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Negative association between body roundness index and constipation: insights from NHANES

Lingting Chen[1], Huirong Xiao[2], Xuchao Yu[2], Bingbin Huang[1], Sirong Guo[1], Ting Yuan[1] and Siyang Deng[2*]

Abstract

Backgrounds The relationship between body roundness index (BRI), a metric that distinguishes heterogeneity in fat distribution, and constipation is unclear. This study is the first to investigate the association between BRI and constipation based on the National Health and Nutrition Examination Survey (NHANES) in the United States, providing a new perspective on the mechanisms of obesity-related gastrointestinal dysfunction.

Methods This cross-sectional study utilized data from the NHANES conducted between 2005 and 2010. Constipation was diagnosed based on the Bristol Stool Form Scale (BSFS). Weighted logistic regression models were employed to assess the association between BRI and constipation prevalence. Restricted cubic splines (RCS) and piecewise linear regression models were applied to evaluate non-linear relationships between BRI and constipation. Propensity score matching (PSM) was implemented to match constipated and non-constipated populations with similar baseline characteristics. Subsequent analyses were conducted to investigate the correlation between BRI and constipation.

Results A total of 12,732 eligible participants were included. A negative correlation was observed between BRI and constipation prevalence, with an adjusted odds ratio (OR) of 0.87 (95% CI: 0.80, 0.95) after controlling for all covariates. When BRI was categorized into quartiles (Q1-Q4), both Q3 and Q4 groups exhibited significantly reduced constipation risk compared to Q1 (OR = 0.72, 95% CI: 0.54–0.97; OR = 0.63, 95% CI: 0.46–0.87). The RCS regression model revealed a linear inverse association between BRI and constipation risk (nonlinearity test $P = 0.083$). Subgroup analyses identified significant interaction effects of BRI with age, alcohol consumption status, and hypertension on constipation risk (interaction $P < 0.05$). Post PSM, constipation patients demonstrated higher BRI levels than non-constipation counterparts ($P = 0.013$).

Conclusion An inverse association was observed between BRI and constipation risk in U.S. adults, suggesting that lower BRI levels may correlate with raised constipation incidence. This underscores the critical importance of maintaining optimal BRI levels for constipation prevention. Further research is warranted to elucidate the underlying mechanisms governing this association.

Keywords Body roundness index, Constipation, Propensity score matching, NHANES, Cross-sectional study

*Correspondence:
Siyang Deng
18170967580@163.com
[1]Jiangxi University of Traditional Chinese Medicine, Nanchang, China
[2]Affiliated Hospital of Jiangxi University of Traditional Chinese Medicine, Nanchang, China

Introduction

Constipation, a prevalent gastrointestinal disorder defined by the World Gastroenterology Organization (WGO), is characterized by reduced defecation frequency (less than three times weekly), difficulty in defecation, or incomplete evacuation [1]. The global incidence of constipation is rising, with an estimated prevalence rate of approximately 15% worldwide [2]. Constipation adversely impacts not only physical health but also psychological and social functioning, thereby diminishing quality of life and imposing substantial burdens on healthcare resources [3, 4]. Multiple factors are associated with constipation [4]. Among these factors, obesity emerges as a critical modifiable risk factor requiring urgent investigation [5, 6].

A Turkish cross-sectional study identified risk factors for constipation in the general population: female gender, advanced age, obesity, low income, low level of education, physical inactivity, pharmacological factors, and dietary elements including low fiber intake, inadequate fluid consumption, and frequent fast-food consumption [7]. This aligns with global trends in obesity epidemiology. Obesity has become a global public health issue [8]. Obesity is defined as a body mass index (BMI) ≥ 30 kg/m^2, characterized by an abnormal accumulation of adipose tissue and accompanied by a range of metabolic abnormalities including insulin resistance, type 2 diabetes mellitus, dyslipidemia, non-alcoholic fatty liver disease (NAFLD) and hypertension [9, 10].

BMI is a commonly used indicator to assess the risk of obesity and chronic diseases in epidemiological studies, but it cannot reflect the characteristics of fat distribution [11]. To compensate for this limitation, the body roundness index (BRI) was proposed in 2013 as a novel tool for assessing body fat distribution and visceral fat [13]. By quantifying height-adjusted body roundness (abdominal obesity) and providing more accurate predictions of body fat percentage and total visceral adipose tissue percentage, BRI demonstrates significant advantages over BMI and other conventional indices in evaluating fat distribution and associated disease risks [12]. Studies have established significant correlations between BRI and cardiovascular diseases, diabetes, bone mineral density and metabolic syndrome [13–15]. However, its relationship with gastrointestinal dysfunction has not been clarified. The specific association between BRI and constipation is still unclear.

The National Health and Nutrition Examination Survey (NHANES) is an extensive cross-sectional database that has been used extensively in epidemiologic studies [16–18]. Therefore, this study aims to provide a new scientific basis for the development of targeted constipation prevention and management strategies by systematically investigating the relationship between BRI (Body Circularity Index) and constipation using data from the National Health and Nutrition Examination Survey (NHANES).

