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The association between magnesium depletion score (MDS) and overactive bladder (OAB) among the U.S. population

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Abstract

Objective This study aimed to assess the relationship between magnesium depletion score (MDS) and overactive bladder (OAB) prevalence.

Methods This study utilized data from the National Health and Nutrition Examination Survey (NHANES) from 2005 to 2018. Multivariate logistic regression was employed to investigate the association between MDS and OAB. Restricted cubic spline (RCS) analysis explored the linear or non-linear relationship between MDS and OAB. Interaction analyses were conducted on subgroups to validate the findings.

Results There was a significant positive association between MDS and OAB. After adjusting for covariates, with each unit increase in MDS, there was an 11% increase in the prevalence of infertility ($P < 0.001$). In addition, the incidence of OAB was significantly increased in the higher MDS group compared to the low MDS group (MDS = 0) (P for trend < 0.001). The dose-response curve indicated a linear association between MDS and OAB, with higher MDS associated with higher OAB.

Conclusion The results of this study show a strong positive correlation between MDS and the prevalence of OAB. These findings suggest that monitoring and managing magnesium status may be a potential strategy for reducing the risk of OAB.

Keywords Overactive bladder, Magnesium depletion score, NHANES, Association, U.S. Population

Introduction

According to the definition by the International Continence Society, an Overactive Bladder (OAB) is a symptom syndrome characterized by urinary urgency, usually accompanied by frequency and nocturia, with or without urge incontinence, and excluding urinary tract infection or other obvious pathology [1]. This condition is quite common and significantly impacts the quality of life, affecting daily activities such as work, travel, physical exercise, sexual activity, and sleep in both men and women [2]. However, the risk factors and pathogenesis of OAB are not fully understood. It is currently believed that OAB may result from involuntary contractions of

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the bladder smooth muscle (detrusor) during the storage phase [3], a reduction in inhibitory neural impulses, and an increase in afferent impulses from the bladder triggering the micturition reflex [4]. Additionally, the detrusor and urethral smooth muscles may become more sensitive to cholinergic stimulation, leading to increased spontaneous activity [5]. Therefore, there is an urgent need for a comprehensive exploration of modifiable factors to prevent and address OAB, which remains a challenging clinical and research issue.

A study of 189 participants from Jordan (2019) has shown that certain dietary intakes can improve urinary and psychological symptoms and quality of life in patients with OAB, such as vitamin D supplementation and increased calcium intake [6]. Magnesium, one of the seven essential macro minerals, is involved in over 350 chemical reactions in the human body, regulating various biochemical processes, including protein synthesis, muscle and nerve function, blood glucose control, and blood pressure regulation [7, 8]. It is crucial for many bodily functions and plays a key role in muscle function throughout the body, including skeletal and smooth muscles [9–11]. Notably, there is limited research on magnesium and OAB, indicating a lack of substantial scientific evidence supporting its use. Magnesium helps maintain normal blood pressure, reduce muscle cramps, and ensure complete bladder emptying. Studies have shown that patients taking magnesium after transurethral resection of bladder tumors have a reduced likelihood of postoperative bladder spasms by half [12]. A recent study published in the Journal of Neuroinflammation in 2020 found that supplementation with L-threonate magnesium (L-TAMS) could treat pain, comorbid depression, and memory deficits in patients with Bladder Pain Syndrome/Interstitial Cystitis (BPS/IC) [13]. The Magnesium Tolerance Test (MTT) is widely regarded as the most reliable method for assessing overall magnesium levels and tolerance [14]. However, due to its invasive and cumbersome nature, requiring 24-hour urine collection after intravenous magnesium administration, its clinical practicality is limited. As an alternative, the Magnesium Deficiency Score (MDS) aggregates four risk factors: diuretics, proton pump inhibitors (PPI), alcohol consumption, and renal function deterioration. This score offers a more precise and reliable method for assessing systemic magnesium levels compared to serum and urine magnesium concentrations [15]. A higher MDS indicates a more severe magnesium deficiency.

To our knowledge, no studies have yet focused on the relationship between the Magnesium Deficiency Score (MDS) and the prevalence of Overactive Bladder (OAB). Therefore, this study aims to elucidate the association between MDS and OAB prevalence using data from NHANES 2005–2018. This research underscores the importance of magnesium in the diet of OAB patients. As the population ages, we also aim to provide targeted prevention and intervention strategies to reduce OAB susceptibility.

Methods

The NHANES aims to evaluate the nutrition and health status of the American population. NHANES provides large-sample, high-quality, and representative data, facilitating valuable research on various health conditions, including OAB, in the general population. Since all data are publicly accessible on the NHANES website (https://www.cdc.gov/nchs/nhanes/index.htm), there is no need for additional ethical approval and informed consent.

