




Women's health factors and altered bowel habits: results of a National Health And Nutrition Examination Survey

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Summary

Background and Aims: Women disproportionately suffer from chronic constipation (CC) and chronic diarrhoea (CD) compared to men. Women's health specific factors may play a role.

Methods: Analyses were performed including women who completed both Bowel Health and Female Reproductive Health Questionnaires from the 2009-2010 National Health and Nutrition Examination Survey (NHANES). CC was defined by Bristol Stool Form Scale (BSFS) Types 1&2 or chronic laxative use and CD was defined as BSFS Types 6&7. Women's health factors, including oral contraception, deliveries, hysterectomy and pelvic floor dysfunction, were evaluated in all women, then separately in pre- vs post-menopausal women with CC and CD.

Results: Post-menopausal status was associated with increase in both CC and CD in comparison to pre-menopause (18.43% vs 14.60%; 10.48% vs 7.06%), but menopause was not associated with CC or CD after adjusting for other variables. None of the women's health factors were associated with CC in the pre- or post-menopause group on univariable or multivariable analyses. On univariable analysis, urinary incontinence ($P = 0.012$) and hysterectomy ($P = 0.028$) in pre-menopausal women, and vaginal delivery ($P = 0.025$) in post-menopausal women were associated with CD. No women's health factors were associated with CD on multivariable analysis.

Conclusions: In this nationally representative population of women in the US, post-menopausal women suffer from CD and CC more than pre-menopausal women, but this study did not find this difference to be associated with menopause or other women's health factors.

Sophie Brigstocke and Judy Nee share first authorship of this manuscript.

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1 | INTRODUCTION

Women suffer disproportionately from both chronic constipation (CC) and diarrhoea (CD).^{1,2} In a recent nationwide sample of adults in North America and the UK, the prevalence of functional constipation and diarrhoea by Rome IV Criteria was approximately 2:1 female to male and 1.2:1 female to male, respectively.³ Women also have a higher prevalence of irritable bowel syndrome (IBS), and within the IBS population, women are more likely to suffer from IBS-C than IBS-D.⁴ In addition to increased prevalence, women with CD and CC are nearly twice as likely to seek consultation for their symptoms and report worse impact on quality of life compared to men.^{5,6} Given these sex differences, it is possible that female specific health factors (eg, sex hormones, pregnancies, gynaecological surgeries, etc.) may be responsible. However, the mechanisms behind how sex differences might affect the bowel habits are poorly understood. Explaining these variations in bowel habits between men and women is essential as it may provide insight to treating CD and CC.

Many women report changes in their bowel habits throughout the menstrual cycle, raising the possibility that female sex hormones may play a role in the sex differences seen in CC and CD.⁷⁻⁹ However, physiological studies have failed to show significant differences in colon or whole gut transit time or stool weight during different menstrual phases.¹⁰ Although previous studies have shown that postmenopausal women report more alterations in bowel habits than do premenopausal women,¹¹ this may be attributable to age-related factors rather than hormone changes.¹²

Gynaecologic surgery, especially hysterectomy, has also been implicated as a cause of altered bowel habits in women.^{13,14} However, to date the data supporting these claims are inconsistent.¹⁵ Existing studies do not account for other factors known to impact bowel function in their analyses and were limited by small sample sizes.

In light of the controversies in the existing literature regarding the impact of women's health factors on bowel habits, we queried the National Health and Nutrition Examination Survey (NHANES) 2009 dataset. Our primary aim was to determine the influence of menopausal status on bowel habits in a large, representative cohort of women in the United States. Secondly, we evaluated the role of other women's health factors that may influence bowel habits such as pelvic floor function, oral contraception (OCPs), hormone replacement therapy (HRT), vaginal deliveries, caesarean section (C-section) and hysterectomy.

2 | MATERIALS AND METHODS

2.1 | Study Cohort

The NHANES is a cross-sectional, health survey program conducted by the National Center for Health Statistics of the Centers of Disease Control (Atlanta, GA).¹⁶ The NHANES survey design includes a nationally representative sample of non-institutionalised respondents in the United States. We included patients from NHANES

2009-2010 to assess the above hypotheses. Participants were considered for inclusion in this study only if they completed both the Bowel Health and Female Reproductive Health Questionnaires. Exclusion criteria included participants less than 20 years old, male gender, current pregnancy and self-reported history of inflammatory bowel disease or celiac disease. Peri-menopausal women, defined as women between 44 and 55 years of age with irregular periods in the last 12 months, were also excluded (Figure 1). All questionnaires in NHANES were completed in the Mobile Examination Center Interview Room using a Computer-Assisted Personal Interview System. Written informed consent was obtained from participants upon entry into NHANES.

2.2 | Bowel Health Questionnaire

The NHANES Bowel Health Questionnaire was used to identify participants with CC and CD. Participants were shown a card with a picture and descriptions of the seven types of Bristol Stool Form Scale (BSFS) as they answered the following written question: "Please look at this card and tell me the number that corresponds with your usual or most common stool type." CC was defined as BSFS type 1 (separate hard lumps, such as nuts), BSFS type 2 (sausage-like, but lumpy), or frequent laxative users (once or more per week in the last 30 days). CD was defined as BSFS type 6 (fluffy pieces with ragged edges, a mushy stool) or BSFS type 7 (watery, no solid pieces).

