Journal of Health, Population and Nutrition

RESEARCH

Open Access

The relationship between dietary live microbe intake and overactive bladder among American adults: a cross-sectional study from NHANES 2007–2018

Yuan-Zhuo Du[1,2†], Hong-Ji Hu[1,2†], Qian-Xi Dong[1,2†], Biao Guo[1,2], Qiang Zhou[1,2*] and Ju Guo[1,2*]

Abstract

Objective The underlying mechanisms of Overactive Bladder (OAB) remain unclear. This research is designed to investigate the correlation between the intake of dietary live microorganisms and OAB.

Methods This analysis encompasses a cross-sectional study of broad population information gathered from the National Health and Nutrition Examination Surveys (NHANES) spanning the years 2007 to 2018. Participants were categorized into three groups—low, medium, and high—according to their consumption of dietary live microorganisms, as per the Sanders Dietary Active Microbiota Classification System. We utilized a weighted logistic regression model, restricted cubic spline (RCS), and subgroup analyses to investigate the relationship between dietary live microorganism intake and OAB.

Results This research encompassed 16,795 subjects. The incidence of OAB was reduced in the group consuming a high amount of live dietary microbes compared to the groups with low and medium intake of such microbes. After detailed adjustments for covariates, analysis revealed that participants in the high live dietary microbe group had notably reduced odds of OAB compared to those in the low live dietary microbe group (OR: 0.84, 95% CI: 0.71–0.99, $p = 0.03$). RCS analysis indicated a nonlinear correlation between high dietary active microbiota intake and the incidence of OAB.

Conclusion This research emphasizes the potential advantages of a high dietary intake of active microbiota for preventing OAB. These findings support incorporating active microbiota into dietary guidelines, demonstrating their connection with a decreased incidence of OAB.

Keywords Dietary live microbe, Overactive bladder, Nocturia, Urge urinary incontinence, NHANES

†Yuan-Zhuo Du, Hong-Ji Hu and Qian-Xi Dong are co-first authors.

*Correspondence:
Qiang Zhou
suisui0706@163.com
Ju Guo
ndyfy02371@ncu.edu.cn
[1]Department of Urology, The First Affiliated Hospital, Jiangxi Medical College, Nanchang University, Nanchang 330000, Jiangxi Province, China
[2]Jiangxi Institute of Urology, Nanchang 330000, Jiangxi Province, China

Introduction

Overactive Bladder (OAB) is defined by the urgent need to urinate, which may or may not be accompanied by incontinence, and often includes frequent urination and nocturia [1]. Research identifies various complex risk factors for OAB including urinary tract infections, physical activity, chronic diseases, and neuropsychiatric conditions such as sleep disorders and depression [2, 3]. OAB is prevalent in both genders, albeit with gender-specific differences, but the overall incidence increases with age and is similar between sexes [4, 5]. In clinical settings, OAB management focuses on long-term comprehensive treatments aimed at alleviating symptoms. Currently, the pharmacological management of OAB typically involves either anticholinergics or β3-adrenoceptor agonists as standalone therapies. While some research supports better outcomes with combination therapies, the effectiveness and specific approaches still require further investigation [6, 7].

Recently, dietary active microorganisms have drawn increasing attention for their roles in immune regulation, circulatory system modulation, and mental health aspects such as anxiety, depression, and autism [8–10]. The concept of the "gut microbiota-gut-brain axis" has become particularly prominent, highlighting how gut microbiota influence central nervous system functions. Foods that introduce beneficial microbes into the gut help maintain a healthy microbiome, enhancing overall health [10, 11]. Prebiotics, as substrates for these beneficial microbes, are crucial in promoting the growth and activity of healthy gut flora [12]. By fermenting prebiotics, gut bacteria produce short-chain fatty acids that may regulate energy balance and glucose metabolism, influencing dietary patterns [13]. This interaction between prebiotics and gut flora potentially contributes to the management of OAB by promoting a dietary pattern that supports gut health and reduces inflammation, which is often seen in patients with OAB. Conversely, the Western diet, known for its high unhealthy fat and low fruit and vegetable content, is infamous for its association with obesity [2, 14, 15]. These findings indicate that dietary habits may influence the development of OAB.

While the pathogenesis of OAB remains incompletely understood and is thought to be multifactorial [16, 17], there have been no studies investigating the link between dietary live microorganisms and OAB. Therefore, our study aims to explore this potential connection through a cross-sectional analysis using data from the National Health and Nutrition Examination Survey (NHANES).

Methods

Study population

This research utilized data from the NHANES, a recurring survey project initiative aimed at evaluating the health and nutritional status of residents in the U.S. Each year, NHANES comprehensively collects health and nutrition-related data from about 5,000 Americans, encompassing demographics, socioeconomic status, dietary habits, and overall health conditions. The data collection involves both face-to-face interviews and thorough physical examinations, which include physiological measurements and lab tests. All participants gave informed consent, with the study design and consent process approved from the Ethics Committee of the National Center for Health Statistics.

For this cross-sectional analysis, data spanning from 2007 to 2018 were extracted from the NHANES database [18]. The selection process for participants was rigorously defined to enhance the representativeness of the study sample. The initial cohort consisted of 59,842 individuals. Inclusion criteria targeted adults aged 20 and above, aligning with our study objectives. Exclusion criteria were systematically applied: individuals below the age of 20 (n=25,072) were excluded, as were those missing essential data on OAB (n=4,983), those without data on intake of dietary live microorganisms (n=1,134), and those lacking significant covariate information (n=11,858). After applying these criteria, 16,795 participants were deemed eligible and included in the final analysis (Fig. 1). These stringent selection criteria were implemented to minimize bias and maximize the reliability of our findings, ensuring that the final sample closely mirrors the broader U.S. population in terms of demographic and health characteristics.

Dietary intake and categories of live microorganisms

The dietary intake and classification of live microorganisms were assessed using the 24-hour dietary recall data sourced from the NHANES. This method involves participants recalling and reporting all foods and beverages consumed in the 24 h prior to the interview. Each participant's recall is conducted by trained interviewers using automated data entry systems that prompt for detailed information on each food item consumed, ensuring comprehensive dietary data collection. To ensure the accuracy of our live microorganism intake data, we engaged four specialists with extensive expertise in microbiology and food science. These experts, identified by their initials (MLM, MES, RH, CH), hold advanced degrees in microbiology, biochemistry, and food science, and possess considerable experience in both academic and applied research settings. Their roles involved meticulously evaluating and categorizing the concentrations of live microorganisms (CFU/g) across 9,388 food entries into 48 distinct categories within the NHANES database. These values were primarily reported in the literature and were supplemented with laboratory analyses where necessary [19].