Study design and population

The data utilized in the present study were sourced from NHANES covering the years 2005 to 2018, encompassing over seven survey cycles. The exclusion criteria were primarily derived from previous research [16, 17], with further specifics provided in Fig. 1. In total, 32,493 eligible participants were included in this study. Of these, 6,716 individuals were diagnosed with OAB, reflecting a weighted prevalence of 16% in the overall population.

Assessment of OAB

According to the International Continence Society [18], OAB is evaluated through a combination of urgent urinary incontinence (UUI) and nocturia. In the NHANES database, professionals assess UUI and nocturia using specific questionnaires. These detailed questionnaires are available in NHANES questionnaires KIQ044, KIQ450, and KIQ480 (https://wwwn.cdc.gov/Nchs/Nhanes/2005-2006/KIQ_U_D.htm). After collecting the responses, professionals used the Overactive Bladder Syndrome Symptom Score (OABSS) to quantify OAB [18]. Participants with a score of 3 or higher were diagnosed with OAB [19, 20]. All scores are provided in Table S1.

Evaluation of MDS

The current study used the MDS to assess whole-body magnesium status. The MDS was calculated based on the participants' total score on four items [17, 21]: diuretic use, proton pump inhibitor use, glomerular filtration rate, and alcohol abuse, as detailed in Table S2. Based on existing studies [22, 23], the present study classified MDS into 4 groups: MDS = 0, MDS = 1, MDS = 2, and MDS ≥ 3.

Covariates

We constructed a directed acyclic graph (DAG) to visualize the hypothesized associations of the primary exposure (Magnesium Depletion Score) with the outcomes of interest (the prevalence of OAB), and potential covariates [24]. Based on previously published studies [16, 17, 25],