Methods

Study design and population

This study utilized publicly available NHANES datasets. NHANES designed to collect comprehensive data on the nutrition and health of the U.S. population. Conducted biennially, the survey employs a cross-sectional study design and implements a complex multistage probability sampling technique.

The NHANES was conducted by the Centers for Disease Control and Prevention (CDC) and received ethical approval from the National Center for Health Statistics (NCHS) Research Ethics Review Board (ERB). All participants provided written informed consent and data were de-identified for public use [19]. The study design and relevant data are accessible through a public platform [20]. All methodologies strictly adhered to relevant ethical standards and regulatory requirements throughout the research process.

This study is a cross-sectional study. The analysis focused on NHANES datasets from 2005 to 2010, initially comprising 31,034 participants. Based on study design and data requirements, exclusions included 14,945 participants aged < 20 years, pregnant individuals, or those lacking weight data; 1,910 excluded due to insufficient constipation data; and 372 excluded for missing data (including covariates, $N = 1{,}075$). Ultimately, 12,732 eligible participants were included in the final analysis (Fig. 1).

Definition of constipation

The definition of constipation was established by referencing the NHANES database and considering bowel movement frequency or stool consistency [21, 22]. Prior to data collection, stool texture and frequency were recorded for 30 days. Participants were instructed to estimate stool consistency using the Bristol Stool Form Scale (BSFS), which involved examining a card displaying colored illustrations and descriptions of seven stool types. They were then directed to identify the numerical code corresponding to their usual or most commonly observed stool type: Type 1 (separate hard lumps resembling nuts), Type 2 (sausage-shaped but smooth), Type 3 (sausage-like with surface cracks), Type 4 (smooth and soft sausage/snake-shaped), Type 5 (soft blobs with clear edges), Type 6 (fluffy pieces with ragged edges), and Type 7 (watery with no solid pieces) [23]. Participants were asked: "Please examine this card and indicate the number corresponding to your usual or most frequent stool type." Constipation was defined as Type 1 or 2, while Types 3–7 were categorized as non-constipation [23]. Bowel

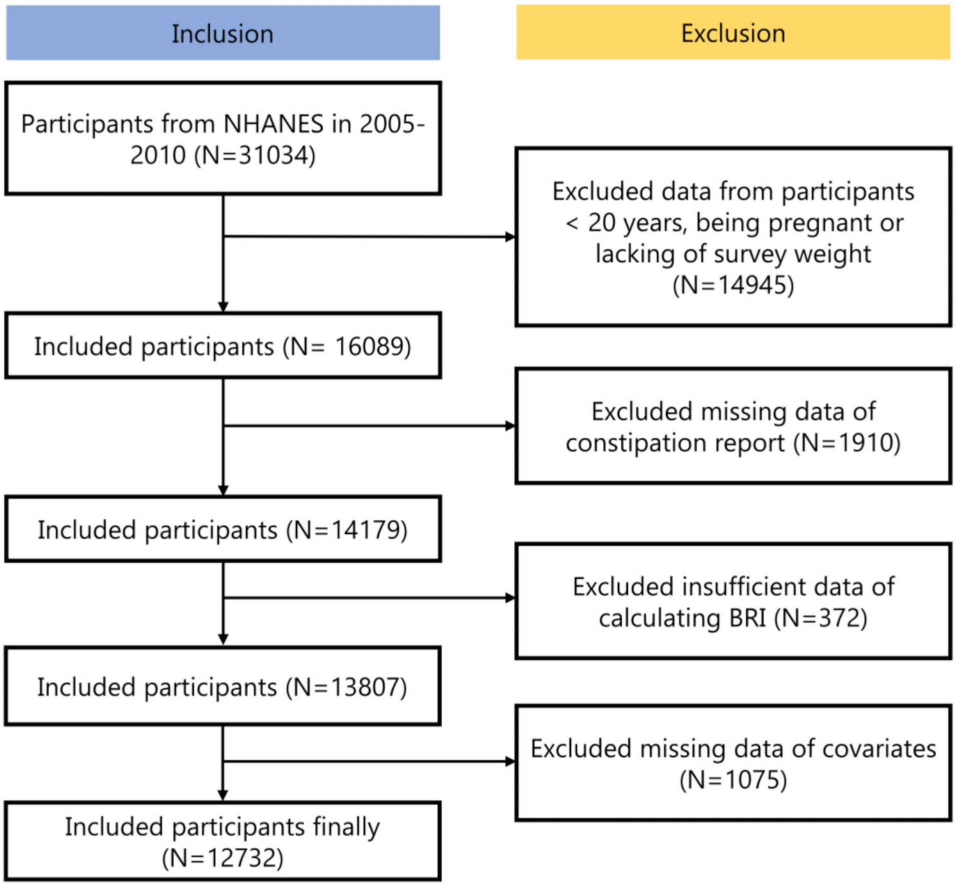

Fig. 1 Screening flow of respondents

movement frequency was assessed through the question: "How many times per week do you typically have bowel movements?" Individuals reporting fewer than three bowel movements weekly were classified as constipated, whereas those reporting three or more movements per week were categorized as non-constipated.