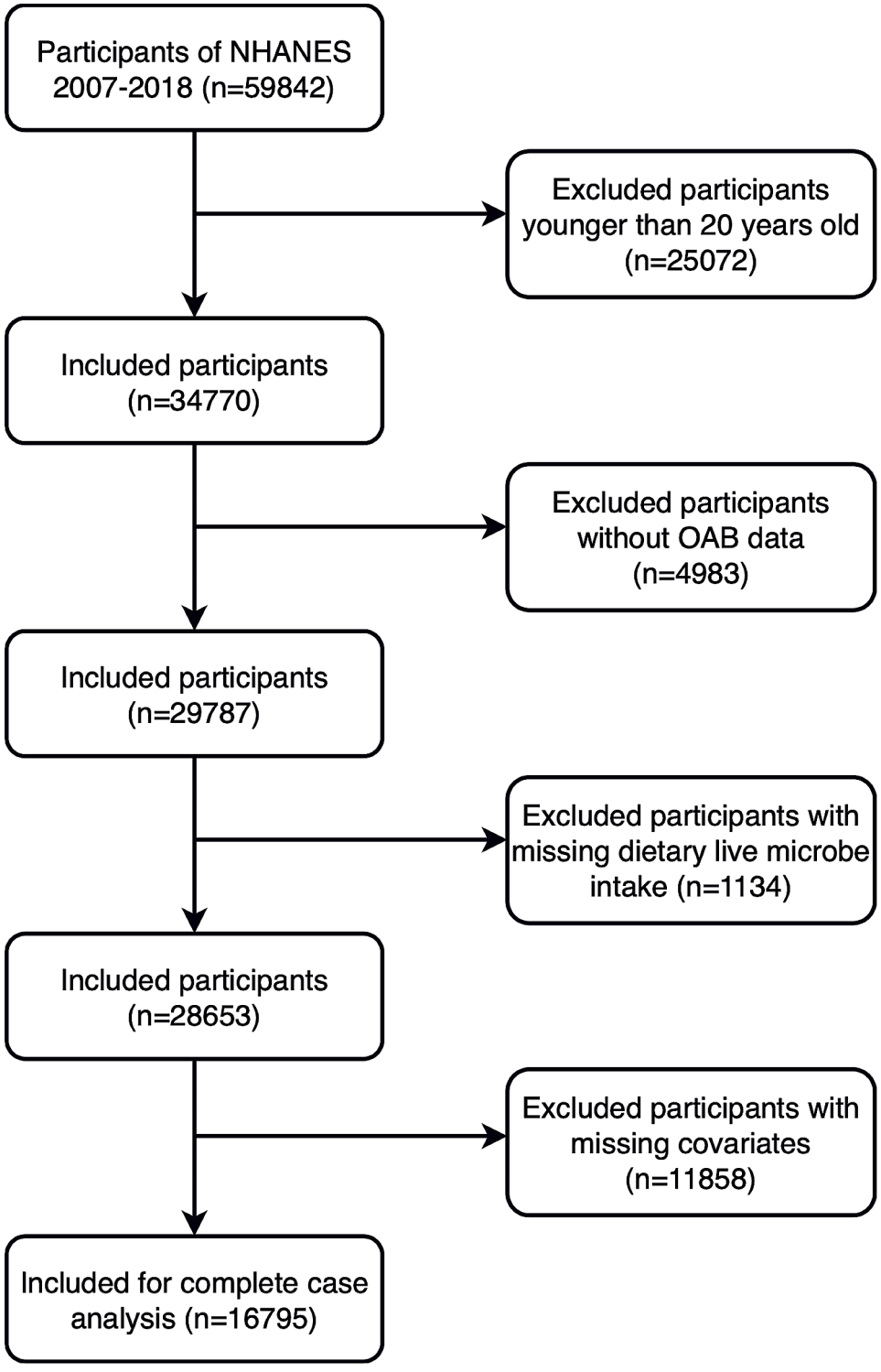

Fig. 1 The participant flow chart

The specialists classified microbial levels into three categories based on the concentration of viable microorganisms per gram of food: low (less than 10^4 CFU/g), moderate (10^4–10^7 CFU/g), or high (greater than 10^7 CFU/g). This classification was validated through a consensus process involving repeated evaluations and cross-references with external microbial databases. In instances of uncertain or conflicting data, external consultation was sought for resolution, involving experts from relevant fields to ensure the reliability and

consistency of the categorization. This included consultations with recognized experts such as Fred Breidt from the USDA Agricultural Research Service.

Prior to the study, these specialists underwent comprehensive training that included standardized protocols for microbial analysis, updates on recent advances in microbial assessment techniques, and familiarization with specific challenges associated with different food types. This preparation ensured that each team member's approach was aligned with the latest scientific standards and methodologies.

The low category predominantly consists of foods treated with pasteurization, the moderate category primarily comprises unpeeled fresh fruits and vegetables, and the high category includes unpasteurized fermented foods and probiotic supplements. Although this classification method can be applied to estimate microbial content in foods, its applicability to estimating overall dietary intake of live microorganisms may be limited. Following the validated methodology of Sanders et al. [19], participants were grouped into three categories according to the total amount of live microorganisms ingested from all foods: (1) a group with low dietary microbe intake (consisting solely of foods with low levels), (2) a group with moderate dietary microbe intake (consuming foods with moderate levels but not high levels), and (3) a group with high dietary microbe intake (consuming any foods with high levels). This previously verified method categorizes participants' dietary patterns according to estimated levels of live microorganisms [20].

This 24-hour dietary recall data collection methodology is utilized in NHANES to capture a snapshot of each participant's diet, which provides a detailed record of intake but limits the ability to capture habitual long-term dietary patterns. Future studies might benefit from employing multiple dietary recalls or food frequency questionnaires to better capture long-term dietary trends and their relationship to health outcomes like OAB.

Diagnosis of overactive bladder

In this study, OAB was characterized by the simultaneous presence of urinary frequency, urge urinary incontinence (UUI), and nocturia. Data collection involved both direct interviews and questionnaire surveys, conducted by research personnel trained to ensure consistency and accuracy in data gathering. The assessment of UUI involved querying participants with: "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?" followed by "How frequently does this occur?" The frequency of these incidents was also recorded to assess the severity of UUI. For nocturia, participants were asked: "During the past 30 days, how many times per night did you most typically get up to urinate, from the time you went to bed at night until the time you got up in the morning?" The responses were used to score the nocturia component of the OAB assessment.

The overall severity of OAB was quantified using the Overactive Bladder Symptom Score (OABSS). As depicted in Fig. 2 of our manuscript, this scoring system evaluates symptoms on a scale from 0 (no symptoms) to 3 (severe symptoms) for both nocturia and UUI. The scores from these categories are then combined, with a total score of 3 or higher indicating the presence of OAB [21]. This threshold was chosen to ensure that only patients with clinically significant symptoms are diagnosed with OAB. While the OABSS facilitates a standardized approach to diagnosing OAB, it should be noted that our study did not explore varying levels of symptom severity beyond the threshold for diagnosis. Our focus was primarily on establishing whether participants met the criteria for OAB, rather than on grading the severity of the condition among those diagnosed. This methodology allows us to uniformly identify patients with OAB for inclusion in the study, providing a clear distinction between affected and unaffected individuals based on a validated and widely recognized scoring system.

Covariates

In this study, we comprehensively considered a range of covariates related to the risk of kidney stones, which are categorized into three major classes: demographic indicators, lifestyle factors, and health status. Demographic indicators include age, gender, race, marital status, level of education, and poverty rate. Lifestyle factors encompass alcohol consumption (categorized as 'no' for <12 drinks in the past year, 'yes' for ≥ 12 drinks) [22], smoking status (determined by a history of smoking over 100 cigarettes), sedentary time (whether sitting for over 5 h per day), and physical activity level (evaluated based on the duration of moderate to vigorous activity for at least 10 min per week, excluding daily work and commuting tasks; less than 10 min is defined as inactive) [23]. Regarding health indicators, we collected body mass index (BMI), estimated glomerular filtration rate (eGFR), diabetes, hypertension, hyperlipidemia, and cardiovascular disease (CVD) through standardized questionnaires and clinical assessments [24].