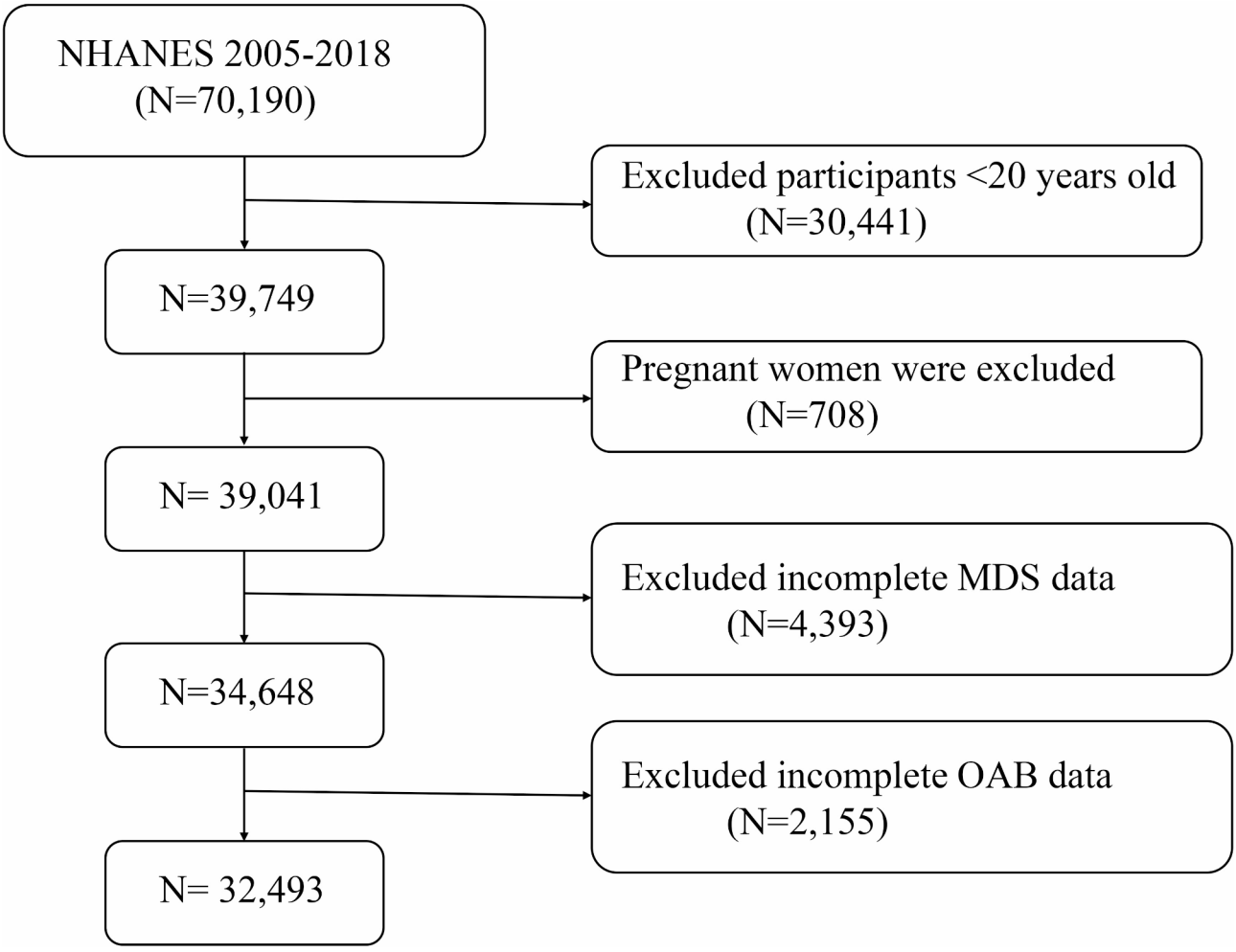

Fig. 1 A flow diagram of eligible participant selection in the national health and nutrition examination slurvey

the covariates in this study included age, gender, education level, marital, Ratio of family income to poverty (PIR), race, obesity, smoking, drinking, hypertension, and diabetes. Detailed information about covariates can be found in Table S2. The resulting DAG is presented in Figure S1.

Statistical analysis

The current study employed the NCHS-recommended weights to ensure the data's national representativeness. Continuous variables were analyzed using t-tests (reported as mean with standard deviation, SD), while categorical variables were examined using chi-square tests (reported as percentages). To explore the association between MDS and OAB, we utilized weighted multiple logistic regression, presenting the results as odds ratios (OR) with 95% confidence intervals (CI). We assessed three models adjusted for covariates: Model 1 was an unadjusted model. Model 2 adjusted for age, gender, education level, marital status, poverty income ratio (PIR), and race to account for potential confounding effects from basic demographic and socioeconomic factors. Model 3 further adjusted for obesity, smoking status, alcohol consumption, hypertension, and diabetes to minimize the impact of metabolic and lifestyle-related confounders. Additionally, we applied a restricted cubic spline (RCS) to evaluate the dose-response relationship between MDS and OAB. The RCS model included three knots positioned at the 10th, 50th, and 90th percentiles of the MDS distribution. RCS was chosen for its ability to flexibly model nonlinear relationships without requiring a predefined parametric form. Compared to polynomial regression, RCS more effectively captures local variations, minimizes overfitting, and provides easily interpretable visual representations. To investigate potential interactions, a multiplicative interaction analysis based on prespecified stratified terms was conducted. We tested multicollinearity in the covariates using the vif () function from the "car" package; a variance inflation factor (VIF) < 10 indicates that multicollinearity is not present [26]. Every VIF in the current investigation was less than two. All analyses were performed using R (v.4.3.1)

statistical software, with significance determined by p-values below 0.05.

Results

Characteristics of the participants

Participants were stratified based on the presence or absence of an OAB diagnosis, with baseline characteristics for all 32,493 participants presented in Table 1 (weighted data). Among the included participants, 6,716 reported having OAB (prevalence: 16%), while 25,777 reported no OAB. Compared to non-OAB participants, those in the OAB group were older, had higher educational attainment, and had a higher poverty-income ratio. Additionally, the OAB group had a higher proportion of females and was more frequently observed among White individuals. Furthermore, OAB patients were more likely to be current smokers and have hypertension.

Association between MDS and OAB

Table 2 summarizes the multivariable logistic regression analysis results for both adjusted and unadjusted models. In crude models (Model 1) and Model 2, a significant positive association was found between MDS and OAB, as detailed below. In Model 1 (unadjusted for covariates), for each one-unit increase in MDS, the prevalence of OAB increased by 59% (COR 1.59, CI 1.53–1.65). In Model 2 (adjusted for age, gender, education level, marital status, PIR, and race), for each one-unit increase in MDS, the prevalence of OAB increased by 17% (AOR 1.17, CI 1.11–1.23). In Model 3, after adjusting for all covariates, this pattern remained consistent, indicating that for each one-unit increase in MDS, the prevalence of OAB increased by 11% (AOR 1.11, CI 1.05–1.19). When MDS was categorized into four groups, higher MDS levels (1, 2, and ≥ 3) were positively associated with OAB compared to MDS = 0 in Models 1 and 2. In Model 3, this significant positive association persisted at MDS = 2 (AOR 1.22, CI 1.02–1.46) and MDS ≥ 3 (AOR 1.43, CI 1.17–1.76). Model 3 has the smallest AIC value while Model 1 has the largest AIC value. Figure 2 further validated the positive correlation between MDS and the incidence of OAB, as indicated by the restricted cubic spline (RCS) analysis.

