BMC Public Health

RESEARCH

Open Access

The Association of moisture intake and constipation among us adults: evidence from NHANES 2005–2010

Deng-Chao Wang[1*], Xue-Feng Peng[1], Wen-Xing Chen[1] and Miao Yu[2]

Abstract

Background Constipation is a common gastrointestinal disorder that affects the quality of life of millions of adults worldwide. Dietary moisture intake is considered to have a significant impact on intestinal health, yet its specific role in constipation has not been thoroughly investigated in large-scale population studies. This study aims to explore the correlation between adult dietary moisture intake and constipation by analyzing the NHANES database, filling a knowledge gap in the literature.

Methods Data from NHANES participants aged 20 years and older from 2005 to 2010 were analyzed. Moisture intake was assessed using dietary recall data, which included moisture from all food and beverages consumed. A weighted logistic regression model was used to assess the relationship between moisture intake and the risk of constipation, calculating the odds ratios (ORs) and their 95% confidence intervals (CIs), while controlling for potential confounders. Additionally, restricted cubic splines (RCS) were applied to further explore potential non-linear patterns in the relationship between moisture intake and constipation, along with subgroup analysis.

Results The study included 14,492 participants, of whom 1,514 reported constipation issues. After adequately adjusting for confounders, a significant negative correlation was observed between moisture intake and constipation risk (OR 0.81; 95% CI: 0.74–0.89). Quartile analysis of moisture intake demonstrated that, compared to the first quartile Q1 (0.06 to 1.90 kg), the constipation risk for the second quartile Q2 (1.91 to 2.53 kg), third quartile Q3 (2.54 to 3.36 kg), and fourth quartile Q4 (3.37 to 16.97 kg) were OR 0.80 (95% CI: 0.64–0.72), OR 0.57 (95% CI: 0.45–0.72), and OR 0.54 (95% CI: 0.44–0.67) respectively, with a trend test *P*-value ofless than 0.001. RCS regression revealed a significant non-linear negative relationship between moisture intake and constipation prevalence ($P < 0.001$). Depression may modulate the relationship between moisture and constipation (interaction effect $P = 0.014$).

Conclusion The findings of this study indicate that appropriate dietary moisture intake is significantly associated with a lower risk of constipation, demonstrating a dose-response relationship. This emphasizes the importance of considering adequate moisture intake in the prevention and management of constipation. Future studies should adopt a prospective design to further verify the causal relationship between dietary moisture intake and constipation progression.

*Correspondence:
Deng-Chao Wang
wangdengchaopwk@163.com

Full list of author information is available at the end of the article

Keywords Moisture, Constipation, NHANES

Introduction

Constipation is a widespread gastrointestinal disorder globally, affecting not only the physical health of adults but also severely impacting their quality of life. Clinically, constipation is often defined as reduced frequency of bowel movements, difficulty in defecation, or a sensation of incomplete evacuation [1, 2]. Studies indicate that approximately 12–19% of adults worldwide regularly experience constipation issues, with a particularly high prevalence among the elderly [3]. Additionally, constipation can lead to various complications such as anal fissures, hemorrhoids, and intestinal obstruction, further increasing the burden on individuals and public health systems [4, 5].

Although the etiology of constipation is multifactorial, dietary factors have consistently been recognized as one of its main influencers. Among these dietary factors, the role of moisture intake is especially critical. Adequate moisture intake can help maintain normal functioning of the digestive system and promote the proper flow of intestinal contents, thereby preventing constipation. However, research on the relationship between moisture intake and constipation has largely been confined to small-scale or short-term clinical trials, lacking long-term observational data from large-scale populations [6, 7].

A previous study utilizing NHANES data (2005–2010) examined the relationship between dietary fiber, water intake, and constipation, finding that lower dietary fiber intake, but not poor water consumption, was associated with constipation [8]. Unlike this research, which focused on total water intake, our study investigates total moisture intake, encompassing all moisture from food and beverages. This approach provides a more comprehensive assessment of hydration and its role in constipation prevention.

The NHANES is a comprehensive, multi-year survey that collects a wide range of data including dietary habits, health status, and nutritional status. These data provide a unique resource for researchers to explore how dietary behaviors affect long-term health outcomes. Specifically, the NHANES data can be used to analyze the relationship between adult dietary moisture intake and constipation, which is crucial for understanding the role of dietary moisture in maintaining intestinal health. In light of the current research gaps, this study leverages the extensive data from the NHANES database to systematically assess the correlation between dietary moisture intake and constipation in adults. Through this research, we aim to reveal potential links between dietary moisture intake and the risk of constipation, and assess whether there is a dose-response relationship. By deepening our understanding of this relationship, this study will provide scientifically based guidance for the prevention and management of constipation. It will also support public health policy-making, promote evidence-based dietary guidelines, and contribute to improving intestinal health and the overall well-being of the public.

Materials and methods

Data source

The data used in this study were sourced from the NHANES, a cross-sectional program organized by the Centers for Disease Control and Prevention (CDC). NHANES aims to assess the health and nutritional status of the U.S. population by collecting data through face-to-face interviews and direct physical examinations, thus obtaining a representative national sample. The survey is updated biennially and continuously gathers data covering health conditions, lifestyle habits, nutritional intake, and various health indicators. Data collection includes, but is not limited to, participants' dietary frequency questionnaires, 24-hour dietary recalls, physical examinations, laboratory tests, and health questionnaires [9]. This study focuses primarily on the relationship between moisture and constipation, specifically using data from the NHANES database from the years 2005 to 2010. Further details on the NHANES survey design, codebooks, and methods can be found on its official website (https://www.cdc.gov/nchs/nhanes/index.htm, last accessed on May 16, 2024).

Study population

This study selected data from three survey cycles of the NHANES database from the years 2005 to 2010, specifically including the cycles from 2005 to 2006, 2007–2008, and 2009–2010. Data included in this study met the following criteria: participants aged ≥ 20 years; complete moisture intake data; and comprehensive information about constipation. During the screening process, the following participants were excluded: those under 20 years of age (13,902 individuals), those lacking data on constipation (1,210 individuals), and those without data on dietary moisture intake (1,430 individuals). After this screening process, data from 14,492 participants met the inclusion criteria for the study. Figure 1 provides a detailed illustration of the inclusion and exclusion process of the study subjects.

