BMC Gastroenterology

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Association between atherogenic index of plasma and chronic diarrhea: a cross-sectional study of the NHANES 2005–2010

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Abstract

Background Chronic diarrhea (CD), a common chronic condition resulting from various mechanisms, has chronic inflammation as a primary determinant. Despite recent research exploring the potential mechanisms linking lipids and diarrhea, clinical studies on the relationship between lipids and the onset of CD are limited. This study aimed to investigate the association between the atherogenic index of plasma (AIP) and CD risk.

Methods This cross-sectional study used data from the 2005–2010 NHANES. The association between AIP and CD was examined through multiple linear regression analyses. A smooth curve-fitting algorithm was applied to assess the potential non-linear dose–response relationship between AIP and CD, and subgroup analyses were conducted.

Results Among 5,948 participants, 440 (7.4%) had CD. After adjusting for potential confounders, AIP was significantly associated with CD (OR, 1.57; 95% CI, 1.08–2.30; $P=0.018$). The highest AIP quartile (Q4; 0.18 to 0.92) showed an adjusted OR for CD of 1.51 (95% CI, 1.10–2.07; $P=0.011$) versus the lowest quartile (Q1; -1.15 to -0.25). Subgroup analyses indicated that diabetic individuals with higher AIP had a higher CD risk (OR, 3.84; 95% CI, 1.45–10.15), with an observed additive interaction (P for interaction = 0.045).

Conclusions This study demonstrates a significant association between AIP and CD risk. AIP may serve as a promising indicator for assessing CD risk, offering valuable insights for prevention and treatment strategies.

Keywords Atherogenic index of plasma, Lipid, Chronic diarrhea, NHANES

Introduction

Chronic diarrhea (CD), which is defined as the recurrent passage of loose stools accompanied by abdominal discomfort, poses a prevalent yet clinically challenging gastrointestinal disorder [1]. Currently, epidemiological trends reveal a rising incidence of CD in the United States, affecting approximately 6% of the general population [2]. A higher prevalence is particularly observed in older adults, women, and individuals with diabetes mellitus. The multifactorial etiology of CD includes age, gender, lifestyle, comorbidities, and dietary patterns, with chronic inflammation emerging as a central pathophysiological driver [3–5]. Notably, recent evidence suggests that dysregulated lipid metabolism may contribute to CD pathogenesis. For instance, high-fat diets (HFDs) can disrupt gut microbiota homeostasis and hinder lipid processing, thus aggravating intestinal inflammation and diarrheal symptoms [6, 7]. Moreover, CD not only imposes significant economic costs on healthcare systems, but also greatly diminishes quality of life by impairing social functioning, daily productivity, and cognitive

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performance [8, 9]. Therefore, accurate diagnosis and effective management of CD are of vital importance for improving patient outcomes and reducing healthcare costs [10].

The atherogenic index of plasma (AIP), which is the logarithm of the ratio between triglycerides and high-density lipoprotein cholesterol (TG/HDL-C), is recognized as a composite biomarker of dyslipidemia and metabolic dysfunction [11]. It was originally proposed by Dobiasova and Frohlich for assessing cardiovascular risk. AIP shows some associations with coronary artery disease, type 2 diabetes mellitus, metabolic syndrome, and non-alcoholic fatty liver disease (NAFLD) [12–15]. Importantly, AIP reflects systemic lipid imbalance and insulin resistance, which are pathological states closely intertwined with chronic inflammation and gut barrier dysfunction [14, 16]. From the perspective of intestinal physiological mechanism, short-chain fatty acids (SCFAs) derived from intestinal microorganisms can regulate liver lipid synthesis and HDL-C metabolism [17–19]. When intestinal permeability is impaired, endotoxin translocation triggers a cascade of pro-inflammatory cytokines (e.g., TNF-α, IL-6), inhibits lipoprotein lipase activity and impairs triglyceride clearance and changes in HDL-C function [20–22]. Collectively, these interrelated pathways imply that AIP may serve as a surrogate marker linking lipid dysregulation to CD progression.

At present, our understanding of the relationship between lipids and diarrhea mainly stems from animal models, with few studies investigating this correlation in clinical practice. AIP is a valuable tool for assessing the pathogenicity and specificity of dyslipidemia. It comprehensively represents dyslipidemia by combining the levels of triglycerides and high-density lipoprotein cholesterol (HDL-C) [12]. Furthermore, it can clarify the complex dynamics of lipid metabolism and identify potential health issues related to insulin resistance and chronic inflammation, which is likely to be associated with CD [14].

To address this research gap, we conducted a cross-sectional analysis based on the 2005–2010 National Health and Nutrition Examination Survey (NHANES) to explore the association between AIP and CD in a nationally representative sample of U.S. adults.