Subgroup analysis between MDS and OAB

As illustrated in Fig. 3, we investigated the association between MDS and OAB across various subgroups defined by age, gender, education level, marital status, PIR, race, obesity, smoking, drinking, hypertension, and diabetes. In most subgroups, MDS was significantly and positively correlated with the odds of OAB, with ORs ranging from 1.02 to 1.22 for each unit increase in MDS. Moreover, no significant interactions were detected between MDS and any subgroups, indicating that the positive correlation between MDS and OAB is consistent across different segments of the population.

Discussion

In this nationally representative sample of U.S. adults, we found a significant positive association between Overactive Bladder (OAB) and the Magnesium Deficiency Score (MDS). This association remained significant in models adjusted for multiple covariates, regardless of baseline characteristics, and was particularly pronounced in individuals with MDS scores greater than 3.

In a urodynamic evaluation, urinary pH was found to be significantly negatively correlated with detrusor pressure [27]. This implies a significant association between acidic urine and OAB, potentially due to acidic urine stimulating the nerve fibers in the bladder epithelium, leading to overactivity. Intake of magnesium salts can enhance citrate excretion and increase urinary pH, thereby alkalinizing the urine. This not only improves lower urinary tract symptoms [28] but also prevents the formation of crystals in the urinary system, reducing the risk of urolithiasis [29].

Magnesium possesses unique antioxidant and anti-inflammatory properties. It has been found to inhibit the activation of NF-kB, potentially reducing inflammation. Oral magnesium supplementation can effectively lower serum CRP (a marker of inflammation), suggesting its significant role in alleviating chronic systemic inflammation [30]. Chronic inflammation can lead to functional changes and increased sensitivity of the bladder, resulting in OAB symptoms. A prospective study indicated that chronic inflammation is associated with Overactive Bladder (OAB) syndrome [31]. Additionally, research has shown elevated cytokine levels in the urine of OAB patients [32]. These findings suggest that the release of inflammatory cells and mediators leads to poor bladder perfusion and an inflammatory response in bladder tissue, triggering OAB symptoms. Therefore, oral magnesium supplementation may reduce inflammatory responses and effectively alleviate symptoms in OAB patients.

As age increases, changes in magnesium metabolism occur in the body, including reduced intake and increased excretion, ultimately leading to magnesium deficiency. Mild magnesium deficiency is common in older adults and is associated with sleep disorders, mood disorders such as depression and anxiety, and cognitive impairment. Research indicates that many human diseases are related to magnesium deficiency, including cardiovascular diseases, hypertension, osteoporosis, metabolic syndrome (MetS), type 2 diabetes, and mental disorders. Additionally, magnesium deficiency is linked to mitochondrial dysfunction and oxidative stress markers [33]. It is well known that aging is accompanied by

Table 1 Baseline characteristics of all participants were stratified by OAB

Characteristic	Total, *N* = 32,493 (100%)	Non-OAB, *N* = 25,777 (84%)	OAB, *N* = 6,716 (16%)	*P* Value
Age (%)				< 0.001
20–40	11,144 (37%)	10,264 (42%)	880 (16%)	
41–60	10,876 (38%)	8,752 (38%)	2,124 (37%)	
> 60	10,473 (25%)	6,761 (21%)	3,712 (48%)	
Gender (%)				**< 0.001**
Male	16,288 (49%)	13,482 (52%)	2,806 (38%)	
Female	16,205 (51%)	12,295 (48%)	3,910 (62%)	
Race (%)				**< 0.001**
Non-Hispanic White	14,148 (69%)	11,401 (69%)	2,747 (65%)	
Non-Hispanic Black	6,987 (11%)	5,060 (9.8%)	1,927 (17%)	
Other	6,342 (12%)	5,267 (13%)	1,075 (11%)	
Mexican American	5,016 (8.2%)	4,049 (8.4%)	967 (7.2%)	
Married/live with partner (%)				**< 0.001**
No	13,208 (37%)	10,015 (36%)	3,193 (42%)	
Yes	19,285 (63%)	15,762 (64%)	3,523 (58%)	
Education level (%)				**< 0.001**
Below high school	7,829 (15%)	5,510 (14%)	2,319 (25%)	
High School or above	24,664 (85%)	20,267 (86%)	4,397 (75%)	
PIR (%)				**< 0.001**
Not Poor	20,680 (80%)	16,942 (81%)	3,738 (71%)	
poor	9,152 (20%)	6,784 (19%)	2,368 (29%)	
Obesity (%)				**< 0.001**
No	19,766 (62%)	16,473 (65%)	3,293 (51%)	
Yes	12,425 (38%)	9,121 (35%)	3,304 (49%)	
Smoking (%)				**< 0.001**
Never	17,748 (55%)	14,485 (56%)	3,263 (48%)	
Former	8,020 (25%)	5,975 (24%)	2,045 (30%)	
Current	6,725 (20%)	5,317 (20%)	1,408 (21%)	
Drinking (%)				**< 0.001**
former	5,230 (13%)	3,672 (12%)	1,558 (22%)	
heavy	6,381 (21%)	5,412 (23%)	969 (15%)	
mild	10,613 (37%)	8,672 (37%)	1,941 (35%)	
moderate	4,864 (18%)	4,053 (18%)	811 (14%)	
never	4,405 (11%)	3,318 (10%)	1,087 (14%)	
Hypertension (%)				**< 0.001**
No	17,961 (61%)	15,678 (65%)	2,283 (40%)	
Yes	14,172 (39%)	9,797 (35%)	4,375 (60%)	
Diabetes (%)				**< 0.001**
No	12,142 (75%)	10,051 (79%)	2,091 (57%)	
Yes	5,837 (25%)	3,698 (21%)	2,139 (43%)	
MDS (%)				**< 0.001**
0	14,621 (44%)	12,585 (47%)	2,036 (30%)	
1	10,644 (35%)	8,438 (35%)	2,206 (35%)	
2	4,898 (15%)	3,351 (13%)	1,547 (22%)	
≥ 3	2,330 (5.9%)	1,403 (4.6%)	927 (13%)	