Statistical analysis

In this study, NHANES sampling weights were employed to calculate statistically representative estimates for the U.S. population. For continuous variables, weighted means and standard errors were presented; for categorical variables, weighted counts and proportions were provided. Weighted linear regression was conducted for continuous variables, and weighted chi-square tests for

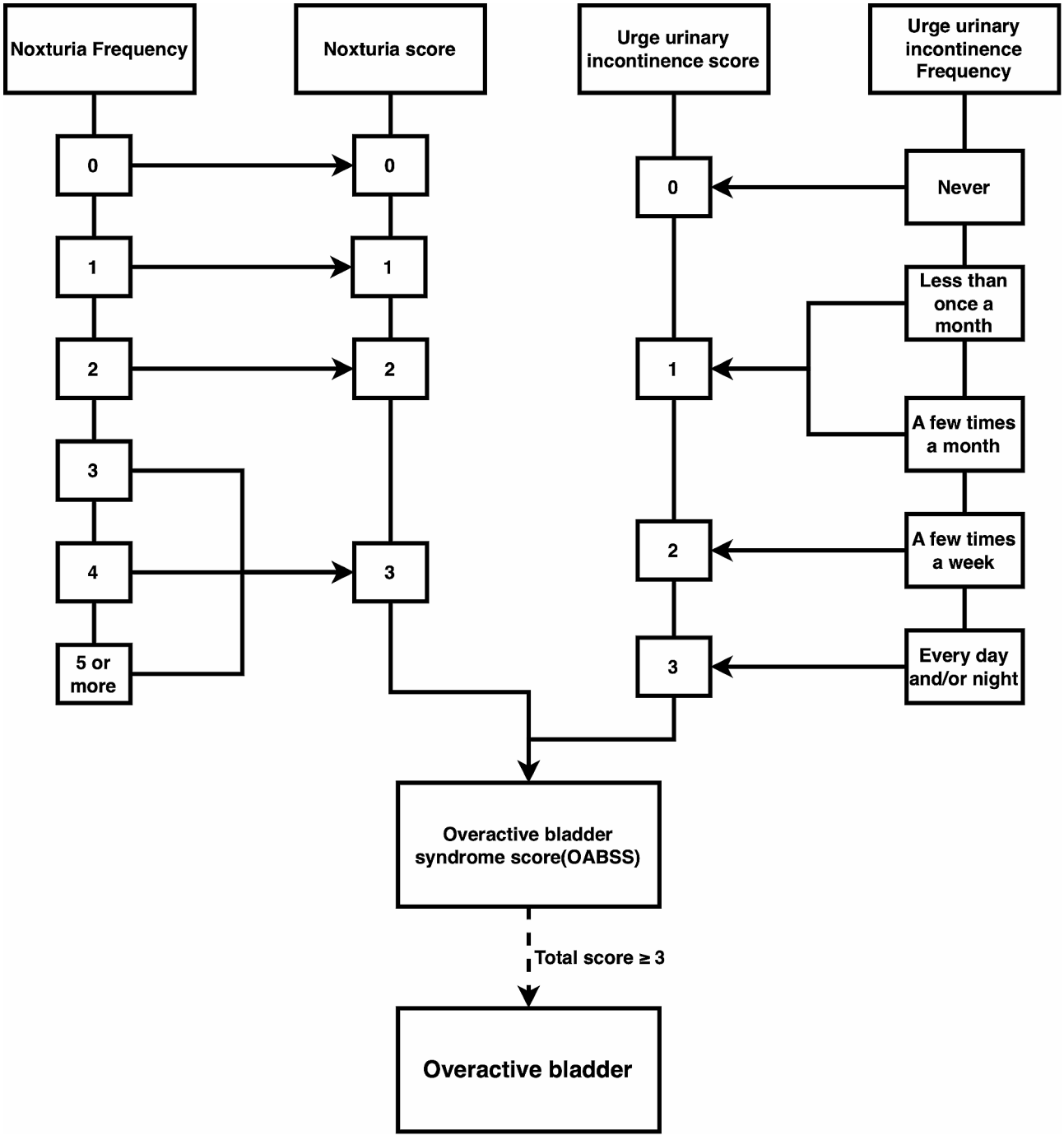

Fig. 2 Flowchart for diagnosing overactive bladder based on overactive bladder syndrome scores

categorical variables, aligning with the complex survey design of NHANES.

To explore the relationship between dietary intake of live microorganisms and the occurrence of OAB, a multivariable logistic regression model was applied. This model was specifically chosen due to its suitability for examining associations between a binary outcome (presence or absence of OAB) and multiple predictor variables, which allows for estimating the odds ratios (ORs) and their 95% confidence intervals (CIs) effectively.

Crude Model: This unadjusted model serves as a foundational comparison, illustrating the relationship without the influence of confounding factors. Model 1: Adjusted for demographic variables such as age, gender, race, education level, marital status, and income level, to control for potential socio-demographic influences on dietary

habits and health outcomes. Model 2: Enhanced with adjustments for lifestyle and health-related variables including smoking status, alcohol consumption, BMI, eGFR, sedentary time, physical activity level, hypertension, diabetes, hyperlipidemia, and CVD. These factors were included to account for potential independent effects on both dietary microbe intake and OAB risk, providing a more precise estimation of the relationship.

Restricted Cubic Spline (RCS) Regression Models were utilized to examine the dose-response relationship between high dietary intake of live microorganisms and OAB risk. This method helps in identifying possible nonlinear interactions and offers a granular view of the diet-OAB relationship. Subgroup analyses were performed to evaluate the robustness of the results across varying demographic characteristics and health conditions, ensuring the generalizability of the findings across diverse subpopulations. All analyses were conducted using R software (version 4.3.2), with statistical significance set at $P<0.05$, affirming the robustness and statistical validity of the findings.

Results

Participants' baseline characteristics

The present study comprised 16,795 participants from NHANES. In Table 1, participants were grouped according to the diagnosis of OAB, and all indicators between the two groups, except for sedentary time, showed differences. Compared to participants without OAB, the patient group diagnosed with OAB exhibited higher age, female gender, non-Hispanic black ethnicity, single status (divorced/separated/widowed), lower educational level, lower poverty rate, higher BMI, smoking, no alcohol consumption, less physical activity, a higher likelihood of having hypertension, diabetes, hyperlipidemia, CVD history, and lower eGFR. Additionally, patients diagnosed with OAB exhibited a higher probability of belonging to the low and medium categories of dietary intake of live microorganisms.

Baseline characteristics of individuals in various dietary live microbe groups

Table 2 presents the initial profiles of patients, grouped according to their intake of dietary live microbes. Participants were sorted into three categories based on their dietary live microbe consumption: low ($n=5807$), medium ($n=6797$), and high ($n=4191$) intake groups, with differences observed in all indicators except for hypertension, hyperlipidemia, and UUI. The high intake group of dietary live microbes, relative to the low and medium intake groups, tended to include individuals who were 60 years or older, female, non-Hispanic white, married/living with a partner, with higher education. They also generally had higher poverty rate, lower BMI, did not smoke, abstained from alcohol, engaged in more physical activity, spent more time sedentary, were less likely to have a history of diabetes, no history of CVD, and lower eGFR. Additionally, the high dietary live microbe group showed a reduced likelihood of experiencing nocturia and OAB.

Association between OAB and different dietary live microbe groups

Using weighted single-variable and multiple-variable logistic regression analyses, the study probed the direct links between groups categorized by groups of dietary live microbe consumption and the incidence of OAB. As shown in Table 3, in the unadjusted model, high dietary live microbe intake was associated with a reduced risk of OAB (OR=0.76, 95% CI: 0.66–0.87). Even after comprehensive adjustment in Model 2, the association persisted, showing that the high dietary live microbe intake group maintained a reduced risk of OAB relative to the low intake group (OR=0.84, 95% CI: 0.71–0.99). However, no significant correlation was observed between medium and lower levels of dietary live microbe consumption in relation to OAB incidence. RCS revealed a nonlinear association between high dietary live microbe intake and OAB risk ($P<0.01$) (Fig. 3).