Methods

Study population

The National Health and Nutrition Examination Survey (NHANES), conducted by the National Center for Disease Control and Prevention, is a cross-sectional survey representative of the national population. It aims to collect data on various aspects related to the non-institutionalized U.S. population, including demographics, diet, examination results, laboratory findings and questionnaires, with some restricted information also accessible. All NHANES participants provided written informed consent, and the survey was approved by the Ethics Review Board of the National Center for Health Statistics. The data used in this study were publicly available on the NHANES website (https://www.cdc.gov/nchs/nhanes). Our study followed the guidelines in the Epidemiologic Statement to enhance the rigor and reporting of observational studies [23].

The data analyzed were derived from NHANES participants surveyed between 2005 and 2010. Due to the eligibility criteria of the Bowel Health Questionnaire, which targets adults aged 20 and older, our analysis was restricted to this age group.

AIP

After an overnight fast, morning blood collection was performed to obtain samples for measuring high-density lipoprotein (HDL) and triglycerides. The atherogenic index of plasma (AIP) was calculated using the formula: AIP = Log10 (triglycerides/high-density lipoprotein cholesterol), with TG and HDL-C measurements expressed in mmol/L.

Definition of chronic diarrhea

The Bowel Health Questionnaire, as employed by the 2005–2010 NHANES, was used to screen participants for symptoms indicative of bowel health concerns. Participants were instructed to: "Please look at this card and tell me the number that corresponds to your usual or most common stool type." Participants were simultaneously shown a card depicting the seven types of the Bristol Stool Form Scale (BSFS; Type 1–Type 7), each accompanied by a colored image and description. Participants who identified their typical stool as either BSFS Type 6 (fluffy pieces with ragged edges, a mushy stool) or BSFS Type 7 (watery, no solid pieces) were diagnosed with CD.

Covariates

Based on existing literature and clinical relevance, the following covariates were selected: demographic and socioeconomic factors (age, sex, race, education, and family income-to-poverty ratio), anthropometric and lifestyle factors (body mass index, physical activity, milk habits, fat intake, and caffeine intake), behavioral factors (smoking status and alcohol use), disease conditions (diabetes, hypertension, depression, and sleep disorders), total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) [24–26].

Dietary intake information was obtained through two 24-h dietary recalls, with trained staff recording all foods and beverages consumed by participants the day before

the interview. Dietary energy intake was calculated as the average of the two days' energy intake.

Self-reported physical activity at work or during recreational activities was classified into mild, moderate, and severe categories. Smoking status was categorized as never smoker (less than 100 cigarettes in lifetime), former smoker (more than 100 cigarettes in lifetime, current non-smoker), and current smoker (more than 100 cigarettes in lifetime, current smoker) [27]. Alcohol use was defined as consuming at least 12 alcoholic drinks per year [28]. Diabetes mellitus was identified through self-reported physician-diagnosed diabetes, use of oral hypoglycemic agents or insulin, or a hemoglobin A1c level of ≥ 6.5% [29]. Hypertension was defined as systolic/diastolic blood pressure of ≥ 140/90 mmHg or use of antihypertensive medications. Depression was determined based on a score of ≥ 10 on the nine-item Patient Health Questionnaire (PHQ-9). Sleep disorders were identified through self-reported physician-diagnosed sleep disorders.

Statistical analysis

In accordance with the NHANES analytical guidelines, descriptive statistics are presented in a standardized manner. Continuous variables are presented as mean ± standard error (SE) or median (interquartile range) [Q2 (Q1, Q3)], whereas categorical variables are displayed as frequency (percentage). Continuous variables were compared using the t-test, while categorical data were analyzed using the χ^2 test. AIP was considered both as a continuous variable and as a categorical variable, divided into quartiles. The odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each unit increase in AIP and for each quartile (with the lowest quartile as the reference) using univariate and multivariate logistic regression models.

We used logistic regression analysis to investigate the association between AIP and CD and developed four different models. Model 1 is an unadjusted covariate model. Model 2 was adjusted for age, gender, race and ethnicity, educational level, and family income. Model 3, the main model, additionally adjusted for body mass index (BMI), physical activity, milk habits, fat intake, caffeine intake, smoking status, alcohol use, diabetes, hypertension, depression, sleep disorders, total cholesterol and low-density lipoprotein cholesterol. Model 4, a sensitivity analysis model based on Model 3, excluded participants taking lipid-lowering drugs (e.g., statins, fibrates, and ezetimibe), antidiarrheal drugs (e.g., montmorillonite and adsorbents), and antibiotics (e.g., metronidazole and amoxicillin). Based on the aforementioned variables, a generalized additive model (GAM) with a natural spline (4 knots) was used to assess the nonlinear relationships between AIP and CD. We conducted subgroup analyses and tested interactions using likelihood ratio tests. The analyses were performed using R software (Version 4.2.2; The R Foundation; http://www.R-project.org) and the Free Statistics analysis platform (Version 2.0; http://www.clinicalscientists.cn/freestatistics). A two-sided P-value of less than 0.05 was considered statistically significant.