Measurement of moisture intake

In this study, the measurement of moisture intake is based on the total daily moisture intake data from the

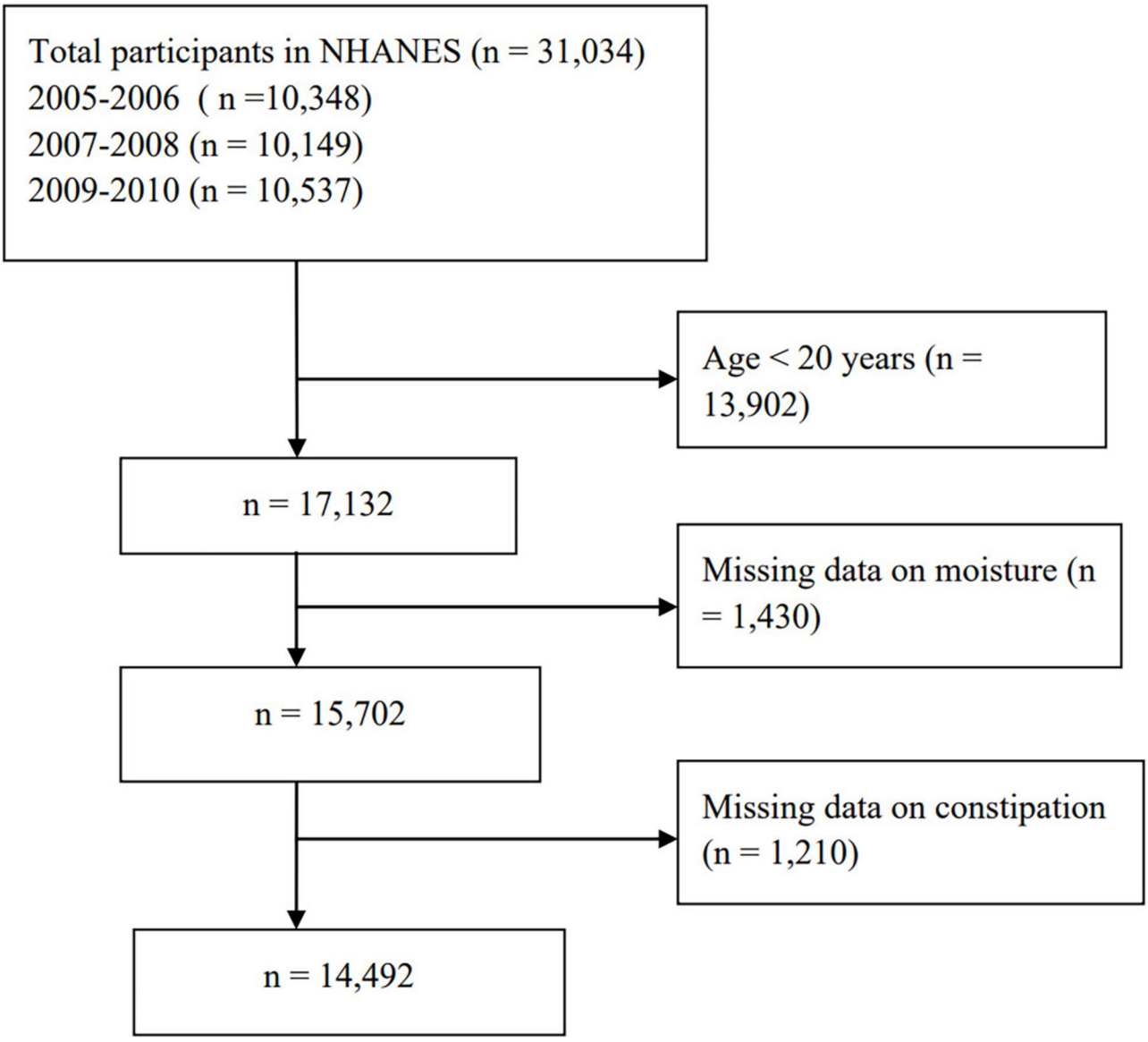

Fig. 1 Flowchart of participant selection from the NHANES database (2005–2010)

NHANES database, which includes all moisture from food and beverages. Moisture intake data in NHANES are recorded under two variables: DR1TMOIS and DR2TMOIS. These variables represent the total moisture intake of survey participants on the first and second days of the survey, respectively, encompassing moisture from all food and drinks, as well as tap and bottled water consumed as drinking water. To estimate the moisture content in food and beverages, NHANES utilizes the USDA Food and Nutrient Database for Dietary Studies (FNDDS). This database provides comprehensive nutrient profiles, including total moisture content, for each food and beverage item reported by participants during the 24-hour dietary recall interviews. These interviews are conducted using the Automated Multiple Pass Method (AMPM), a standardized approach designed to enhance the accuracy of dietary data collection by minimizing recall bias. To obtain a more accurate estimate of moisture intake, this study calculated the average total moisture intake over the two days of dietary recall. By combining data from both days, variability in daily intake that might affect the study results is minimized, thereby enhancing the reliability and accuracy of the moisture intake estimation.

Definition of constipation

According to data from the NHANES, constipation is commonly defined based on stool consistency or defecation frequency in prior studies. Although previous research has indicated a weak correlation between stool

consistency and defecation frequency, this study has incorporated both metrics to provide a comprehensive assessment of constipation. Data on stool consistency and defecation frequency were prospectively recorded over a continuous 30-day period prior to the collection of other data. Stool consistency was evaluated using the Bristol Stool Form Scale, which utilizes a series of color-coded cards and detailed descriptions to categorize stool into seven types. According to the Bristol scale, Types 1 (hard, nut-like lumps) and 2 (sausage-shaped but lumpy) are classified as constipated, whereas Types 3 to 7 are considered indicative of non-constipated states. Defecation frequency was assessed by asking participants, "How often do you typically have bowel movements each week?" In this study, constipation was defined as meeting either one or both of the following criteria: (1) stool consistency corresponding to Bristol Stool Form Scale Types 1 or 2; or (2) defecation frequency of fewer than three bowel movements per week. Participants who met at least one of these criteria were classified as constipated, while those meeting neither criterion were considered non-constipated [10, 11].