Subgroup and sensitivity analysis

Furthermore, subgroup analysis was conducted to explore whether covariates influenced the relationship between different dietary live microbe intake groups and OAB incidence. The findings depicted in Fig. 4 show that this association was influenced by having hyperlipidemia ($P<0.05$). It is noteworthy that, except for grouping by age, race, hypertension, diabetes, hypertension, and CVD, in other subgroupings, the high intake group of dietary live microbes demonstrated a reduced incidence of OAB in comparison to the low intake group.

In summary, the sensitivity analysis demonstrates stability, as detailed in Table 4. By removing individuals with diabetes from the analysis, the fully adjusted outcomes of the multivariate logistic regression model are consistent with the principal results.

Discussion

In this study, we explored the correlation between the consumption of active microbes in the diet and the incidence of adult OAB through the comprehensive analysis of NHANES from 2007 to 2018. The findings suggest a notable correlation between high dietary consumption of active microbes and a lower incidence of OAB. To validate the universality of these correlations, we employed stratified analysis, which confirmed the consistency of the protective effects across different subgroups within the American adult population. Therefore, it is reasonable

Table 1 Baseline characteristics of the study population by OAB

Variable	Overall (*n* = 23708)	Without OAB (*n* = 14007)	With OAB (*n* = 2788)	*P*-value
Age, y, mean (SE)	45.52(0.28)	44.02(0.28)	55.65(0.46)	< 0.0001
Age strata, y, n (%)				< 0.0001
20–39	6537(39.72)	6052(42.83)	485(18.75)	
40–59	5765(38.54)	4835(38.71)	930(37.42)	
≥60	4493(21.73)	3120(18.46)	1373(43.83)	
Sex, n (%)				< 0.0001
Female	7908(48.65)	6354(46.90)	1554(60.44)	
Male	8887(51.35)	7653(53.10)	1234(39.56)	
Race, n (%)				< 0.0001
Mexican American	2394(7.80)	2024(7.93)	370(6.90)	
Non-Hispanic White	7751(71.27)	6566(71.82)	1185(67.58)	
Non-Hispanic Black	3293(9.44)	2490(8.43)	803(16.27)	
Other Hispanic	1619(5.10)	1344(5.11)	275(5.05)	
Other Race	1738(6.38)	1583(6.71)	155(4.20)	
Marital status, n (%)				< 0.0001
Divorced/Separated/Widowed	3312(16.70)	2410(15.10)	902(27.47)	
Married/Living with a partner	10,104(64.12)	8609(64.70)	1495(60.24)	
Never married	3379(19.18)	2988(20.20)	391(12.29)	
Education levels, n (%)				< 0.0001
High school and below	6751(32.88)	5327(31.29)	1424(43.61)	
Above high school	10,044(67.12)	8680(68.71)	1364(56.39)	
Poverty ratio, n (%)				< 0.0001
<1.3	4584(17.90)	3621(16.94)	963(24.38)	
1.3–3.5	6227(33.92)	5123(33.24)	1104(38.50)	
>3.5	5984(48.18)	5263(49.82)	721(37.13)	
BMI, n (%)				< 0.0001
<25	4933(30.29)	4367(31.81)	566(20.00)	
25-29.99	5588(33.15)	4747(33.51)	841(30.69)	
≥30	6274(36.56)	4893(34.68)	1381(49.31)	
Smoke, n (%)				< 0.0001
No	8692(53.35)	7497(54.66)	1195(44.49)	
Yes	8103(46.65)	6510(45.34)	1593(55.51)	
Alcohol user, n (%)				< 0.0001
No	6101(35.81)	4949(34.59)	1152(44.06)	
Yes	10,694(64.19)	9058(65.41)	1636(55.94)	
Moderate recreational activity, n (%)				< 0.0001
No	7827(41.01)	6127(38.70)	1700(56.62)	
Yes	8968(58.99)	7880(61.30)	1088(43.38)	
Sitting time, n (%)				0.96
<5	6702(36.19)	5605(36.19)	1097(36.25)	
≥5	10,093(63.81)	8402(63.81)	1691(63.75)	
Hypertension, n (%)				< 0.0001
No	11,395(71.02)	10,098(74.05)	1297(50.51)	
Yes	5400(28.98)	3909(25.95)	1491(49.49)	
Diabetes, n (%)				< 0.0001
No	14,814(90.74)	12,691(92.46)	2123(79.08)	
Borderline	347(1.81)	255(1.60)	92(3.25)	
Yes	1634(7.45)	1061(5.94)	573(17.67)	
Hyperlipidemia, n (%)				< 0.0001
No	5155(31.37)	4570(32.97)	585(20.52)	
Yes	11,640(68.63)	9437(67.03)	2203(79.48)	
CVD, n (%)				< 0.0001
No	16,428(98.50)	13,788(98.91)	2640(95.72)	

Table 1 (continued)

Variable	Overall (*n* = 23708)	Without OAB (*n* = 14007)	With OAB (*n* = 2788)	*P*-value
Yes	367(1.50)	219(1.09)	148(4.28)	
eGFR (mL/min), mean (SE)	96.04(0.35)	97.16(0.35)	88.47(0.68)	< 0.0001
Dietary live microbe group, n (%)				< 0.001
Low	5807(31.15)	4748(30.66)	1059(34.44)	
Medium	6797(38.77)	5679(38.66)	1118(39.51)	
High	4191(30.09)	3580(30.68)	611(26.05)	

BMI Body mass index, eGFR estimated glomerular filtration rate, CVD Cardiovascular Disease, OAB Overactive bladder

to hypothesize that a diet high in active microbes may reduce the incidence of OAB in the population. Moreover, this protective effect implies guidance in the long-term comprehensive treatment of OAB patients.

However, despite these promising findings, the applicability of our results to populations outside of the United States remains to be determined. Future research should specifically focus on replicating this study in diverse international settings to explore the potential influence of varying dietary habits and microbiome compositions on the incidence of OAB. Such studies will be crucial in establishing the global relevance of our findings and in understanding how different cultural and environmental factors may affect the relationship between diet and OAB.

Our findings contribute to the growing body of literature emphasizing the pivotal role of diet in the management of OAB. Consistent with prior research [17, 25–27], our results reinforce the concept that micronutrient intake, specifically vitamin D, potassium, and protein, can significantly impact OAB outcomes. While these nutrients have been traditionally highlighted, our study uniquely focuses on the broader impact of dietary microbes on OAB, extending the discussion beyond single nutrients to consider dietary patterns. Previous investigations have demonstrated a correlation between high-fat and high-sugar diets and the increased incidence of OAB [2, 15]. These findings align with our observations that diets rich in active microbes—typically abundant in vegetables, fruits, and dairy products—tend to be associated with a lower prevalence of OAB. This suggests a potential protective role of these diets, which is further supported by the inverse relationship we observed between microbial-rich diets and OAB symptoms. Furthermore, the study by Demirbas et al. [28]. , which reported that 61.4% of OAB patients had acidic urine, complements our findings regarding the impact of diet on urine pH levels. Our study extends this by showing that diets high in active microbes can modulate urine acidity, potentially influencing OAB dynamics. This aligns with broader dietary impacts, such as those from Western diets characterized by high fat and protein intake, which are known to lower urine pH and are associated with increased OAB risk [29–31].