BRI measurement

Anthropometric data (including body height [BH], body weight, and waist circumference [WC]) were collected by professionally trained examiners at mobile examination centers equipped with standardized instruments. Participants' body weight was measured using a calibrated platform scale with 0.1 kg precision, while standing height was determined to the nearest 0.1 cm using a stadimeter. All measurements were conducted with participants wearing lightweight clothing and no footwear to ensure data accuracy. Consistent with previous studies, the Body Roundness Index (BRI) was calculated using the formula developed by Thomas et al. [12]:

$$\mathrm{BRI} = .364.2 - 365.5 * \sqrt{\frac{1 - [\mathrm{WC(m)}/2\pi\,]^2}{[0.5*\mathrm{height(m)}]^2}}$$

Covariates

This study utilized questionnaire and physical examination data collected by investigators from the NHANES database, encompassing demographic information (age, sex, race/ethnicity, family income-to-poverty ratio [PIR], education level, and marital status), behavioral factors (smoking and alcohol consumption information) and complications (hypertension, diabetes). Detailed definitions of covariates are given in Supplementary Table 1.

Statistical analysis

Weighted statistical analysis was performed for each participant according to NHANES complex multi-stage cluster sampling design. Group differences in categorical variables were assessed using Chi-square tests, while Analysis of Variance (ANOVA) was applied for continuous variables. To investigate the relationship between BRI and constipation, three multivariable logistic regression models were constructed: Model I without covariate adjustment, Model II adjusted for age, sex, and race/ethnicity, and Model III additionally adjusted for marital status, education level, PIR, smoking status, alcohol use, hypertension, cardiovascular disease, and diabetes history. Subgroup analyses stratified by sex, age, and other key variables were conducted to assess potential interaction effects between BRI and grouping variables on constipation progression. Smooth curve fitting was utilized to detect nonlinear relationships between BRI and constipation, with potential threshold effects examined using piecewise linear regression models. Propensity score matching (PSM) analysis employed nearest-neighbor matching at a 1:1 ratio to pair constipation patients with controls. Confounding variables including age, sex, race, PIR, education level, marital status, smoking status, alcohol consumption, diabetes, hypertension history, WBC, and CRP were adjusted during matching. Statistical analyses were performed using SPSS version 25.0 [24] and R software version 4.1 [25]. A *p*-value < 0.05 was considered statistically significant.

Results

Characteristics of participants

Table 1 presents the baseline characteristics of 12,732 NHANES participants from 2005 to 2010, among whom 1,271 were diagnosed with constipation. Approximately half (50.5%) were female and proportion of participants

Table 1 Characteristics of participants grouped by constipation in NHANES 2005–2010

Variables	Total	Non-constipation group	Constipation group	*P*
n	12,732	11,461	1271	
Age, n				0.001
20–39	4213 (36.8)	3711 (36.2)	502 (42.5)	
40–59	4300 (40.2)	3887 (40.5)	413 (37.3)	
≥ 60	4219 (23)	3863 (23.3)	356 (20.2)	
Gender, n (%)				< 0.001
Male	6460 (49.5)	6066 (51.9)	394 (26.1)	
Female	6272 (50.5)	5395 (48.1)	877 (73.9)	
Race (%)				< 0.001
Mexican American	2227 (7.7)	2023 (7.7)	204 (7.9)	
Other Hispanic	1003 (4.1)	888 (4)	115 (4.9)	
Non-Hispanic White	6461 (72.3)	5886 (72.9)	575 (66.5)	
Non-Hispanic Black	2535 (10.6)	2200 (10.1)	335 (16.2)	
Other Race-Including Multi-Race	506 (5.2)	464 (5.3)	42 (4.4)	
Education (%)				< 0.001
Less than high school	3447 (17.6)	3050 (17.2)	397 (21.7)	
High school grad/GED or equivalent	3060 (24.3)	2701 (23.8)	359 (29.5)	
Higher than high school	6225 (58.1)	5710 (59)	515 (48.9)	
Marital status, n (%)				0.001
Married/living with partner	7820 (65.3)	7113 (65.9)	707 (59.3)	
Widowed/divorced/separated	2861 (18.4)	2546 (18)	315 (22.1)	
Never married	2051 (16.3)	1802 (16.1)	249 (18.7)	
PIR, n (%)				< 0.001
≤ 1.3	3706 (18.9)	3223 (18)	483 (27.6)	
1.3–3.5	4930 (36.2)	4440 (36)	490 (37.8)	
> 3.5	4096 (45)	3798 (46)	298 (34.6)	
Smoking status, n (%)				0.001
Non smokers	6599 (52.5)	5872 (52)	727 (57.9)	
Former smokers	3257 (24.9)	3005 (25.5)	252 (19.1)	
Current smokers	2876 (22.6)	2584 (22.5)	292 (23.1)	
Drinking status, n (%)				< 0.001
Non drinkers	4109 (26.5)	3616 (25.9)	493 (32.8)	
Moderate drinkers	7665 (64.9)	6947 (65.2)	718 (61.7)	
Heavy drinkers	958 (8.6)	898 (8.9)	60 (5.4)	
Diabetes, n (%)				0.784
Yes	1428 (7.8)	1279 (7.8)	149 (8)	
No	11,304 (92.2)	10,182 (92.2)	1122 (92)	
Hypertension, n (%)				0.012
Yes	4444 (30.3)	4059 (30.7)	385 (27.1)	
No	8288 (69.7)	7402 (69.3)	886 (72.9)	
BRI, mean (SD)	5.14 (1.19)	5.14 (1.19)	5.16 (1.19)	0.599

aged 40 to 59 (40.2%) was the highest. By comparing the differences in the distribution of different variables between the non-constipated and constipated groups, it was found that the constipated population had a significantly higher percentage of females (73.9% vs. 48.1%), blacks (16.2% vs. 10.1%), low education (21.7% vs. 17.2%), and low PIR (27.6% vs. 18%).

