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Association of body roundness index with chronic diarrhea and constipation, NHANES 2005–2010

Yan Zhuang[1], Laifu Li[1], Jingyan Sun[2], Yanqi Zhang[1] and Fei Dai[1*]

Abstract

Background Chronic diarrhea and constipation are known to be associated with obesity. Body roundness index (BRI), as a novel physical dimension assessment indicator, provides a more comprehensive evaluation of body and visceral fat than traditional methods. However, the relationship between BRI, chronic diarrhea, and constipation remains unclear. We aimed to investigate the relationship between BRI, chronic diarrhea, and constipation.

Methods A cross-sectional study based on the National Health and Nutrition Examination Survey 2005–2010 was conducted. Weighted multivariable logistic regression was used to analyze the association between BRI, chronic diarrhea, and constipation. Restricted cubic spline curves were plotted to verify the linear associations.

Results 7182 participants were included in this study, among whom 491 had chronic diarrhea and 441 had constipation. Significant positive correlations were discovered between BRI and chronic diarrhea, while no correlation was detected with constipation in the fully adjusted multivariable logistic regression analysis. Restricted cubic spline curves confirmed the linear relationship described above. Further treating BRI as categorical variables, compared with the lowest tertile, the highest BRI tertile showed a 79% increase in chronic diarrhea incidence and a 35% decrease in chronic constipation incidence. Consistent findings were observed across different subgroups, and sensitivity analyses generally confirmed the robustness of our results.

Conclusions BRI is significantly and linearly associated with chronic diarrhea. Higher body and visceral fat increase the risk of chronic diarrhea while reducing the risk of chronic constipation.

Keywords BRI, Chronic diarrhea, Chronic constipation, Cross-sectional study, NHANES

Introduction

Chronic gastrointestinal symptoms present a complex and common issue for clinicians. Chronic diarrhea involves increased water content in stool and is characterized by increased bowel frequency and loose stools persisting over 4 weeks [1]. Patients with chronic constipation present with a bowel movement frequency of less than 3 times/week, often accompanied by hard or lumpy stools, incomplete evacuation, and bloating [2]. Globally, chronic constipation is estimated to affect 15% of the population [2], while chronic diarrhea affects 4–5%, approximately half that of chronic constipation [1, 3]. It is noteworthy that unlike chronic constipation, which is more likely to be experienced among the elderly, chronic diarrhea is common among younger populations. The pathogenesis of chronic diarrhea and constipation is multifactorial, involving genetic susceptibility, infections, hormonal imbalances, and other factors [4, 5]. In the

*Correspondence:
Fei Dai
daifei68@xjtu.edu.cn
[1] Department of Gastroenterology, The Second Affiliated Hospital of Xi'an Jiaotong University, Xi'an, China
[2] Department of Cardiovascular Surgery, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, China

United States, chronic diarrhea is more likely to be functional [5], influenced significantly by lifestyle, diet, and physical condition [6]. Given the considerable economic burden of chronic gastrointestinal diseases on communities, identifying and early intervention in the risk factors for chronic diarrhea and constipation are particularly crucial.

Obesity is defined as an excessive accumulation of adipose tissue due to elevated energy intake and decreased energy expenditure, manifested by a disproportionate weight for height [7]. Nowadays, over one-third of the population is identified as overweight [8], which is progressively becoming a major social concern. As an increasingly prevalent chronic disease, obesity significantly affects physical health and is often coexisted with various diseases such as type 2 diabetes, cardiovascular disease, etc. [7]. Furthermore, several studies indicated a significant positive association between higher Body Mass Index (BMI) and diarrhea [9, 10], while negatively associated with constipation [11]. The fact that obesity is often accompanied by more frequent gastrointestinal disorders and appears earlier in the natural history of obesity suggests that obesity has become an alarm signal for gastrointestinal disorders. Enhancing control over obesity rates holds crucial public health significance in improving gut health.

There is a growing belief that visceral fat poses greater health risks than subcutaneous fat [12, 13]. To better characterize the visceral fat composition and differentiate various types of obesity, researchers have proposed a metric called the body roundness index (BRI), which, based on BMI, is a more comprehensive predictor of visceral adipose tissue and body fat percentage [14, 15]. Previous research has demonstrated that BRI is superior in predicting diseases such as colorectal cancer [16] and metabolic syndrome [17] compared to traditional body measurement indices like BMI. However, it is unknown how BRI, chronic diarrhea, and constipation are related. To address this gap, we investigated the connection between BRI, chronic diarrhea, and constipation through the National Health and Nutrition Examination Survey (NHANES).

Methods

Study population

The NHANES data between 2005 and 2010 was utilized in this cross-sectional study. NHANES, an ongoing project led by the National Center for Health Statistics, is a nationally representative survey conducted in the U.S. It encompasses various dietary, questionnaire, examination, and laboratory data targeting the American population. For more detailed information, please visit the Website: https://www.cdc.gov/nchs/nhanes/about_nhanes.htm.

Between 2005 and 2010, 31,034 participants were randomly recruited, of whom 17,132 were aged 20 years or older. After excluding 2513 participants without gut health data, 14,619 participants were included. Among them, 379 participants with missing BRI information were further excluded. To ensure robust findings, those who were pregnant (n = 373), had colorectal cancer diagnosis (n = 100), or incomplete covariables (n = 6585) were excluded. Ultimately, the analysis included 7182 study participants (shown in Fig. 1).