The gut microbiota constitutes a group of microorganisms living in the digestive tract that play a crucial role in the host's health and disease [32]. Although our stratified analysis considered the influence of different populations on the association between dietary microbe intake and OAB, variations in dietary habits across different demographic groups may lead to variations in OAB prevalence. For instance, demographic characteristics such as age, gender, ethnicity, and geographical location might significantly influence dietary preferences and digestive functions, which in turn affect the composition and diversity of the gut microbiota. Additionally, populations from different cultural and geographic backgrounds may adopt different dietary patterns, further influencing the epidemiological characteristics of OAB. For example, a Mediterranean diet, rich in fibers, fruits, and olive oil, might promote a higher diversity of gut microbiota compared to a Western diet predominantly consisting of processed foods [33], potentially playing different roles in OAB management. Additionally, the antioxidant properties of fruits and the timing of their consumption may influence gut microbiota [34], thereby indirectly affecting OAB symptoms. The "gut microbiota-gut-brain axis" appears to play a significant role in this relationship, as suggested by recent studies showing how dietary patterns influence gut microbiota diversity and, subsequently, host health [35]. Our findings suggest that enhancing gut microbiota diversity through diets rich in active microbes may not only improve gut health but also mitigate OAB symptoms, a novel insight that adds to the existing literature on the gut-brain connection in OAB management.

Moreover, lifestyle factors such as sleep patterns and psychological health could also confound the observed relationships. A study indicated a significant increase in the risk of OAB in patients with moderate and poor sleep patterns by 26% and 38%, respectively [36]. Psychological factors such as anxiety and depression, which are prevalent in OAB patients, can further exacerbate the condition and thus form a vicious cycle [3, 32]. Additionally, the quality of life, sleep quality, and psychological health of OAB patients are severely affected, with psychological factors such as anxiety and depression often being risk factors, which may further reduce the quality of life of OAB patients, thus forming a vicious cycle [3, 37]. This is

Table 2 Baseline characteristics of the study population by various dietary live microbes

Variable	Overall (*n* = 23708)	Low dietary live microbe group (*n* = 5807)	Medium dietary live microbe group (*n* = 6797)	High dietary live microbe group (*n* = 4191)	*P*-value
Age, y, mean (SE)	45.52(0.28)	43.09(0.34)	46.82(0.37)	46.35(0.37)	< 0.0001
Age strata, y, n (%)					< 0.0001
20–39	6537(39.72)	2476(45.12)	2426(36.85)	1635(37.83)	
40–59	5765(38.54)	1962(38.05)	2387(39.38)	1416(37.97)	
≥60	4493(21.73)	1369(16.83)	1984(23.76)	1140(24.20)	
Sex, n (%)					< 0.0001
Female	7908(48.65)	2471(42.83)	3216(49.23)	2221(53.92)	
Male	8887(51.35)	3336(57.17)	3581(50.77)	1970(46.08)	
Race, n (%)					< 0.0001
Mexican American	2394(7.80)	739(7.86)	1172(9.62)	483(5.40)	
Non-Hispanic White	7751(71.27)	2373(65.30)	3012(69.70)	2366(79.47)	
Non-Hispanic Black	3293(9.44)	1594(14.63)	1181(8.58)	518(5.18)	
Other Hispanic	1619(5.10)	517(5.30)	690(5.36)	412(4.57)	
Other Race	1738(6.38)	584(6.92)	742(6.73)	412(5.38)	
Marital status, n (%)					< 0.0001
Divorced/Separated/Widowed	3312(16.70)	1247(18.26)	1320(16.93)	745(14.78)	
Married/Living with a partner	10,104(64.12)	3200(58.60)	4247(65.53)	2657(68.01)	
Never married	3379(19.18)	1360(23.14)	1230(17.53)	789(17.21)	
Education levels, n (%)					< 0.0001
High school and below	6751(32.88)	2822(43.15)	2668(30.91)	1261(24.77)	
Above high school	10,044(67.12)	2985(56.85)	4129(69.09)	2930(75.23)	
Poverty ratio, n (%)					< 0.0001
<1.3	4584(17.90)	2008(24.77)	1706(16.16)	870(13.02)	
1.3–3.5	6227(33.92)	2274(37.88)	2529(33.02)	1424(30.97)	
>3.5	5984(48.18)	1525(37.35)	2562(50.82)	1897(56.01)	
BMI, n (%)					< 0.0001
<25	4933(30.29)	1630(28.10)	1982(30.36)	1321(32.46)	
25-29.99	5588(33.15)	1813(30.74)	2310(33.50)	1465(35.18)	
≥30	6274(36.56)	2364(41.16)	2505(36.13)	1405(32.36)	
Smoke, n (%)					< 0.0001
No	8692(53.35)	2728(47.36)	3628(54.79)	2336(57.69)	
Yes	8103(46.65)	3079(52.64)	3169(45.21)	1855(42.31)	
Alcohol user, n (%)					< 0.0001
No	6101(35.81)	1841(30.83)	2594(37.16)	1666(39.24)	
Yes	10,694(64.19)	3966(69.17)	4203(62.84)	2525(60.76)	
Moderate recreational activity, n (%)					< 0.0001
No	7827(41.01)	3129(50.32)	3067(39.35)	1631(33.49)	
Yes	8968(58.99)	2678(49.68)	3730(60.65)	2560(66.51)	
Sitting time, n (%)					< 0.001
<5	6702(36.19)	2291(36.77)	2901(38.10)	1510(33.14)	
≥5	10,093(63.81)	3516(63.23)	3896(61.90)	2681(66.86)	
Hypertension, n (%)					0.43
No	11,395(71.02)	3877(70.27)	4594(70.94)	2924(71.89)	
Yes	5400(28.98)	1930(29.73)	2203(29.06)	1267(28.11)	
Diabetes, n (%)					0.04
No	14,814(90.74)	5121(90.67)	5926(89.90)	3767(91.90)	
Borderline	347(1.81)	106(1.53)	155(2.08)	86(1.76)	
Yes	1634(7.45)	580(7.80)	716(8.03)	338(6.34)	
Hyperlipidemia, n (%)					0.06
No	5155(31.37)	1811(31.89)	2008(30.03)	1336(32.55)	
Yes	11,640(68.63)	3996(68.11)	4789(69.97)	2855(67.45)	
CVD, n (%)					0.03

Table 2 (continued)

Variable	Overall (*n* = 23708)	Low dietary live microbe group (*n* = 5807)	Medium dietary live microbe group (*n* = 6797)	High dietary live microbe group (*n* = 4191)	*P*-value
No	16,428(98.50)	5652(98.19)	6659(98.43)	4117(98.90)	
Yes	367(1.50)	155(1.81)	138(1.57)	74(1.10)	
eGFR (mL/min), mean (SE)	96.04(0.35)	98.36(0.44)	94.98(0.46)	94.98(0.48)	< 0.0001
UUI frequency, n (%)					0.21
Never	13,332(81.76)	4601(82.06)	5390(81.15)	3341(82.23)	
Less than once a month	1714(9.45)	607(9.13)	675(9.41)	432(9.84)	
A few times a month	1070(5.60)	350(5.44)	463(6.19)	257(4.99)	
A few times a week	438(2.15)	172(2.48)	164(2.15)	102(1.80)	
Every day and/or night	241(1.04)	77(0.89)	105(1.09)	59(1.14)	
Nocturia frequency, n (%)					< 0.001
0	5613(36.35)	1915(36.28)	2199(35.43)	1499(37.61)	
1	6618(41.46)	2162(39.15)	2771(42.48)	1685(42.54)	
2	2826(14.60)	1047(15.63)	1140(14.55)	639(13.61)	
3	1243(5.60)	486(6.38)	494(5.72)	263(4.63)	
4	340(1.44)	131(1.80)	130(1.28)	79(1.28)	
5 or more?	155(0.55)	66(0.77)	63(0.53)	26(0.33)	
OAB, n (%)					< 0.001
No	14,007(87.11)	4748(85.74)	5679(86.86)	3580(88.84)	
Yes	2788(12.89)	1059(14.26)	1118(13.14)	611(11.16)	

