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Analysis of Factors Associated with Constipation in the Population with Obesity: Evidence from the National Health and Nutrition Examination Survey

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Keywords
Constipation · Hypertension · Polypharmacy · Functional bowel disorders · Obesity

Abstract
Introduction: Obesity and constipation are both global problems, but the factors associated with constipation in individuals with obesity are currently understudied. The aim of our study was to explore the factors associated with constipation in people with obesity. ***Methods:*** From three cycles of the National Health and Nutrition Examination Survey (NHANES) 2005–2010, data from 14,048 persons aged ≥20 years were collected. Variables included demographics, lifestyle, comorbidities, and dietary data. Multiple logistic regression analysis was used to calculate adjusted prevalence odds ratio (OR) and assess the relationship between different variables and constipation in population with obesity. ***Results:*** Using stool consistency definition, multivariate analysis revealed that education ≥12th grade (OR: 0.456; 95% CI: 0.300, 0.694; $p = 0.00024$), hypertension (OR: 0.505; 95% CI: 0.334, 0.763; $p = 0.00119$), polypharmacy (OR: 1.669; 95% CI: 1.104, 2.521; $p = 0.01507$), high cholesterol (OR: 0.400; 95% CI: 0.213, 0.750; $p = 0.00430$), and high dietary fiber (OR: 0.454; 95% CI: 0.245, 0.841; $p = 0.01206$) were substantially linked with constipation in the population with obesity. For constipation defined using stool frequency, multivariate regression analysis show constipation in people with obesity had a significant association with the female sex (OR: 2.684; 95% CI: 1.379, 5.223; $p = 0.00366$ multivariate), Mexican American (OR: 0.142; 95% CI, 0.033, 0.616; $p = 0.00914$ multivariate), hypertension (OR: 0.569; 95% CI: 0.324, 0.998; $p = 0.04916$), depression (OR: 2.280; 95% CI: 1.240, 4.195; $p = 0.00803$), occasional/often milk consumption (OR: 0.473; 95% CI: 0.286, 0.782; $p = 0.00356$), medium energy (OR: 0.318; 95% CI: 0.118, 0.856; $p = 0.02338$), polypharmacy (OR: 1.939; 95% CI: 1.115, 3.373; $p = 0.01907$), and medium moisture (OR: 0.534; 95% CI: 0.285, 0.999; $p = 0.04959$). In nonobese people, constipation was significantly associated with the female sex and high moisture but not with hypertension and polypharmacy. ***Conclusion:*** This study suggests that the population with obesity has many factors that affect constipation such as hypertension, polypharmacy, cholesterol, dietary fiber, depression, and so on, of which hypertension and polypharmacy were significant associated with constipation, regardless of definitions of constipation. Notably, hypertension might be associated with a reduced risk of constipation in people with obesity.

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Introduction

Constipation is one of the most prevalent gastrointestinal conditions worldwide, with a previous study reporting that it affects up to 10.2% of females and 4% of males [1]. Physical functioning, mental health, and social functioning are all compromised in patients with the condition [2, 3]. Patients with constipation inevitably to seek medical assistance and the cost of medical treatment is relatively high. Nearly USD 230 million is spent on constipation treatment in the US each year [4] There are many factors associated with constipation, with a cross-sectional study conducted in Turkey revealing that physical inactivity, reduced fiber and water intake, aging, the female sex, and obesity were associated with an increased risk of constipation [5].

The global rate of obesity and obesity-related diseases continues to increase, with the number of individuals with excess body weight now exceeding 2 billion [6]. Obesity is associated with many diseases. It can increase the risk of peripheral vascular disease, type 2 diabetes, coronary heart disease, and tumors such as colon, stomach, breast, and kidney cancer [7–9]. Many studies have examined the relationship between obesity and constipation. One study found no statistically significant association between obesity or overweight and constipation in children [10], whereas others suggested that obesity might be a risk factor for constipation in adults [11]. However, little is known about the factors associated with constipation in people with obesity. A recent study on constipation reported a significant association between constipation and the concomitant use of at least five medications, younger age and former smoking in adults with class II and class III obesity [12]. There were 150 patients in the single-center study whose sample was not large enough. People with constipation who were not obese during the study period were excluded from the study, and there was no stratified comparison of relevant factors. Therefore, a more complete study of a larger population is required to identify the factors associated with constipation in people with obesity.

This study aimed to determine the various factors associated with constipation in population with obesity. Using data from the National Health and Nutrition Examination Survey (NHANES), we examined a number of variables, including demographic factors, lifestyle, comorbidities, and dietary data, to identify factors associated with constipation.

Materials and Methods

This study was conducted per relevant guidelines and regulations. NHANES is a long-running survey that began in the 1960s and continues today to examine the health and nutritional statuses of various groups in the USA. The National Center for Health Statistics of the US Centers for Disease Control and Prevention is in charge of the program. Each year the survey examines a nationally representative sample of people from cities across the country. The National Center for Health Statistics Ethics Review Board approved the NHANES, and all participants gave their written informed consent before taking the survey.

We used data from the NHANES 2005–2006, 2007–2008, and 2009–2010 cycles, with a total of 17,132 participants aged ≥20 years. A total of 2,401 participants lacking data on fecal concentration and frequency, 134 people lacking body measurement data and 409 pregnant women were excluded from the study. The final sample to be analyzed comprised 14,048 participants (Table 1).

Definition of Obesity and Constipation

Body measurements were taken at the Mobile Examination Center for NHANES by qualified health technicians (MEC). According to the body mass index (BMI, kg/m^2), which was calculated from body measurements, participants were classified as either obese (BMI ≥30.0 kg/m^2) or non-obese (BMI <30.0 kg/m^2).