Ethical approval

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the U.S. Centers for Disease Control and Prevention's National Center for Health Statistics Ethics Review Board. The ethical approval number is Protocol #2005–06. Written informed consent was obtained from all subjects. Verbal consent was witnessed and formally recorded.

Chronic diarrhea and constipation

The Bristol Stool Scale assessment was used to classify participants based on their usual type of feces. In NHANES, participants were shown the Bristol Stool Form Scale card, and the common stool type was obtained by responding to the question "Please look at this card and tell me the number that corresponds to your usual or most common stool". According to previous research, individuals with type 1 (firm stools, separate hard lumps) and type 2 (stools shaped like sausages but with a lumpy texture) stools were defined as having chronic constipation [18], while type 6 (stools characterized by fluffy pieces with uneven edges and a mushy texture) and type 7 (stools that are entirely liquid, watery, no solid pieces) stools were defined as chronic diarrhea [19]. Individuals with the remaining types of stools were defined as having normal bowel health.

Body roundness index

Based on the method proposed by Thomas DM et al., the calculation is performed as follows: $364.2-365.5\times(1-[\mathrm{WC}\ (\mathrm{m})/2\pi]^2/[0.5\times\mathrm{height}(\mathrm{m})]^2)^{1/2}$ [15]. This indicator provides a more comprehensive quantitative estimate of body and visceral fat percentage by combining waist circumference and height. The mobile examination center provided information on waist circumference and height in NHANES.

Covariates

Based on previous research, potential demographic, lifestyle, and health confounding variables were included in this study. Demographic variables included sex (male,

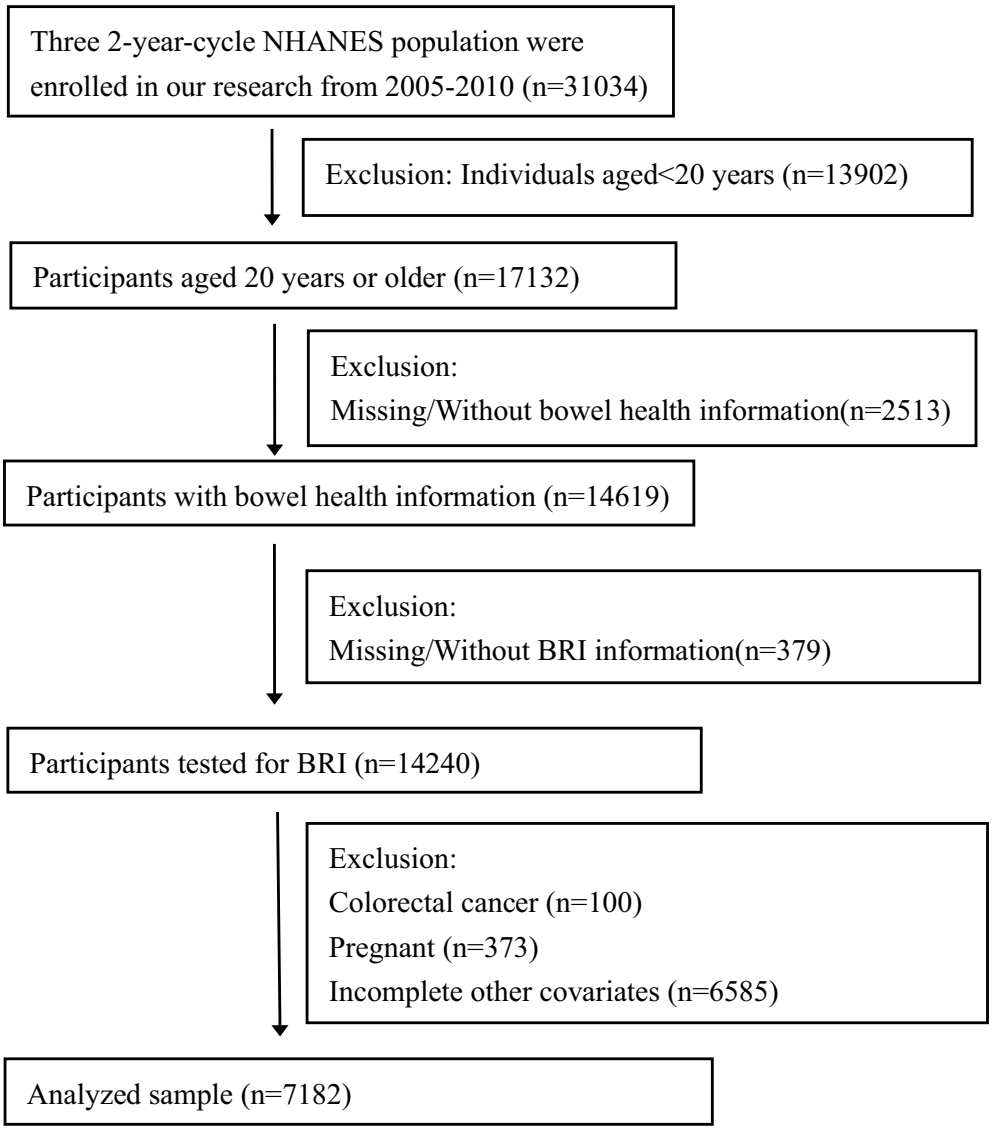

Fig. 1 Flowchart of participants included in the final analysis (N = 7182), NHANES, 2005–2010. *Notes* BRI, body roundness index; NHANES, National Health and Nutrition Examination Survey