Mean (SD) for continuous variables: the *P* value was calculated by the weighted linear regression model

Percentages (weighted *N*, %) for categorical variables: the *P* value was calculated by the weighted chi-square test

an increase in urinary disorders, which also contribute to the fibrosis of the bladder detrusor muscle, and exacerbates bladder ischemia and hypoxia. This can increase the production of free radicals, leading to oxidative stress and the activation of inflammatory responses, ultimately resulting in reduced bladder compliance and overactivity [34]. All these factors are risk factors for the symptoms experienced by OAB patients.

Studies have found that magnesium supplementation at certain doses can help improve these chronic conditions.

Table 2 Adjusted odds ratios of MDS and OAB, NHANES 2005–2018

MDS	Model 1 [COR (95% CI)]	*p*-value	Model 2 [AOR (95% CI)]	*p*-value	Model 3 [AOR (95% CI)]	*p*-value
Continuous	1.59 (1.53, 1.65)	< 0.001	1.17 (1.11, 1.23)	< 0.001	1.11 (1.05, 1.19)	< 0.001
AIC	27744.91		23585.54		12604.87	
Categories						
MDS = 0	1 (ref.)		1 (ref.)		1 (ref.)	
MDS = 1	1.53 (1.40, 1.68)	< 0.001	1.08 (0.96, 1.22)	0.200	1.10 (0.95, 1.28)	0.200
MDS = 2	2.65 (2.36, 2.97)	< 0.001	1.36 (1.17, 1.58)	< 0.001	1.22 (1.02, 1.46)	0.034
MDS > = 3	4.32 (3.84, 4.86)	< 0.001	1.65 (1.40, 1.95)	< 0.001	1.43 (1.17, 1.76)	< 0.001
AIC	27735.24		23586.44		12610.47	
P for trend	< 0.001		< 0.001		< 0.001	

Model 1: no covariates were adjusted

Model 2: age, gender, education level, marital, PIR, and race were adjusted

Model 3: age, gender, education level, marital, PIR, race, obesity, smoking, drinking, hypertension, and diabetes

Abbreviation: COR, crude odds ratio; AOR, adjusted odds ratio; MDS, Magnesium Depletion Score; OAB, overactive bladder; PIR, Ratio of family income to poverty; OR, odds ratio; CI, confidence interval; AIC, Akaike's Information Criterion value

Magnesium can enhance sleep by regulating a brain chemical called GABA, which is crucial for sleep. It is also suggested as an adjunct treatment for insomnia, as it helps relax muscles and regulate the nervous system. Good sleep can alleviate OAB symptoms. Magnesium plays a significant role in the occurrence and development of Metabolic Syndrome (MetS). Oral magnesium supplements can improve MetS events, significantly reducing hypertension, hyperglycemia, and hypertriglyceridemia. Lowering the incidence of MetS events can help reduce the prevalence of OAB [35]. In a prospective, randomized, double-blind, placebo-controlled study, women who took magnesium supplements experienced a reduction in nighttime awakenings to urinate and improved bladder control during the day [36]. The exact etiology of OAB remains unclear, and current pharmacological treatments mainly involve anticholinergic drugs, which have side effects such as dry mouth and constipation. However, magnesium supplementation can potentially prevent and treat OAB, avoiding these adverse drug reactions.