BMI Body mass index, eGFR estimated glomerular filtration rate, CVD Cardiovascular Disease, UUI urge urinary incontinence, OAB Overactive bladder

Table 3 Association of different dietary live microbe groups with OAB

Exposure	Crude model		Model 1		Model 2	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Dietary Live Microbe Intake group						
Low	1 (Ref.)		1 (Ref.)		1 (Ref.)	
Medium	0.91(0.80,1.04)	0.16	0.85(0.74,0.98)	0.02	0.91(0.78,1.05)	0.19
High	0.76(0.66,0.87)	< 0.001	0.77(0.65,0.90)	0.001	0.84(0.71,0.99)	0.03
P for trend		< 0.001		0.001		0.03

Crude model: unadjusted model;

Model 1: Adjusted for age, sex, race, education levels, marital status, poverty ratio;

Model 2: Additionally adjusted for BMI, smoke, alcohol user, recreational activity, sitting time, eGFR, hypertension, diabetes, hyperlipidemia and CVD.

OR odds ratio, CI confidence interval

consistent with our observations, suggesting that dietary interventions could potentially alleviate some symptoms by improving overall psychological well-being and sleep quality.

In light of these insights, our study supports the notion that a comprehensive dietary plan enriched with active microbes could be a viable strategy for the long-term management of OAB. This approach not only aims to adjust dietary patterns to enhance microbial intake but also considers the holistic impact of diet on the gut microbiota, psychological factors, and overall health. To translate these findings into clinical practice, healthcare providers could integrate dietary advice focusing on active microbial consumption into routine management strategies for OAB patients. This dietary guidance could be tailored to individual patient needs based on their dietary habits and health status, promoting a proactive and personalized approach to OAB management. In terms of public health interventions, our findings advocate for the development of educational campaigns and nutritional guidelines that emphasize the benefits of microbial-rich diets. Public health authorities could collaborate with dietitians and clinicians to create and disseminate these guidelines, aiming to reduce the prevalence of OAB and improve urinary health across the population. Additionally, these interventions could be included in broader health promotion programs that address dietary habits, potentially mitigating other diet-related conditions and enhancing overall well-being. The potential for dietary interventions to address psychosomatic aspects of OAB introduces an innovative angle for future research and therapy. By demonstrating a significant correlation between diet and OAB, our research paves the way for more integrative treatment protocols

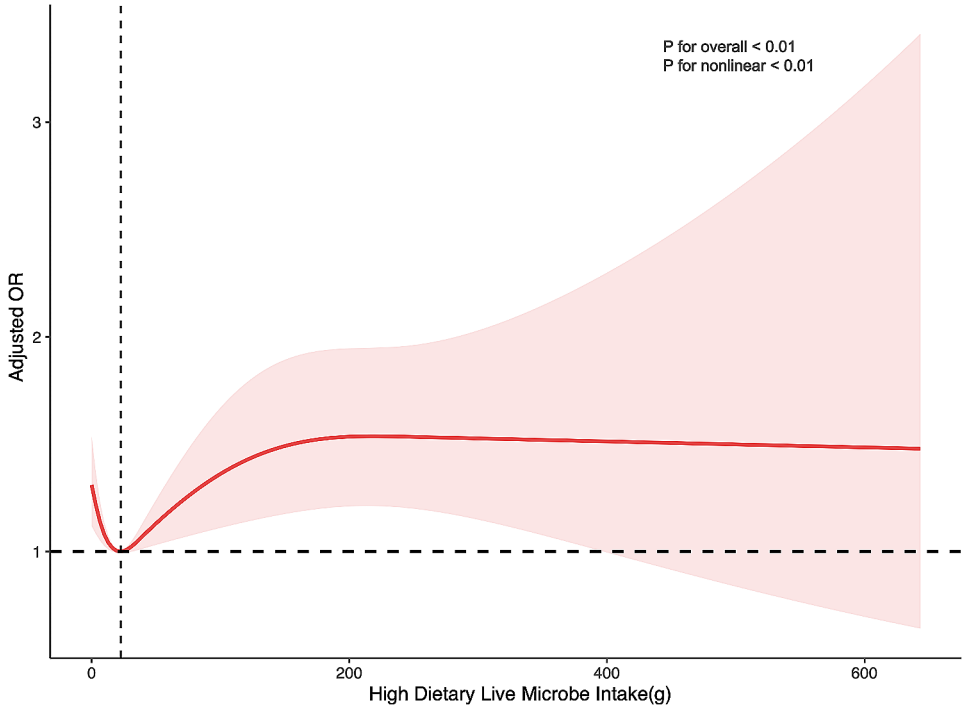

Fig. 3 Illustrates the correlation between OAB and high dietary live microbe intake. The ORs, represented by solid lines, were adjusted for sex, age, race, education levers, marital status, poverty ratio, BMI, smoking, alcohol user, recreational activity, sitting time, eGFR, hypertension, diabetes, hyperlipidemia and CVD, while their corresponding 95% CIs (shaded areas) were also taken into account

that combine dietary management with conventional medical therapies. This holistic approach could potentially lead to better patient outcomes, fewer side effects, and a greater emphasis on prevention rather than solely treatment.

The strengths of our study are multifaceted. Firstly, it utilizes a substantial sample from the NHANES database, enhancing the reliability and generalizability of our findings across diverse populations. Secondly, this study is the first to explore the link between the consumption of active microbes and the development of OAB. Additionally, the accuracy of the model was improved by incorporating a variety of influencing factors. Despite some observed discrepancies, both the unadjusted model and Models 1 and 2 demonstrated consistent outcomes. However, this study is not without limitations. The reliance on cross-sectional and retrospective data from the NHANES poses challenges in establishing a causal link between the dietary intake of active microbes and OAB. The retrospective nature of NHANES data may introduce recall biases and limits our ability to make causal claims. The accuracy of participant-reported dietary intake and OAB symptoms, especially over prolonged durations, could lead to classification errors, where dietary habits and symptom severities are inaccurately reported. Our study's cross-sectional design is effective for identifying associations at a specific time point but is limited in establishing causality between the intake of dietary live microbes and OAB. A primary drawback of this approach is its inability to determine the temporal sequence of the relationships observed. With dietary intake and OAB symptoms assessed simultaneously, it is difficult to discern whether a high intake of live microbes precedes a reduction in OAB symptoms or if individuals with fewer symptoms are more inclined to consume such diets. Moreover, categorizing live microorganism intake into distinct levels (low, medium, high) may oversimplify the complexities of dietary patterns and obscure subtle correlations between microbe levels and OAB outcomes. Variations in NHANES methods for assessing dietary intake over the years might also influence the consistency and accuracy of this categorization, potentially introducing additional variability that could skew the results.

To address some of the biases inherent in retrospective data, we employed multivariable logistic regression and RCS regression models, adjusting for a wide array of known confounders. To further mitigate the limitations associated with retrospective data and categorization, future research should consider prospective cohort studies that facilitate real-time data collection and enable a more detailed analysis of dietary intake. Longitudinal designs would allow for a clearer observation of temporal relationships and causal mechanisms.

