adult female participants aged <60, utilizing data from the National Health and Nutrition Examination Survey (NHANES) database between 2011 and 2018. The appendicular skeletal muscle mass index (ASMI) was assessed using dual-energy X-ray absorptiometry, and sarcopenia was determined based on the resulting ASMI values (< 0.512). The type of urinary incontinence was evaluated using the Kidney Condition-Urology Questionnaire, which categorized incontinence as stress urinary incontinence, urgency urinary incontinence, or mixed urinary incontinence based on the results of the questionnaire. Multivariate adjustment models were constructed to analyze the relationship between ASMI, sarcopenia, and different types of urinary incontinence. The model incorporated a range of sociodemographic characteristics, lifestyle habits, and medical histories as covariates. Restricted cubic spline model was employed to assess the non-linear dose-response relationship between ASMI and urinary incontinence.

Results: The results demonstrated a significant negative correlation between ASMI and the development of urinary incontinence. The risk of developing stress urinary incontinence, urgency urinary incontinence, and mixed urinary incontinence all increased significantly as ASMI decreased. The prevalence of urinary incontinence was significantly higher in patients with sarcopenia than in those without sarcopenia. Subgroup analysis demonstrated that the inverse relationship between ASMI and urinary incontinence persisted across most subgroups.

Conclusion: This study identifies a significant inverse association between sarcopenia and urinary incontinence in adult women under 60, emphasizing the role of muscle health in bladder function. These findings provide valuable insights for clinical risk assessment and intervention strategies.

Keywords: sarcopenia, urinary incontinence, adult women under 60, appendicular skeletal muscle mass index, NHANES, risk factors

Introduction

Sarcopenia is a syndrome characterized by the loss of skeletal muscle mass, reduced strength, and impaired function. In recent years, it has gained increasing attention in medical research.^{1,2} The prevalence of sarcopenia ranges from approximately 8% to 36% among individuals under 60 years of age and from 10% to 27% among those over 60 years of age.³ In particular, the prevalence of sarcopenia has been observed to increase gradually among adult females, with substantial implications for their health and quality of life. Additionally, it has been linked to an elevated risk of falls, fractures, and a range of chronic conditions.^{2,3} Concurrently, the prevalence of urinary incontinence (UI), a prevalent urinary dysfunction in women, ranges from 10% to 50%, and it is associated with an increased risk of adverse effects on daily life and psychological well-being.⁴⁻⁶

Although there may be some pathophysiologic commonalities between sarcopenia and UI, such as their association with aging, hormonal changes, lifestyle, and chronic diseases,^{1,6–8} there is a paucity of in-depth research and definitive conclusions regarding the specific mechanisms of their association. Potentially shared mechanisms include neuromuscular impairment, pelvic floor muscle weakness, and chronic inflammation, all of which contribute to both sarcopenia and UI. Many studies have previously examined the possible relationship between sarcopenia and UI in older populations or specific disease states. For instance, several studies have demonstrated a high prevalence of both sarcopenia and UI in the elderly population and a correlation between the two; however, the specific physiologic mechanisms and causal relationships have not been thoroughly explored.^{9–11} A study of patients with dysphagia found that grip strength was associated with urinary dysfunction, suggesting that low grip strength may be a marker of weak pelvic floor muscle strength, which, in turn, is related to UI.¹² However, research on adult women younger than 60 years, an age group with a high incidence of UI at first, is limited. Furthermore, previous studies are deficient in exploring the differences in the association between sarcopenia and different types of UI, and they have limitations in controlling for confounding factors (eg, socioeconomic status, lifestyle habits, etc).

Given these gaps in research, this study aims to investigate the relationship between sarcopenia and UI in adult women under 60. By leveraging the National Health and Nutrition Examination Survey (NHANES) data, we seek to provide new insights into their underlying mechanisms and offer a foundation for targeted clinical interventions.

Methods

Study Population

The data resources utilized in this study were obtained from the NHANES database between 2011 and 2018. The database was constructed from cross-sectional surveys administered by the Centers for Disease Control and Prevention (CDC) every two years. The study design was formally approved by the Ethics Review Board of the National Center for Health Statistics (NCHS), which ensured that all participants signed consent forms on a fully informed basis. According to NIH policies, NHANES data are publicly available and do not require additional institutional ethics approval, as they were not collected through direct contact with participants. In light of the considerations above, the Changzhou Third People's Hospital Ethics Committee concluded that an additional ethical review was not required for the NHANES data utilized in this study.

In the initial phase of the study, data from a total of 39,156 participants from four consecutive cycles of the NHANES survey were included. Afterward, participants were screened and excluded based on exclusion criteria. This included males, individuals under the age of 20, pregnant individuals, and those with missing data related to UI, appendicular skeletal muscle mass (ASM), demographic characteristics, chronic diseases, or body mass index (BMI). Furthermore, as the NHANES only conducted dual-energy X-ray absorptiometry (DXA) testing on participants below the age of 60 (participants aged 8–59 were eligible) during this investigative cycle, 4,553 adult female participants below the age of 60 were ultimately enrolled in this study as a result of the screening above process (Figure 1).

Assessment of Sarcopenia

This study employed DXA to evaluate ASM, a reliable indicator of overall lean body mass in the arms and legs. The appendicular skeletal muscle mass index (ASMI) was calculated for further analysis, with the ratio of ASM to BMI (ASM/BMI) as the adjustment factor. Based on the criteria established by the Foundation for the National Institutes of Health (FNIH), the diagnosis of sarcopenia is made when the ASMI value is less than 0.789 for males and 0.512 for females.¹³ The FNIH criteria were selected as they are widely used in epidemiological studies and validated for assessing muscle mass in population-based studies.

Assessment of UI

This study was based on data from the Kidney Conditions - Urology questionnaire document to assess the history of UI. Specifically, the type of incontinence was defined by the following question: “During the past 12 months, have you leaked or lost control of even a small amount of urine with an activity like coughing, lifting or exercise?” Those who