The bowel health questionnaire in NHANES is primarily a survey that records data on the frequency and consistency of participants' bowel movements over the previous 30 days. The frequency of bowel movements was determined by asking participants how many times per week they had a bowel movement. Constipation was judged as <3 bowel movements (BMs) per week and non-constipation as ≥3. Stool consistency was determined by showing participants a colored card containing descriptions of the seven stool types using the Bristol Stool Form Scale [13] and asking them about the usual or most common type of stool. In line with earlier studies [1, 14, 15], constipation was characterized as BSFS type 1 (separate hard lumps, like nuts) or type 2 (sausage-like, but lumpy) stool type. In this study, we mainly used stool consistency to define constipation and defined constipation in terms of stool frequency as a complementary study.

Study Variables

Demographic data included data on age (divided into three groups: <45, 45–65, ≥65), sex (male, female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic American, and other race/ethnicity), education level (below high school, high school, and above), marital status (never married, widowed/divorced/separated, married), and household income to poverty ratio (divided into two groups <2, ≥2).

We derived the metabolic equivalent of task (MET) per hour (MET-h) index by multiplying the time spent in each activity per week by its MET value. In the post-2007 cycle, due to changes in the questionnaire, we multiplied the number of minutes of moderate and vigorous activity per week for participants by the corresponding met values to estimate the weekly MET-min. Participants with a MET-min week of 500 or more were classified physically active, whereas those with a MET-min week of less than 500 were labeled non-active, according to the US Department of Health and Human Services [16]. According to their smoking statuses, participants were categorized as never smokers (never smoked or smoked <100 cigarettes in their lives), current smokers (smoked ≥100 cigarettes in their lives and are still smoking), and

Table 1. Baseline characteristics of the study sample from NHANES 2005–2010 (using the Stool Consistency Definition of Constipation)

Variable	Constipation (n = 1,052), n (%)	No constipation (n = 12,996), n (%)	p value
Gender			<**0.001**
Male	341 (32.4)	6,731 (51.8)	
Female	711 (67.6)	6,265 (48.2)	
Age, years			**0.005**
<45	488 (46.4)	5,381 (41.4)	
≥45, <65	320 (30.4)	4,455 (34.3)	
≥65	244 (23.2)	3,160 (24.3)	
Ethnicity			<**0.001**
Non-Hispanic white	456 (43.3)	6,481 (49.9)	
Non-Hispanic black	246 (23.4)	2,555 (19.7)	
Mexican American	195 (18.5)	2,350 (18.1)	
Other	155 (14.7)	1,610 (12.4)	
BMI			<**0.001**
Normal	370 (35.17)	3,656 (28.13)	
Overweight	347 (32.98)	4,490 (34.55)	
Obesity	335 (31.84)	4,850 (37.32)	
Education			<**0.001**
<12th grade	643 (61.3)	6,669 (51.4)	
≥High school	406 (38.7)	6,316 (48.6)	
Marital status			<**0.001**
Never married	279 (26.5)	3,110 (23.9)	
Widowed/divorced	499 (47.4)	6,965 (53.6)	
Separated	274 (26.0)	2,913 (22.4)	
Income-poverty ratio			<**0.001**
<2	522 (53.8)	5,439 (45.1)	
≥2	449 (46.2)	6,611 (54.9)	
Physical activity			**0.018**
<500	396 (42.7)	4,506 (38.7)	
≥500	532 (57.3)	7,123 (61.3)	
Drinking			<**0.001**
No	406 (38.7)	3,526 (27.1)	
Yes	644 (61.3)	9,462 (72.9)	
Smoking			<**0.001**
Never	606 (57.6)	6,701 (51.6)	
Current	215 (20.4)	2,944 (22.7)	
Former	231 (22.0)	3,346 (25.8)	
Diabetes			0.159
No	910 (86.7)	11,028 (85.1)	
Yes	140 (13.3)	1,937 (14.9)	
Depression			<**0.001**
No	915 (87.0)	11,867 (91.3)	
Yes	137 (13.0)	1,129 (8.7)	
Hypertension			**0.002**
No	568 (54.8)	6,421 (49.9)	
Yes	468 (45.2)	6,436 (50.1)	
Asthma			0.061
No	886 (84.2)	11,204 (86.3)	
Yes	166 (15.8)	1,779 (13.7)	

Table 1 (continued)

Variable	Constipation (n = 1,052), n (%)	No constipation (n = 12,996), n (%)	p value
COPD			0.337
No	930 (93.5)	11,552 (94.2)	
Yes	65 (6.5)	710 (5.8)	
Vitamin D deficiency			0.692
No	601 (64.3)	7,743 (64.9)	
Yes	334 (35.7)	4,184 (35.1)	
Milk			0.993
Never/rarely	327 (31.1)	4,018 (30.9)	
Occasionally/often	721 (68.5)	8,929 (68.7)	
Energy, kcal			<**0.001**
Low (0–1,596)	434 (41.8)	4,167 (32.6)	
Medium (1,596–2,257)	349 (33.6)	4,261 (33.3)	
High (>2,257)	256 (24.6)	4,353 (34.1)	
Protein, g			<**0.001**
Low (0–61.3)	454 (43.7)	4,150 (32.5)	
Medium (61.3–88.4)	339 (32.6)	4,268 (33.4)	
High (>88.4)	246 (23.7)	4,363 (34.1)	
Carbohydrate, g			**0.003**
Low (0–195)	394 (37.9)	4,210 (32.9)	
Medium (195–277.5)	335 (32.2)	4,272 (33.4)	
High (>277.5)	310 (29.8)	4,299 (33.6)	
Total sugars, g			0.448
Low (0–78.4)	351 (33.8)	4,255 (33.3)	
Medium (78.4–126.9)	328 (31.6)	4,277 (33.5)	
High (>126.9)	359 (34.6)	4,248 (33.2)	
Dietary fiber, g			<**0.001**
Low (0–11.7)	438 (42.2)	4,148 (32.5)	
Medium (11.7–18.2)	327 (31.5)	4,281 (33.5)	
High (>18.2)	273 (26.3)	4,347 (34.0)	
Total fat, g			<**0.001**
Low (0–55.6)	430 (41.4)	4,173 (32.7)	
Medium (55.6–85.5)	353 (34.0)	4,254 (33.3)	
High (>85.5)	255 (24.6)	4,353 (34.1)	
Cholesterol, mg			<**0.001**
Low (0–176.5)	426 (41.0)	4,176 (32.7)	
Medium (176.5–317.5)	334 (32.2)	4,263 (33.4)	
High (>317.5)	278 (26.8)	4,333 (33.9)	
Moisture, g			<**0.001**
Low (0–2,101.7)	465 (44.8)	4,139 (32.4)	
Medium (2,101.7–3,042.7)	329 (31.7)	4,278 (33.5)	
High (>3,042.7)	245 (23.6)	4,364 (34.1)	
Polypharmacy			0.315
No	422 (68.3)	5,251 (70.2)	
Yes	196 (31.7)	2,228 (29.8)	
Hypertension drugs			**0.005**
No	368 (58.506)	4,080 (52.693)	
Yes	261 (41.494)	3,663 (47.307)	