Covariates

In this study, multiple covariates were selected for analysis based on the NHANES database and recommendations from related literature. These include age (categorized into three groups: 20 to 39 years, 40 to 59 years, and 60 years and above), gender (male, female), education level (less than high school, high school or equivalent, college or above), marital status (married, widowed, divorced, separated, never married, living with partner), and race (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, other races). The Poverty Income Ratio (PIR) was analyzed in three categories: less than 1.30, 1.30 to 3.49, and 3.50 or greater [12]. Body Mass Index (BMI) was assessed with the following brackets: less than 18.5 kg/m², 18.5 to 24.9 kg/m², 25 to 29.9 kg/m², and 30 kg/m² or greater [13]. Lifestyle factors such as daily alcohol intake (< 10 g/d, 10–30 g/d, ≥ 30 g/d) and smoking status (never, former, current) were also evaluated [14, 15]. Additionally, health conditions such as diabetes (yes, no), hypertension (yes, no) and depressive symptoms (yes, no), along with physical activity levels (recommended activity, insufficient activity) were considered. Daily energy intakewas assessed through participants' 24-hour dietary recall records.

Statistical analyses

This study strictly adhered to the analytical guidelines of the NHANES, utilizing the "Full Sample 2 Year MEC Exam Weight". Categorical variables were expressed as percentages and compared using the Chi-square test. For continuous variables that followed a normal distribution, means and standard deviations were reported, and comparisons were made using the independent samples t-test. For continuous variables not normally distributed, medians and interquartile ranges (IQR) were described, and the Wilcoxon rank-sum test was applied for analysis. In the logistic regression models, dietary moisture content (categorized into quartiles from Q1 to Q4) was used as the independent variable to explore its relationship with constipation. Model 1 is the crude model without any adjustments; Model 2 adjusted for age, gender, education, marital status, race, PIR, and BMI. Model 3 further adjusted for daily alcohol intake, smoking, hypertension, diabetes, depression, physical activity, and daily energy intake. We used the RCS method to investigate potential non-linear relationships between moisture content and constipation. Additionally, subgroup analyses based on multiple characteristics and tests for interactions among these characteristics were conducted. All statistical analyses were performed using the statistical software packages R (version 4.2.2) and Free Statistics (version 1.7). A significance level was set at a p-value of less than 0.05 for two-sided tests. Descriptive analyses were conducted for all participants to ensure the accuracy and reliability of the analysis results.

Results

Participants and demographic characteristics

This study utilized the NHANES database, covering data from 2005 to 2010, and included 14,492 eligible participants, of whom 1,514 were identified with constipation. Moisture levels were divided into four quartile groups: Q1 (0.06–1.90 kg), Q2 (1.91–2.53 kg), Q3 (2.54–3.36 kg), and Q4 (3.37–16.97 kg). Significant differences were observed among the moisture quartiles in terms of age, gender, education, marital status, race, PIR, BMI, daily alcohol intake, smoking status, hypertension, diabetes, depression, physical activity, and daily energy intake ($P < 0.01$). Participants in Q4 tended to be aged 40–59, male, with an education level of College or above, marital status of living with partner, race of Non-Hispanic White, a PIR of ≥ 3.50, a BMI of ≥ 30, daily alcohol intake of ≥ 30 g/d,, currently smoking, absence of hypertension, absence of diabetes, absence of depression, engaging in recommended activity, and no constipation. They also had higher daily energy intake. Detailed baseline characteristics are presented in Table 1.

Association between moisture and constipation

Table 2 presents the association between moisture and constipation, analyzed using multivariate logistic regression models. In Model 1, where moisture was treated as a continuous variable, a significant negative association was observed between moisture and constipation (OR: 0.71, 95% CI: 0.64–0.77; $P < 0.001$). This negative