In conclusion, while our study indicates a potential protective role of active microbes against OAB, the limitations inherent in using retrospective, self-reported

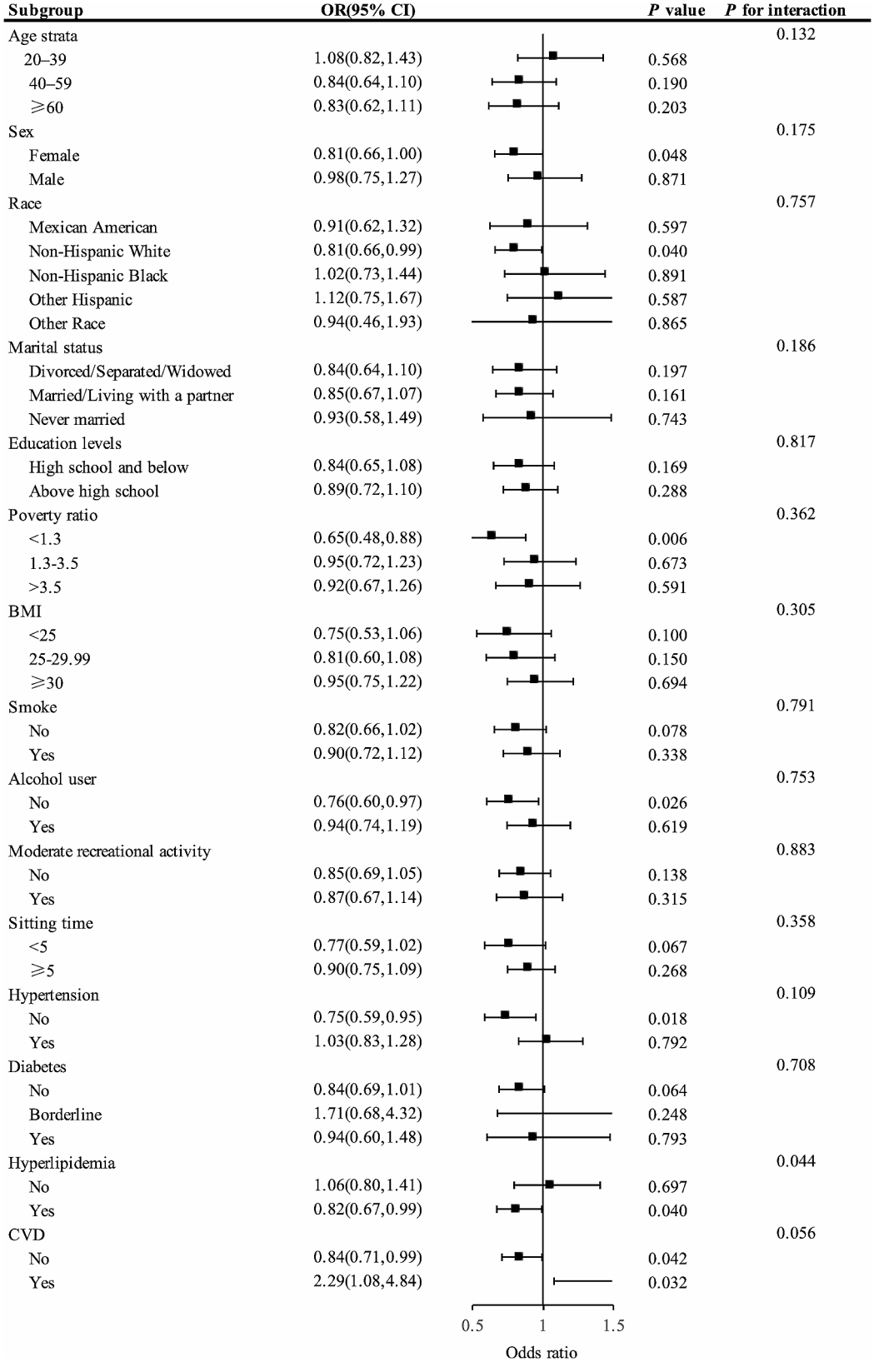

Fig. 4 Stratified analysis of the correlation between high and low dietary intake of live microbial groups and OAB

Table 4 Sensitivity analysis of the association of different dietary live microbe groups with OAB

Exposure	Excluding participants with diabetes history		
	Cases/participants	OR (95% CI)	*P*-value
Dietary Live Microbe Intake group			
Low	820/5121	1 (Ref.)	
Medium	828/5926	0.89(0.75,1.06)	0.19
High	475/3767	0.81(0.67,0.98)	0.03
P for trend	2123/14,814		0.03

ORs and 95% CIs were adjusted for age, sex, race, education levels, marital status, poverty ratio, BMI, smoke, alcohol user, recreational activity, sitting time, eGFR, hypertension, hyperlipidemia and CVD.

OR odds ratio, CI confidence interval

NHANES data necessitate a cautious interpretation of these findings. Prospective studies and experimental research that utilize more objective methods for assessing dietary intake and OAB symptoms are crucial to confirm and expand our understanding of these relationships. Employing such methodological rigor will establish a more reliable, causally-informed basis for dietary recommendations in managing OAB.

Conclusion

Our study indicates that a high dietary intake of live microorganisms is correlated with a lower incidence of OAB. Furthermore, additional prospective studies and animal experiments are needed to explore the causal relationship and specific pathological mechanisms between the dietary intake of active microbes and OAB.

Acknowledgements
We extend our gratitude to the NHANES databases for providing access to this valuable data.

Author contributions
DYZ, HHJ, DQX: Contributed to paper design, data processing and involved in data collection. GB: Drafted the manuscript. ZQ, GJ: Revised the manuscript.

Funding
Natural Science Foundation of Jiangxi Province (Grant No. 20212BAB216018, 20224BAB206027).

Data availability
All data used in this study are available in the NHANES database, accessible at https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Consent for publication
Relevant data from participants were collected from the publicly accessible NHANES database, eliminating the need for obtaining additional consent.

Ethical approval and consent to participate
The studies involving human participants were reviewed and approved by NCHS Research Ethics Review Board (ERB). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Competing interests
The authors declare no competing interests.

Conflict of interest
The authors declared no conflict of interest.