COPD, chronic obstructive pulmonary. Significant values are shown in bold ($p < 0.05$).

former smokers (smoked ≥100 cigarettes in their lives but are no longer smoking). Drinkers were defined as those who consumed at least 12 alcoholic beverages per year.

Diabetes is defined as a condition diagnosed by a medical professional, or having a glycosylated hemoglobin level of ≥6.5%. Asthma and chronic obstructive pulmonary disease (COPD) were defined as having been diagnosed by a medical professional and yet not being cured. Patients with hypertension were classified as those who had been diagnosed by a medical professional or who were taking hypertension medication, or whose systolic blood pressure was greater than 130 mm Hg, or whose diastolic blood pressure was greater than 80 mm Hg. Determine whether to use hypertensive drugs based on each individual's prescription drug information. According to a previous study, a score of ≥10 on the Patient Health Questionnaire (PHQ-9) was considered to indicate depression [17]. Vitamin D deficiency was defined as serum 25-hydroxyvitamin D levels of less than 50 nmol/L (20 ng/mL) [18]. Polypharmacy was defined as taking five or more drugs at the same time [19].

The NHANES database collected information on participants' dietary intake (including information on all foods and beverages) for the 2 days prior to the interview. The average dietary data for 2 days including energy, fiber, water, carbohydrates, sugar, protein, fat, and cholesterol were selected for this study. The dietary variables described above were divided into tertiles in this study. According to their milk consumption, the participants of this study were divided into two categories: never consume/rarely consume (less than once a week) and occasionally consume/often consume (once a week or more).

Statistical Analysis

We used weights in our analysis to better reflect the population representation of the NHANES database. All statistical analyses were performed using R version 3.4.3 (http://www.R-project.org/) and Empower Stats 2.0 (http://www.empowerstats.com). Categorical variables were presented as frequencies and percentages, and they were compared using χ^2 tests. Continuous variables were transformed into categorical variables and analyzed as the latter. First, we used univariate logistic regression analyses to identify potential risk factors for constipation in obese and nonobese participants. Variables that were statistically significant in the univariate analysis were assessed using multivariate logistic regression models, with adjustments for other variables associated with constipation in the analysis. In this study, constipation was characterized by stool consistency or frequency. The p value of <0.05 was considered statistically significant.

Results

Study Sample

Out of the 31,034 people who participated in the three cycles, we included 17,132 persons aged ≥20 years in the study. Of these, 2,401 participants did not have data on stool consistency and frequency, which led to their exclusion from the study. 409 pregnant women and those who did not measure their BMIs (n = 134) were excluded from the study, reducing the final sample to 14,048 people (7,072 males and 6,976 females). Constipation (as determined based on stool consistency) was present in 7.5% of the study population. Using the frequency-based definition of constipation (<3 BMs/week), the prevalence of constipation was reduced to 3.4%. Table 1 shows the clinical characteristics of the study participants according to stool consistency definition. Constipation was significantly associated with gender, age, ethnicity, BMI, education, marriage, the income-poverty ratio, smoking, physical activity, drinking, depression, hypertension, energy, carbohydrate, dietary fiber, total fat, total saturated fatty acids, and moisture ($p < 0.05$).

Univariate and Multivariate Regression Analysis of Constipation in a Population with Obesity

Based on the different definitions of constipation, Tables 2 and 3 show the interaction between different factors and constipation in obese and nonobese participants. In the multivariate regression analysis, we adjusted for gender, age, ethnicity, BMI, education, marriage, income-poverty ratio, smoking, physical activity, drinking, depression, hypertension, diabetes, asthma, chronic obstructive pulmonary, energy, vitamin D deficiency, milk, polypharmacy, carbohydrate, total sugars, dietary fiber, total fat, total saturated fatty acids, and moisture. In multifactorial regression analyses based on the stool consistency-based definition of constipation, education ≥12th grade (odds ratio [OR]: 0.456; 95% CI: 0.300, 0.694; p = 0.00024), hypertension (OR: 0.505; 95% CI: 0.334, 0.763; p = 0.00119), polypharmacy(OR: 1.669; 95% CI: 1.104, 2.521; p = 0.01507), high cholesterol (OR: 0.400; 9.95% CI: 0.213, 0.750; p = 0.00430), and high dietary fiber (OR: 0.454; 95% CI: 0.245, 0.841; p = 0.01206) were significantly associated with constipation in the population with obesity, in line with the results of the univariate regression analysis. Similarly, in the nonobese participants, the female sex (OR: 2.373; 95% CI: 1.743, 3.231; $p < 0.00001$), education ≥12th grade (OR: 0.731; 95% CI: 0.555, 0.964; p = 0.02643), high moisture (OR: 0.572; 95% CI: 0.392, 0.836: p = 0.00387), high total sugars (OR: 1.812; 95% CI: 1.119, 2.933: p = 0.01564), and hypertensive drugs (OR: 0.680; 95% CI: 0.466, 0.994: p = 0.04664) were significantly associated with constipation. For constipation defined using the stool frequency, univariate and multivariate regression analyses demonstrated that constipation in people with obesity was significantly associated with the female sex (OR: 2.684; 95% CI: 1.379,