Table 1 Baseline characteristics of the study participants

Variables	Total (*n* = 14,492)	Moisture (Kg)				P-value
		Q1 (0.06 ~ 1.90)	Q2 (1.91 ~ 2.53)	Q3 (2.54 ~ 3.36)	Q4 (3.37 ~ 16.97)	
		(*n* = 3,623)	(*n* = 3,623)	(*n* = 3,623)	(*n* = 3,623)	
Weighted sample size	554,031,744	107,919,049	130,534,950	146,126,572	169,451,173	
Age, **n (%)**						< 0.001
20 ~ 39 years	4,968 (34.3)	1,107 (30.6)	1,137 (31.4)	1,256 (34.7)	1468 (40.5)	
40 ~ 59 years	4,683 (32.3)	887 (24.5)	1,088 (30)	1,268 (35)	1,440 (39.7)	
> 60 years	4,841 (33.4)	1,629 (45)	1,398 (38.6)	1,099 (30.3)	715 (19.7)	
Gender, **n (%)**						< 0.001
Male	7,117 (49.1)	1,342 (37)	1,632 (45)	1,866 (51.5)	2,277 (62.8)	
Female	7,375 (50.9)	2,281 (63)	1,991 (55)	1,757 (48.5)	1,346 (37.2)	
Education, **n (%)**						< 0.001
Less than high school	4,074 (28.1)	1,379 (38.1)	1,084 (30)	831 (22.9)	780 (21.5)	
High school or equivalent	3,476 (24.0)	889 (24.6)	847 (23.4)	900 (24.8)	840 (23.2)	
College or above	6,929 (47.9)	1,348 (37.3)	1,686 (46.6)	1,892 (52.2)	2,003 (55.3)	
Marital status, **n (%)**						< 0.001
Married	7,746 (53.5)	1,719 (47.5)	1,965 (54.3)	2,054 (56.7)	2,008 (55.5)	
Widowed	1,208 (8.3)	485 (13.4)	341 (9.4)	245 (6.8)	137 (3.8)	
Divorced	1,560 (10.8)	377 (10.4)	391 (10.8)	371 (10.2)	421 (11.6)	
Separated	470 (3.2)	131 (3.6)	126 (3.5)	113 (3.1)	100 (2.8)	
Never married	2,354 (16.3)	636 (17.6)	538 (14.9)	559 (15.4)	621 (17.2)	
Living with partner	1,146 (7.9)	274 (7.6)	261 (7.2)	279 (7.7)	332 (9.2)	
Race, **n (%)**						< 0.001
Mexican American	2,665 (18.4)	721 (19.9)	674 (18.6)	661 (18.2)	609 (16.8)	
Other Hispanic	1,213 (8.4)	392 (10.8)	333 (9.2)	253 (7)	235 (6.5)	
Non-Hispanic White	7,162 (49.4)	1,386 (38.3)	1,696 (46.8)	1,921 (53)	2,159 (59.6)	
Non-Hispanic Black	2,870 (19.8)	991 (27.4)	789 (21.8)	628 (17.3)	462 (12.8)	
Other Race	582 (4.0)	133 (3.7)	131 (3.6)	160 (4.4)	158 (4.4)	
PIR, **n (%)**						< 0.001
< 1.30	3,955 (27.3)	1,182 (32.6)	967 (26.7)	925 (25.5)	881 (24.3)	
1.30–3.49	5,176 (35.7)	1,408 (38.9)	1,315 (36.3)	1,246 (34.4)	1,207 (33.3)	
≥ 3.50	4,305 (29.7)	729 (20.1)	1,056 (29.1)	1,197 (33)	1,323 (36.5)	
BMI, **n (%)**						< 0.001
< 18.5 kg/m^2	215 (1.5)	79 (2.2)	55 (1.5)	38 (1)	43 (1.2)	
18.5–24.9 kg/m^2	3,886 (26.8)	1,057 (29.2)	973 (26.9)	940 (25.9)	916 (25.3)	
25–29.9 kg/m^2	4,941 (34.1)	1,215 (33.5)	1,228 (33.9)	1,251 (34.5)	1,247 (34.4)	
≥ 30 kg/m^2	5,318 (36.7)	1,223 (33.8)	1,329 (36.7)	1,376 (38)	1,390 (38.4)	
Daily alcohol intake						< 0.001
< 10 g/d	11,417 (78.8)	3,266 (90.1)	2,977 (82.2)	2,812 (77.6)	2,362 (65.2)	
10 ~ 30 g/d	1,622 (11.2)	261 (7.2)	422 (11.6)	459 (12.7)	480 (13.2)	
≥ 30 g/d	1,453 (10.0)	96 (2.6)	224 (6.2)	352 (9.7)	781 (21.6)	
Smoking, **n (%)**						< 0.001
Never	7,610 (52.5)	2,115 (58.4)	1,970 (54.4)	1,871 (51.6)	1,654 (45.7)	
Former	3,693 (25.5)	864 (23.8)	948 (26.2)	972 (26.8)	909 (25.1)	
Now	3,186 (22.0)	643 (17.7)	704 (19.4)	780 (21.5)	1,059 (29.2)	
Hypertension						< 0.001
Yes	6,016 (42.2)	1,712 (48)	1,571 (44.1)	1,412 (39.5)	1,321 (37.1)	
No	8,252 (57.8)	1,854 (52)	1,989 (55.9)	2,165 (60.5)	2,244 (62.9)	
Diabetes, **n (%)**						< 0.001
Yes	1,680 (11.6)	491 (13.6)	446 (12.3)	402 (11.1)	341 (9.4)	
No	12,535 (86.5)	3,057 (84.4)	3,098 (85.5)	3,162 (87.3)	3,218 (88.8)	
Depression, **n (%)**						0.006
Yes	1,307 (9.0)	378 (10.4)	316 (8.7)	299 (8.3)	314 (8.7)	
No	13,185 (91.0)	3,245 (89.6)	3,307 (91.3)	3,324 (91.7)	3,309 (91.3)	

Table 1 (continued)

Variables	Total (*n* = 14,492)	Moisture (Kg)				P-value
		Q1 (0.06 ~ 1.90) (*n* = 3,623)	Q2 (1.91 ~ 2.53) (*n* = 3,623)	Q3 (2.54 ~ 3.36) (*n* = 3,623)	Q4 (3.37 ~ 16.97) (*n* = 3,623)	
Physical activity, n (%)						< 0.001
Insufficient activity	1604 (11.1)	364 (10)	392 (10.8)	416 (11.5)	432 (11.9)	
Recommended activity	2238 (15.4)	440 (12.1)	504 (13.9)	569 (15.7)	725 (20)	
Constipation, n (%)						< 0.001
Yes	1,514 (10.4)	547 (15.1)	406 (11.2)	301 (8.3)	260 (7.2)	
No	12,978 (89.6)	3,076 (84.9)	3,217 (88.8)	3,322 (91.7)	3,363 (92.8)	
Daily energy intake (kcal), **Mean ± SD**	2049.0 ± 870.3	1531.4 ± 553.6	1914.9 ± 632.3	2162.7 ± 748.3	2587.0 ± 1084.3	< 0.001

Q1 (0.06 ~ 1.90): Represents the lowest 25% of participants in terms of moisture content, specifically ranging from 0.06 to 1.90 kg

Q2 (1.91 ~ 2.53): Represents participants whose moisture content falls between the 25th and 50th percentiles, specifically ranging from 1.91 to 2.53 kg

Q3 (2.54 ~ 3.36): Represents participants whose moisture content is between the 50th and 75th percentiles, specifically ranging from 2.54 to 3.36 kg

Q4 (3.37 ~ 16.97): Represents the highest 25% of participants in terms of moisture content, with values ranging from 3.37 to 16.97 kg

Abbreviations: BMI: body mass index; IQR: interquartile range; PIR: poverty-to-income ratio

Table 2 The associations between moisture and constipation

	Model 1		Model 2		Model 3	
	OR (95%CI)	*P*-value	OR (95%CI)	*P*-value	OR (95%CI)	*P*-value
Continuous	0.71(0.64, 0.77)	< 0.001	0.80(0.74, 0.87)	< 0.001	0.81(0.74, 0.89)	< 0.001
Quartile						
Q1	Reference		Reference		Reference	
Q2	0.67(0.54, 0.82)	< 0.001	0.80(0.64, 1.01)	0.06	0.80(0.64, 1.01)	0.064
Q3	0.43(0.35, 0. 53)	< 0.001	0.58(0.47, 0.71)	< 0.001	0.57(0.45, 0.72)	< 0.001
Q4	0.35(0.29, 0.43)	< 0.001	0.51(0.42, 0.62)	< 0.001	0.54(0.44, 0.67)	< 0.001
P for trend		< 0.001		< 0.001		< 0.001