This study reveals a significant positive correlation between MDS and the prevalence of OAB, suggesting that magnesium deficiency may play an important role in the onset and progression of OAB. Magnesium, as a key physiological regulator, is involved in nerve conduction, muscle contraction, and smooth muscle function regulation [37]. In the nervous system, magnesium stabilizes neurotransmitter release and modulates neuronal excitability [38]. Magnesium deficiency may enhance neuronal excitability, leading to bladder overactivity. Additionally, the impact of magnesium on bladder smooth muscle cannot be ignored. Research indicates that magnesium deficiency can promote excessive smooth muscle contraction by altering intracellular calcium ion concentrations [39], which exacerbates OAB symptoms. On the other hand, magnesium has significant anti-inflammatory effects [40]. Magnesium deficiency may lead to an increase in chronic low-grade inflammation, further activating inflammatory factors such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6), which play crucial roles in bladder tissue damage and dysfunction. Therefore, magnesium affects bladder function through multiple pathways, and maintaining appropriate magnesium levels may offer new approaches for the prevention and treatment of OAB.

Insufficient magnesium intake is the primary cause of magnesium deficiency, influenced by various factors such as unbalanced dietary patterns and excessive softening or purification of drinking water or seawater. Additionally, gastrointestinal malabsorption, alcohol consumption, the use of diuretics, PPIs, and other causes of excessive urinary magnesium excretion can also contribute to magnesium deficiency. Surveys indicate that a significant portion of the U.S. population has inadequate dietary magnesium intake, well below the recommended daily allowance [41]. This is attributed to the unbalanced food intake typical of Western diets, characterized by excessive consumption of high-fat meats and processed foods, and insufficient intake of whole grains and green vegetables. The 2020–2025 Dietary Guidelines for Americans have refined recommendations for a healthy eating pattern, suggesting a daily intake of approximately 170 g of grains, with at least half being whole grains [42]. This highlights the nutritional community's emphasis on whole grain consumption. Additionally, cooking and refining processes can significantly reduce the magnesium content in foods, as a substantial amount of magnesium is lost during these processes. Over-softening or purification of drinking water or seawater also contributes to insufficient magnesium intake. The World Health Organization (WHO) has not specified a recommended magnesium content for drinking water in its guidelines [43]. Excessive urinary magnesium excretion often results from alcohol consumption and the use of loop diuretics, leading to a