Table 2. Logistic regression analysis of factors associated with constipation (consistency-based) in an obese subgroup

	Obesity (univariate)		Non-obese		Obesity (multivariate)		Non-obese	
	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value
Gender								
Male	1		1		1		1	
Female	2.081 (1.637, 2.646)	<**0.001**	2.376 (2.023, 2.792)	<**0.001**	1.496 (0.958, 2.336)	0.076	2.373 (1.743, 3.231)	<**0.001**
Age, years								
<45	1		1		1		1	
≥45, <65	0.785 (0.610, 1.009)	0.059	0.819 (0.683, 0.982)	**0.031**	1.039 (0.630, 1.713)	0.881	0.754 (0.526, 1.081)	0.125
≥65	0.837 (0.625, 1.121)	0.233	0.858 (0.709, 1.039)	0.117	0.779 (0.420, 1.442)	0.426	0.710 (0.467, 1.079)	0.109
Ethnicity								
Non-Hispanic white	1		1		1		1	
Non-Hispanic black	1.767 (1.353, 2.307)	**0.003**	1.231 (0.998, 1.517)	0.052	1.584 (0.986, 2.544)	0.057	1.079 (0.722, 1.611)	0.712
Mexican American	1.242 (0.904, 1.706)	0.181	1.180 (0.957, 1.454)	0.122	0.760 (0.399, 1.445)	0.402	0.852 (0.541, 1.341)	0.488
Other	1.463 (1.017, 2.105)	**0.040**	1.328 (1.062, 1.660)	**0.013**	1.071 (0.569, 2.016)	0.832	1.187 (0.793, 1.777)	0.404
Education								
<12th grade	1		1		1		1	
≥High school	0.565 (0.447, 0.714)	<**0.001**	0.710 (0.608, 0.829)	<**0.001**	0.456 (0.300, 0.694)	<**0.001**	0.731 (0.555, 0.964)	**0.026**
Marital status								
Never married	1		1		1		1	
Widowed/divorced	0.674 (0.514, 0.884)	**0.004**	0.876 (0.728, 1.053)	0.158	0.829 (0.488, 1.407)	0.487	0.986 (0.683, 1.425)	0.942
Separated	0.949 (0.701, 1.285)	0.735	1.116 (0.902, 1.381)	0.312	0.856 (0.478, 1.533)	0.600	1.056 (0.694, 1.607)	0.799
Income-poverty ratio								
<2	1		1		1		1	
≥2	0.544 (0.429, 0.689)	<**0.001**	0.792 (0.676, 0.929)	**0.004**	0.842 (0.558, 1.271)	0.413	0.975 (0.738, 1.289)	0.859
Physical activity								
<500	1		1		1		1	
≥500	0.822 (0.647, 1.045)	0.109	0.848 (0.719, 0.999)	**0.049**	1.079 (0.740, 1.572)	0.694	0.995 (0.766, 1.292)	0.968
Drinking								
No	1		1		1		1	
Yes	0.604 (0.482, 0.757)	**0.001**	0.565 (0.481, 0.663)	<**0.001**	0.850 (0.573, 1.260)	0.418	0.855 (0.642, 1.139)	0.284
Smoking								
Never	1		1		1		1	
Current	0.856 (0.639, 1.146)	0.296	0.781 (0.643, 0.948)	0.012	0.733 (0.439, 1.222)	0.233	1.026 (0.735, 1.432)	0.881
Former	0.949 (0.728, 1.235)	0.695	0.683 (0.562, 0.832)	<0.001	0.971 (0.633, 1.488)	0.892	0.833 (0.610, 1.137)	0.249

Table 2 (continued)