Model 1: No covariates adjusted

Model 2: Adjusted for age, gender, education, marital status, race, poverty income ratio (PIR), and body mass index (BMI)

Model 3: Adjusted for age, gender, education, marital status, race, PIR, BMI, daily alcohol intake, smoking, hypertension, diabetes, depression, physical activity, and daily energy intake

Abbreviations: OR: odds ratio. CI: confidence interval

association remained significant in Model 2 (OR: 0.80, 95% CI: 0.74–0.87) and Model 3 (OR: 0.81, 95% CI: 0.74–0.89). As moisture levels increased, the negative association with constipation became more pronounced, especially in Model 3, where the OR for the Q4 of moisture, compared to the Q1, was significantly lower (OR: 0.54, 95% CI: 0.44–0.67). After accounting for all potential confounders, RCS analysis indicated a significant negative correlation between increased moisture levels and the risk of constipation, with this relationship exhibiting non-linear characteristics (P for non-linearity = 0.003, P for overall < 0.001), as shown in Fig. 2.

Subgroup analyses

Stratified and interaction analyses were conducted for factors such as age, gender, educational level, marital status, race, PIR, BMI, daily alcohol intake, smoking, hypertension, diabetes, depression, and physical activity. According to the results of the subgroup analysis, younger age (20–39 years), male, higher education level (High school or equivalent, College or above), married, Non-Hispanic White, higher socioeconomic status (PIR ≥ 3.50), BMI of 25–29.9 kg/m², daily alcohol intake < 10 g/d, never smokers, and without diabetes, hypertension, or depression show a lower risk of constipation. Notably, in the presence of depressive symptoms, the *P* value for the interaction was less than 0.05 (P for interaction = 0.014), suggesting that depressive symptoms may modulate the association between moisture and constipation. For detailed results, see Fig. 3.

Discussion

This study utilized the NHANES database from 2005 to 2010 to conduct a systematic analysis of the relationship between dietary moisture intake and constipation in adults aged 20 and over. We used a weighted logistic regression model for the analysis. The results revealed a negative association between moisture intake and the risk of constipation, with an OR of 0.81 (95% CI: 0.74–0.89). This indicates that higher moisture intake correlates with a lower risk of constipation. Quartile analysis further supported this finding. Compared to the Q1, the risk of constipation significantly decreased in the Q2, Q3, and Q4 quartiles. This suggests a significant downward

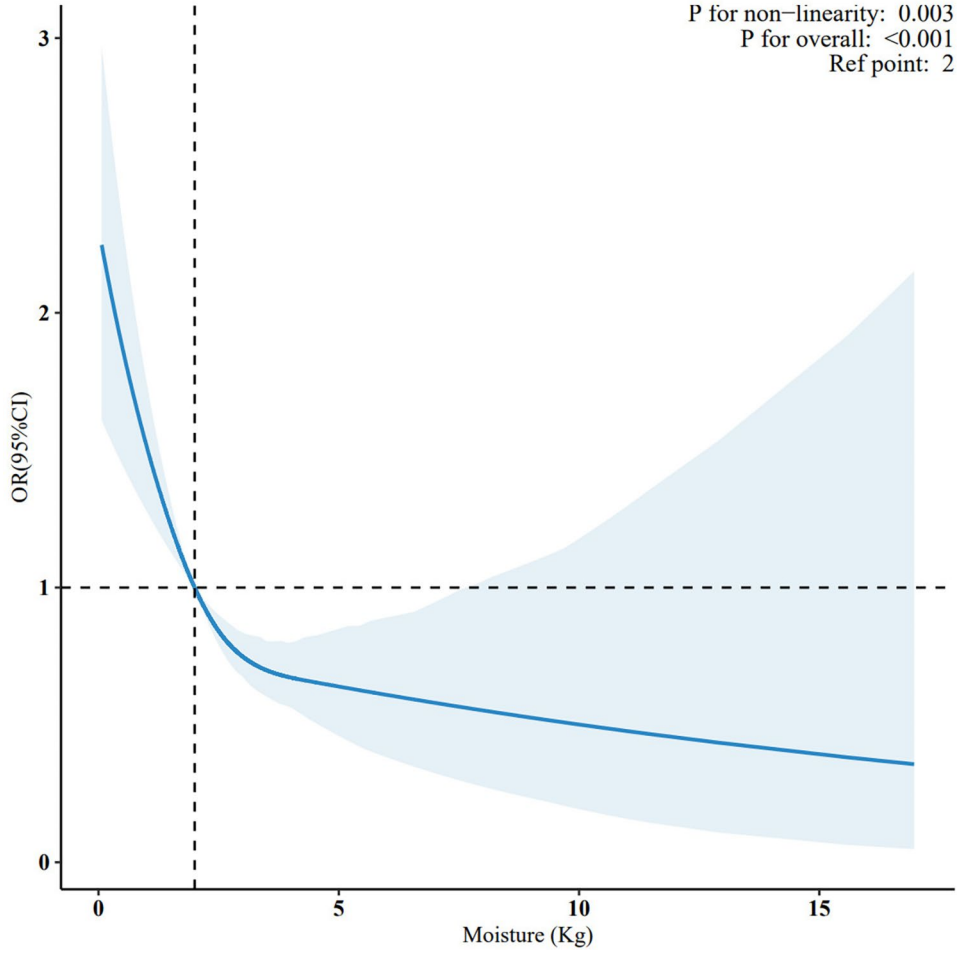

Fig. 2 Restricted cubic spline analysis (RCS) showing the multivariate-adjusted associations between dietary moisture intake and the prevalence of constipation. Statistical significance was observed (P for non-linearity = 0.025, P for overall association < 0.001). The model was adjusted for age, gender, education, marital status, race, poverty-to-income ratio (PIR), body mass index (BMI), alcohol use, smoking, diabetes, depression, physical activity, and daily energy intake

trend in constipation risk with increasing moisture intake. Additionally, RCS analysis revealed a significant non-linear negative correlation between moisture intake and constipation prevalence ($p < 0.001$), indicating a more complex non-linear pattern between the reduction in constipation risk and moisture intake. These findings collectively suggest that appropriately increasing dietary moisture intake can help reduce the risk of constipation. We also found a noteworthy interaction between depressive states and the relationship between moisture intake and constipation risk. Individuals with depression often report a higher incidence of constipation, possibly due to lifestyle changes and medication use in depressive conditions [16–18]. Future research should further explore how depressive states affect the relationship between moisture intake and constipation to develop more personalized prevention and treatment strategies.