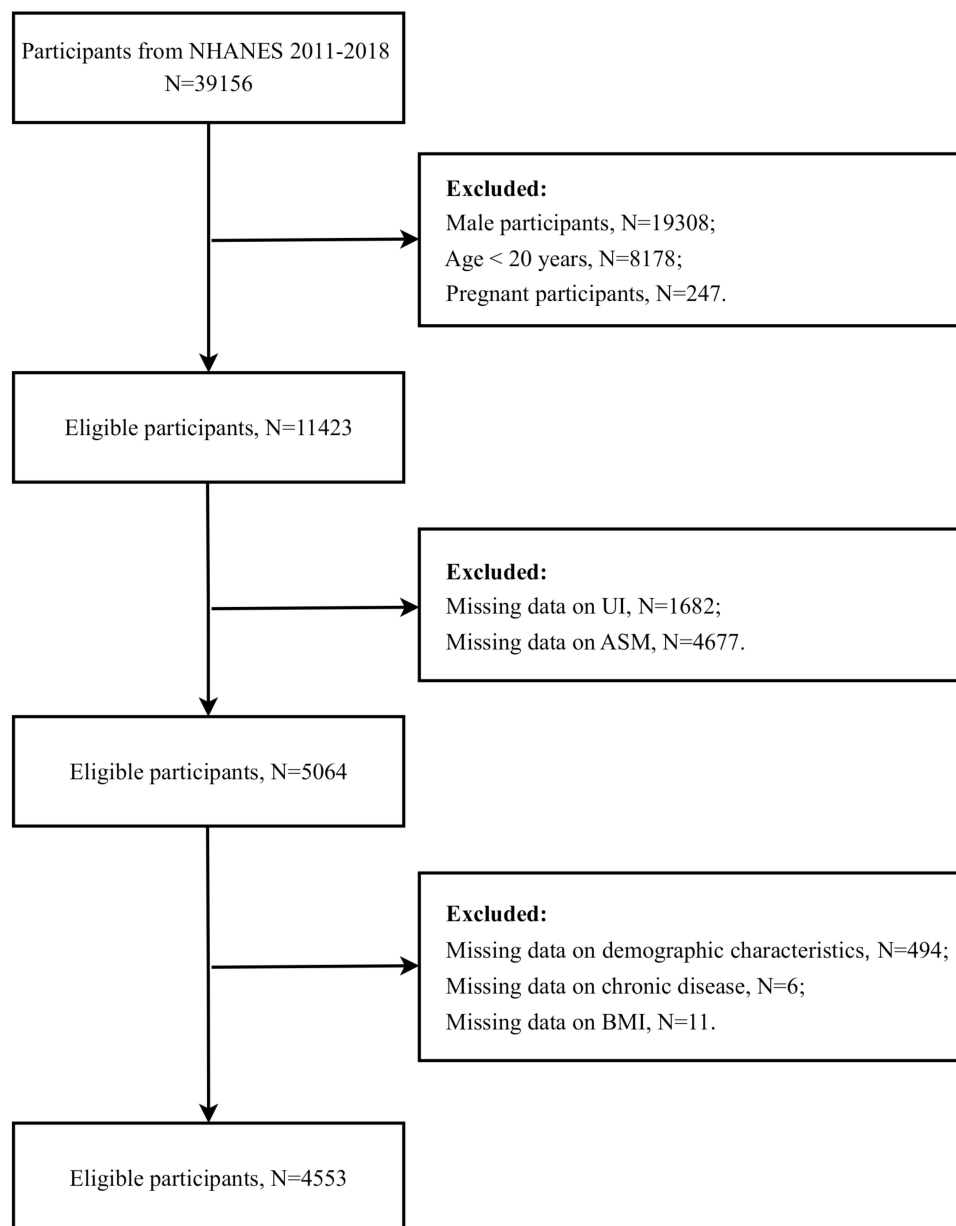


Figure 1 Participant screening flowchart.

Abbreviations: UI, Urinary incontinence; ASM, Appendicular skeletal muscle mass; BMI, Body mass index.

answered “yes” were categorized as having a history of stress urinary incontinence (SUI), while those who answered “no” were considered to have no history of SUI. A second question assessed urgency urinary incontinence (UUI): “During the past 12 months, have you leaked or lost control of even a small amount of urine with an urge or pressure to urinate and you could not get to the toilet fast enough?” Once more, those who responded affirmatively were classified as having a history of UUI, while those who answered negatively were categorized as having no history of UUI. Furthermore, individuals who exhibited symptoms of both SUI and UUI were classified as having mixed urinary incontinence (MUI).¹⁴ Although self-reported questionnaires provide valuable insights, they may introduce recall bias.

Covariate Assessment

Multivariate adjustment models were constructed in this study to investigate the effect of confounding variables on the association between ASMI, sarcopenia, and UI. The model incorporated sociodemographic characteristics, lifestyle

habits, and chronic disease history as covariates. Specifically, the covariates included age (years), racial classification (Mexican American, non-Hispanic white, non-Hispanic black, and other race), educational attainment (less than 9th grade, 9th-12th grade, and more than 12th grade), marital status (cohabitation and solitude), and family income status (categorized as low ($PIR \leq 1.3$), medium ($1.3 < PIR \leq 3.5$) and high ($PIR > 3.5$)), alcohol consumption (defined as the consumption of at least 12 alcoholic beverages of any type in a year), smoking status (determined based on whether she had smoked at least 100 cigarettes in their lifetime and the current smoking status), level of physical activity (vigorous, moderate, and inactive), and menopausal status (assessed using the Reproductive Health Questionnaire). Regarding medical history variables, the diagnosis of diabetes mellitus (DM) was based on a physician's diagnosis, a fasting plasma glucose level of ≥ 126 mg/dL, a hemoglobin A1c level of $\geq 6.5\%$, or the use of diabetes medication or insulin. The diagnosis of hypertension was based on physician notification and the use of prescription drugs. The history of coronary heart disease, stroke, and cancer was based on physician notification of the diagnosis, ensuring the accuracy and reliability of the reported information.

Statistical Analysis

The Kolmogorov–Smirnov test was employed to assess the normal distribution of continuous variables. This revealed that all continuous variables in the study did not conform to a normal distribution. Consequently, they were described using the median (and the 25th and 75th percentiles). The Mann–Whitney and Kruskal–Wallis tests were then used for between-group difference analysis. Categorical variables were subsequently presented as frequencies and percentages, and differences between groups were compared using the chi-square test.

To investigate the correlation between ASMI, ASMI quartiles, sarcopenia, and UI, we constructed logistic regression models and calculated the odds ratios (OR) and their 95% confidence intervals (CI). Three models were built to assess these relationships and address potential confounding variables. Model 1 was unadjusted, while Model 2 was adjusted for age and race based on Model 1. Model 3 incorporated additional variables, including educational attainment, marital status, family PIR, smoking, alcohol consumption, physical activity, menopausal status, DM, hypertension, coronary heart disease, stroke, and cancer, based on Model 2.

Furthermore, we employed restricted cubic spline (RCS) curve modeling to investigate the potential dose-response relationship between ASMI and UI. To further analyze the relationship between ASMI and risk of UI in different subgroups, we performed stratified and interaction analyses based on variables such as race, education, marital status, family PIR, smoking, alcohol consumption, physical activity, menopausal status, DM, and hypertension.

All statistical analyses were conducted using two-sided tests, with a P-value of less than 0.05 considered statistically significant. All statistical analyses were conducted using R 4.4.2 (courtesy of the R Foundation, <http://www.R-project.org>) and SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Graphical representations were generated using GraphPad Prism version 9.0 (GraphPad Software, Inc., USA).

Results

Baseline Characteristics of Participants Based on ASMI Quartiles

The results demonstrated a statistically significant inverse correlation between age and ASMI quartiles ($P < 0.001$). Regarding the racial distribution, the proportion of non-Hispanic white participants and non-Hispanic black participants exhibited a gradual increase as ASMI levels rose ($P < 0.001$). Furthermore, as ASMI increased, participants tended towards higher educational attainment, accompanied by a corresponding rise in the proportion of those residing alone and elevated family incomes ($P < 0.001$). About lifestyle habits, the proportion of individuals who consume alcohol increased in conjunction with ASMI, while the intensity of physical activity exhibited a notable increase. Conversely, the proportion of postmenopausal women was relatively low ($P < 0.001$). About the prevalence of chronic diseases, a decreasing trend was observed in the prevalence of DM, hypertension, coronary heart disease, stroke, and cancer with increasing ASMI levels ($P < 0.05$). As ASMI increased, there was a corresponding decrease in both BMI and waist circumference (WC). Additionally, the prevalence of SUI, UI, and MUI demonstrated a notable decline ($P < 0.001$) with rising ASMI levels (Table 1).