female), age, education (less than high school, high school, above high school), race (non-Hispanic white, non-Hispanic Black, others), marital status (married, never married, windowed, divorced, separated, living with partner), and poverty-to-income ratio (PIR) (≤ 1, 1.1–3, > 3). Lifestyle variables included smoking status (never, ever, current), physical activity (low, moderate, high), drinking status (no, moderate, heavy), total fat, dietary fiber, protein, carbohydrates, total sugar, caffeine, and energy intake. Health variables included diabetes (no, borderline, yes), hypertension (no and yes), and total cholesterol levels. Participants who had not consumed alcohol in the past year were defined as non-drinkers. In addition, individuals who consumed < 4 drinks/day on average for women and < 5 drinks/day on average for men in the past year were categorized as moderate drinkers, while those who exceeded these limits were categorized as heavy drinkers. Never smokers were considered to have smoked fewer than 100 cigarettes in their lifetime, while the rest were categorized as former smokers and current smokers based on their current smoking status. Physical activity was calculated as standard metabolic equivalents (MET) values × weekly exercise time (min) to quantify the energy expenditure value of the participants' average weekly exercise, and categorized into low, moderate, and high groups at a cut-off value of 600 and 3000

[20]. Dietary intake information was obtained through a 24-h dietary review questionnaire. Hypertension and diabetes were diagnosed by index measurements, medication use, and self-report.

Statistical analysis

To generalize the findings of this study to the U.S. population, according to NHANES analysis guidelines, WTMEC2YR/3 was selected as the analytic weight. Weighted baseline demographic characteristics by BRI tri-categories are shown in Table 1. Numbers (weighted percentages) were used to represent categorical variables, with chi-square (χ^2) tests used to assess inter-group differences. Weighted means (standard deviations) were used to represent continuous variables, with group differences assessed using one-way analysis of variance.

The relationship between BRI, chronic diarrhea, and constipation was evaluated based on multiple multivariable weighted logistic regression models: the crude model was not adjusted for covariates. Model 1 adjusted for age, sex, education, marital status, race, and PIR. Model 2 additionally considered physical activity, smoking, and drinking status. Model 3 additionally controlled for total daily fat, dietary fiber, protein, carbohydrates, total sugar, caffeine, energy intake, diabetes, hypertension, and total cholesterol levels. BRI was included in the regression models either as continuous or categorical variables based on tertiles. Trend effects for progressively increasing exposure groups were calculated using integer values (1, 2, 3). We then plotted restricted cubic spline (RCS) curves to analyze the exposure–response relationship between BRI, chronic diarrhea, and constipation, with linear associations tested using Wald tests. Further stratified and interaction analyses were conducted by sex, age, race, education, marital status, physical activity, PIR, drinking and smoking status, diabetes mellitus, and hypertension to explore whether the above associations were heterogeneous across subgroups. Finally, we excluded chronic diarrhea and constipation populations separately, additionally adjusted for BMI, and implied multiple imputations for missing covariates to verify the robustness of the results.

The R (4.3.1) was utilized for all statistical analyses, and a two-sided *P*-value of less than 0.05 was considered statistically significant.

Results

Baseline characteristics of the study population

This study involved a total of 7182 individuals, among whom 491 had chronic diarrhea and 443 had chronic constipation. Table 1 presents the baseline demographic characteristics of the population stratified by BRI tertiles. The clinical characteristics of the included population are shown in Table S1. Participants in the highest tertile BRI group, compared to those in the BRI T1 group, were more likely to be female, older, non-Hispanic black, widowed or divorced, and had lower educational attainment, physical activity, and PIR. They were also more likely to be non-drinkers, former smokers, and have diabetes and hypertension. In the preliminary analysis, individuals in the high BRI group were more susceptible to diarrhea. This result suggested the potential of BRI as a risk predictor for chronic diarrhea. To better illustrate the characteristics of the study population, we further compared the baseline characteristics between the included and excluded subjects (Table S2).

Association between BRI and chronic diarrhea

The correlation between BRI and chronic diarrhea remained consistent in each weighted logistic regression model. In the fully adjusted continuous model, there was a significant correlation between each 1-unit increase in BRI and an increased risk of chronic diarrhea (OR: 1.15, 95% CI: 1.09, 1.21). Further analysis using the BRI tertiles supported this finding, showing that participants in the T3 group had significantly increased odds of chronic diarrhea (OR: 1.79, 95% CI: 1.33, 2.40) compared to those in the T1 group. Additionally, as BRI tertiles increased, the prevalence of chronic diarrhea progressively increased (P for trend < 0.05) (Table 2). To better understand the relationship between BRI and chronic diarrhea, the RCS curve was conducted to better capture the dose–response association, which showed a significant positive linear dose–response relationship between BRI and chronic diarrhea (overall $P < 0.001$, nonlinear $P = 0.631$) (shown in Fig. 2A). Overall, higher BRI was significantly and linearly associated with increased risk of chronic diarrhea.