By employing the NHANES database, our study ensured adequate statistical power to detect associations in the data, benefiting from its substantial sample size. The sample size was determined based on the available data, in accordance with common practice, without prior statistical power calculation. To ensure sufficient statistical power, we performed a post hoc power analysis using the observed effect size (Cohen's $d = 0.242$) and $\alpha = 0.05$. The analysis was conducted using G*Power v3.1.9, which confirmed a statistical power of 99.8%, thereby ensuring sufficient sensitivity to detect a meaningful effect.

Results

We included 31,034 participants from the NHANES (2005–2010) in this study at first. Of these, 21,489 were excluded due to invalid AIP data, and 2,696 were excluded due to missing CD data. Additionally, 41 participants with a history of colon or rectal cancer and 860 with missing essential covariate data (including demographics, comorbidities, and blood biochemistry indicators) were excluded. The final sample consisted of 5,948 participants. Figure 1 presents a comprehensive flow chart of the participant selection process.

Characteristic of the participants

Baseline characteristics of the study population (5,948 individuals) are presented in Table 1, stratified into four AIP groups. In the total cohort, 2,897 participants (48.7%) were male, with a mean age of 49.2 ± 17.9 years. The overall CD prevalence was 7.4%. Notably, this prevalence increased from 5.4% in the lowest AIP quartile to 10.1% in the highest quartile ($p < 0.001$). Compared with lower AIP groups, participants in the highest AIP quartile were more likely to be male, of Mexican American ethnicity, have lower education levels, be current or former smokers, and have a history of diabetes, hypertension, depression, sleep disorders, and mild physical activity. They also exhibited higher age, BMI, caffeine intake, TC, and LDL-C levels. Except for alcohol consumption and fat intake, all variables showed statistical significance across the four AIP quartiles ($p < 0.05$).

Association between AIP and CD

Table 2 presents multivariable logistic regression analysis results for the association between AIP and CD. Higher AIP scores are significantly associated with an increased

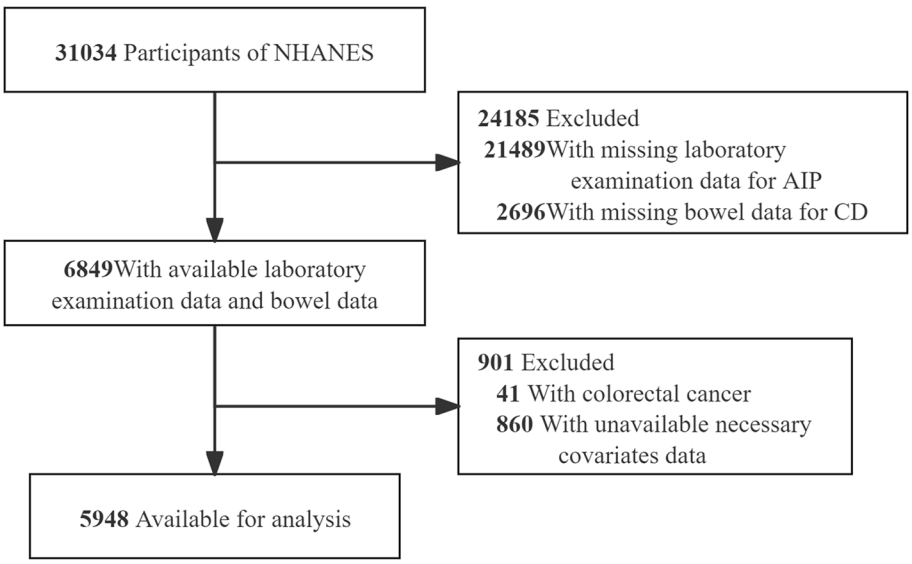

Fig. 1 Flowchart of Sample Selection from NHANES 2005–2010

CD risk. When analyzed as a continuous variable, the CD risk in the total population increases with each unit increase in AIP: by 1.26 times (OR, 2.26; 95% CI, 1.63–3.31; $P<0.001$) in the crude model, by 1.20 times (OR, 2.20; 95% CI, 1.55–3.12; $P<0.001$) in the minimally adjusted model, and by 1.57 times (OR, 1.57; 95% CI, 1.08–2.30; $P=0.018$) in the fully adjusted Model 3. After excluding participants taking lipid-lowering drugs, antidiarrheal drugs, and antibiotics ($n=4,836$), AIP remained associated with CD (OR, 1.57; 95% CI, 1.05–2.36; $P=0.030$).