Our research results are consistent with several previous studies that have also highlighted the importance of moisture intake for intestinal health. For example, Boilesen et al. conducted a systematic review on the role of moisture intake in the prevention and treatment of functional intestinal constipation in children and adolescents. They included 11 studies evaluating children and adolescents and found an association between low moisture intake and intestinal constipation, with three studies explicitly showing this association [19]. Another study supporting our findings is by Murakami et al., which examined the relationship between dietary fiber, water, and magnesium intake and functional constipation in young Japanese women. Their results indicated that low food moisture intake significantly increased the incidence of constipation [20]. Specifically, women with low moisture intake had a significantly higher incidence of constipation. Additionally, a study by Anti et al. also supports the importance of moisture intake in alleviating constipation. They conducted a randomized controlled trial involving 117 adults with chronic functional

Subgroup	Participants/Constipation cases	OR (95%CI)	P value	P for interaction
Age				0.549
20~39 years	4,968/626	0.79(0.70, 0.89)	<0.001	
40~59 years	4,683/456	0.85(0.73, 1.00)	0.050	
⩾60 years	4,841/432	0.85(0.72, 1.00)	0.050	
Gender				0.136
Male	7,117/439	0.75(0.63, 0.88)	0.001	
Female	7,375/1,075	0.86(0.78, 0.95)	0.010	
Education				0.679
Less than high school	4,074/495	0.83(0.71, 0.98)	0.030	
High school or equivalent	3,476/416	0.78(0.65, 0.93)	0.010	
College or above	6,929/600	0.84(0.73, 0.96)	0.010	
Marital status				0.422
Married	7,746/717	0.76(0.66, 0.87)	<0.001	
Widowed	1,208/138	0.87(0.64, 1.18)	0.350	
Divorced	1,560/175	0.77(0.61, 0.98)	0.040	
Separated	470/51	0.85(0.62, 1.15)	0.270	
Never married	2,354/292	0.90(0.74, 1.10)	0.300	
Living with partner	1,146/141	0.93(0.71, 1.22)	0.590	
Race				0.548
Mexican American	2,665/260	0.86(0.71, 1.03)	0.100	
Other Hispanic	1,213/151	0.84(0.69, 1.03)	0.090	
Non−Hispanic White	7,162/661	0.82(0.73, 0.92)	0.002	
Non−Hispanic Black	2,870/388	0.84(0.71, 1.00)	0.050	
Other Race	582/54	0.71(0.42, 1.21)	0.200	
PIR				0.162
<1.30	3,955/532	0.80(0.69, 0.92)	0.003	
1.30~3.49	5,176/542	0.91(0.79, 1.05)	0.170	
⩾3.50	4,305/320	0.74(0.63, 0.88)	0.001	
BMI				0.640
<18.5 kg/m^2	215/30	0.70(0.36, 1.38)	0.240	
18.5~24.9 kg/m^2	3,886/493	0.82(0.71, 0.94)	0.010	
25~29.9 kg/m^2	4,941/488	0.76(0.68, 0.85)	<0.001	
⩾30 kg/m^2	5,318/486	0.88(0.75, 1.03)	0.110	
Daily alcohol intake				0.717
<10 g/d	11,417/1,325	0.83(0.75, 0.92)	<0.001	
10~30 g/d	1,622/104	0.69(0.50, 0.94)	0.020	
⩾30 g/d	1,453/85	0.77(0.64, 0.94)	0.010	
Smoking				0.261
Never	7,610/878	0.77(0.68, 0.88)	<0.001	
Former	3,693/310	0.79(0.67, 0.92)	0.005	
Now	3,186/326	0.92(0.77, 1.09)	0.320	
Diabetes				0.960
Yes	1,680/170	0.87(0.65, 1.17)	0.330	
No	12,535/1,326	0.82(0.74, 0.90)	<0.001	
Hypertension				0.711
Yes	6,016/555	0.84(0.74, 0.95)	0.010	
No	8,252/922	0.81(0.71, 0.92)	0.002	
Depression				0.014
Yes	1,307/232	1.00(0.82, 1.21)	0.990	
No	13,185/1,282	0.78(0.72, 0.86)	<0.001	
Physical activity				0.777
Recommended activity	2,238/210	0.87(0.65, 1.16)	0.220	
Insufficient activity	1,604/156	0.75(0.44, 1.30)	0.200	

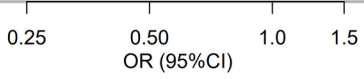

Fig. 3 Subgroup analysis of the association between dietary moisture intake and constipation risk. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for each subgroup using a multivariate logistic regression model. The model adjusted for covariates, including age, gender, education, marital status, race, poverty-to-income ratio (PIR), body mass index (BMI), alcohol consumption, smoking status, diabetes, depression, physical activity, and daily energy intake

constipation and found that a high-fiber diet combined with the daily intake of 2 L of mineral water significantly increased bowel movement frequency and reduced the use of laxatives [21]. Shen et al. conducted a similar study using NHANES data from 2005 to 2010, focusing on the relationship between dietary fiber, water consumption, and constipation. They found that lower dietary fiber intake, but not total water consumption, was significantly associated with an increased risk of constipation [8]. In comparison, the present study has several significant advantages. First, we used a large representative sample from the 2005–2010 NHANES, which enhances the external validity of our results. Second, we employed advanced statistical methods, including weighted logistic regression models and RCS, to comprehensively explore the relationship between moisture intake and constipation. These methods not only considered linear relationships but also investigated potential non-linear patterns. Furthermore, we rigorously controlled for various potential confounders, such as dietary habits, physical activity levels, and health conditions, ensuring the reliability and accuracy of our results. These methodological strengths make our findings more compelling and valuable for reference in similar studies.