Association between BRI and chronic constipation

In the fully adjusted continuous model, the negative correlation between BRI and chronic constipation showed no significant association (OR: 0.94, 95% CI: 0.87, 1.01). Treating BRI as a categorical variable (tertiles), compared to the T1 group, participants in the T3 group showed significantly decreased odds of chronic constipation (OR 0.65, 95% CI: 0.45, 0.93). Trend analyses also demonstrated that participants with a higher BRI had a significantly decreased risk of chronic constipation (P for trend < 0.05) (Table 2). RCS curves showed no significant linear dose–response relationship between BRI with chronic constipation (overall $P = 0.058$, nonlinear $P = 0.849$) (shown in Fig. 2B). The results of the above analysis suggested that continuous BRI showed a

Table 1 Survey-weighted participant characteristics in NHANES (2005–2010)

Characteristics	Overall	T1	T2	T3	*P*-value[a]
N	7182	2393	2395	2394	
Gender					< 0.01
Male	3972(53.01)	1301 (49.91)	1459 (59.40)	1212 (49.78)	
Female	3210 (46.99)	1092 (50.09)	936 (40.60)	1182 (50.22)	
Age	45.63 (15.39)	40.73 (14.69)	47.44 (15.05)	49.77 (14.98)	< 0.01
Race					< 0.01
Non-Hispanic White	4033 (76.98)	1441 (78.82)	1319 (76.80)	1273 (74.86)	
Non-Hispanic Black	1215 (8.29)	421 (7.91)	360 (7.19)	434 (9.97)	
Others	1934 (14.74)	531 (13.27)	716 (16.01)	687 (15.16)	
Education					< 0.01
Less than high school graduate	1554 (13.82)	401 (10.73)	531 (13.96)	622 (17.53)	
High school graduate or GED	1662 (22.49)	495 (18.94)	560 (23.26)	607 (26.10)	
Some college or above	3966 (63.69)	1497 (70.33)	1304 (62.79)	1165 (56.37)	
Marital status					< 0.01
Married	3994 (59.58)	1175 (53.41)	1477 (64.97)	1342 (61.34)	
Widowed	385 (3.74)	76 (2.07)	122 (3.81)	187 (5.74)	
Divorced	786 (10.15)	229 (8.48)	243 (10.49)	314 (11.87)	
Separated	212 (2.14)	70 (2.61)	67 (1.76)	75 (1.96)	
Never married	1202 (16.34)	594 (23.43)	297 (11.71)	311 (12.60)	
Living with partner	603 (8.06)	249 (10.01)	189 (7.27)	165 (6.49)	
PIR					< 0.01
≤ 1	1227 (10.59)	420 (11.13)	384 (9.36)	423 (11.28)	
1–3	2745 (31.40)	823 (29.15)	906 (29.85)	1016 (35.92)	
> 3	3210 (58.01)	1150 (59.72)	1105 (60.78)	955 (52.80)	
Physical Activity, MET-min/wk					0.05
< 600	2197 (31.85)	677 (29.57)	740 (31.65)	780 (34.94)	
600–3000	2707 (38.34)	901 (38.94)	888 (38.56)	918 (37.35)	
≥ 3000	2278 (29.81)	815 (31.49)	767 (29.80)	696 (27.71)	
Drinking status					< 0.01
No	1429 (16.33)	322 (10.74)	455 (15.89)	652 (23.80)	
Moderate	4673 (69.18)	1679 (73.81)	1571 (69.02)	1423 (63.56)	
Heavy	1080 (14.49)	392 (15.45)	369 (15.09)	319 (12.63)	
Smoking status					< 0.01
Never	3465 (49.74)	1184 (51.49)	1155 (48.78)	1126 (48.61)	
Ever	2014 (27.53)	511 (22.14)	708 (29.98)	795 (31.56)	
Current	1703 (22.73)	698 (26.37)	532 (21.25)	473 (19.83)	
Diabetes					< 0.01
No	5590 (82.23)	2176 (92.88)	1911 (83.89)	1503 (67.04)	
Borderline	620 (7.96)	121 (4.23)	233 (9.42)	266 (11.00)	
Yes	972 (9.82)	96 (2.89)	251 (6.70)	625 (21.96)	
Hypertension					< 0.01
No	4479 (66.62)	1876 (81.18)	1516 (65.45)	1087 (49.67)	
Yes	2703 (33.38)	517 (18.82)	879 (34.55)	1307 (50.33)	
Constipation					0.09
No	6739 (94.21)	2228 (93.63)	2239 (93.88)	2272 (95.31)	
Yes	443 (5.79)	165 (6.37)	156 (6.12)	122 (4.69)	
Diarrhea					< 0.01
No	6691 (93.99)	2279 (95.52)	2246 (94.61)	2166 (91.37)	
Yes	491 (6.01)	114 (4.48)	149 (5.39)	228 (8.63)	

Table 1 (continued)

[a] For continuous variables, the one-way analysis of variance test was used for between-group comparisons; and for categorical variables, the chi-square test was used for between-group comparisons. Continuous variables were expressed as weighted means (standard deviations), and categorical variables were expressed as unweighted numbers (weighted percentages)

MET: metabolic equivalents; PIR, poverty-to-income ratio

Table 2 Multivariable logistic regression analysis between BRI, chronic diarrhea, and constipation