	Obesity (univariate)		Non-obese		Obesity (multivariate)		Non-obese	
	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value
Hypertension								
No	1		1		1		1	
Yes	0.702 (0.561, 0.879)	**0.002**	0.939 (0.803, 1.098)	0.429	0.505 (0.334, 0.763)	**0.001**	0.924 (0.690, 1.238)	0.598
Depression								
No	1		1		1		1	
Yes	1.344 (0.969, 1.865)	0.077	1.765 (1.398, 2.230)	<**0.001**	1.070 (0.619, 1.849)	0.809	1.390 (0.933, 2.072)	0.106
Diabetes								
No	1		1		1		1	
Yes	0.958 (0.728, 1.262)	0.760	0.878 (0.682, 1.131)	0.313	0.925 (0.594, 1.441)	0.730	0.807 (0.542, 1.199)	0.288
Asthma								
No	1		1		1		1	
Yes	1.108 (0.826, 1.485)	0.495	1.253 (1.011, 1.554)	**0.039**	0.889 (0.552, 1.431)	0.628	1.371 (0.976, 1.925)	0.069
COPD								
No	1		1		1		1	
Yes	1.127 (0.738, 1.721)	0.581	1.180 (0.844, 1.650)	0.334	0.932 (0.483, 1.797)	0.834	0.794 (0.474, 1.331)	0.381
Vitamin D deficiency								
No	1		1		1		1	
Yes	1.168 (0.925, 1.476)	0.192	1.011 (0.847, 1.207)	0.905	0.738 (0.489, 1.114)	0.148	0.902 (0.652, 1.248)	0.535
Milk								
Never/rarely	1		1		1		1	
Occasionally/often	0.874 (0.691, 1.104)	0.258	1.055 (0.892, 1.246)	0.532	1.365 (0.891, 2.089)	0.153	1.154 (0.864, 1.541)	0.331
Energy, kcal								
Low (0–1,596)	1		1		1		1	
Medium (1,596–2,257)	0.702 (0.540, 0.912)	**0.008**	0.817 (0.683, 0.976)	**0.026**	1.065 (0.511, 2.220)	0.866	0.689 (0.433, 1.097)	0.116
High (>2,257)	0.561 (0.424, 0.742)	<**0.001**	0.559 (0.460, 0.680)	<**0.001**	1.071 (0.339, 3.386)	0.907	0.699 (0.333, 1.469)	0.345
Protein, g								
Low (0–61.3)	1		1		1		1	
Medium (61.3–88.4)	0.632 (0.488, 0.820)	<**0.001**	0.775 (0.648, 0.926)	**0.005**	1.321 (0.784, 2.226)	0.296	1.077 (0.761, 1.525)	0.674
High (>88.4)	0.461 (0.347, 0.612)	<**0.001**	0.544 (0.447, 0.661)	<**0.001**	1.169 (0.540, 2.532)	0.692	1.119 (0.673, 1.862)	0.665
Carbohydrate, g								
Low (0–195)	1		1		1		1	
Medium (195–277.5)	0.750 (0.573, 0.982)	**0.036**	0.866 (0.720, 1.042)	0.127	1.613 (0.818, 3.180)	0.167	1.177 (0.762, 1.819)	0.462
High (>277.5)	0.808 (0.618, 1.057)	0.119	0.739 (0.611, 0.893)	**0.002**	1.747 (0.626, 4.881)	0.287	1.431 (0.752, 2.722)	0.275

Table 2 (continued)

	Obesity (univariate)		Non-obese		Obesity (multivariate)		Non-obese	
	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value
Total sugars, g								
Low (0–78.4)	1		1		1		1	
Medium (78.4–126.9)	0.759 (0.577, 0.999)	**0.049**	1.012 (0.835, 1.226)	0.903	0.667 (0.381, 1.168)	0.157	1.180 (0.815, 1.707)	0.380
High (>126.9)	0.939 (0.721, 1.223)	0.642	1.054 (0.873, 1.273)	0.585	1.008 (0.485, 2.098)	0.982	1.812 (1.119, 2.933)	**0.015**
Dietary fiber, g								
Low (0–11.7)	1		1		1		1	
Medium (11.7–18.2)	0.641 (0.496, 0.828)	<**0.001**	0.768 (0.639, 0.924)	**0.005**	0.716 (0.459, 1.116)	0.139	0.855 (0.619, 1.182)	0.342
High (>18.2)	0.462 (0.344, 0.621)	<**0.001**	0.647 (0.536, 0.781)	<**0.001**	0.454 (0.245, 0.841)	**0.012**	0.842 (0.568, 1.249)	0.393
Total fat, g								
Low (0–55.6)	1		1		1		1	
Medium (55.6–85.5)	0.655 (0.502, 0.854)	**0.002**	0.878 (0.735, 1.049)	0.152	0.618 (0.347, 1.099)	0.101	1.111 (0.770, 1.605)	0.573
High (>85.5)	0.534 (0.405, 0.703)	<**0.001**	0.588 (0.483, 0.717)	<**0.001**	0.972 (0.447, 2.115)	0.944	0.872 (0.507, 1.502)	0.622
Cholesterol, mg								
Low (0–176.5)	1		1		1		1	
Medium (176.5–317.5)	0.744 (0.572, 0.967)	**0.027**	0.786 (0.655, 0.943)	**0.009**	0.735 (0.461, 1.172)	0.196	1.206 (0.878, 1.658)	0.248
High (>317.5)	0.564 (0.427, 0.745)	**0.005**	0.672 (0.555, 0.813)	**0.004**	0.400 (0.213, 0.750)	**0.004**	1.134 (0.760, 1.692)	0.538
Moisture, g								
Low (0–2,101.7)	1		1		1		1	
Medium (2,101.7–3,042.7)	0.610 (0.467, 0.796)	<**0.001**	0.728 (0.609, 0.869)	<**0.001**	0.868 (0.550, 1.369)	0.542	0.889 (0.657, 1.202)	0.443
High (>3,042.7)	0.530 (0.403, 0.697)	<**0.001**	0.489 (0.401, 0.596)	<**0.001**	0.842 (0.500, 1.420)	0.519	0.572 (0.392, 0.836)	**0.004**
Polypharmacy								
No	1		1		1		1	
Yes	1.334 (1.007, 1.766)	**0.044**	1.043 (0.826, 1.319)	0.722	1.669 (1.104, 2.521)	**0.015**	1.212 (0.879, 1.671)	0.239
Hypertension drugs								
No	1		1		1		1	
Yes	0.920 (0.696, 1.217)	0.559	0.791 (0.641, 0.977)	**0.029**	0.800 (0.449, 1.424)	0.447	0.680 (0.466, 0.994)	**0.046**

Adjusted for gender, age, ethnicity, education, marital status, income-poverty ratio, physical activity, drinking, smoking, hypertension, depression, diabetes, asthma, COPD, vitamin D deficiency, milk, energy, protein, carbohydrate, total sugars, dietary fiber, total fat, cholesterol, moisture, and polypharmacy. Significant values are shown in bold ($p < 0.05$).

5.223; $p = 0.00366$), Mexican American ethnicity (OR: 0.142; 95% CI: 0.033, 0.616; $p = 0.00914$), hypertension (OR: 0.569; 95% CI: 0.324, 0.998; $p = 0.04916$), depression (OR: 2.280; 95% CI: 1.240, 4.195; $p = 0.00803$), occasional/frequent milk consumption (OR: 0.473; 95% CI: 0.286, 0.782; $p = 0.00356$), medium energy (OR: 0.318; 95% CI: 0.118, 0.856; $p = 0.02338$), polypharmacy (OR: 1.939; 95% CI: 1.115, 3.373; $p = 0.01907$), and medium moisture (OR: 0.534; 95% CI: 0.285, 0.999; $p = 0.04959$). For the nonobese population, the female sex, age ≥45, an income-poverty ratio of ≥2, and high moisture were significantly associated with constipation.