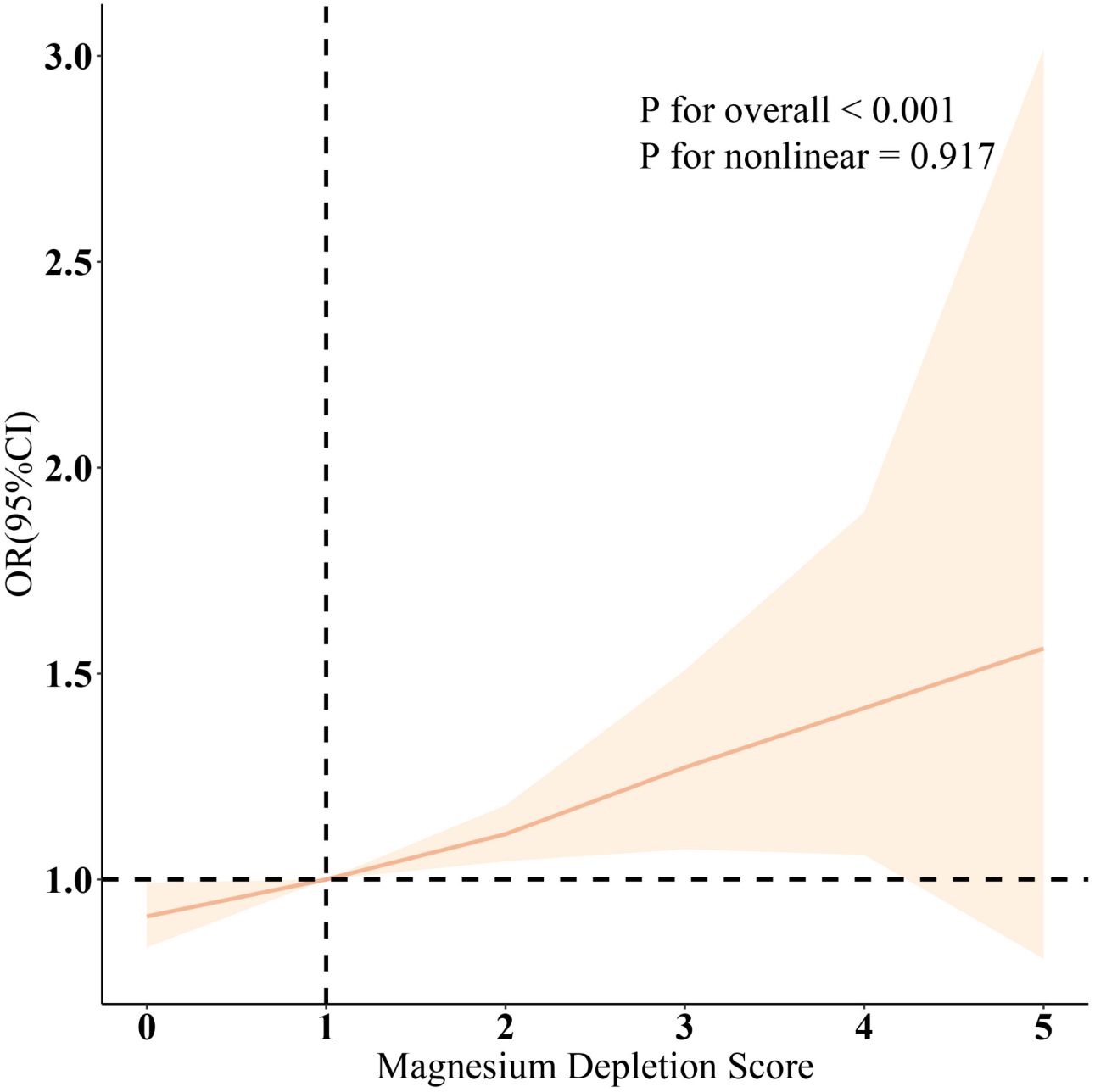

Fig. 2 Dose-response relationships between MDS and OAB. OR (solid lines) and 95% confidence levels (shaded areas) were adjusted for age, gender, education level, marital, PIR, race, obesity, smoking, drinking, hypertension, and diabetes

negative magnesium balance. Inhibition of gastric acid secretion has been shown to increase the pH levels of the small intestine and colon. This increase in pH reduces the solubility of Mg^{2+}, leading to decreased paracellular absorption of Mg^{2+} in the small intestine [44].

Given the numerous potential benefits of magnesium and its association with many chronic diseases, maintaining adequate magnesium levels in the body should be an important public health goal. There is a need to address insufficient magnesium intake, accurately evaluate recommended magnesium intake levels for the population, and promote magnesium supplementation through food. This includes reducing the refinement of grains, advocating for the consumption of whole grains and dark green vegetables rich in magnesium, and minimizing the over-purification or softening of drinking water. In the context of an aging population, maintaining optimal magnesium balance throughout life could help prevent related chronic diseases and may become a cost-effective and safe health strategy. This requires