Table 1 Baseline Characteristics of Participants Based on ASMI Quartiles

Variables	ASMI				P
	Quartile 1 (n = 1138)	Quartile 2 (n = 1138)	Quartile 3 (n = 1138)	Quartile 4 (n = 1139)	
Age (years)	44.50 (34.00,53.00)	41.00 (31.00,50.00)	39.00 (28.00,48.00)	34.00 (26.00,45.00)	<0.001
Race, n (%)					<0.001
Mexican American	329 (28.91)	182 (15.99)	90 (7.91)	47 (4.13)	
Non-Hispanic White	345 (30.32)	409 (35.94)	439 (38.58)	494 (43.37)	
Non-Hispanic Black	97 (8.52)	218 (19.16)	311 (27.33)	371 (32.57)	
Other Race	367 (32.25)	329 (28.91)	298 (26.19)	227 (19.93)	
Education Level, n (%)					<0.001
Less than 9th grade	123 (10.81)	51 (4.48)	24 (2.11)	8 (0.70)	
9–12th grade	425 (37.35)	379 (33.30)	312 (27.42)	235 (20.63)	
More than 12th grade	590 (51.85)	708 (62.21)	802 (70.47)	896 (78.67)	
Marital Status, n (%)					<0.001
Cohabitation	731 (64.24)	669 (58.79)	611 (53.69)	578 (50.75)	
Solitude	407 (35.76)	469 (41.21)	527 (46.31)	561 (49.25)	
Family PIR, n (%)					<0.001
Low (≤ 1.3)	448 (39.37)	408 (35.85)	357 (31.37)	309 (27.13)	
Medium (1.3–3.5)	386 (33.92)	411 (36.12)	413 (36.29)	400 (35.12)	
High (> 3.5)	304 (26.71)	319 (28.03)	368 (32.34)	430 (37.75)	
Smoke, n (%)					0.718
Yes	370 (32.51)	385 (33.83)	390 (34.27)	395 (34.68)	
No	768 (67.49)	753 (66.17)	748 (65.73)	744 (65.32)	
Alcohol, n (%)					<0.001
Yes	622 (54.66)	680 (59.75)	741 (65.11)	855 (75.07)	
No	516 (45.34)	458 (40.25)	397 (34.89)	284 (24.93)	
Physical Activity, n (%)					<0.001
Inactive	371 (32.60)	299 (26.27)	230 (20.21)	162 (14.22)	
Moderate	460 (40.42)	490 (43.06)	475 (41.74)	362 (31.78)	
Vigorous	307 (26.98)	349 (30.67)	433 (38.05)	615 (53.99)	
Menopausal, n (%)					<0.001
Yes	410 (36.03)	318 (27.94)	278 (24.43)	177 (15.54)	
No	728 (63.97)	820 (72.06)	860 (75.57)	962 (84.46)	
Diabetes mellitus, n (%)					<0.001
Yes	229 (20.12)	177 (15.55)	117 (10.28)	72 (6.32)	
No	909 (79.88)	961 (84.45)	1021 (89.72)	1067 (93.68)	
Hypertension, n (%)					<0.001
Yes	352 (30.93)	293 (25.75)	259 (22.76)	167 (14.66)	
No	786 (69.07)	845 (74.25)	879 (77.24)	972 (85.34)	
Coronary heart disease, n (%)					0.030
Yes	13 (1.14)	8 (0.70)	3 (0.26)	4 (0.35)	
No	1125 (98.86)	1130 (99.30)	1135 (99.74)	1135 (99.65)	
Stroke, n (%)					0.007
Yes	31 (2.72)	11 (0.97)	18 (1.58)	15 (1.32)	
No	1107 (97.28)	1127 (99.03)	1120 (98.42)	1124 (98.68)	
Cancer, n (%)					0.031
Yes	74 (6.50)	66 (5.80)	56 (4.92)	44 (3.86)	
No	1064 (93.50)	1072 (94.20)	1082 (95.08)	1095 (96.14)	
BMI (kg/m ²)	32.30 (27.50,37.60)	29.90 (25.60,35.60)	27.20 (22.90,32.48)	23.70 (21.10,27.80)	<0.001
WC (cm)	102.25 (91.00,113.88)	98.50 (87.50,111.35)	91.90 (82.20,103.97)	83.70 (76.65,94.20)	<0.001

(Continued)

Table 1 (Continued).

Variables	ASMI				P
	Quartile 1 (n = 1138)	Quartile 2 (n = 1138)	Quartile 3 (n = 1138)	Quartile 4 (n = 1139)	
SUI, n (%)					<0.001
Yes	542 (47.63)	453 (39.81)	408 (35.85)	315 (27.66)	
No	596 (52.37)	685 (60.19)	730 (64.15)	824 (72.34)	
UUI, n (%)					<0.001
Yes	308 (27.07)	252 (22.14)	248 (21.79)	178 (15.63)	
No	830 (72.93)	886 (77.86)	890 (78.21)	961 (84.37)	
MUI, n (%)					<0.001
Yes	215 (18.89)	162 (14.24)	143 (12.57)	87 (7.64)	
No	923 (81.11)	976 (85.76)	995 (87.43)	1052 (92.36)	

Notes: Data are shown as median (25th, 75th percentiles) or percentages, $p < 0.05$ considered statistically significant.

Abbreviations: ASMI, Appendicular skeletal muscle mass index; PIR, Poverty-to-income ratio; BMI, Body mass index; WC, Waist circumference; SUI, Stress urinary incontinence; UUI, Urgency urinary incontinence; MUI, Mixed urinary incontinence.

Baseline Characteristics of Participants with and without Sarcopenia

Of the 4,553 individuals who participated in this study, 376 were definitively diagnosed with sarcopenia. The mean age of patients with sarcopenia was significantly higher than that of non-sarcopenia participants (46.00 vs 39.00 years, $P < 0.001$). Additionally, a substantially higher percentage of Mexican American individuals were included in the sarcopenia group than in the non-sarcopenia group (36.44% vs 12.23%, $P < 0.001$). The proportion of individuals with less education was significantly higher in the sarcopenia group than in the non-sarcopenia group (14.63% vs 3.62%, $P < 0.001$). Furthermore, the proportion of cohabitation individuals was higher in the sarcopenia group than in the non-sarcopenia group. Additionally, the proportion of low-income individuals exhibited a significantly higher trend ($P < 0.01$). Regarding lifestyle habits, patients with sarcopenia exhibited a relatively lower proportion of alcohol consumption and a weaker intensity of physical activity ($P < 0.001$). Furthermore, the proportion of postmenopausal individuals was significantly higher in the sarcopenia group than in the non-sarcopenia group ($P < 0.001$). About the prevalence of chronic disease, the incidence of DM, hypertension, stroke, and cancer was markedly elevated in the sarcopenia group relative to the non-sarcopenia group ($P < 0.05$). Both BMI and WC were significantly higher in patients with sarcopenia than in those without ($P < 0.001$). About UI, the prevalence of SUI, UUI, and MUI was significantly higher in patients with sarcopenia than in non-sarcopenia participants ($P < 0.01$) (Table 2).

Table 2 Baseline Characteristics of Participants with and without Sarcopenia

Variables	Total (n = 4553)	Non-Sarcopenia (n = 4177)	Sarcopenia (n = 376)	P
Age (years)	40.00 (29.00, 49.00)	39.00 (29.00, 49.00)	46.00 (36.00, 54.00)	<0.001
Race, n (%)				<0.001
Mexican American	648 (14.23)	511 (12.23)	137 (36.44)	
Non-Hispanic White	1687 (37.05)	1581 (37.85)	106 (28.19)	
Non-Hispanic Black	997 (21.90)	969 (23.20)	28 (7.45)	
Other Race	1221 (26.82)	1116 (26.72)	105 (27.93)	
Education Level, n (%)				<0.001
Less than 9th grade	206 (4.52)	151 (3.62)	55 (14.63)	
9–12th grade	1351 (29.67)	1203 (28.80)	148 (39.36)	
More than 12th grade	2996 (65.80)	2823 (67.58)	173 (46.01)	

(Continued)

Table 2 (Continued).