The associations of BRI and consolidation in weighted logistic regression models

Table 2 displayed the results of three weighted logistic regression model. In Model 1, the risk of constipation was not associated with BRI level. However, In Model 2, after adjusting for age, gender, race, education, PIR, marital status, the risk of constipation decreased by 13% with a unit increment in BRI in continuous analyses (OR: 0.87, 95% CI: 0.80,0.95). In categorical analyses, the objects in Q3 and Q4 group had a lower risk of constipation compared with Q1 group with the OR (95% CI) of 0.73 (0.54, 0.97) and 0.64 (0.47, 0.88) and the linear trend was significant (P for trend = 0.001). After adjusting for all covariates, the risk of constipation also decreased by 13% with a unit increment in BRI in continuous analyses (OR: 0.87, 95% CI: 0.80,0.95). In categorical analyses, the objects in Q3 and Q4 group had a lower risk of constipation compared with Q1 group with the OR (95% CI) of 0.72 (0.54, 0.97) and 0.63 (0.46, 0.87) and the linear trend was obvious (P for trend = 0.001).

The associations between BRI and constipation stages in RCS repression model

We established RCS regression model to explore the non-linear relationship between constipation and BRI (Fig. 2). The RCS regression model indicated a linear negative association between BRI and the risk of constipation after considering all covariates (P for non-linear = 0.083).

Subgroup analysis

After that, we explored the associations of BRI with constipation according to different groups of gender, age, race, education, PIR, marital status, drinking status, smoking status, diabetes and hypertension (Fig. 3). BRI were negatively with the risk of constipation in the overwhelming majority of groups. It was interesting that BRI and age, drinking status and hypertension had a significant interaction effect on constipation (P for interaction < 0.05).

PSM analysis

PSM analysis was conducted to evaluate the association between BRI and constipation in total participants. We adjusted all covariates between constipation patients and those without constipation (Table 3). The BRIs in constipation patients were higher than those in patients without constipation ($P = 0.013$). In addition, SMDs of all variables were less than 0.1, which indicated that good matching effect (Fig. 4).

Discussion

This study is the first to systematically explore the association between BRI and constipation based on NHANES 2005–2010 data. A cross-sectional analysis of 12,732 participants revealed that BRI was significantly and negatively associated with the risk of constipation after adjusting for confounders such as age, sex, and ethnicity (aOR = 0.87, 95% CI: 0.80–0.95). rcs-type confirmed that there was a linear negative correlation. Notably, subgroup analyses revealed a significant interaction between the effect of BRI on constipation in age, drinking status and hypertension. After propensity score matching, constipated patients still had significantly higher BRI levels than the non-constipated population. These results suggest that maintaining appropriate BRI levels may be clinically important for the prevention of constipation.

As a novel obesity indicator, the Body Roundness Index (BRI) exhibits distinct advantages over traditional measures such as Body Mass Index (BMI), waist circumference, and waist-to-hip ratio. First, BRI more accurately reflects body fat distribution, particularly abdominal adiposity, as it incorporates both weight-height proportionality and abdominal fat parameters [26]. Second, BRI demonstrates enhanced adaptability to demographic

Table 2 The associations of BRI and consolidation in weighted logistic regression models

	Model 1		Model 2		Model 3	
	OR (95% CI)	***P***	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
Continuous	1.02 (0.95, 1.09)	0.595	0.87 (0.80, 0.95)	0.003	0.87 (0.80, 0.95)	0.003
Q1	Reference				Reference	
Q2	1.12 (0.87, 1.43)	0.378	1.09 (0.84, 1.43)	0.49	1.1 (0.84, 1.43)	0.479
Q3	0.9 (0.69, 1.17)	0.415	0.73 (0.54, 0.97)	0.033	0.72 (0.54, 0.97)	0.032
Q4	1.04 (0.81, 1.35)	0.736	0.64 (0.47, 0.88)	0.007	0.63 (0.46, 0.87)	0.007
P for trend	0.903		0.001		0.001	

Model 1 was not adjusted for any covariate

Model 2 was adjusted for age, gender, race, education, PIR, marital status

Model 3 was adjusted for age, gender, race, education, PIR, marital status, smoking status, drinking status, diabetes and hypertension