When analyzed as a categorical variable, individuals in the highest AIP quartile (Q4) had a 1.51 times increased CD risk (OR, 1.51; 95% CI, 1.10–2.07; $P=0.011$) compared with those in the lowest quartile (Q1), after adjusting for confounding variables in the fully adjusted Model 3. The trend test was statistically significant ($P=0.008$).

Adjusted and smoothed plots indicated a linear relationship between AIP and CD (Fig. 2; P for non-linearity = 0.441; P for overall = 0.024). The highest and lowest 0.5% of AIP measures were trimmed. As AIP levels increase, an upward trend in the associated CD risk is evident.

Subgroup analysis

After adjusting for multiple confounders, gender, age, BMI, diabetes, hypertension, depression, and sleep disorders were used as stratification variables to examine effect size trends. Figure 3 presents a forest plot of the results. Subgroup analyses revealed a positive correlation between AIP and CD. Notably, stratified analysis by diabetes status indicated a heightened CD risk among diabetic participants, who had a greater association with AIP (OR, 3.84; 95% CI, 1.45–10.15) compared with non-diabetic participants (OR, 1.22; 95% CI, 0.81–1.86). The P-value for interaction between diabetes and AIP was 0.045, indicating a statistically significant interaction effect. Further logistic regression analysis of interaction revealed an additive interaction between diabetes and AIP (AP = 0.38, $P=0.02$), suggesting that 38% of the excess risk was due to synergism when diabetes and AIP co-existed (Table S1).

Discussion

The results of this cross-sectional analysis, which included 5,948 participants from a nationally representative US cohort, revealed a significant positive association between the atherogenic index of plasma (AIP) and chronic diarrhea (CD). After full adjustment for demographic, anthropometric, and clinical covariates, each unit increase in AIP was associated with a 57% higher risk of CD (OR = 1.57, 95% CI: 1.08—2.30), with a near-linear dose–response relationship observed across AIP quartiles. The robustness of this association was confirmed through generalized linear models and sensitivity analyses. Stratified analyses demonstrated consistent directional effects across subgroups, though the magnitude of association appeared stronger in diabetics (p for interaction = 0.08), suggesting potential disease-specific susceptibility that warrants further investigation.

The metabolic state with elevated triglycerides (TG) and reduced high-density lipoprotein cholesterol