Variables	Total (n = 4553)	Non-Sarcopenia (n = 4177)	Sarcopenia (n = 376)	P
Marital Status, n (%)				0.004
Cohabitation	2589 (56.86)	2349 (56.24)	240 (63.83)	
Solitude	1964 (43.14)	1828 (43.76)	136 (36.17)	
Family PIR, n (%)				<0.001
Low (≤ 1.3)	1522 (33.43)	1355 (32.44)	167 (44.41)	
Medium (1.3–3.5)	1610 (35.36)	1485 (35.55)	125 (33.24)	
High (>3.5)	1421 (31.21)	1337 (32.01)	84 (22.34)	
Smoke, n (%)				0.134
Yes	1540 (33.82)	1426 (34.14)	114 (30.32)	
No	3013 (66.18)	2751 (65.86)	262 (69.68)	
Alcohol, n (%)				<0.001
Yes	2898 (63.65)	2708 (64.83)	190 (50.53)	
No	1655 (36.35)	1469 (35.17)	186 (49.47)	
Physical Activity, n (%)				<0.001
Inactive	1062 (23.33)	933 (22.34)	129 (34.31)	
Moderate	1787 (39.25)	1632 (39.07)	155 (41.22)	
Vigorous	1704 (37.43)	1612 (38.59)	92 (24.47)	
Menopausal, n (%)				<0.001
Yes	1183 (25.98)	1023 (24.49)	160 (42.55)	
No	3370 (74.02)	3154 (75.51)	216 (57.45)	
Diabetes mellitus, n (%)				<0.001
Yes	595 (13.07)	499 (11.95)	96 (25.53)	
No	3958 (86.93)	3678 (88.05)	280 (74.47)	
Hypertension, n (%)				<0.001
Yes	1071 (23.52)	949 (22.72)	122 (32.45)	
No	3482 (76.48)	3228 (77.28)	254 (67.55)	
Coronary heart disease, n (%)				1.000
Yes	28 (0.61)	26 (0.62)	2 (0.53)	
No	4525 (99.39)	4151 (99.38)	374 (99.47)	
Stroke, n (%)				0.004
Yes	75 (1.65)	62 (1.48)	13 (3.46)	
No	4478 (98.35)	4115 (98.52)	363 (96.54)	
Cancer, n (%)				0.003
Yes	240 (5.27)	208 (4.98)	32 (8.51)	
No	4313 (94.73)	3969 (95.02)	344 (91.49)	
BMI (kg/m ²)	28.20 (23.50, 33.80)	27.60 (23.20, 33.20)	34.50 (30.20, 39.90)	<0.001
WC (cm)	94.00 (83.00, 107.10)	92.90 (82.20, 105.60)	106.85 (95.75, 116.50)	<0.001
ASMI	0.64 (0.57, 0.71)	0.65 (0.59, 0.72)	0.48 (0.46, 0.50)	<0.001
SUI, n (%)				<0.001
Yes	1718 (37.73)	1537 (36.80)	181 (48.14)	
No	2835 (62.27)	2640 (63.20)	195 (51.86)	
UUI, n (%)				0.003
Yes	986 (21.66)	882 (21.12)	104 (27.66)	
No	3567 (78.34)	3295 (78.88)	272 (72.34)	
MUI, n (%)				<0.001
Yes	607 (13.33)	530 (12.69)	77 (20.48)	
No	3946 (86.67)	3647 (87.31)	299 (79.52)	

Notes: Data are shown as median (25th, 75th percentiles) or percentages, $p < 0.05$ considered statistically significant.

Abbreviations: PIR, Poverty-to-income ratio; BMI, Body mass index; WC, Waist circumference; ASMI, Appendicular skeletal muscle mass index; SUI, Stress urinary incontinence; UUI, Urgency urinary incontinence; MUI, Mixed urinary incontinence.

Relationship Between ASMI, Sarcopenia and UI

This study used three models to analyze the relationship between ASMI, sarcopenia, and different UI types. In Model 1 (unadjusted model), a significant negative correlation was observed between ASMI and SUI, UUI, and MUI ($P < 0.001$). These associations remained significant in Model 2 (adjusted for age and race) and Model 3 (further adjusted for education level, marital status, family PIR, smoking, alcohol intake, physical activity, menopausal status, DM, hypertension, coronary heart disease, stroke, and cancer). Specifically, there was a significant and negative correlation between ASMI and the development of UI, whereby an increase in ASMI was associated with a reduction in the risk of UI. Furthermore, the risk of UI was markedly elevated in the sarcopenia cohort relative to the non-sarcopenia cohort. After adjusting for many confounding variables, the OR of sarcopenia to SUI, UUI, and MUI were 1.26, 1.30, and 1.44, respectively, and all were statistically significant ($P < 0.05$) (Table 3).

Table 3 Relationship Between ASMI, Sarcopenia, and Urinary Incontinence in Different Models

Variables	Model 1		Model 2		Model 3	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Stress urinary incontinence						
ASMI	0.04 (0.02 ~ 0.07)	<0.001	0.15 (0.08 ~ 0.30)	<0.001	0.16 (0.08 ~ 0.33)	<0.001
Categories						
Quartile 1	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Quartile 2	0.73 (0.62 ~ 0.86)	<0.001	0.84 (0.71 ~ 1.00)	0.055	0.85 (0.71 ~ 1.01)	0.072
Quartile 3	0.61 (0.52 ~ 0.73)	<0.001	0.80 (0.66 ~ 0.96)	0.014	0.82 (0.68 ~ 0.98)	0.034
Quartile 4	0.42 (0.35 ~ 0.50)	<0.001	0.60 (0.50 ~ 0.73)	<0.001	0.62 (0.51 ~ 0.76)	<0.001
Sarcopenia						
No	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Yes	1.59 (1.29 ~ 1.97)	<0.001	1.27 (1.02 ~ 1.58)	0.035	1.26 (1.01 ~ 1.59)	0.041
Urgency urinary incontinence						
ASMI	0.12 (0.06 ~ 0.24)	<0.001	0.17 (0.08 ~ 0.39)	<0.001	0.23 (0.10 ~ 0.52)	<0.001
Categories						
Quartile 1	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Quartile 2	0.77 (0.63 ~ 0.93)	0.006	0.78 (0.64 ~ 0.95)	0.015	0.80 (0.66 ~ 0.98)	0.034
Quartile 3	0.75 (0.62 ~ 0.91)	0.003	0.78 (0.64 ~ 0.96)	0.021	0.82 (0.66 ~ 1.01)	0.066
Quartile 4	0.50 (0.41 ~ 0.61)	<0.001	0.54 (0.43 ~ 0.68)	<0.001	0.58 (0.46 ~ 0.74)	<0.001
Sarcopenia						
No	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Yes	1.43 (1.13 ~ 1.81)	0.003	1.54 (1.21 ~ 1.97)	<0.001	1.30 (1.01 ~ 1.67)	0.045
Mixed urinary incontinence						
ASMI	0.03 (0.01 ~ 0.06)	<0.001	0.08 (0.03 ~ 0.20)	<0.001	0.11 (0.04 ~ 0.30)	<0.001
Categories						
Quartile 1	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Quartile 2	0.71 (0.57 ~ 0.89)	0.003	0.79 (0.62 ~ 0.99)	0.043	0.83 (0.65 ~ 1.05)	0.113
Quartile 3	0.62 (0.49 ~ 0.78)	<0.001	0.73 (0.57 ~ 0.94)	0.014	0.79 (0.61 ~ 1.01)	0.065
Quartile 4	0.36 (0.27 ~ 0.46)	<0.001	0.47 (0.35 ~ 0.62)	<0.001	0.52 (0.39 ~ 0.70)	<0.001
Sarcopenia						
No	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Yes	1.77 (1.36 ~ 2.31)	<0.001	1.34 (1.01 ~ 1.78)	0.042	1.44 (1.08 ~ 1.92)	0.013

Notes: Model 1: crude; Model 2: adjusted for Age, Race; Model 3: adjusted for Age, Race, Education Level, Marital Status, Family PIR, smoking, Alcohol, Physical Activity, Menopause status, Diabetes mellitus, Hypertension, Coronary heart disease, Stroke, Cancer.