Models	Diarrhea		Constipation	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Crude model				
Continuous	**1.16(1.11,1.21)**	**< 0.001**	0.95(0.89,1.02)	0.16
Classification				
T1	Ref		Ref	
T2	1.21(0.90,1.63)	0.19	0.96(0.74,1.24)	0.74
T3	**2.01(1.58,2.57)**	**< 0.001**	**0.72(0.53,0.99)**	**0.05**
P for trend		**< 0.001**		**0.04**
Model 1				
Continuous	**1.14(1.09,1.19)**	**< 0.001**	0.94(0.87,1.01)	0.07
Classification				
T1	Ref		Ref	
T2	1.15(0.86,1.54)	0.34	1.03(0.77,1.38)	0.84
T3	**1.76(1.36,2.28)**	**< 0.001**	**0.66(0.47,0.93)**	**0.02**
P for trend		**< 0.001**		**0.02**
Model 2				
Continuous	**1.14(1.09,1.19)**	**< 0.001**	0.94(0.87,1.01)	0.07
Classification				
T1	Ref		Ref	
T2	1.15(0.86,1.54)	0.32	1.04(0.77,1.40)	0.82
T3	**1.77(1.36,2.31)**	**< 0.001**	**0.66(0.46,0.93)**	**0.02**
P for trend		**< 0.001**		**0.02**
Model 3				
Continuous	**1.15(1.09,1.21)**	**< 0.001**	0.94(0.87,1.01)	0.08
Classification				
T1	Ref		Ref	
T2	1.17(0.87,1.58)	0.27	1.01(0.73,1.39)	0.95
T3	**1.79(1.33,2.40)**	**< 0.001**	**0.65(0.45,0.93)**	**0.02**
P for trend		**< 0.001**		**0.03**

Crude model: not adjusted for covariates

Model 1: adjusted for sex, age, race, marital status, education, and PIR

Model 2: Additionally adjusted for smoking, alcohol consumption, and physical activity

Model 3: Further adjusted for diabetes, hypertension, total daily fat, dietary fiber, protein, carbohydrates, total sugar, caffeine, energy intake, and total cholesterol levels

The bold number indicates the $P < 0.05$

BRI, body roundness index; CI: confidence interval; OR: odds ratio; ref, reference

borderline negative correlation with chronic constipation, and high levels of BRI seem to have an ameliorative effect on chronic constipation.

Stratified analysis

Table 3 presents the findings from stratified analysis using fully adjusted models with sample-weighted surveys. The results showed no significant interaction effects in different subgroups (all *P* interaction > 0.05), indicating consistent associations between BRI, chronic diarrhea, and constipation across different groups.

Sensitivity analysis

After excluding participants with chronic constipation and diarrhea respectively, we further explored the association of BRI with chronic diarrhea and constipation. The correlation between BRI, chronic diarrhea, and constipation remained stable after correcting for all confounding variables. Compared to the T1 group, participants in the highest BRI tertile had an OR of 1.75 (95% CI 1.32, 2.34) for chronic diarrhea and an OR of 0.69 (95% CI 0.48, 0.98) for chronic constipation. As tertiles increased, we observed similar trend test values (All *P* for trend < 0.05). Additionally adjusting for BMI, BRI remained significantly positively associated with chronic diarrhea but no significant association with chronic constipation. Consistent results were found when multiple imputation was applied to the missing covariates (Table 4). The above findings all demonstrated the robustness of the main results.

Discussion

Our study investigated the association of BRI with chronic diarrhea and constipation among 7,182 participants in the US population, confirming a significant linear positive association between BRI and chronic diarrhea, with individuals in the third tertile having a 79% elevated odds of developing chronic diarrhea and a 35% reduced odds of chronic constipation compared with the lowest tertile of BRI. The above association did not differ significantly across subgroups. Our study suggested that controlling body and visceral fat at lower levels may be beneficial in reducing chronic diarrhea, while the potential for increased chronic constipation risk due to low levels of the body and visceral fat should be noted.

Obesity is widely recognized as a risk factor for many gastrointestinal disorders, potentially impairing gut health to varying degrees [21]. Several studies explored the correlation between obesity, chronic diarrhea, and constipation through the BMI index. A survey of the