Table 1 Characteristics of Participants in the NHANES 2005–2010 Cycles

	Participants					
	Total	Q1	Q2	Q3	Q4	
Characteristic	*N* = 5948	(−1.15 to −0.25)	(−0.25 to −0.04)	(−0.04 to 0.18)	(0.18 to 0.92)	*P* value
Gender						< 0.001
Male	2897 (48.7)	521 (35)	698 (46.9)	766 (51.5)	912 (61.3)	
Female	3051 (51.3)	966 (65)	789 (53.1)	721 (48.5)	575 (38.7)	
Age	49.2 ± 17.9	46.6 ± 17.9	49.6 ± 18.3	50.1 ± 18.2	50.3 ± 16.9	< 0.001
Race and Ethnicity						< 0.001
Mexican American	1061 (17.8)	182 (12.2)	231 (15.5)	310 (20.8)	338 (22.7)	
Non-Hispanic	466 (7.8)	104 (7)	106 (7.1)	113 (7.6)	143 (9.6)	
White	3039 (51.1)	705 (47.4)	791 (53.2)	743 (50)	800 (53.8)	
Black	1140 (19.2)	435 (29.3)	299 (20.1)	256 (17.2)	150 (10.1)	
Other	242 (4.1)	61 (4.1)	60 (4)	65 (4.4)	56 (3.8)	
Education						< 0.001
Less than high school	1598 (26.9)	303 (20.4)	379 (25.5)	406 (27.3)	510 (34.3)	
High school or higher	4350 (73.1)	1184 (79.6)	1108 (74.5)	1081 (72.7)	977 (65.7)	
Family Income						< 0.001
Low	1709 (28.7)	368 (24.7)	416 (28)	402 (27)	523 (35.2)	
Medium	2320 (39.0)	573 (38.5)	576 (38.7)	622 (41.8)	549 (36.9)	
High	1919 (32.3)	546 (36.7)	495 (33.3)	463 (31.1)	415 (27.9)	
Body Mass Index	27.9(24.3,32.3)	24.9(21.9, 28.7)	27.3(24.1,31.4)	29.1(25.5,33.2)	30.1(26.9, 34.4)	< 0.001
Smoking Status						< 0.001
Never	3132 (52.7)	920 (61.9)	786 (52.9)	755 (50.8)	671 (45.1)	
Former	1542 (25.9)	312 (21)	392 (26.4)	408 (27.4)	430 (28.9)	
Now	1274 (21.4)	255 (17.1)	309 (20.8)	324 (21.8)	386 (26)	
Alcohol Use						0.92
No	1682 (28.3)	419 (28.2)	429 (28.9)	422 (28.4)	412 (27.7)	
Yes	4266 (71.7)	1068 (71.8)	1058 (71.1)	1065 (71.6)	1075 (72.3)	
Chronic Diarrhea						< 0.001
No	5508 (92.6)	1407 (94.6)	1389 (93.4)	1375 (92.5)	1337 (89.9)	
Yes	440 (7.4)	80 (5.4)	98 (6.6)	112 (7.5)	150 (10.1)	
Diabetes						< 0.001
No	5172 (87.0)	1385 (93.1)	1336 (89.8)	1257 (84.5)	1194 (80.3)	
Yes	776 (13.0)	102 (6.9)	151 (10.2)	230 (15.5)	293 (19.7)	
Hypertension						< 0.001
No	3681 (61.9)	1063 (71.5)	921 (61.9)	877 (59)	820 (55.1)	
Yes	2267 (38.1)	424 (28.5)	566 (38.1)	610 (41)	667 (44.9)	
Depression						< 0.001
No	5478 (92.1)	1390 (93.5)	1383 (93)	1371 (92.2)	1334 (89.7)	
Yes	470 (7.9)	97 (6.5)	104 (7)	116 (7.8)	153 (10.3)	
Sleep Disorders						0.002
No	4530 (76.2)	1178 (79.2)	1126 (75.7)	1137 (76.5)	1089 (73.2)	
Yes	1418 (23.8)	309 (20.8)	361 (24.3)	350 (23.5)	398 (26.8)	
Physical Activity						0.002
Mild	4038 (67.9)	955 (64.2)	1006 (67.7)	1047 (70.4)	1030 (69.3)	
Moderate and Severe	1910 (32.1)	532 (35.8)	481 (32.3)	440 (29.6)	457 (30.7)	
Milk Habit						0.023
No	3408 (57.3)	902 (60.7)	835 (56.2)	844 (56.8)	827 (55.6)	
Yes	2540 (42.7)	585 (39.3)	652 (43.8)	643 (43.2)	660 (44.4)	
Fat Intake	79.3 ± 45.7	79.3 ± 44.6	80.0 ± 47.5	79.2 ± 46.0	78.7 ± 44.5	0.893

Table 1 (continued)

Characteristic	Participants					
	Total	Q1	Q2	Q3	Q4	
	N = 5948	(−1.15 to −0.25)	(−0.25 to −0.04)	(−0.04 to 0.18)	(0.18 to 0.92)	*P* value
Caffeine Intake	160.0 ± 211.3	142.2 ± 179.4	159.9 ± 204.3	160.0 ± 200.5	178.0 ± 252.8	< 0.001
Total cholesterol	5.1 ± 1.1	4.9 ± 1.0	5.0 ± 1.0	5.1 ± 1.1	5.3 ± 1.1	< 0.001
LDL-cholesterol	3.0 ± 0.9	2.7 ± 0.8	3.0 ± 0.9	3.1 ± 1.0	3.1 ± 1.0	< 0.001

Table 2 Association between Atherogenic Index of Plasma and Chronic Diarrhea

	Model 1		Model 2		Model 3		Model 4	
	OR (95%CI)	*P* value	OR (95%CI)	*P* value	OR (95%CI)	*P* value	OR (95%CI)	*P* value
AIP	2.26 (1.63 ~ 3.13)	< 0.001	2.20 (1.55 ~ 3.12)	< 0.001	1.57 (1.08 ~ 2.30)	0.018	1.57 (1.05 ~ 2.36)	0.030
Quartile								
Q1	1(Ref)		1(Ref)		1(Ref)		1(Ref)	
Q2	1.24 (0.92 ~ 1.68)	0.165	1.22 (0.90 ~ 1.67)	0.200	1.12 (0.81 ~ 1.54)	0.497	1.05 (0.75 ~ 1.49)	0.770
Q3	1.43 (1.07 ~ 1.93)	0.017	1.41 (1.04 ~ 1.90)	0.027	1.20 (0.87 ~ 1.65)	0.263	1.27 (0.91 ~ 1.77)	0.162
Q4	1.97 (1.49 ~ 2.61)	< 0.001	1.92 (1.43 ~ 2.58)	< 0.001	1.51 (1.10 ~ 2.07)	0.011	1.37 (0.97 ~ 1.93)	0.073
Trend. test		< 0.001		< 0.001		0.008		0.039