Abbreviations: ASMI, Appendicular skeletal muscle mass index; PIR, Poverty-to-income ratio; OR, Odds ratio; CI, Confidence interval.

RCS Analysis

The RCS analysis revealed a statistically significant negative correlation between ASMI and SUI ($P < 0.001$) (Figure 2A). Additionally, this relationship's nonlinear trend was not significant ($P\text{-Nonlinear} = 0.609$). This finding indicates that as ASMI increases, there is a gradual decline in the risk of developing SUI, with a linear trend in this reduction. Similarly, the analysis of UII (Figure 2B) revealed a significant negative correlation between ASMI and UII ($P = 0.002$), with the nonlinear character of this relationship also failing to reach statistical significance ($P\text{-Nonlinear} = 0.532$). This suggests that elevated ASMI levels contribute to a reduction in the incidence of UII and that this effect exhibits a stable linear pattern. Moreover, the analysis of MUI (Figure 2C) revealed a significant negative correlation between ASMI and MUI ($P < 0.001$), and again, a nonlinear trend was not observed ($P\text{-Nonlinear} = 0.744$). This finding further corroborates the pivotal role of ASMI in mitigating the risk of MUI, suggesting that the underlying mechanism may also follow a linear trajectory.

Subgroup Analysis

As illustrated in Figure 3, the inverse correlation between ASMI and SUI remained consistently statistically significant ($P < 0.05$) across most demographic categories, including marital status, family PIR, smoking habits, alcohol intake, physical activity, hypertension, and DM status. However, this correlation did not achieve statistical significance ($P > 0.05$) in the specific subgroups of Mexican American individuals, non-Hispanic black individuals, those with less than 9th-grade education, and menopausal women. Notably, no significant interactions were observed between any of the subgroups ($P\text{-value for interaction} > 0.05$), indicating that the effect of ASMI on SUI risk demonstrated relative stability across subgroups. Figure 4 depicts the findings of the subgroup analysis examining the correlation between ASMI and UII. In most subgroups, a significant negative correlation was observed between ASMI and UII ($P < 0.05$). In particular, the subgroup analysis of family income revealed an interaction ($P = 0.008$), with a significant negative correlation between ASMI and UII observed in the high-income subgroup. In contrast, no significant correlation was evident in the middle- and low-income subgroups. No significant interaction was identified between the remaining subgroups ($P\text{-value for interaction} > 0.05$). Figure 5 presents the results of the subgroup analysis of the relationship between ASMI and MUI. A significant negative correlation was observed between ASMI and MUI in several subgroups. Similarly, no significant interactions were observed between all subgroups ($P\text{-value for interaction} > 0.05$).

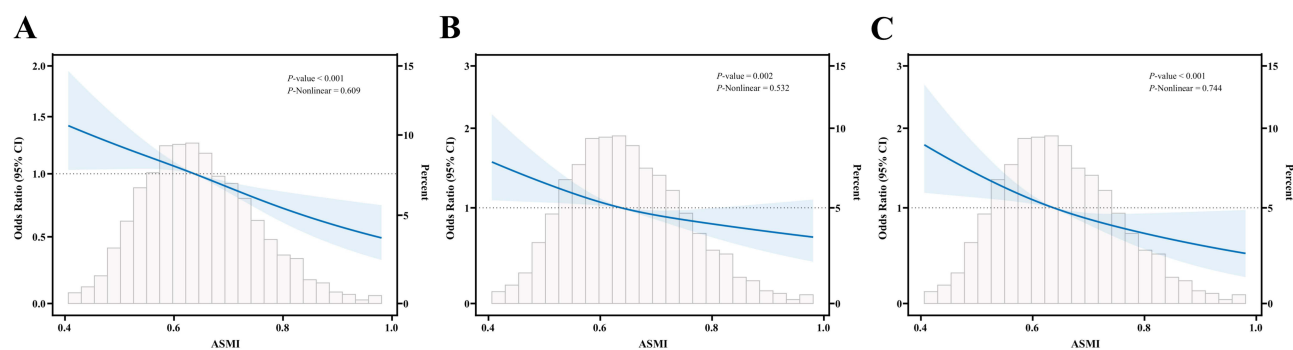


Figure 2 Non-linear relationship between ASMI and SUI (A), UII (B), and MUI (C). The solid line displays the odds ratio, with the 95% CI represented by shading. They were adjusted for age, race, education level, marital status, family PIR, smoking, alcohol, physical activity, menopause status, diabetes mellitus, hypertension, coronary heart disease, stroke, and cancer.

Abbreviations: ASMI, Appendicular skeletal muscle mass index; CI, Confidence interval; PIR, Poverty-to-income ratio; SUI, Stress urinary incontinence; UII, Urgency urinary incontinence; MUI, Mixed urinary incontinence.