From a mechanistic perspective, the impact of adequate moisture intake on intestinal health may involve several aspects. First, insufficient moisture intake can lead to dry and hardened stools, increasing the difficulty of bowel passage and causing constipation. When the body lacks sufficient moisture, the colon absorbs water from the stool to maintain the body's water balance, resulting in drier and harder stools that are difficult to pass. This phenomenon is due to the body's water retention mechanism, which reduces water excretion to maintain internal water balance when moisture intake is inadequate, thereby affecting stool texture and ease of defecation [6, 22, 23]. Second, moisture intake helps soften stools and promotes intestinal peristalsis, reducing the retention time of stools in the intestines [24, 25]. Adequate moisture helps maintain stool moisture, making it easier to pass through the intestines. Increasing moisture intake can promote the movement of intestinal contents and reduce the incidence of constipation [26–28]. Additionally, moisture can indirectly improve intestinal health by regulating gut microbiota balance and enhancing the intestinal mucosal barrier function. Adequate moisture intake helps maintain the stability of the intestinal environment, promotes the growth of beneficial bacteria, and inhibits the proliferation of harmful bacteria. This microbial balance is crucial for maintaining normal digestive function and preventing constipation [22, 29]. Studies have also shown that insufficient moisture intake can affect the electrolyte balance and fluid transport mechanisms in the intestines, further exacerbating constipation symptoms. The balance of fluids and electrolytes in the intestines is essential for maintaining normal intestinal peristalsis and digestive function. By appropriately increasing moisture intake, the electrolyte balance in the intestines can be maintained, promoting intestinal peristalsis and thereby improving constipation [6, 30–32]. Future research should further explore these mechanisms using prospective designs to verify the causal relationship between dietary moisture intake and constipation progression, providing a more solid scientific basis for the prevention and management of constipation. These studies will help formulate more effective dietary recommendations, aiding people in improving intestinal health and preventing and alleviating constipation through adequate moisture intake.

Despite providing important insights into the relationship between dietary moisture intake and constipation risk based on the large-scale NHANES database, this study has several limitations that need to be considered. First, this study is cross-sectional and cannot establish causality. Although we found a significant association between moisture intake and constipation risk, we cannot determine whether increasing moisture intake directly leads to a reduced risk of constipation. Future studies should employ prospective designs to verify the causal relationship. Secondly, this study relies on self-reported data from participants, which may be subject to reporting bias. For instance, participants may not accurately recall or report their actual moisture intake and constipation status, affecting the accuracy of the results. Additionally, the dataset contains extreme values, such as very low or very high moisture intake (e.g., 0.06 kg and 16.97 kg), which may reflect abnormal dietary habits or reporting errors. Additionally, this study provides preliminary evidence on the relationship between total moisture intake and constipation, but the lack of distinction between moisture sources is a key limitation. Water from beverages and food may have different effects, potentially influenced by cultural and dietary variations. For example, drinking water may directly impact stool water content, while food moisture could interact with dietary fiber. Future research should classify and evaluate the contributions of different moisture sources to better understand their role in gut health. Although we adjusted for various potential confounders in our analysis, such as dietary habits and physical activity levels, there may still be other uncontrolled confounders, such as gut microbiota and medication use, that could also influence the risk of constipation. Lastly, the sample in this study is primarily from the United States, which may limit the external validity of the results. Dietary habits and lifestyles can vary across different countries and regions, so the applicability of the findings to other populations needs further validation. Future research should be conducted in

different geographical and cultural contexts to confirm whether our findings have universal applicability.

Conclusion

This study systematically analyzed the relationship between dietary moisture intake and constipation in adults. The results showed a significant negative correlation between moisture intake and the risk of constipation, indicating that increasing moisture intake helps reduce the risk of constipation. Additionally, depressive states may interact with the relationship between moisture intake and constipation risk, which should be considered in the prevention and management of constipation. Although this study provides important evidence, the limitations of its cross-sectional design, reliance on self-reported data, and lack of detailed differentiation of moisture sources caution us to interpret the results carefully. Future research should employ prospective designs and be conducted in different geographical and cultural contexts to validate and extend these findings. Overall, this study highlights the importance of adequate moisture intake in the prevention and management of constipation and provides a scientific basis for public health interventions.

Acknowledgements
None.

Author contributions
Deng-Chao Wang: Oversaw the entire project, ensuring the study adhered to the highest standards. Involved in the study design, data interpretation, and critical revisions of the manuscript. Provided final approval of the version to be published and agrees to be accountable for all aspects of the work. Xue-Feng Peng: Contributed to the conception and design of the study, drafted the manuscript, revised it critically for important intellectual content, and participated in the statistical analysis and interpretation of data. Wen-Xing Chen: Assisted in the design of the study, was involved in the acquisition and analysis of data, and contributed to the drafting and critical revision of the manuscript. Miao Yu: Participated in data collection and management, ensuring the accuracy and integrity of the data, assisted in preliminary data analysis, and contributed to the writing of the methodology section.

Funding
No funding was received for this study.

Data availability
This research utilized datasets that are publicly accessible. The raw data for this analysis was sourced exclusively from the NHANES public data portal (https://wwwn.cdc.gov/nchs/nhanes/analyticguidelines.aspx).

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the principles of the Helsinki Declaration and reviewed by the Institutional Review Board of the CDC's National Center for Health Statistics. All participants provided written informed consent. As the analysis utilized secondary data, no further ethical approval was required.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of General Surgery, Zigong Fourth People's Hospital, 19 Tanmulin Road, Zigong 643000, Sichuan, China
[2]Department of Basic Medicine, Sichuan Vocational College of Health and Rehabilitation, Zigong 643000, Sichuan, China

Received: 14 July 2024 / Accepted: 6 January 2025
Published online: 31 January 2025