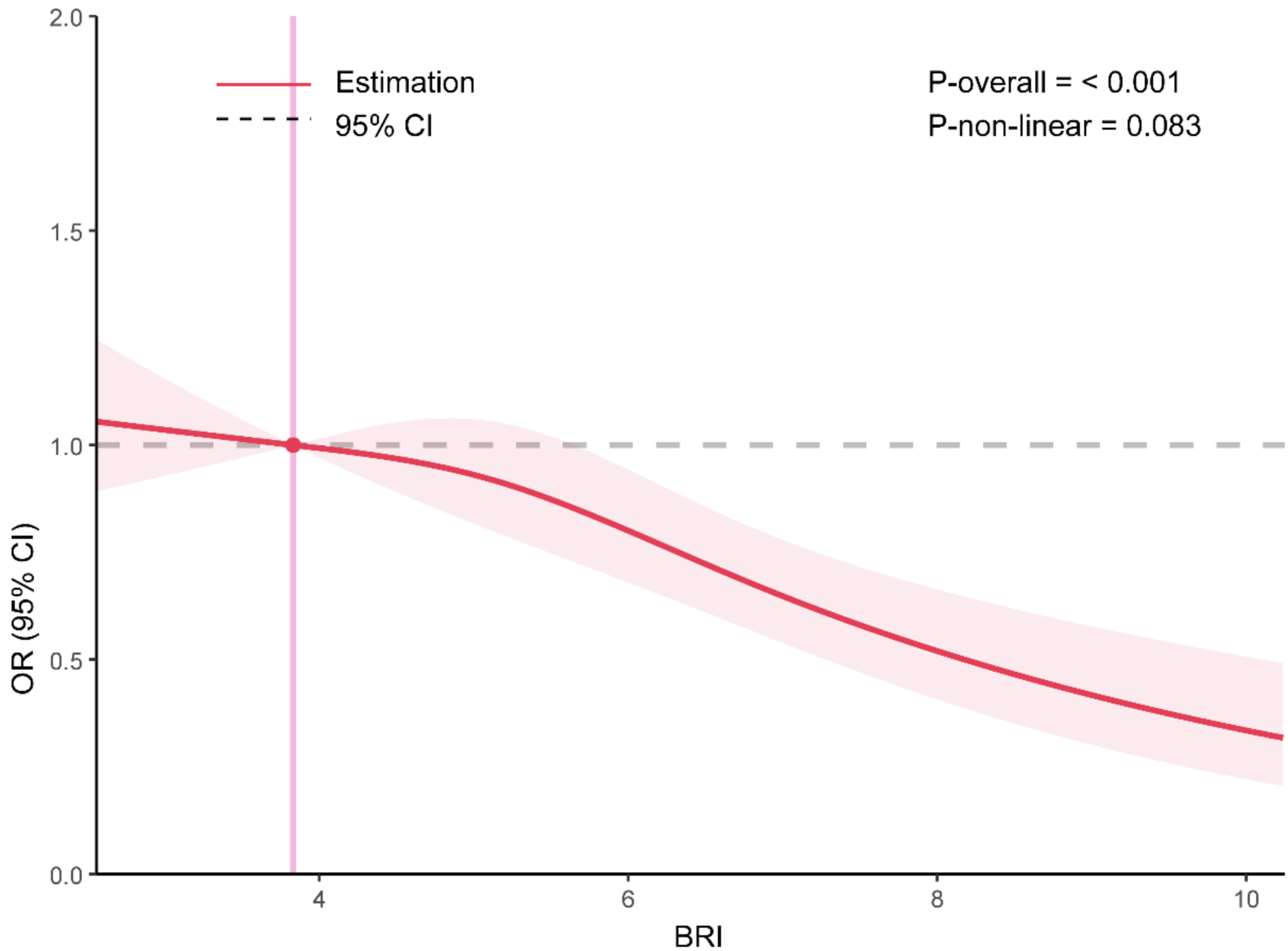

Fig. 2 RCS regression model. The model was adjusted for all covariates

variations, including gender differences and age-related adiposity distribution patterns, effectively mitigating the biases inherent in traditional BMI assessments [14]. Third, unlike BMI which overlooks metabolic heterogeneity across subgroups, BRI provides a precision medicine-oriented evaluation of obesity patterns. Building on this capability, BRI exhibits superior sensitivity and specificity in detecting early-stage obesity-related health risks, even in individuals without overt obesity, thereby enabling timely health interventions [27]. In conclusion, BRI offers a comprehensive and accurate perspective for obesity evaluation, particularly valuable for individuals whose BMI values inadequately reflect their physiological status. Given its superior sensitivity in detecting preclinical risks, BRI is poised to play a transformative role in clinical obesity management. With ongoing research advancements, its utility in preventing obesity-related comorbidities is expected to expand substantially.

The relationship between obesity and constipation remains highly controversial, with growing evidence suggesting a complex interplay between the two [5]. A study indicates no correlation between constipation frequency and body weight in adolescents, while systematic reviews by Eslick and large-scale French studies confirm no significant association between obesity and constipation in adult populations [28, 29]. However, studies on specific populations yield conflicting findings: within Iranian ethnic groups, overweight children exhibit rising constipation prevalence, and 60% of constipated adults are overweight [6]. The Xiang study reveals a nonlinear relationship where constipation risk decreases as BMI approaches 28 kg/m^2, but sharply increases beyond this threshold [30]. These discrepancies suggest that age stratification and obesity assessment criteria may critically influence research conclusions.