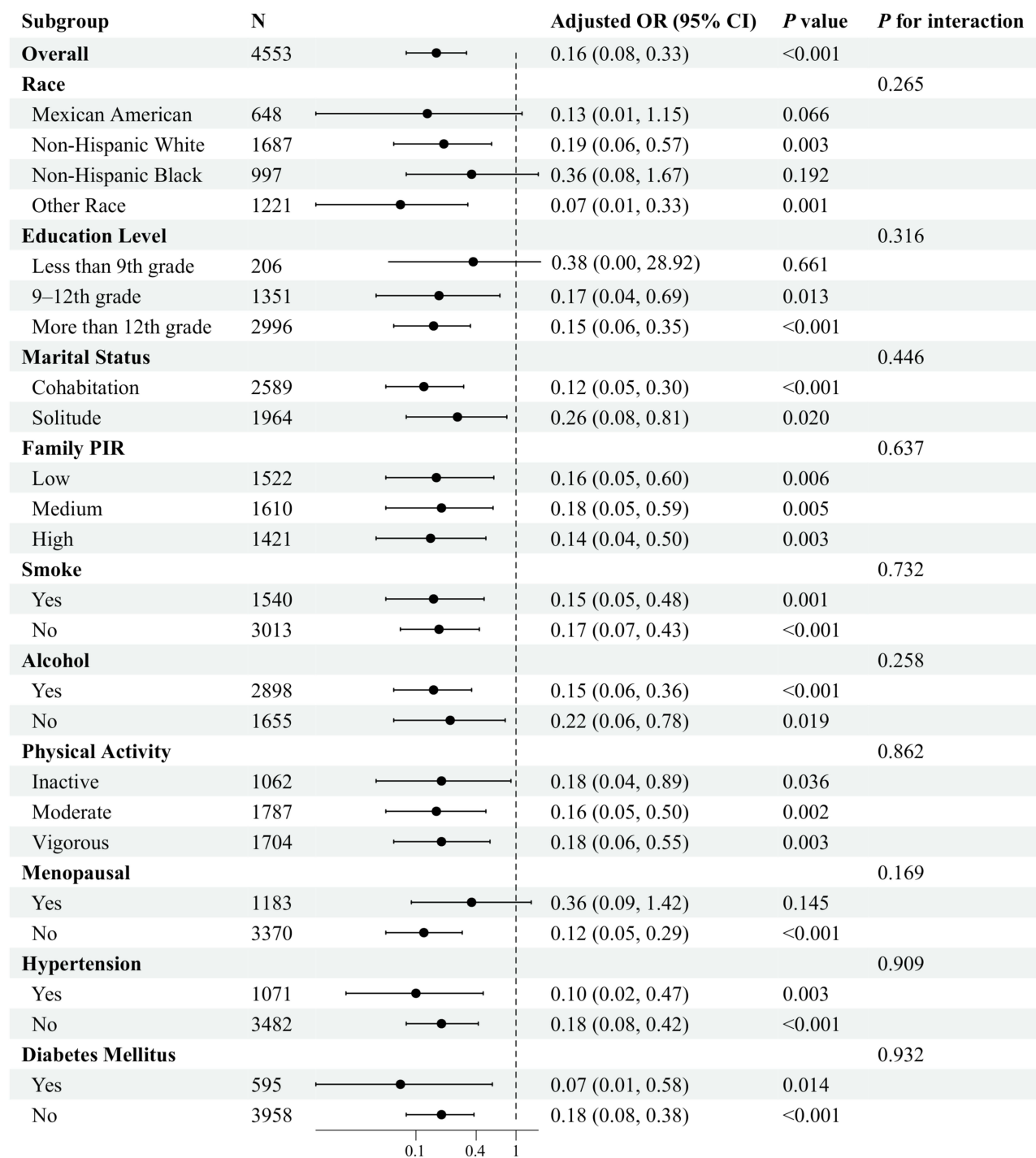


Figure 3 Subgroup analysis of the relationship between ASMI and stress urinary incontinence. Adjusted variables: age, race, education level, marital status, family PIR, smoking, alcohol, physical activity, menopause status, diabetes mellitus, hypertension, coronary heart disease, stroke, and cancer. The model was not adjusted for the stratification variables themselves in the corresponding stratification analysis.

Abbreviations: ASMI, Appendicular skeletal muscle mass index; PIR, Poverty-to-income ratio; OR, odds ratio; CI, confidence interval.

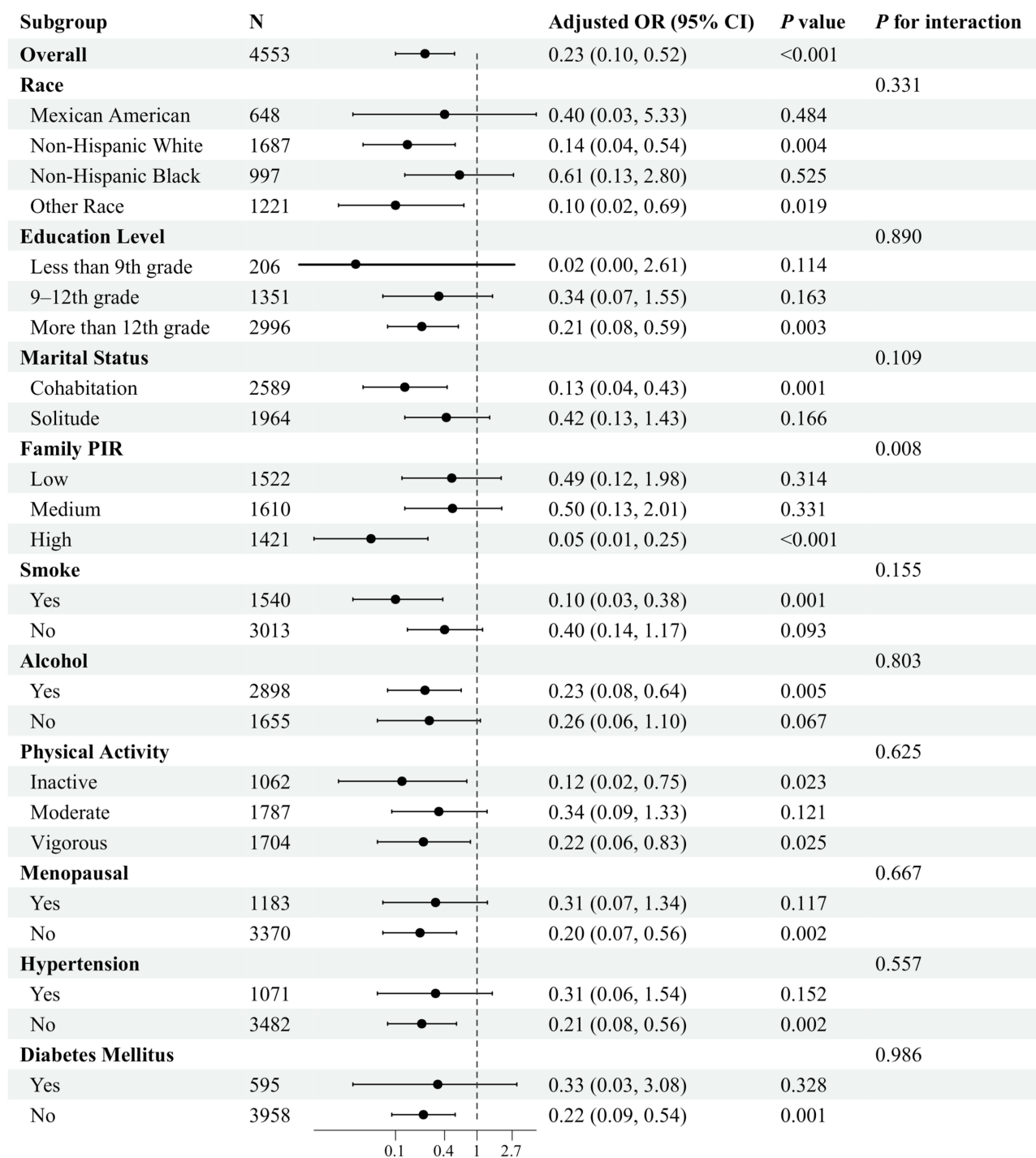


Figure 4 Subgroup analysis of the relationship between ASMI and urgency urinary incontinence. Adjusted variables: age, race, education level, marital status, family PIR, smoking, alcohol, physical activity, menopause status, diabetes mellitus, hypertension, coronary heart disease, stroke, and cancer. The model was not adjusted for the stratification variables themselves in the corresponding stratification analysis.

Abbreviations: ASMI, Appendicular skeletal muscle mass index; PIR, Poverty-to-income ratio; OR, odds ratio; CI, confidence interval.