References

1. Barberio B, Judge C, Savarino EV, Ford AC. Global prevalence of functional constipation according to the Rome criteria: a systematic review and meta-analysis. Lancet Gastroenterol Hepatol. 2021;6(8):638–48.
2. Schmidt FM, Santos VL. Prevalence of constipation in the general adult population: an integrative review. J Wound Ostomy Cont Nurs. 2014;41(1):70–. – 6; quiz E1-2.
3. Włodarczyk J, Waśniewska A, Fichna J, Dziki A, Dziki Ł, Włodarczyk M. Current overview on Clinical Management of Chronic Constipation. J Clin Med. 2021;10(8):1738.
4. Talley NJ, Lasch KL, Baum CL. A gap in our understanding: chronic constipation and its comorbid conditions. Clin Gastroenterol Hepatol. 2009;7(1):9–19.
5. Oh SJ, Fuller G, Patel D, Khalil C, Spalding W, Nag A, Spiegel BMR, Almario CV. Chronic constipation in the United States: results from a Population-based survey assessing Healthcare seeking and use of Pharmacotherapy. Am J Gastroenterol. 2020;115(6):895–905.
6. Liska D, Mah E, Brisbois T, Barrios PL, Baker LB, Spriet LL. Narrative Review of Hydration and Selected Health Outcomes in the General Population. Nutrients. 2019;11(1):70.
7. Popkin BM, D'Anci KE, Rosenberg IH. Water, hydration, and health. Nutr Rev. 2010;68(8):439–58.
8. Shen L, Huang C, Lu X, et al. Lower dietary fibre intake, but not total water consumption, is associated with constipation: a population-based analysis. J Hum Nutr Diet. 2019;32(4):422–31.
9. NCfH S, Nchs Ethics Review Board (Erb). (2022) Approval. Available online at: https://doi.org/wwwcdcgov/nchs/nhanes/irba98htm
10. Zhao X, Wang L, Quan L. Association between dietary phosphorus intake and chronic constipation in adults: evidence from the National Health and Nutrition Examination Survey. BMC Gastroenterol. 2023;23(1):24.
11. Liu Q, Kang Y, Yan J. Association between overall dietary quality and constipation in American adults: a cross-sectional study. BMC Public Health. 2022;22(1):1971.
12. Liao ZY, Xiao MH, She Q, Xiong BQ. Association between the composite dietary antioxidant index and metabolic syndrome: evidence from NHANES 2003–2018. Eur Rev Med Pharmacol Sci. 2024;28(4):1513–23.
13. Zhang Y, Pu J. The Saturation Effect of Obesity on Bone Mineral Density for Older People: The NHZhang Y, Pu J. The Saturation Effect of Obesity on Bone Mineral Density for Older People: The NHANES 2017–2020. Front Endocrinol (Lausanne). 2022;13:883862.
14. Bazal P, Gea A, Martínez-González MA, et al. Mediterranean alcohol-drinking pattern, low to moderate alcohol intake and risk of atrial fibrillation in the PREDIMED study. Nutr Metab Cardiovasc Dis. 2019;29(7):676–83.
15. Veldheer S, Yingst J, Zhu J, Foulds J. Ten-year weight gain in smokers who quit, smokers who continued smoking and never smokers in the United States, NHANES 2003–2012. Int J Obes (Lond). 2015;39(12):1727–32.
16. Zhu Y, Wang Z. Association between joint physical activity and healthy dietary patterns and hypertension in US adults: cross-sectional NHANES study. BMC Public Health. 2024;24(1):855.
17. Albiani JJ, Hart SL, Katz L, Berian J, Del Rosario A, Lee J, Varma M. Impact of depression and anxiety on the quality of life of constipated patients. J Clin Psychol Med Settings. 2013;20(1):123–32.
18. Norton C. Constipation in older patients: effects on quality of life. Br J Nurs. 2006;15(4):188–92.
19. Boilesen SN, Tahan S, Dias FC, Melli LCFL, de Morais MB. Water and fluid intake in the prevention and treatment of functional constipation in children and adolescents: is there evidence? J Pediatr (Rio J). 2017;93(4):320–7.
20. Murakami K, Sasaki S, Okubo H, Takahashi Y, Hosoi Y, Itabashi M. Freshmen in Dietetic Courses Study II Group. Association between dietary fiber, water

and magnesium intake and functional constipation among young Japanese women. Eur J Clin Nutr. 2007;61(5):616–22.
21. Anti M, Pignataro G, Armuzzi A, Valenti A, Iascone E, Marmo R, Lamazza A, Pretaroli AR, Pace V, Leo P, Castelli A, Gasbarrini G. Water supplementation enhances the effect of high-fiber diet on stool frequency and laxative consumption in adult patients with functional constipation. Hepatogastroenterology. 1998;45(21):727–32.
22. Sato K, Hara-Chikuma M, Yasui M, Inoue J, Kim YG. Sufficient water intake maintains the gut microbiota and immune homeostasis and promotes pathogen elimination. iScience. 2024;27(6):109903.
23. Yurtdaş G, Acar-Tek N, Akbulut G, Cemali Ö, Arslan N, Beyaz Coşkun A, Zengin FH. Risk factors for constipation in adults: a cross-sectional study. J Am Coll Nutr. 2020;39(8):713–9.
24. Ma X, Lu Q, Lu Y, Li X. Risk and main contributing factors for constipation in patients with gastrointestinal cancer: a multicenter cross-sectional study in China. Support Care Cancer. 2022;30(10):8119–27.
25. McRorie JW, Daggy BP, Morel JG, Diersing PS, Miner PB, Robinson M. Psyllium is superior to docusate sodium for treatment of chronic constipation. Aliment Pharmacol Ther. 1998;12(5):491–7.
26. Infante DD, Segarra OO, Redecillas SS, Alvarez MM, Miserachs MM. Modification of stool's water content in constipated infants: management with an adapted infant formula. Nutr J. 2011;10:55.
27. Bellini M, Tonarelli S, Barracca F, Rettura F, Pancetti A, Ceccarelli L, Ricchiuti A, Costa F, de Bortoli N, Marchi S, Rossi A. Chronic Constipation: Is a Nutritional Approach Reasonable? Nutrients. 2021;13(10):3386.
28. Hsieh C. Treatment of constipation in older adults. Am Fam Physician. 2005;72(11):2277–84.
29. Zhao Q, Chen YY, Xu DQ, Yue SJ, Fu RJ, Yang J, Xing LM, Tang YP. Action Mode of Gut Motility, Fluid and Electrolyte Transport in Chronic Constipation. Front Pharmacol. 2021;12:630249.
30. Fruhwald S, Holzer P, Metzler H. Intestinal motility disturbances in intensive care patients pathogenesis and clinical impact. Intensive Care Med. 2007;33(1):36–44.
31. Penfold JA, Wells CI, Du P, Qian A, Vather R, Bissett IP, O'Grady G. Relationships between serum electrolyte concentrations and ileus: a joint clinical and mathematical modeling study. Physiol Rep. 2021;9(3):e14735.
32. Camilleri M. Gastrointestinal motility disorders in neurologic disease. J Clin Invest. 2021;131(4):e143771.

Publisher's note