However, contradictory findings have emerged. A two-sample Mendelian randomization analysis demonstrates that adult overweight reduces constipation risk, whereas the opposite trend occurs in pediatric populations [31]. A study of 354 constipated patients identifies an inverse correlation between BMI and colonic transit time, with overweight patients showing shorter rectosigmoid and total colonic transit durations compared to normal-BMI counterparts, alongside improved colonic

Characteristic	OR (95%CI)	P value	P for interaction
Age			0.023
20-39	0.92 (0.84, 1.01)	0.090	
40-59	0.84 (0.74, 0.96)	0.015	
≥60	0.75 (0.64, 0.87)	<0.001	
Gender			0.268
Male	0.90 (0.78, 1.03)	0.124	
Female	0.86 (0.78, 0.95)	0.006	
Education			0.824
Less than high school	0.89 (0.77, 1.04)	0.164	
High school grad/GED or equivalent	0.92 (0.80, 1.06)	0.250	
Higher than high school	0.81 (0.72, 0.92)	0.002	
PIR			0.453
≤1.3	0.98 (0.86, 1.11)	0.751	
1.3-3.5	0.79 (0.70, 0.90)	<0.001	
>3.5	0.85 (0.74, 0.97)	0.023	
Marital status			0.215
Married/living with partner	0.87 (0.80, 0.96)	0.005	
Widowed/divorced/separated	0.79 (0.67, 0.92)	0.004	
Never married	0.92 (0.80, 1.05)	0.235	
Race			0.205
Mexican American	0.99 (0.86, 1.14)	0.855	
Other Hispanic	0.70 (0.56, 0.87)	0.003	
Non-Hispanic White	0.87 (0.79, 0.96)	0.011	
Non-Hispanic Black	0.88 (0.78, 0.99)	0.033	
Other Race - Including Multi-Racial	0.66 (0.45, 0.97)	0.038	
Smoking status			0.239
Non smokers	0.84 (0.75, 0.94)	0.003	
Former smokers	0.92 (0.77, 1.09)	0.321	
Current smokers	0.89 (0.79, 1.01)	0.087	
Drinking status			0.004
Non drinkers	0.74 (0.65, 0.83)	<0.001	
Moderate drinkers	0.94 (0.85, 1.03)	0.194	
Heavy drinkers	0.91 (0.70, 1.18)	0.498	
Diabetes			0.781
Yes	0.81 (0.63, 1.03)	0.092	
No	0.87 (0.80, 0.94)	0.002	
Hypertension			0.003
Yes	0.74 (0.66, 0.83)	<0.001	
No	0.91 (0.83, 1.00)	0.068	

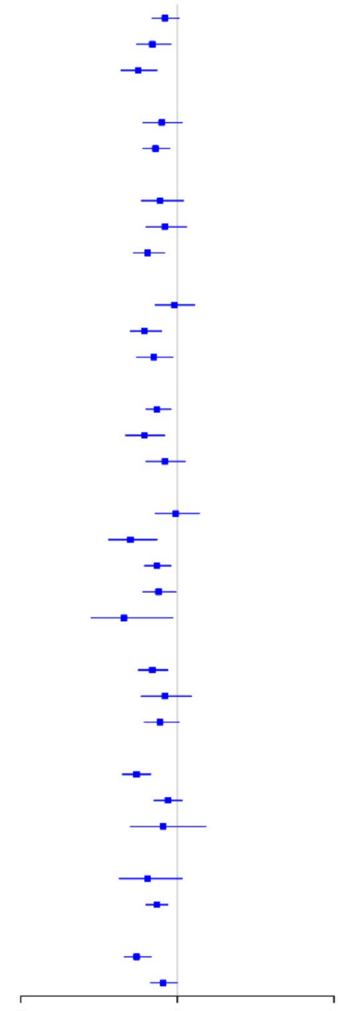

Fig. 3 Subgroup analysis of the associations between BRI and consolidation

motility, stool consistency, and defecation frequency [32]. The Hong study corroborates that obese individuals exhibit lower susceptibility to constipation [33]. Notably, multiple studies indicate that underweight populations are more prone to constipation [34, 35]. Variations in study populations and obesity metrics may alter the obesity-constipation association, potentially leading to divergent conclusions. Therefore, to investigate the complex relationship between obesity and constipation, and given that existing studies predominantly rely on BMI indices while BRI demonstrates superior performance in obesity assessment, we analyzed NHANES data from 2005 to 2010 to explore the correlation between BRI and constipation in adults aged 20 years and older. Also, the RCS analysis results showed that BRI was linearly and negatively associated with the risk of constipation. Tube machine learning methods perform well in complex association analysis [36–38], but the idea of capturing nonlinear effects through RCS analysis [39] is consistent with machine learning feature engineering.