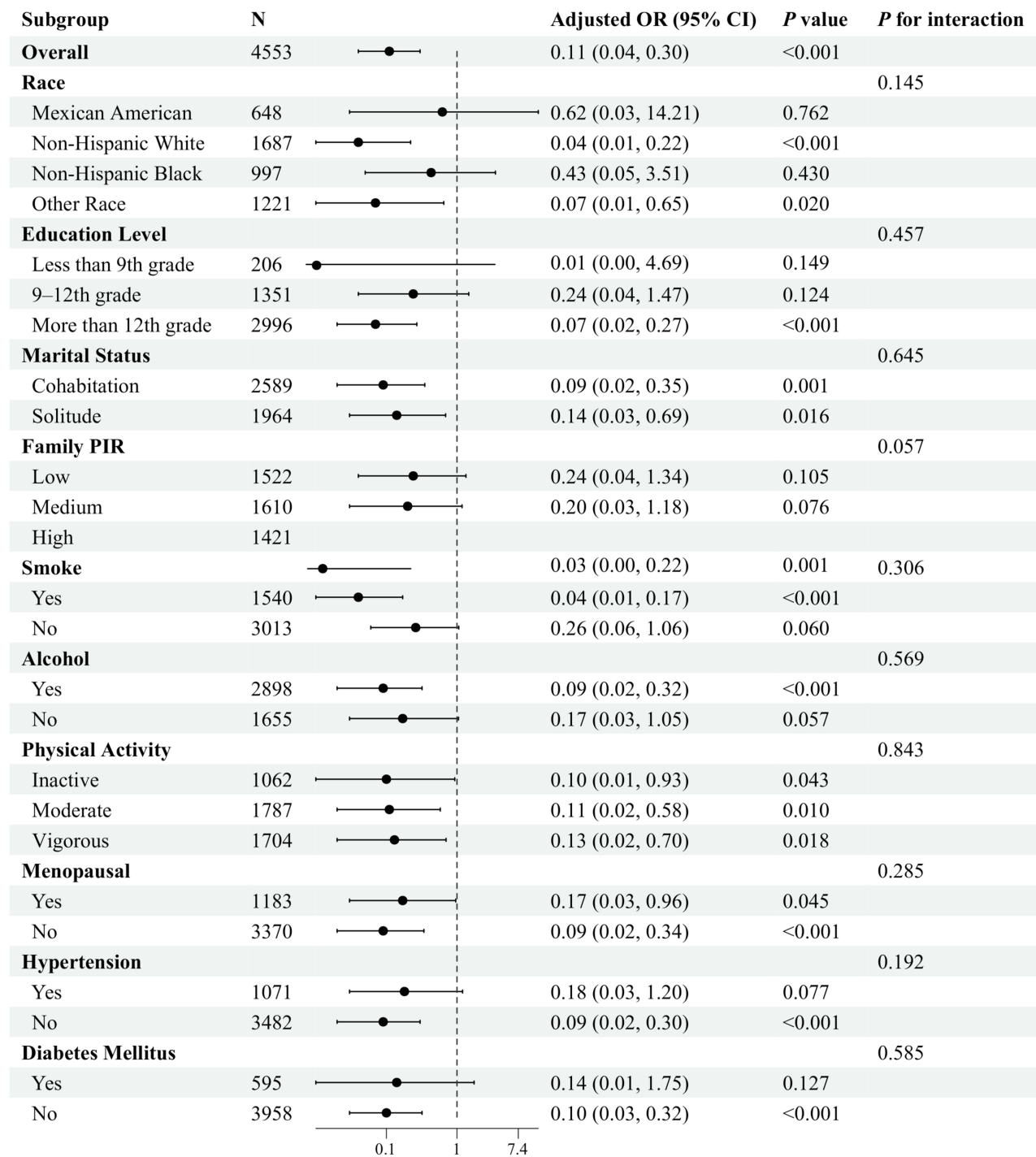


Figure 5 Subgroup analysis of the relationship between ASMI and mixed urinary incontinence. Adjusted variables: age, race, education level, marital status, family PIR, smoking, alcohol, physical activity, menopause status, diabetes mellitus, hypertension, coronary heart disease, stroke, and cancer. The model was not adjusted for the stratification variables themselves in the corresponding stratification analysis.

Abbreviations: ASMI, Appendicular skeletal muscle mass index; PIR, Poverty-to-income ratio; OR, odds ratio; CI, confidence interval.

Discussion

The findings of this study indicated a notable negative correlation between ASMI and the onset of UI. As ASMI decreased, the risk of UI, including SUI, UUI, and MUI, increased significantly. Furthermore, the prevalence of UI was markedly elevated in patients with sarcopenia in comparison to those without sarcopenia. These findings not only corroborate the close association between sarcopenia and UI but also provide new insights into the underlying physiological mechanisms of this association.

Some different mechanisms may explain the relationship between sarcopenia and UI. It is postulated that impaired pelvic floor muscle structure and function, impaired neuromuscular transmission, changes in hormone levels, and lifestyle and habits may play a significant role in the association between sarcopenia and UI. The pelvic floor muscles are vital in maintaining the normal position and function of the bladder and urethra. A reduction in skeletal muscle mass resulting from sarcopenia may directly influence the structure and function of the pelvic floor muscles.^{15,16} As muscle mass diminishes, the pelvic floor muscles may exhibit reduced elasticity and contractility, impairing their capacity to support the bladder and urethra. Such structural and functional impairment may serve to increase the risk of UI. Sarcopenia has been observed to affect not only the muscles themselves but also to hurt neuromuscular conduction.^{17,18} Impairments in neuromuscular transmission may result in a diminished or delayed response of the pelvic floor muscles to bladder filling and voiding commands. Such a weakened or delayed response may serve to exacerbate the symptoms of UI.

Changes in hormone levels have been demonstrated to play an essential role in the development of both sarcopenia and UI. For example, a reduction in postmenopausal estrogen may result in atrophy and dysfunction of the pelvic floor muscles, thereby increasing the risk of UI.^{19,20} Additionally, estrogen deficiency may contribute to the onset of sarcopenia.^{21,22} It can be inferred that alterations in hormone levels may serve as a crucial link between sarcopenia and UI. In this study, the prevalence of both sarcopenia and UI was significantly higher in postmenopausal women. In addition to age, hormone levels may play an essential role in this association. Furthermore, several chronic diseases may influence the relationship between sarcopenia and UI. Prior research conducted by our team has demonstrated a significant correlation between metabolic dysfunction-associated steatotic liver disease and the risk of developing UI in adult women.¹⁴ Lifestyle and habits may also affect the association between sarcopenia and UI.¹⁶ A lack of physical activity and poor dietary habits may reduce muscle mass and atrophy of the pelvic floor muscles, thereby increasing the risk of UI.^{11,23}

Subgroup analyses were conducted to investigate potential variations in the relationship between ASMI and UI across different population characteristics further. The results demonstrated that the inverse relationship between ASMI and UI remained statistically significant in most subgroups. However, in some specific subgroups, the correlation did not reach statistical significance. These findings may be attributed to discrepancies in muscle mass, pelvic floor structure, and the etiology of UI among women of diverse racial backgrounds, educational levels, and physiological states. Furthermore, an interaction effect of family income on the relationship between ASMI and UUI was observed. The negative correlation between ASMI and UUI was significant in the high-income subgroup, whereas no significant correlation was observed in the middle- and low-income subgroups. This suggests that socioeconomic factors may play a role in the pathogenesis of UI and that further investigation of this topic is warranted.

From the clinical application perspective, this study's results provide valuable guidance. In adult women under 60, enhancing muscle mass by evaluating ASMI and implementing appropriate interventions may assist in mitigating the risk of UI. This may not only improve the quality of life for women but also reduce the burden on the healthcare system. Nevertheless, it is essential to acknowledge that the findings of this study require further validation in other populations and that additional research is necessary to elucidate the precise mechanisms through which sarcopenia and UI interact.

It should be noted that this study has limitations. Firstly, the inherent design of the NHANES database limited the study, as it failed to obtain comprehensive assessment data on participants' pelvic floor muscle function (eg, muscle strength, endurance, and electrophysiologic properties). Available evidence suggests a significant association between pelvic floor muscle functional status and the development of UI.²⁴ However, the study could not provide insight into the direct pathophysiologic association between sarcopenia and UI due to the absence of key intermediate variables (ie, pelvic floor muscle function parameters). Secondly, the results of this study may have been influenced by the presence of

other confounding variables that were not included in the model. In future studies, it would be beneficial to employ more comprehensive and detailed assessment methods and consider additional confounding variables to understand better the association between sarcopenia and UI and its underlying mechanism of action.