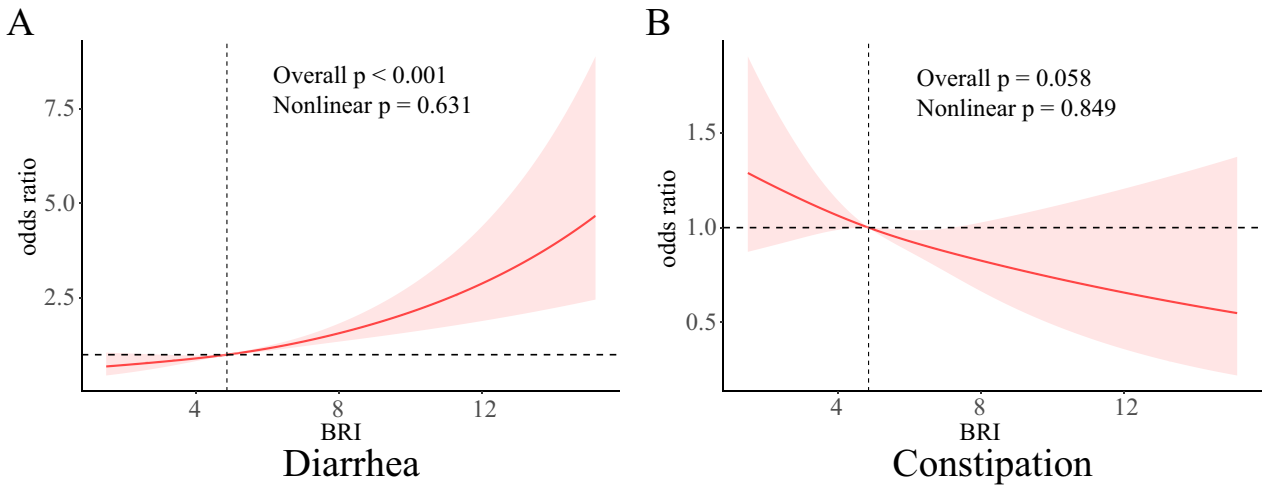

Fig. 2 Dose–response associations between BRI, chronic diarrhea (A), and constipation (B). *Notes* All models were adjusted for sex, age, race, marital status, education, PIR, smoking, alcohol consumption, physical activity, diabetes, hypertension, total daily fat, dietary fiber, protein, carbohydrates, total sugar, caffeine, energy intake, and total cholesterol levels. The solid lines and shaded areas represent the central risk estimates and 95% CIs. Abbreviations: BRI, body roundness index; CI, confidence interval; PIR, poverty income ratio

prevalence of chronic diarrhea and its association with obesity in a representative community of Chinese residents showed that obese individuals had an increased risk of chronic diarrhea compared with normal-weight individuals after adjusting for potential confounders [22]. Similarly, a study by Alkhowaiter S et al. reported a significant association between high BMI and diarrhea in a Saudi population, with no clear link between BMI and constipation [9]. Recently, with the creation of metrics to assess body fat levels, several studies have focused on the impact of body and visceral fat on intestinal disorders. A study from NHANES found that reductions in various body measurement indices (BMI, waist circumference, waist-stature ratio, and lipid accumulation products) were associated with reduced prevalence of constipation. Additionally, the weight-adjusted-waist index, an indicator primarily reflecting abdominal obesity regardless of body weight, showed an increase associated with reduced constipation risk [23]. A case–control study was conducted to investigate the relationship between abdominal obesity and the risk of irritable bowel syndrome utilizing visceral adipose tissue, waist circumference indicators, etc. The results found that visceral fat deposition was significantly associated with an increased risk of diarrhea-predominant irritable bowel syndrome, suggesting the risk effect of abdominal obesity in chronic diarrhea [24]. Collectively, the above studies strongly supported a significant relationship between higher BMI and diarrhea, while the relationship with constipation remains debated, possibly due to inadequate assessment of visceral obesity. Given the limitations of BMI in assessing visceral fat composition and distinguishing between different types of obesity [14], we utilized a more representative adiposity parameter, BRI, for a comprehensive evaluation of body fat and visceral adipose tissue percentage, aiming to provide more reliable predictive indicators for chronic gastrointestinal diseases.

Several potential mechanisms may account for the high prevalence of diarrhea associated with obesity: Firstly, alterations in bile acids could potentially be a significant contributor to diarrhea. Studies have shown that obesity may induce an increase in bile acid pools [25], leading to bile acid diarrhea due to increased bile acid concentration in the small intestine [26]; Secondly, as BMI increases, a trend for faster colonic transit in people with obesity (normal weight: 2.4 ± 0.2 h; overweight: 2.5 ± 0.2 h; obesity: 2.9 ± 0.23 h) was observed [27], which may contribute to varying degrees of diarrhea; Additionally, the interaction between obesity and intestinal inflammation is widely supported. A meta-analysis presented evidence supporting a positive correlation of obesity with C-reactive protein levels; furthermore, similar associations were observed for key inflammatory cytokines and erythrocyte sedimentation rate [28]. Visceral fat is thought to be more closely associated with inflammation than subcutaneous fat [29]. Studies have confirmed that visceral fat is strongly associated with IL-6 levels [30]. The substantial release of pro-inflammatory cytokines in obese patients leads to low-grade intestinal inflammation, altering visceral sensitivity and motility, significantly increasing the risk of functional gastrointestinal disorders [21]; Interestingly, similar changes in gut microbiota composition are prevalent between obese and diarrheic patients. Ley et al. demonstrated a significantly decreased relative

Table 3 Subgroup analysis of the association between BRI, chronic diarrhea, and constipation in NHANES 2005–2010 (n = 7182)