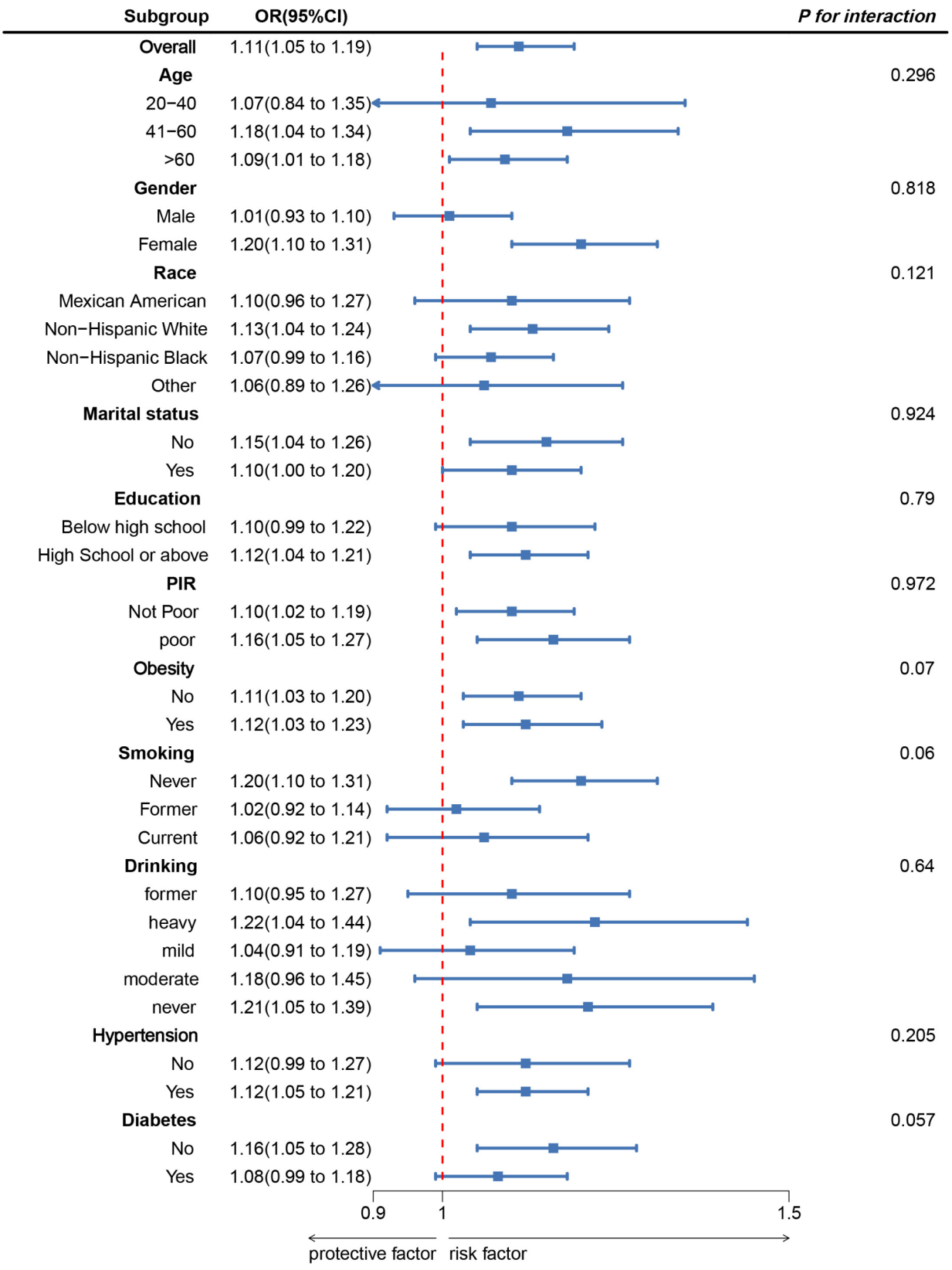

Fig. 3 Subgroup analysis between MDS and OAB. ORs were calculated as each unit increased in MDS. Analyses were adjusted for age, gender, education level, marital, PIR, race, obesity, smoking, drinking, hypertension, and diabetes

significant attention from the medical, nutritional, and social sectors.

Our study has several strengths. First, we utilized the NHANES database, which provides a large, multiethnic sample, ensuring the representativeness of our sample size. We carefully adjusted for covariates such as age, gender, race, and comorbidities, and assessed their stability across various statistical models. Second, the diagnosis of OAB was based on a scoring system rather than self-report, which helps reduce recall and subjective biases. We also performed sensitivity analyses, including subgroup analysis, to validate the robustness of our findings.

However, certain limitations must be acknowledged. As a cross-sectional study, despite adjustments for numerous confounding factors, we cannot entirely rule out the presence of unmeasured confounders and cannot establish causal relationships between variables. Although our study identifies a significant association between a higher MDS and increased OAB prevalence, the cross-sectional design precludes causal inferences. Future longitudinal or interventional studies are needed to determine whether improving magnesium levels can effectively alleviate OAB symptoms. Additionally, Future studies could consider clinical intervention trials, bladder histological assessments, and the detection of relevant molecular biomarkers to provide stronger evidence for the potential role of magnesium in OAB treatment.

Conclusion

In conclusion, our study identified a significant positive association between MDS and OAB and further examined the differences among various subgroups. Since diet is a modifiable factor, these findings have substantial implications for clinical practice and public health. The results support the implementation of tailored dietary interventions and social support measures for OAB patients to increase magnesium levels and reduce the risk of OAB.

Abbreviations

MDS	Magnesium Depletion Score
OAB	Overactive bladder
PIR	Ratio of family income to poverty
PHDI	Planetary Health Diet Index

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41043-025-00846-x.

Supplementary Material 1

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Author contributions

H.G. contributed to the original draft, Methodology, Supervision, Project administration, and Formal analysis. W.Z. contributed to Conceptualization, Methodology, Validation, Formal analysis, Resources, and Data curation. S.C. contributed to Validation, Formal analysis, Resources, and Data curation. S.H. was involved in Writing– review & editing, Supervision, Project administration, and Investigation.

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Data availability

The study involved the analysis of publicly available datasets. The data can be accessed at the following URL: https://www.cdc.gov/nchs/nhanes/.

Declarations

Ethics approval and consent to participate

The data survey conducted by NHANES has been approved by the NCHS Research Ethics Review Board (ERB). All information from the NHANES program is available and free for the public, so an individual investigator was not necessary to obtain approval from the institution's internal ethics review board.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

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