Table 3. Logistic regression analysis of factors associated with constipation (frequency-based) in an obese subgroup

	Obesity (univariate)		Non-obese		Obesity (multivariate)		Non-obese	
	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value
Gender								
Male	1		1		1		1	
Female	3.830 (2.547, 5.758)	<**0.001**	3.437 (2.666, 4.431)	<**0.001**	2.684 (1.379, 5.223)	**0.004**	2.133 (1.308, 3.476)	**0.002**
Age, years								
<45	1		1		1		1	
≥45, <65	0.676 (0.470, 0.973)	**0.034**	0.677 (0.520, 0.880)	**0.003**	0.877 (0.453, 1.698)	0.696	0.504 (0.291, 0.873)	**0.014**
≥65	0.693 (0.450, 1.067)	0.095	0.586 (0.436, 0.788)	<**0.001**	0.751 (0.328, 1.721)	0.498	0.314 (0.164, 0.603)	<**0.001**
Ethnicity								
Non-Hispanic white	1		1		1		1	
Non-Hispanic black	1.648 (1.166, 2.330)	**0.005**	2.225 (1.717, 2.883)	<**0.001**	1.031 (0.561, 1.898)	0.921	1.399 (0.807, 2.426)	0.231
Mexican American	0.333 (0.171, 0.648)	**0.001**	0.795 (0.557, 1.133)	0.204	0.142 (0.033, 0.616)	**0.009**	0.792 (0.382, 1.639)	0.529
Other	0.568 (0.291, 1.107)	0.097	0.922 (0.634, 1.341)	0.672	0.443 (0.163, 1.203)	0.110	0.702 (0.342, 1.442)	0.335
Education								
<12th grade	1		1		1		1	
≥High school	0.593 (0.423, 0.833)	**0.002**	0.782 (0.625, 0.978)	**0.031**	0.824 (0.483, 1.406)	0.477	0.854 (0.554, 1.318)	0.477
Marital status								
Never married	1		1		1		1	
Widowed/divorced	0.516 (0.353, 0.755)	<**0.001**	0.664 (0.511, 0.862)	**0.002**	0.818 (0.412, 1.623)	0.565	1.148 (0.652, 2.022)	0.633
Separated	0.781 (0.512, 1.192)	0.252	0.969 (0.720, 1.302)	0.833	0.802 (0.380, 1.697)	0.564	1.368 (0.729, 2.567)	0.329
Income-poverty ratio								
<2	1		1		1		1	
≥2	0.413 (0.290, 0.587)	<**0.001**	0.565 (0.446, 0.715)	<**0.001**	0.636 (0.362, 1.116)	0.114	0.646 (0.420, 0.995)	**0.047**
Physical activity								
<500	1		1		1		1	
≥500	0.756 (0.537, 1.064)	0.108	0.801 (0.630, 1.019)	0.070	0.984 (0.594, 1.631)	0.951	0.792 (0.531, 1.181)	0.251
Drinking								
No	1		1		1		1	
Yes	0.546 (0.396, 0.754)	<**0.001**	0.643 (0.508, 0.813)	<**0.001**	0.808 (0.478, 1.368)	0.428	1.055 (0.674, 1.649)	0.815
Smoking								
Never	1		1		1		1	
Current	1.320 (0.905, 1.925)	0.149	1.150 (0.885, 1.494)	0.296	1.120 (0.607, 2.065)	0.716	1.079 (0.660, 1.764)	0.761
Former	0.771 (0.506, 1.173)	0.223	0.746 (0.556, 1.000)	**0.049**	0.726 (0.387, 1.361)	0.317	0.734 (0.441, 1.220)	0.232

Table 3 (continued)

	Obesity (univariate)		Non-obese		Obesity (multivariate)		Non-obese	
	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value
Hypertension								
No	1		1		1		1	
Yes	0.684 (0.494, 0.946)	**0.021**	1.006 (0.803, 1.261)	0.956	0.569 (0.324, 0.998)	**0.049**	1.537 (0.962, 2.458)	0.072
Depression								
No	1		1		1		1	
Yes	1.932 (1.270, 2.939)	**0.002**	2.658 (1.983, 3.563)	<**0.001**	2.280 (1.240, 4.195)	**0.008**	1.666 (0.963, 2.882)	0.067
Diabetes								
No	1		1		1		1	
Yes	1.118 (0.762, 1.641)	0.566	0.899 (0.623, 1.297)	0.570	1.238 (0.695, 2.205)	0.468	0.774 (0.428, 1.402)	0.398
Asthma								
No	1		1		1		1	
Yes	1.569 (1.068, 2.305)	**0.021**	1.472 (1.096, 1.977)	**0.010**	1.626 (0.926, 2.858)	0.091	1.150 (0.673, 1.963)	0.608
COPD								
No	1		1		1		1	
Yes	1.432 (0.816, 2.512)	0.211	1.543 (0.997, 2.389)	0.051	0.546 (0.218, 1.367)	0.196	1.027 (0.506, 2.086)	0.940
Vitamin D deficiency								
No	1		1		1		1	
Yes	1.745 (1.248, 2.441)	**0.001**	1.514 (1.190, 1.926)	<**0.001**	0.957 (0.556, 1.646)	0.873	0.821 (0.508, 1.328)	0.422
Milk								
Never/rarely	1		1		1		1	
Occasionally/often	0.643 (0.464, 0.893)	**0.008**	0.717 (0.570, 0.901)	**0.004**	0.473 (0.286, 0.782)	**0.003**	0.818 (0.539, 1.241)	0.343
Energy, kcal								
Low (0–1,596)	1		1		1		1	
Medium (1,596–2,257)	0.664 (0.450, 0.980)	**0.039**	0.778 (0.603, 1.004)	0.053	0.318 (0.118, 0.856)	**0.023**	1.482 (0.745, 2.946)	0.262
High (>2,257)	0.681 (0.463, 1.003)	0.051	0.470 (0.351, 0.631)	<**0.001**	0.458 (0.101, 2.067)	0.309	0.932 (0.278, 3.128)	0.909
Protein, g								
Low (0–61.3)	1		1		1		1	
Medium (61.3–88.4)	0.510 (0.346, 0.752)	<**0.001**	0.663 (0.515, 0.854)	**0.001**	0.954 (0.453, 2.011)	0.901	0.602 (0.352, 1.030)	0.064
High (>88.4)	0.470 (0.315, 0.699)	<**0.001**	0.373 (0.276, 0.505)	<**0.001**	1.389 (0.485, 3.977)	0.539	0.787 (0.348, 1.777)	0.564
Carbohydrate, g								
Low (0–195)	1		1		1		1	
Medium (195–277.5)	1.256 (0.859, 1.838)	0.239	0.883 (0.685, 1.139)	0.339	2.593 (1.030, 6.531) **0.043**		1.300 (0.692, 2.443)	0.414
High (>277.5)	0.994 (0.661, 1.494)	0.976	0.502 (0.374, 0.674)	<**0.001**	2.408 (0.574, 10.106)	0.229	1.037 (0.376, 2.861)	0.943