Model 1: Crude model

Model 2: Adjusted for age, gender, race and ethnicity, educational level, and family income

Model 3: Additionally adjusted for body mass index, physical activity, milk habits, fat intake, caffeine intake, smoking status, alcohol use, diabetes, hypertension, depression, sleep disorders, total cholesterol and low-density lipoprotein cholesterol

Model 4: Sensitivity analysis model based on Model 3, with the exclusion of participants who were taking lipid-lowering drugs, antidiarrheal drugs, and antibiotics

(HDL-C), as indicated by a higher atherogenic index of plasma (AIP), may drive chronic diarrhea development through interconnected biological mechanisms. Studies show that oxidized TG derivatives like epoxy triglycerides can directly damage the intestinal barrier by triggering inflammatory pathways such as Caspase-1/NLRP3/GSDMD and cGAS-STING signaling. These processes lead to epithelial pyroptosis and degradation of tight junction proteins [30]. This barrier disruption creates a permissive environment for gut microbial dysbiosis, where reduced short-chain fatty acid (SCFA) production may disrupt their regulatory effects on hepatic lipid synthesis and HDL-C metabolism [17–19]. Dietary components like ethanol can interact with unsaturated fats, further exacerbating barrier disruption by promoting NF-κB-mediated cytoskeletal disorganization and mucus layer alterations [31, 32]. The resulting increase in intestinal permeability allows endotoxins like lipopolysaccharides (LPS) to cross into circulation [33]. These endotoxins trigger proinflammatory cytokine cascades (TNF-α, IL-6) that sustain mucosal inflammation and systemically inhibit lipoprotein lipase activity, impairing triglyceride clearance [20–22]. This pathway critically links metabolic dysregulation to diarrheal pathophysiology. While protective mechanisms like SCFA-activated AMPK may partially counteract these effects, sustained TG elevation in high AIP states likely overwhelms these compensatory mechanisms [34, 35].

Concurrent HDL-C depletion establishes a secondary pathogenic axis. Emerging evidence indicates that gut microbiota-derived SCFAs modulate hepatic lipid synthesis and HDL-C remodeling through PPAR-α signaling and bile acid metabolism [36]. Inflammation stemming from intestinal barrier defects not only reduces HDL-C levels but also alters its functional properties. It modifies lipoprotein composition to reduce cholesterol efflux capacity while converting HDL from an anti-inflammatory to a pro-inflammatory mediator [37, 38]. This functional shift proves particularly consequential given HDL's role in endotoxin neutralization. Structural modifications during inflammation impair HDL's LPS-binding capacity, permitting endotoxin accumulation that sustains systemic inflammation and intestinal dysfunction [39, 40].

The interplay between these mechanisms may establish a self-reinforcing cycle: Increased intestinal permeability