Received: 20 June 2024 / Accepted: 31 July 2024
Published online: 10 August 2024

References

1. Milsom I, Abrams P, Cardozo L, Roberts RG, Thuroff J, Wein AJ. How widespread are the symptoms of an overactive bladder and how are they managed? A population-based prevalence study. BJU Int. 2001;87(9):760–6.
2. Bozkurt YE, Temeltas G, Muezzinoglu T, Ucer O. Mediterranean Diet and overactive bladder. Int Neurourol J. 2022;26(2):129–34.
3. Brown JS, McGhan WF, Chokroverty S. Comorbidities associated with overactive bladder. Am J Manag Care. 2000;6(11 Suppl):S574–579.
4. Coyne KS, Sexton CC, Thompson CL, Milsom I, Irwin D, Kopp ZS, Chapple CR, Kaplan S, Tubaro A, Aiyer LP, et al. The prevalence of lower urinary tract symptoms (LUTS) in the USA, the UK and Sweden: results from the epidemiology of LUTS (EpiLUTS) study. BJU Int. 2009;104(3):352–60.
5. Irwin DE, Milsom I, Hunskaar S, Reilly K, Kopp Z, Herschorn S, Coyne K, Kelleher C, Hampel C, Artibani W, et al. Population-based survey of urinary incontinence, overactive bladder, and other lower urinary tract symptoms in five countries: results of the EPIC study. Eur Urol. 2006;50(6):1306–14. discussion 1314 – 1305.
6. El-Zawahry A. Combination pharmacotherapy for treatment of overactive bladder (OAB). Curr Urol Rep. 2019;20(6):33.
7. Athanasopoulos A. The pharmacotherapy of overactive bladder. Expert Opin Pharmacother. 2011;12(7):1003–5.
8. Wang X, Wang H, Yu Q, Fu S, Yang Z, Ye Q, Lin F, Cai G. High dietary live microbe intake is correlated with reduced risk of depressive symptoms: a cross-sectional study of NHANES 2007–2016. J Affect Disord. 2024;344:198–206.
9. Sanchez B, Delgado S, Blanco-Miguez A, Lourenco A, Gueimonde M, Margolles A. Probiotics, gut microbiota, and their influence on host health and disease. Mol Nutr Food Res 2017, 61(1).
10. Snigdha S, Ha K, Tsai P, Dinan TG, Bartos JD, Shahid M. Probiotics: potential novel therapeutics for microbiota-gut-brain axis dysfunction across gender and lifespan. Pharmacol Ther. 2022;231:107978.
11. Naureen Z, Bonetti G, Medori MC, Aquilanti B, Velluti V, Matera G, Iaconelli A, Bertelli M. Foods of the Mediterranean diet: lacto-fermented food, the food pyramid and food combinations. J Prev Med Hyg. 2022;63(2 Suppl 3):E28–35.
12. Yoo S, Jung SC, Kwak K, Kim JS. The role of Prebiotics in modulating gut microbiota: implications for Human Health. Int J Mol Sci 2024, 25(9).
13. Ashaolu TJ, Ashaolu JO, Adeyeye SAO. Fermentation of prebiotics by human colonic microbiota in vitro and short-chain fatty acids production: a critical review. J Appl Microbiol. 2021;130(3):677–87.
14. Garcia-Montero C, Fraile-Martinez O, Gomez-Lahoz AM, Pekarek L, Castellanos AJ, Noguerales-Fraguas F, Coca S, Guijarro LG, Garcia-Honduvilla N, Asunsolo A et al. Nutritional Components in Western Diet Versus Mediterranean Diet at the Gut Microbiota-Immune System Interplay. Implications for Health and Disease. Nutrients 2021, 13(2).
15. Dallosso HM, McGrother CW, Matthews RJ, Donaldson MM, Leicestershire MRCISG. The association of diet and other lifestyle factors with overactive bladder and stress incontinence: a longitudinal study in women. BJU Int. 2003;92(1):69–77.
16. Zhang Q, Zhang Z, He X, Liu Z, Shen L, Long C, Wei G, Liu X, Guo C. Vitamin D levels and the risk of overactive bladder: a systematic review and meta-analysis. Nutr Rev. 2024;82(2):166–75.
17. Dallosso HM, McGrother CW, Matthews RJ, Donaldson MM, Leicestershire MRCISG. Nutrient composition of the diet and the development of overactive bladder: a longitudinal study in women. Neurourol Urodyn. 2004;23(3):204–10.
18. Centers for Disease Control and Prevention NCfHS. National Health and Nutrition Examination Survey Data. In. Hyattsville, MD; 2007–2018.
19. Marco ML, Hutkins R, Hill C, Fulgoni VL, Cifelli CJ, Gahche J, Slavin JL, Merenstein D, Tancredi DJ, Sanders ME. A classification system for defining and estimating Dietary Intake of Live microbes in US adults and children. J Nutr. 2022;152(7):1729–36.

20. Han L, Wang Q. Association of Dietary Live Microbe Intake with Cardiovascular Disease in US adults: a cross-sectional study of NHANES 2007–2018. Nutrients 2022, 14(22).
21. Zhu S, Wang Z, Tao Z, Wang S, Wang Z. Relationship between Marijuana Use and overactive bladder (OAB): a cross-sectional research of NHANES 2005 to 2018. Am J Med. 2023;136(1):72–8.
22. Qi X, Huang Q, Chen X, Qiu L, Wang S, Ouyang K, Chen Y. Associations between urinary glyphosate and diabetes mellitus in the US general adult: a cross-sectional study from NHANES 2013–2016. Environ Sci Pollut Res Int. 2023;30(59):124195–203.
23. Vasquez E, Batsis JA, Germain CM, Shaw BA. Impact of obesity and physical activity on functional outcomes in the elderly: data from NHANES 2005–2010. J Aging Health. 2014;26(6):1032–46.
24. Scinicariello F, Buser MC, Feroe AG, Attanasio R. Antimony and sleep-related disorders: NHANES 2005–2008. Environ Res. 2017;156:247–52.
25. Markland AD, Vaughan CP, Huang AJ, Kim E, Bubes VY, Tangpricha V, Buring JR, Lee IM, Cook NR, Manson JE, et al. Effect of vitamin D supplementation on overactive bladder and urinary incontinence symptoms in older men: ancillary findings from a Randomized Trial. J Urol. 2023;209(1):243–52.
26. Kilic MK, Kizilarslanoglu MC, Kara O, Arik G, Varan HD, Kuyumcu ME, Yesil Y, Yavuz BB, Halil M, Cankurtaran M. Hypovitaminosis D is an independent associated factor of overactive bladder in older adults. Arch Gerontol Geriatr. 2016;65:128–32.
27. Li N, Ding H, Li Z, Liu Y, Wang P. Effect of high-fat diet-induced obesity on the small-conductance ca(2+)-activated K(+) channel function affecting the contractility of rat detrusor smooth muscle. Int Urol Nephrol. 2019;51(1):61–72.
28. Demirbas A, Sarici H, Kilinc MF, Telli O, Ozgur BC, Doluoglu OG, Bozkurt S. The relationship between acidic urinary pH and overactive bladder; alkalization of urine improves the symptoms of overactive bladder. Urol Int. 2015;95(2):223–6.
29. Siener R, Hesse A. The effect of different diets on urine composition and the risk of calcium oxalate crystallisation in healthy subjects. Eur Urol. 2002;42(3):289–96.
30. Siener R, Hesse A. The effect of a vegetarian and different omnivorous diets on urinary risk factors for uric acid stone formation. Eur J Nutr. 2003;42(6):332–7.
31. Siener R, Bitterlich N, Birwe H, Hesse A. The impact of Diet on urinary risk factors for Cystine Stone formation. Nutrients 2021, 13(2).
32. Feng W, Liu J, Cheng H, Zhang D, Tan Y, Peng C. Dietary compounds in modulation of gut microbiota-derived metabolites. Front Nutr. 2022;9:939571.
33. Shanahan ER, McMaster JJ, Staudacher HM. Conducting research on diet-microbiome interactions: a review of current challenges, essential methodological principles, and recommendations for best practice in study design. J Hum Nutr Diet. 2021;34(4):631–44.
34. Katsirma Z, Dimidi E, Rodriguez-Mateos A, Whelan K. Fruits and their impact on the gut microbiota, gut motility and constipation. Food Funct. 2021;12(19):8850–66.
35. Lv JJ, Li XY, Wang JB, Yang XT, Yin MY, Yang CH. Association of dietary live microbe intake with various cognitive domains in US adults aged 60 years or older. Sci Rep. 2024;14(1):5714.
36. Lu Z, Zhang J, Lin S, Fan Z, He Z, Tang F. Associations between overactive bladder and sleep patterns: a cross-sectional study based on 2007–2014 NHANES. BMC Urol. 2023;23(1):184.
37. Eapen RS, Radomski SB. Review of the epidemiology of overactive bladder. Res Rep Urol. 2016;8:71–6.

Publisher's Note