Table 3 (continued)

	Obesity (univariate)		Non-obese		Obesity (multivariate)		Non-obese	
	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value	odds ratio	*p* value
Total sugars, g								
Low (0–78.4)	1		1		1		1	
Medium (78.4–126.9)	0.802 (0.528, 1.217)	0.299	0.905 (0.689, 1.188)	0.471	0.489 (0.227, 1.058)	0.069	0.968 (0.571, 1.642)	0.905
High (>126.9)	1.350 (0.930, 1.960)	0.113	0.867 (0.659, 1.139)	0.304	1.175 (0.451, 3.063)	0.741	0.986 (0.476, 2.046)	0.970
Dietary fiber, g								
Low (0–11.7)	1		1		1		1	
Medium (11.7–18.2)	0.918 (0.647, 1.302)	0.631	0.519 (0.400, 0.672)	<**0.001**	0.898 (0.486, 1.661)	0.732	0.657 (0.404, 1.068)	0.089
High (>18.2)	0.386 (0.239, 0.621)	<**0.001**	0.288 (0.212, 0.390)	<**0.001**	0.689 (0.287, 1.654)	0.404	0.615 (0.328, 1.150)	0.127
Total fat, g								
Low (0–55.6)	1		1		1		1	
Medium (55.6–85.5)	0.802 (0.549, 1.171)	0.252	0.951 (0.736, 1.228)	0.698	1.815 (0.874, 3.770)	0.109	1.184 (0.681, 2.058)	0.550
High (>85.5)	0.620 (0.417, 0.923)	**0.018**	0.613 (0.459, 0.820)	<**0.001**	2.158 (0.707, 6.590)	0.176	1.475 (0.651, 3.345)	0.351
Cholesterol, mg								
Low (0–176.5)	1		1		1		1	
Medium (176.5–317.5)	0.607 (0.414, 0.892)	**0.011**	0.749 (0.577, 0.972)	**0.029**	0.596 (0.307, 1.160)	0.127	0.971 (0.600, 1.573)	0.904
High (>317.5)	0.531 (0.358, 0.787)	**0.001**	0.593 (0.447, 0.785)	<**0.001**	0.510 (0.220, 1.183)	0.116	0.762 (0.398, 1.458)	0.411
Moisture, g								
Low (0–2,101.7)	1		1		1		1	
Medium (2,101.7–3,042.7)	0.501 (0.342, 0.735)	<**0.001**	0.529 (0.409, 0.685)	<**0.001**	0.534 (0.285, 0.999)	**0.049**	0.669 (0.423, 1.058)	0.085
High (>3,042.7)	0.413 (0.276, 0.617)	<**0.001**	0.302 (0.220, 0.413)	<**0.001**	0.591 (0.297, 1.173)	0.132	0.296 (0.152, 0.579)	<**0.001**
Polypharmacy								
No	1		1		1		1	
Yes	1.609 (1.094, 2.366)	**0.015**	1.404 (1.008, 1.955)	**0.044**	1.939 (1.115, 3.373)	**0.019**	1.579 (0.976, 2.554)	0.062
Hypertension drugs								
No	1		1		1		1	
Yes	0.865 (0.591, 1.266)	0.454	0.839 (0.615, 1.144)	0.266	0.721 (0.339, 1.535)	0.396	0.632 (0.364, 1.098)	0.103

Adjusted for gender, age, ethnicity, education, marital status, Income-poverty ratio, physical activity, drinking, smoking, hypertension, depression, diabetes, asthma, COPD, vitamin D deficiency, milk, energy, protein, carbohydrate, total sugars, dietary fiber, total fat, cholesterol, moisture, and polypharmacy. Significant values are shown in bold ($p < 0.05$).

Discussion

In this study, we mainly explored the factors associated with constipation in the population with obesity by marshaling several variables from the NHANES database. Simultaneously, we also analyzed the factors associated with constipation in nonobese participants. For the difference in the definition of constipation, we analyzed the data related to the two definitions of constipation and found not exactly the same results. Hypertension and

polypharmacy showed significant associations with constipation populations with obesity across two different definitions, whereas demographic and dietary factors did not have the same variables associated with the two constipation types.