Subgroup	Diarrhea			Constipation		
	OR (95% CI)	*P*	*P* for interaction	OR (95% CI)	*P*	*P* for interaction
Sex			0.963			0.134
Male	1.167(1.075,1.268)	< 0.001		1.030(0.901,1.177)	0.650	
Female	1.136(1.061,1.216)	< 0.001		0.914(0.852,0.981)	0.016	
Age			0.119			0.296
≤ 60	1.162(1.101,1.226)	< 0.001		0.944(0.872,1.023)	0.149	
> 60	1.093(0.975,1.226)	0.121		0.884(0.761,1.027)	0.103	
Race			0.965			0.325
Non-Hispanic White	1.147(1.076,1.223)	< 0.001		0.956(0.875,1.044)	0.299	
Non-Hispanic Black	1.129(0.986,1.293)	0.075		0.972(0.878,1.077)	0.573	
Others	1.173(1.050,1.310)	0.007		0.830(0.739,0.933)	0.003	
Marital status			0.352			0.165
Married/ Living with partner	1.172(1.090,1.262)	< 0.001		0.913(0.844,0.987)	0.024	
Widowed/Divorced/Separated/ Never married	1.121(1.045,1.202)	0.003		0.962(0.857,1.079)	0.487	
Education			0.936			0.159
Less than high school graduate	1.150(1.041,1.271)	0.008		0.977(0.859,1.112)	0.715	
High school graduate or GED	1.164(1.051,1.289)	0.006		0.997(0.878,1.131)	0.957	
Some college or above	1.139(1.080,1.201)	< 0.001		0.902(0.801,1.015)	0.084	
PIR			0.752			0.176
≤ 1	1.089(0.982,1.208)	0.101		1.012(0.895,1.145)	0.839	
1–3	1.161(1.062,1.269)	0.002		0.963(0.857,1.081)	0.504	
> 3	1.159(1.077,1.248)	< 0.001		0.885(0.797,0.982)	0.024	
Drinking status			0.731			0.129
No	1.132(1.029,1.245)	0.013		0.894(0.765,1.045)	0.152	
Moderate	1.154(1.093,1.218)	< 0.001		0.926(0.854,1.003)	0.058	
Heavy	1.165(1.037,1.308)	0.012		1.059(0.877,1.279)	0.532	
Smoking status			0.527			0.108
Never	1.130(1.053,1.213)	0.002		0.869(0.779,0.969)	0.014	
Ever	1.125(1.010,1.253)	0.034		1.030(0.892,1.191)	0.672	
Current	1.223(1.100,1.359)	< 0.001		1.009(0.892,1.141)	0.885	
Physical Activity			0.750			0.418
Low	1.119(1.050,1.193)	0.001		0.944(0.854,1.044)	0.251	
Moderate	1.183(1.096,1.277)	< 0.001		0.891(0.788,1.007)	0.064	
High	1.143(1.026,1.273)	0.017		0.981(0.841,1.144)	0.800	
Diabetes			0.111			0.458
No	1.142(1.081,1.206)	< 0.001		0.931(0.862,1.006)	0.067	
Borderline	1.052(0.875,1.265)	0.573		1.066(0.865, 1.315)	0.530	
Yes	1.218(1.087,1.365)	0.002		0.899(0.742,1.090)	0.263	
Hypertension			0.733			0.722
No	1.149(1.069,1.234)	< 0.001		0.934(0.859,1.017)	0.109	
Yes	1.152(1.052,1.261)	0.004		0.945(0.843,1.060)	0.315	

Each stratification was adjusted for sex, age, race, marital status, education, PIR, smoking, alcohol consumption, physical activity, diabetes, hypertension, total daily fat, dietary fiber, protein, carbohydrates, total sugar, caffeine, energy intake, and total cholesterol levels. When the association between each stratified variable and chronic diarrhea as well as constipation was evaluated, this variable was excluded from the adjustment

BRI, body roundness index; CI, confidence interval; NHANES, National Health and Nutrition Examination Surveys; OR, odds ratio; PIR, poverty income ratio

Table 4 Association between BRI, chronic diarrhea, and constipation in NHANES 2005–2010 (n = 7182)

	Diarrhea		Constipation	
	OR (95% CI)	***P*-value**	**OR (95% CI)**	***P*-value**
Sensitivity analysis 1				
Continuous	**1.15(1.09,1.21)**	**< 0.001**	0.95(0.88,1.02)	0.14
Classification				
T1	Ref		Ref	
T2	1.16(0.87,1.54)	0.3	0.97(0.70,1.35)	0.86
T3	**1.75(1.32,2.34)**	**< 0.001**	**0.69(0.48,0.98)**	**0.04**
P for trend		**< 0.001**		**0.04**
Sensitivity analysis 2				
Continuous	**1.25(1.05,1.48)**	**0.01**	1.04(0.86,1.27)	0.66
Classification				
T1	Ref		Ref	
T2	1.01(0.73,1.39)	0.96	1.06(0.73,1.54)	0.76
T3	1.25(0.78,1.99)	0.34	0.72(0.37,1.42)	0.32
P for trend		0.36		0.43
Sensitivity analysis 3				
Continuous	**1.12(1.08,1.16)**	**< 0.001**	0.94(0.82,1.04)	0.06
Classification				
T1	Ref		Ref	
T2	1.18(0.92,1.51)	0.17	0.84(0.67,1.05)	0.12
T3	**1.71(1.37,2.13)**	**< 0.001**	**0.63(0.50,0.79)**	**< 0.001**
P for trend		**< 0.001**		**< 0.001**

Sensitivity analysis 1: excluded chronic diarrhea and constipation populations separately

Sensitivity analysis 2: additionally adjusted for BMI

Sensitivity analysis 3: multiple imputation of missing covariates

All models were adjusted for sex, age, race, marital status, education, PIR, smoking, alcohol consumption, physical activity, diabetes, hypertension, total daily fat, dietary fiber, protein, carbohydrates, total sugar, caffeine, energy intake, and total cholesterol levels; Bold number indicates the *P* value < 0.05

BRI, body roundness index; CI, confidence interval; NHANES, National Health and Nutrition Examination Surveys; OR, odds ratio; ref, reference

abundance of Bacteroidetes but an elevated abundance of Firmicutes in obese individuals' fecal microbiota compared to lean participants [31], with similar fecal and mucosal microbiota alterations observed in patients with irritable bowel syndrome [32–34].