The weighted logistic regression model adjusted for all covariates revealed that each 1-unit increase in BRI was associated with a 13% reduction in constipation risk (OR: 0.87, 95% CI: 0.80–0.95), while subgroup analyses demonstrated the ubiquity of this inverse correlation with significant interactions observed for age, alcohol consumption, and hypertension ($P < 0.05$). This inverse association may operate through three synergistic pathways: First, obesity correlates with microbial dysbiosis [40, 41], where imbalanced gut microbiota promotes pathogenic bacterial overgrowth, predisposing to diarrheal disorders like ulcerative colitis and Crohn's disease rather than constipation [42, 43]. Additionally, psychosocial factors (e.g., anxiety, depression) prevalent in younger populations may link to early gut microbiota alterations [44, 45], with diminished bacterial diversity and modified

Table 3 PSM analysis

Variables	Non-constipation group	Constipation group	*P*
n	1271	1271	
Age, n			
20–39	504 (39.7)	502 (39.5)	0.801
40–59	399 (31.4)	413 (32.5)	
≥ 60	368 (29.0)	356 (28.0)	
Gender, n (%)			
Male	395 (31.1)	394 (31.0)	1
Female	876 (68.9)	877 (69.0)	
Race (%)			
Mexican American	199 (15.7)	204 (16.1)	0.152
Other Hispanic	97 (7.6)	115 (9.0)	
Non-Hispanic White	600 (47.2)	575 (45.2)	
Non-Hispanic Black	313 (24.6)	335 (26.4)	
Other Race-Including Multi-Race	62 (4.9)	42 (3.3)	
Education (%)			
Less than high school	386 (30.4)	397 (31.2)	0.573
High school grad/GED or equivalent	344 (27.1)	359 (28.2)	
Higher than high school	541 (42.6)	515 (40.5)	
Marital status, n (%)			
Married/living with partner	468 (36.8)	483 (38.0)	0.766
Widowed/divorced/separated	507 (39.9)	490 (38.6)	
Never married	296 (23.3)	298 (23.4)	
PIR, n (%)			
≤ 1.3	737 (58.0)	707 (55.6)	0.483
1.3–3.5	300 (23.6)	315 (24.8)	
> 3.5	234 (18.4)	249 (19.6)	
Smoking status, n (%)			
Non smokers	738 (58.1)	727 (57.2)	0.863
Former smokers	252 (19.8)	252 (19.8)	
Current smokers	281 (22.1)	292 (23.0)	
Drinking status, n (%)			
Non drinkers	508 (40.0)	493 (38.8)	0.828
Moderate drinkers	705 (55.5)	718 (56.5)	
Heavy drinkers	58 (4.6)	60 (4.7)	
Diabetes, n (%)			
Yes	143 (11.3)	149 (11.7)	0.756
No	1128 (88.7)	1122 (88.3)	
Hypertension, n (%)			
Yes	365 (28.7)	385 (30.3)	0.409
No	906 (71.3)	886 (69.7)	
BRI, mean (SD)	5.42 (1.26)	5.30 (1.21)	0.013

metabolic pathways potentially contributing to constipation development, aligning with elevated risk observed in pediatric cohorts. Second, chronic alcohol intake induces pathological aggregation of α-synuclein (SNCA) in both central and enteric nervous systems. SNCA propagates bidirectionally along the gut-brain axis from enteric nerve terminals to the central nervous system, causing dopaminergic dysfunction that disrupts neural regulation of intestinal motility, manifesting as reduced peristaltic frequency–a mechanism corroborated in animal models [46]. Finally, hypertension patients exhibit elevated Firmicutes-to-Bacteroidetes ratios indicative of dysbiosis [47, 48], which interacts with gut pathology, intestinal permeability, and the gut-brain axis to promote enteric inflammation—a process paradoxically associated with reduced constipation incidence. These multipathway mechanisms collectively elucidate the inverse relationship between BRI and constipation risk.

In addition, our study found significant differences in social, economic, and racial factors between constipated and no constipated populations. For example, in the constipated group, there were significantly higher