An interesting finding of our study was that people with both obesity and hypertension were less predisposed to constipation (OR: 0.505; 95% CI: 0.334, 0.763; p = 0.00119 consistency-related constipation). To the best of our knowledge, only a few studies have examined the relationship between hypertension and constipation. One such study [20] identified hypertension as a possible risk factor for constipation in older patients, which is contrary to our results. However, the specific diagnostic criteria for hypertension were not mentioned in the literature, so no comparisons could be made. Our diagnostic criteria for hypertension were based on the 2017 American College of Cardiology/American Heart Association 2017 (ACC/AHA 2017) guidelines that reduce the diagnostic threshold to ≥130/80 mm Hg. The prevalence of hypertension in our study population was 49.7%, with an increase in prevalence due to the lower diagnostic threshold value. In the nonobese population, hypertension did not show a significant association with constipation (OR: 0.924; 95% CI: 0.690, 1.238; p = 0.59790). Hypertension might be associated with a reduced risk of constipation in people with obesity. To verify whether the above results were due to the use of hypertensive medication, we analyzed the hypertensive medication variable and found no correlation between the use of hypertensive medication and constipation. Studies have suggested that the ratio of Firmicutes to Bacteroidetes in the intestine of a hypertensive patient is significantly increased, which is a manifestation of intestinal dysbiosis [21–25]. Hypertension may interact with intestinal dysbiosis through intestinal pathology, intestinal permeability, and the gut-brain axis. Several studies have shown that obesity is associated with microbial imbalances and endotoxemia [26–29]. Dysbiosis is an imbalance in the microbiological environment of the gut with an overgrowth of harmful bacteria that can lead to a variety of diseases such as ulcerative colitis and Crohn's disease, which are characterized by diarrhea and increased frequency of bowel movements [30, 31]. Therefore, we consider that hypertension may exacerbate dysbiosis in population with obesity, causing intestinal tract inflammation, which may increase the frequency of BMs and change the stool consistency to some extent, ultimately reducing the incidence of constipation. Therefore, for people with obesity and hypertension, even if they do not have symptoms of constipation, there may be a dysbiosis in the gut. In stool consistency-related constipation, high cholesterol intake is associated with a reduced incidence of constipation in population with obesity. Long-term cholesterol diet consumption alters the intestinal flora composition, intestinal barrier function, and immune system [32]. High cholesterol intake may also alter stool consistency through intestinal dysfunction caused by bacterial imbalance.

Constipation is a common side effect of medication. Many drugs such as furosemide, levothyroxine sodium, opioids, and ibuprofen can cause constipation [33, 34]. Polypharmacy can amplify this side effect. Our study showed that polypharmacy increased the risk of constipation in the population with obesity, but not in the nonobese participants.

Evidence from many previous studies suggests that higher dietary fiber intake may reduce the risk of functional constipation [35–37]. In stool consistency-based constipation, high dietary fiber intake is associated with a low risk of constipation in the people with obesity. This is consistent with the findings of a study that concluded that dietary fiber intake primarily relieves consistency-based constipation [38]. Another meta-analysis reported that dietary fiber intake contributed to an increase in stool frequency but did not improve stool consistency, which was contrary to our findings. Our results showed no correlation between dietary fiber and frequency-based constipation.

Many health experts recommend lifestyle changes and increased water intake to relieve constipation [39, 40]. The relationship between water and constipation has also been reported in studies conducted in different countries worldwide. A study of factors associated with functional constipation in young Japanese women showed that low magnesium intake and low dietary water intake were independent risk factors for constipation in these young women [41]. According to a study conducted in Korea, the nonconsumption of meat and drinking fewer than 500 mL of water per day were both substantial predictors of constipation in young children [42]. Our results suggest that high moisture levels in nonobese people can reduce the risk of constipation regardless of the definition of constipation. In people with obesity, the effect of water on constipation was not as significant, and only in frequency-related constipation was medium water consumption associated with constipation.

Among other factors, the female sex significantly increased the risk of stool frequency-based constipation in population with obesity and was also significantly associated with constipation in the nonobese population. Mexican Americans are the only ethnic group whose

people with obesity were found to be at a lower risk of frequency-based constipation. Depression, one of the most widespread psychiatric disorders, was significantly associated with constipation in the above-mentioned groups. In terms of diet, our results indicate that occasional/often milk consumption and medium energy could reduce the risk of constipation in people with obesity.

In conclusion, our study shows a significant difference in the factors associated with constipation in the obese and nonobese participants. The population with obesity has specific factors that affect constipation such as hypertension, polypharmacy, cholesterol, dietary fiber, depression, and so on (of which hypertension and polypharmacy were significantly associated with constipation), regardless of the definition of constipation that was employed. We also used two different definitions of constipation, which makes the results more comprehensive. Further research is needed to verify the accuracy of the results.

Nevertheless, this study had some limitations. First, only dietary data for the 2 days preceding the interview (which might not represent long-term dietary habits) were available. Second, this was a cross-sectional study based on the NHANES database; therefore, it is not possible to determine the causal relationship between various factors and constipation. Third, the NHANES survey also used interviews and questionnaires to obtain self-reported information, which may involve recall bias.

Statement of Ethics

The survey protocol was reviewed and approved by the National Center for Health Statistics Ethics Review Board, approval number (2005-06). NHANES data is de-identified, so data analysis does not require approval from an Institutional Review Board or written informed consent from study participants.

Conflict of Interest Statement

No potential conflict of interest was reported by the author(s).

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Author Contributions

The idea for the article was conceived by Junping Liu. The manuscript was drafted by Yongping Hong. Statistical analyses were performed by Xingxing Chen. The manuscript was critically reviewed by Junping Liu and Yongping Hong. All authors reviewed and approved the final version of the manuscript.

Data Availability Statement

The data that support the findings of this study are available from NHANES and do not require any permissions. Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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