Conclusion

In conclusion, this study identified a significant negative association between sarcopenia and UI in adult women younger than 60 years of age, thereby providing new insights into the underlying mechanisms between the two. The early identification and intervention of sarcopenia may prove an effective strategy for reducing the risk of UI and improving patients' quality of life. Further research is required to elucidate the precise mechanisms by which sarcopenia and UI interact and to evaluate the efficacy of sarcopenia intervention in preventing UI.

Institutional Review Board Statement

The studies involving humans were approved by the National Center for Health Statistics Ethics Review Board. The participants provided their written informed consent to participate in this study. As NHANES is a publicly accessible database, the Changzhou Third People's Hospital Ethics Committee granted approval to waive ethical review and approved the study protocol (02A-A2024018).

Data Sharing Statement

The National Health and Nutrition Examination Survey dataset is publicly available at the National Center for Health Statistics of the Centers for Disease Control and Prevention (<https://www.cdc.gov/nchs/nhanes/>).

Acknowledgments

We thank the NHANES participants and staff for their contributions.

Author Contributions

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

Funding

This work was supported by the Science and Technology Project of Changzhou [CJ20243023] and the Key Talents Project of Changzhou Third People's Hospital.

Disclosure

The authors declare no conflicts of interest in this study.

References

1. Cruz-Jentoft AJ, Sayer AA. Sarcopenia. *Lancet*. 2019;393(10191):2636–2646. doi:10.1016/S0140-6736(19)31138-9
2. Sayer AA, Cooper R, Arai H, et al. Sarcopenia. *Nat Rev Dis Primers*. 2024;10(1):68. doi:10.1038/s41572-024-00550-w
3. Petermann-Rocha F, Balntzi V, Gray SR, et al. Global prevalence of sarcopenia and severe sarcopenia: a systematic review and meta-analysis. *J Cachexia Sarcopenia Muscle*. 2022;13(1):86–99. doi:10.1002/jcsm.12783
4. Vaughan CP, Markland AD. Urinary Incontinence in Women. *Ann Intern Med*. 2020;172(3):Itc17–itc32. doi:10.7326/AITC202002040
5. Abufaraj M, Xu T, Cao C, et al. Prevalence and trends in urinary incontinence among women in the United States, 2005–2018. *Am J Obstet Gynecol*. 2021;225(2):166.e1–166.e12. doi:10.1016/j.ajog.2021.03.016
6. Aoki Y, Brown HW, Brubaker L, Cornu JN, Daly JO, Cartwright R. Urinary incontinence in women. *Nat Rev Dis Primers*. 2017;3:17042. doi:10.1038/nrdp.2017.42
7. Yuan S, Larsson SC. Epidemiology of sarcopenia: prevalence, risk factors, and consequences. *Metabolism*. 2023;144:155533. doi:10.1016/j.metabol.2023.155533
8. Wu JM. Stress incontinence in women. *N Engl J Med*. 2021;384(25):2428–2436. doi:10.1056/NEJMcp1914037

9. Erdogan T, Bahat G, Kilic C, et al. The relationship between sarcopenia and urinary incontinence. *Eur Geriatr Med.* 2019;10(6):923–929. doi:10.1007/s41999-019-00232-x
10. Jerez-Roig J, Farrés-Godayol P, Yildirim M, et al. Prevalence of urinary incontinence and associated factors in nursing homes: a multicentre cross-sectional study. *BMC Geriatr.* 2024;24(1):169. doi:10.1186/s12877-024-04748-1
11. Escribà-Salvans A, Jerez-Roig J, Molas-Tuneu M, et al. Sarcopenia and associated factors according to the EWGSOP2 criteria in older people living in nursing homes: a cross-sectional study. *BMC Geriatr.* 2022;22(1):350. doi:10.1186/s12877-022-02827-9
12. Kakehi S, Wakabayashi H, Isono E, et al. Association between sarcopenia and urinary dysfunction in patients with dysphagia. *Arch Gerontol Geriatr.* 2024;127:105577. doi:10.1016/j.archger.2024.105577
13. Studenski SA, Peters KW, Alley DE, et al. The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. *J Gerontol a Biol Sci Med Sci.* 2014;69(5):547–558. doi:10.1093/gerona/glu010
14. Zhang F, Li W. Correlation between metabolic dysfunction-associated steatotic liver disease and the risk of urinary incontinence in adult women. *Int J Women's Health.* 2024;16:1607–1624. doi:10.2147/IJWH.S489959
15. Bag Soytaş R, Soytaş M, Danacıoğlu YO, et al. Relationship between the types of urinary incontinence, handgrip strength, and pelvic floor muscle strength in adult women. *NeuroUrol Urodyn.* 2021;40(6):1532–1538. doi:10.1002/nau.24699
16. Grosman Y, Kalichman L. Bidirectional relationships between sarcopenia and pelvic floor disorders. *Int J Environ Res Public Health.* 2024;21(7):879. doi:10.3390/ijerph21070879
17. Ryall JG, Schertzer JD, Lynch GS. Cellular and molecular mechanisms underlying age-related skeletal muscle wasting and weakness. *Biogerontology.* 2008;9(4):213–228. doi:10.1007/s10522-008-9131-0
18. Iyer SR, Shah SB, Lovering RM. The neuromuscular junction: roles in aging and neuromuscular disease. *Int J mol Sci.* 2021;22(15):8058. doi:10.3390/ijms22158058
19. Huang H, Ding G, Li M, Deng Y, Cheng Y, Jin H. Menopause and stress urinary incontinence: the risk factors of stress urinary incontinence in perimenopausal and postmenopausal women. *J Obstet Gynaecol Res.* 2023;49(10):2509–2518. doi:10.1111/jog.15742
20. Russo E, Caretto M, Giannini A, et al. Management of urinary incontinence in postmenopausal women: an EMAS clinical guide. *Maturitas.* 2021;143:223–230. doi:10.1016/j.maturitas.2020.09.005
21. Lu L, Tian L. Postmenopausal osteoporosis coexisting with sarcopenia: the role and mechanisms of estrogen. *J Endocrinol.* 2023;259(1):e230116. doi:10.1530/JOE-23-0116
22. Yoh K, Ikeda K, Horie K, Inoue S. Roles of estrogen, estrogen receptors, and estrogen-related receptors in skeletal muscle: regulation of mitochondrial function. *Int J mol Sci.* 2023;24(3):1853. doi:10.3390/ijms24031853
23. Peinado-Molina RA, Martínez-Vázquez S, Hernández-Martínez A, Martínez-Galiano JM. Impact and influence of urinary incontinence on physical activity levels. *Eur Urol Open Sci.* 2023;55:50–58. doi:10.1016/j.euros.2023.07.004
24. Sahiner Z, Mangır N, Güner M, et al. The relationship between urinary incontinence and abdominal muscle thickness in community-dwelling older women undergoing comprehensive geriatric assessment. *Eur Geriatr Med.* 2023;14(6):1319–1325. doi:10.1007/s41999-023-00874-y

International Journal of Women's Health

Publish your work in this journal

The International Journal of Women's Health is an international, peer-reviewed open-access journal publishing original research, reports, editorials, reviews and commentaries on all aspects of women's healthcare including gynecology, obstetrics, and breast cancer. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/international-journal-of-womens-health-journal>

Dovepress
Taylor & Francis Group