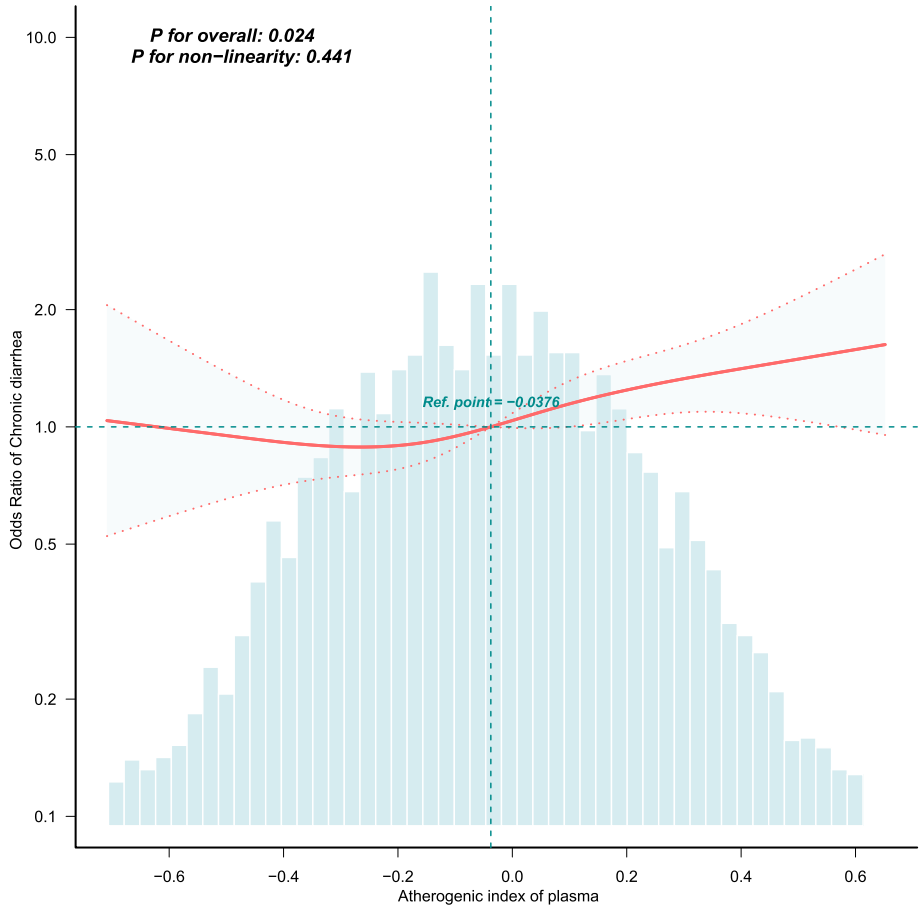

Fig. 2 Analysis of Restricted Cubic Spline Regression. **The covariates adjusted in this model are identical to those in Model 3 (the main model), as detailed in the Statistical Analysis section*

from TG-related barrier defects facilitates endotoxin translocation, which intensifies systemic inflammation and accelerates HDL-C dysfunction [41, 42]. This vicious cycle aligns with findings from environmental stress studies, where synergistic interactions between metabolic dysregulation and immune activation were shown to amplify tissue damage [43]. Furthermore, the observed dose–response relationship between AIP and chronic diarrhea risk suggests that even moderate, sustained elevations in AIP might progressively drive gastrointestinal pathophysiology through these compounded effects. Such dynamic interactions between lipid metabolism and inflammatory cascades highlight the need for integrated therapeutic strategies targeting both pathways simultaneously.

To our knowledge, this is the first study to examine the association between AIP and CD in a large, nationally representative sample of US adults. Our findings suggest that AIP may be a promising predictor of CD risk. However, several limitations should be acknowledged. First, the observational nature of this study precludes the establishment of a causal relationship between AIP and CD risk in the US population. Although we adjusted for relevant confounders in the multivariate model, unmeasured or unknown residual confounders, such as variations in gut microbiota composition, might affect the observed associations. This research used a US sample; further investigation is necessary to verify whether our findings can be generalized to other demographics. Additionally, CD assessment primarily relied on the Bristol stool scale, without a gastroenterologist's evaluation to confirm the diagnosis or supply further details for clarifying the classification of diarrhea. Future research should employ prospective cohort studies to clarify the temporal relationship between lipids and chronic diarrhea symptoms. Analysis of gut microbiota and integration of genetic data with environmental exposures could help clarify causal pathways.