Recently Linghu E et al. proposed a new term: Linghu's obesity-diarrhea syndrome (ODS) to refer to obesity with chronic diarrhea but without organic pathology [35], and further studies have shown that the jejunal mucosa of patients with ODS has extensive transcriptomic changes, mainly in the form of up-regulation of nutrient transport, digestion, and absorption, and down-regulation of DNA expression, rRNA processing, mitochondrial translation, and anti-microbial humoral responses, which may affect the intestinal barrier function, leading to obesity and chronic diarrhea phenotype [36]. Furthermore, a comprehensive proteomic analysis of jejunal tissue from patients with obesity and chronic diarrhea suggested that the collagen alpha-1(III) chain may be involved in obesity-associated chronic diarrhea by affecting intestinal epithelial structure and integrity through the extracellular matrix-receptor interaction pathway [37]. These also provide new insights into the mechanisms of obesity and diarrhea. In summary, we hypothesized that alterations in intestinal motility, barrier function, inflammation, and microbiota are common in both obesity and chronic diarrhea, which may explain their link.

Interestingly, our study found that although the negative association between BRI and constipation was insignificant, participants in the T3 BRI group experienced a notably lower prevalence of constipation. Currently, there is ongoing debate regarding the association between obesity and constipation. Previous studies have largely supported that obese individuals are more likely to experience symptoms of constipation, possibly related to factors such as inflammatory cytokine release induced by obesity [38]. However, studies focusing on constipated patients have also revealed a notable inverse correlation of BMI with colonic transit time [39]. The contradictory mechanisms between these findings may partially offset the significant association between obesity and constipation. Nevertheless, our study still suggested to some extent that avoiding excessively low levels of body and visceral fat was important for preventing chronic constipation.

We did not find differences in the relationship between BRI, chronic constipation, and diarrhea in different subgroups, suggesting that the potential association does not vary according to individual factors. Notably, a French epidemiological study involving over 35,000 individuals found an association between BMI and functional diarrhea in women but not men, indicating intergroup heterogeneity between BMI and functional diarrhea by sex [40]. This indirectly underscores the stability of BRI as a more comprehensive indicator reflecting lean and fat mass in predicting diseases across diverse populations. Additionally, we further adjusted for BMI in our sensitivity analyses. Despite both BMI and BRI being adjusted for height, our findings consistently demonstrated that BRI was positively correlated with chronic diarrhea, reaffirming the clinical importance of considering body fat mass in predicting chronic diarrhea.

There are certain strengths of our study. Firstly, we innovatively used the BRI index to link body fat with chronic diarrhea and constipation to explore the potential association. Secondly, we conducted subgroup and sensitivity analyses to validate the generalizability and robustness of our results. Finally, leveraging the NHANES database enabled us to analyze the association in a large population cohort. However, undeniable limitations

persist in our study. Firstly, due to the inherent limitations of cross-sectional studies, we can only infer associations, but not causality in the relationship between BRI, chronic diarrhea, and constipation. Secondly, relying on questionnaire data for chronic diarrhea and constipation introduces unavoidable recall biases, which may result in the acquisition of data that do not correspond to reality, affecting the reliability of the results. Thirdly, despite rigorous adjustment and extensive covariate control, potential confounding factors may still influence our findings.

Conclusion

BRI levels are linearly positively associated with chronic diarrhea, but not with constipation. Individuals with higher BRI show an increased risk of chronic diarrhea and a decreased risk of constipation. Controlling BRI at lower levels may help prevent diarrhea, while caution is needed regarding the increased risk of constipation due to excessively low BRI. As a novel indicator of body dimension assessment, BRI holds significant value in predicting gastrointestinal symptoms. More prospective cohort studies are still needed in the future to confirm the causality of the above associations. Additionally, future clinical studies are needed to focus on the effects of controlling body and visceral fat in reasonable ranges on the management of chronic constipation and diarrhea.

Abbreviations

ANOVA	Analysis of variance
BMI	Body mass index
BRI	Body Roundness Index
CI	Confidence interval
MEC	Mobile examination center
MET	Metabolic equivalents
NHANES	National Health and Nutrition Examination Survey
ODS	Linghu's obesity-diarrhea syndrome
OR	Odds ratio
PIR	Poverty-to-income ratio
RCS	Restricted cubic spline
SD	Standard deviation

Supplementary Information

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Additional file 1.

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Author contributions

YZ designed the study and wrote the main part of the paper. LFL analyzed the data and made a critical revision of the manuscript for important intellectual content. JYS and YQZ were responsible for the proper layout of images. FD conceived and supervised this manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analysed during the current study are available in the NHANES repository, https://www.cdc.gov/nchs/nhanes/index.htm. Data will be made available to the editors of the journal for review or query upon request.

Declarations

Ethics approval and consent to participate

This is an observational study. This study protocol was reviewed and approved by the U.S. Centers for Disease Control and Prevention's National Center for Health Statistics Ethics Review Board, approval number: Protocol #2005–06 (January 1, 2005- December 31, 2010). Written informed consent was obtained from participants prior to the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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