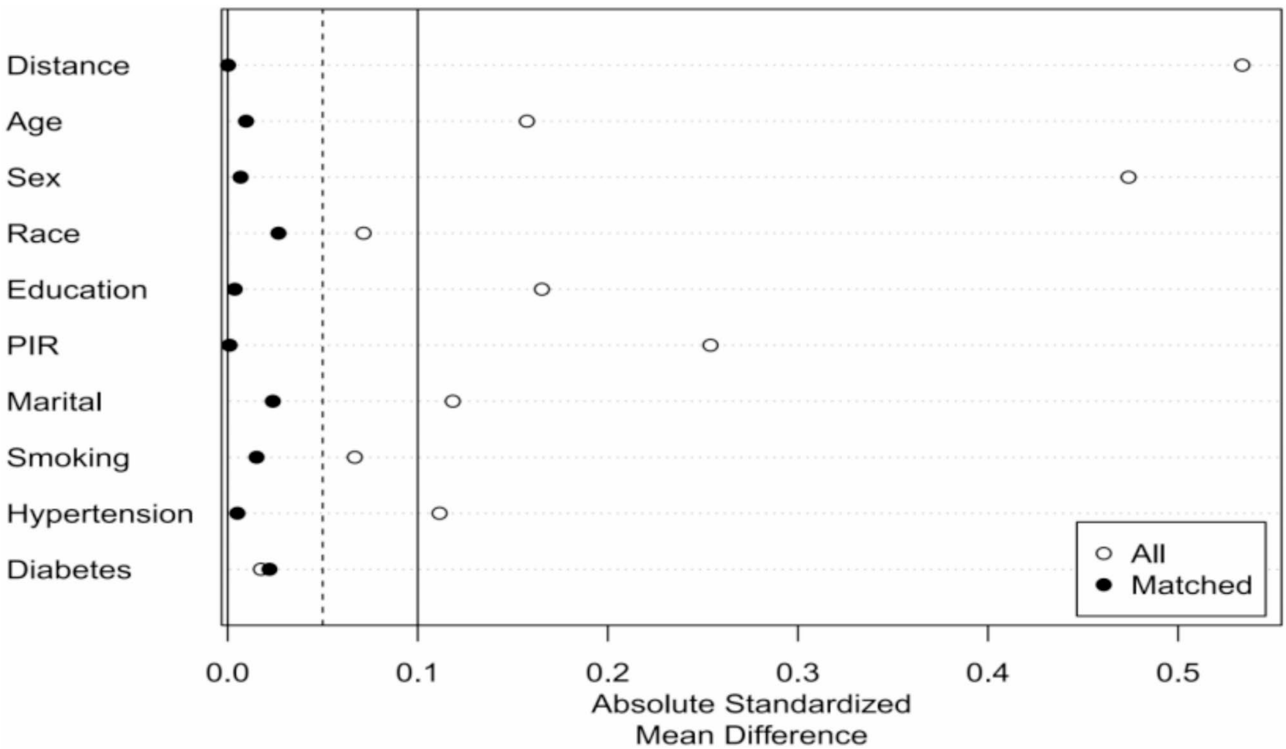

Fig. 4 Balanced diagnostic plot of PSM

proportions of females, blacks, those with lower levels of education (Less than high school), low household income (PIR ≤ 1.3), and those who were not partnered (Widowed/divorced/separated/Never married). This finding is consistent with the results of several studies on health inequalities [49]. These results are consistent with the theory of social determinants of health, suggesting that the risk of constipation is not only influenced by biological factors, but is also strongly associated with socioeconomic status [50]. The higher risk of constipation in women may be related to hormone levels, differences in pelvic floor function, and behavioral factors related to social roles [51]. The higher risk of constipation in the black population may reflect differences in access to healthcare resources, differences in dietary patterns, and the impact of structural racism on health [52]. The association of lower levels of education and household income with increased risk of constipation may stem from multiple factors such as health literacy limitations, difficulties in accessing healthy foods, and higher levels of stress [53]. The correlation between partner lessness and constipation risk, on the other hand, may reflect the positive impact of social support on health behaviors, including regular diet and healthcare-seeking behaviors [54]. These findings emphasize the need to consider differences in sociodemographic factors in constipation prevention and management.

Although the present study provides new scientific evidence, there are still several limitations that need to be elucidated. First, limited by the cross-sectional study design, we were unable to infer a causal relationship between BRI and constipation, and future longitudinal studies are needed to further validate this. Second, the study population was primarily based on a U.S. sample, and extrapolation of the findings to African or Asian populations may be limited due to racial differences and geographic factors. In addition, the definition of disease in this study relied heavily on patients' self-reported data, which may have introduced recall bias. Additionally, due to database limitations, some of our indicators of interest were not included in the analysis, such as gut microbiota composition, congenital developmental malformations, digestive surgery, and gene expression, and the possibility of residual confounders from these unmeasured factors remains. What's more, while PSM improves comparability between groups, potential selection bias and loss of sample size during matching may affect the robustness of the results. Finally, although bioelectrical impedance analysis (BIA) is a commonly used method for assessing body fat content, we were unable to analyze BRI in comparison with BIA measurements due to the lack of BIA-related data in the cycle of the database used in this study, which limits the comprehensiveness of the findings to some extent.

Conclusion

The present study, based on US NHANES data, found for the first time that BRI was significantly negatively associated with the risk of constipation and that this negative association showed a linear dose-response relationship. Subgroup analyses revealed significant differences in this association across age, drinking status, and hypertension, and the results remained robust after propensity score matching. The study suggests that maintaining an appropriate body fat distribution may help prevent constipation and provides a new perspective on the mechanisms of obesity-related gastrointestinal dysfunction, which needs to be validated in prospective cohorts and further explored for its underlying biological mechanisms.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

The authors' responsibilities were as follows—Siyang Deng: designed the research, and had primary responsibility for the final content; Lingting Chen: conducted analyses and wrote the first draft of the paper; Huirong Xiao and Xuchao Yu: revised the manuscript; Bingbin Huang performed data collection and statistical analysis. Sirong Guo and Ting Yuanwere responsible for investigation and validation of results and all authors: read and approved the final manuscript and approved the final submitted version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethical approval

This study does not require ethical approval, as it does not involve human participants, personal data, or animal subjects. All data utilized in this research are publicly available and de-identified, thus exempting it from the need for ethical review.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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