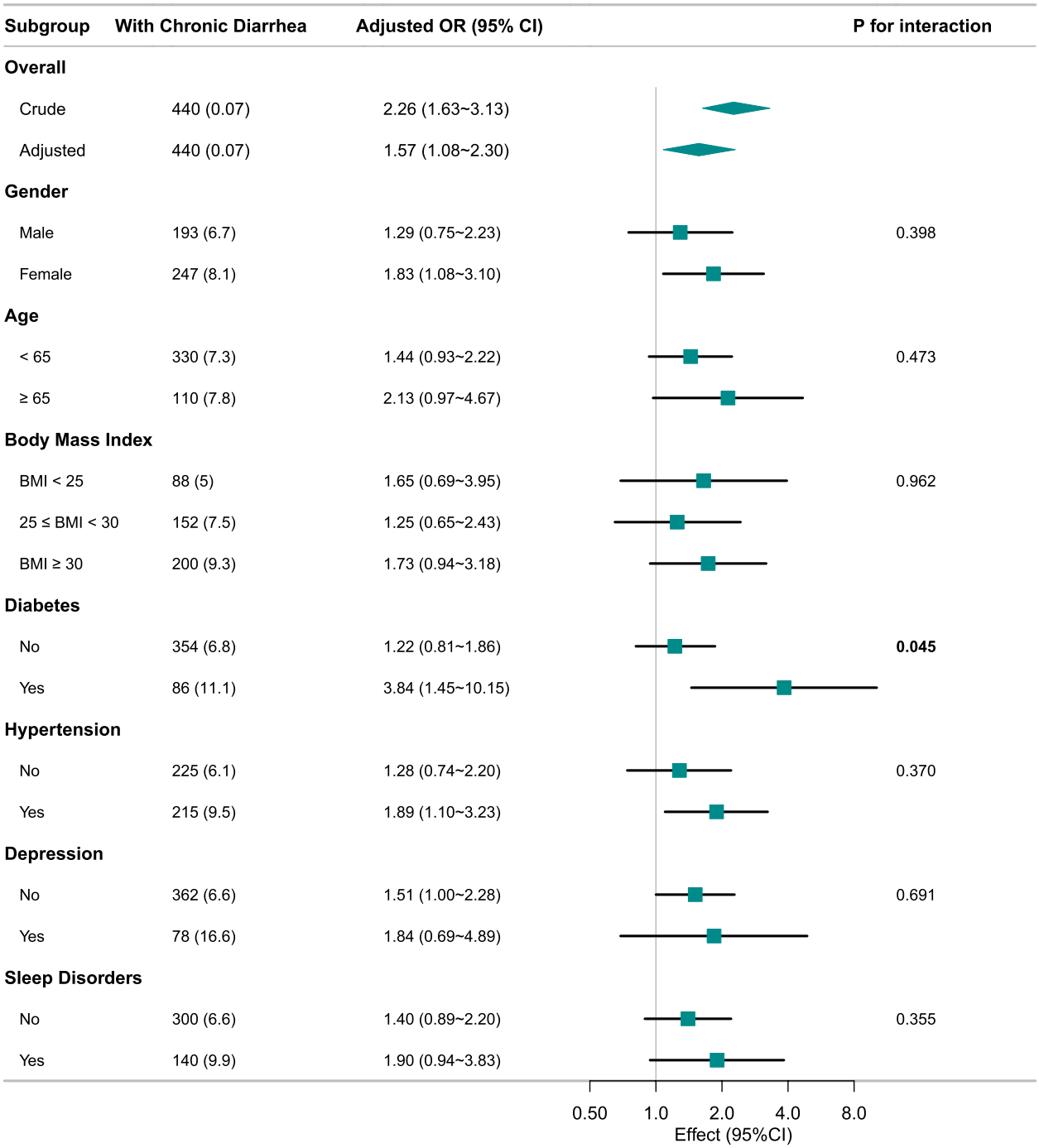

Fig. 3 Subgroup Analysis. **The covariates adjusted in this model are identical to those in Model 3 (the main model), as detailed in the Statistical Analysis section*

Conclusion

The results of this study demonstrated that the atherogenic index of plasma (AIP) is independently associated with the risk of chronic diarrhea (CD). AIP may serve as a promising indicator for assessing the risk of CD, offering valuable insights for its prevention and treatment strategies.

Abbreviations

CD	Chronic diarrhea
HFDs	High-fat diets
AIP	Atherogenic index of plasma
HDL-C	High-density lipoprotein cholesterol
TG	Triglycerides
NAFLD	Non-alcoholic fatty liver disease
SCFAs	Short-chain fatty acids
NHANES	National Health and Nutrition Examination Survey

BSFS	Bristol Stool Form Scale
PHQ-9	9-Item Patient Health Questionnaire
TC	Total cholesterol
LDL-C	Low-density lipoprotein cholesterol
BMI	Body mass index
SE	Standard error
OR	Odds ratio
CI	Confidence interval
GAM	Generalized additive model
LPS	Lipopolysaccharides

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12876-025-03784-4.

Additional file 1. Table S1. Interaction analysis of diabetes and AIP in chronic diarrhea risk. Note: AIP was divided into high AIP group and low AIP group by median. The covariates adjusted in this model are identical to those in Model 3 (the main model), as detailed in the Statistical Analysis section.

Acknowledgements
We extend our gratitude to Pengfei Wang Ph.D. (China Academy of Chinese Medical Sciences, Beijing, China) for assistance with this revision.

Authors' contributions
RC and GW were responsible for the study design, writing, and revision of the manuscript. Zexin Fu participated in data analysis and contributed to the manuscript writing and revision. FX participated in data collection and organization. Zhicheng Feng participated in data interpretation. All authors have read and approved the final manuscript for publication and are responsible for the accuracy and completeness of the research findings.

Funding
This research was funded by the Science and Technology Program of Guangzhou [Grant Number: 2023A03J0418], Featured Clinical Technique of Guangzhou [Grant Number: 2023C-TS47], plan on enhancing scientific research in GMU and Guangzhou Medical University Student Innovation Ability Promoting Program.

Data availability
The data from the aforementioned survey are freely and publicly available for download from the NHANES website (http://www.cdc.gov/nchs/nhanes.htm) by users and researchers worldwide.

Declarations

Ethics approval and consent to participate
The protocol for the NHANES survey was approved by the NCHS Research Ethics Review Committee. Participation in the survey was contingent upon the provision of informed consent by all participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 24 December 2024 Accepted: 13 March 2025
Published online: 26 March 2025

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