2.3 | Reproductive Health Questionnaire

Women 20 years and older completed an interviewer-administered reproductive health questionnaire. They were asked "Have you had at least one menstrual period in the past 12 months? (Please do not include bleeding caused by medical conditions, hormone therapy, or surgeries)." Participants who answered "no" were subsequently asked "What is the reason that you have not had a period in the past 12 months?" Based on these two questions, women were categorised by their menopausal status. Pre-menopause was defined as women ages 20-55 with regular periods in the past 12 months or women ages 20-44 with irregular periods specifically due to hysterectomy alone (ie lack of period due to surgery rather than due to hormonal changes). Post-menopause was defined as women ≥ 55 years old without a period in the last 12 months or women >20 with surgical menopause specifically due to bilateral oophorectomy.

2.4 | Co-variables

We evaluated a set of co-variables (adapted from previously published data) potentially associated with CD, CC.^{2,17,18} We divided these variables into three categories: demographics, medical conditions and lifestyle/dietary data. Demographic variables included age, race/ethnicity, educational level and poverty-income ratio.

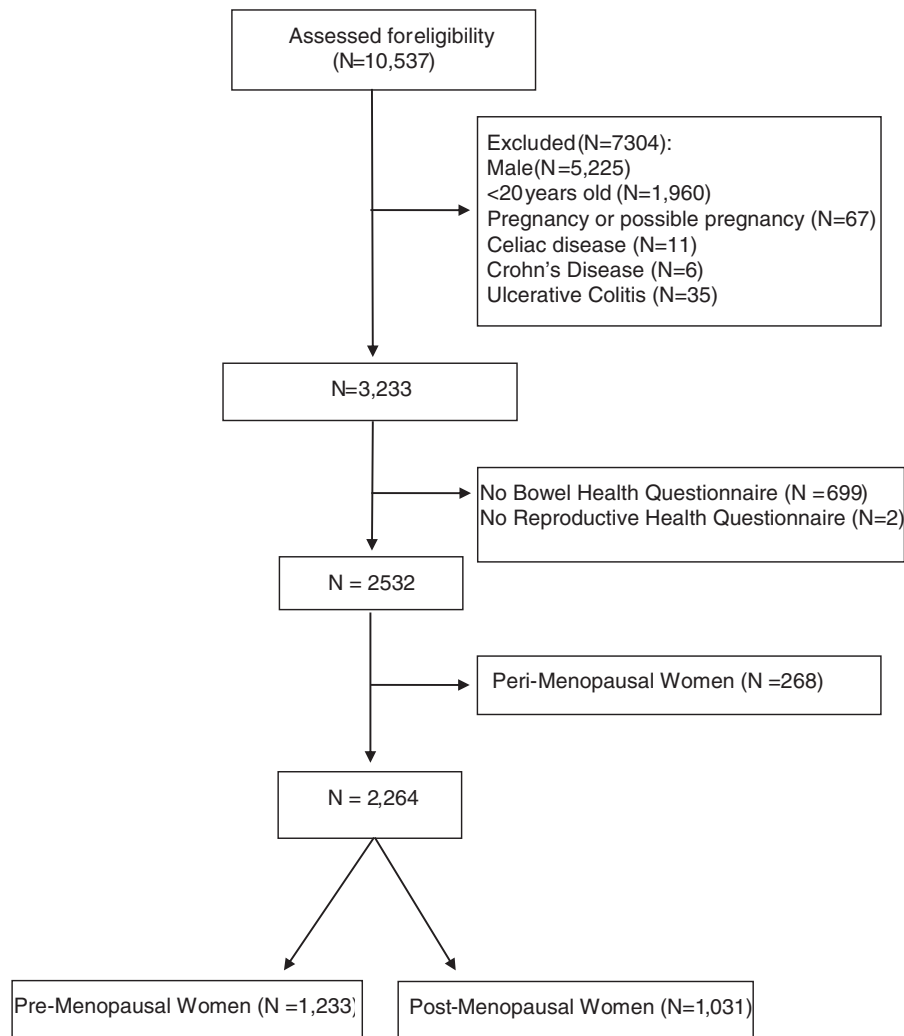


FIGURE 1 NHANES 2009-2010 eligibility flow diagram. After exclusions, 2264 women were eligible for analysis. These women were categorised into pre ($n = 1233$) and post-menopause ($n = 1031$)

Age was expressed either as a continuous variable or in decades. Race/ethnicity was categorised into Non-Hispanic Caucasian American, Non-Hispanic African American, Hispanic (including Mexican American) and other race (including multiracial). Education was categorised into three levels: less than high school, high school or GED and more than high school. Poverty income ratio was categorised as ≤ 2 times and > 2 times the poverty threshold. Medical conditions included body mass index (BMI), number of daily medications and depressed mood. BMI was classified as normal (BMI < 25.0), overweight (BMI 25.0-29.9) or obese (BMI ≥ 30). Participants self-reported feeling low, depressed or hopeless more than half the days or everyday over the last 2 weeks were defined as having a depressed mood. Lifestyle and dietary variables included physical activity and dietary intake. Alcohol intake was defined into six groups: never, former, rare, light, moderate and heavy drinker. Milk intake was categorised into four groups: never, rare, sometimes and often consumers. Other dietary data, including fibre, liquid, total sugar, protein and fat intake were obtained from a 24-hour dietary recall.

In further analysis, other female health factors, including OCPs, HRT, deliveries, pelvic floor dysfunction and surgeries were evaluated in pre- vs post-menopausal women with CC and CD. Contraception included OCPs and progesterone injection. HRT included oestrogen-only pills, progestin-only pills, combined pills and oestrogen/progestin patches. History of vaginal delivery and c-section were defined as women who had at least one vaginal delivery or one c-section, respectively. Urinary incontinence was defined as a severity score of ≥ 3 on the incontinence severity index.¹⁹ This index is based on responses to "how often do you have urinary leakage" and "how much urine do you lose each time?" Based on this information about frequency categorised in four levels and amount of leakage in three levels, these variables were multiplied to obtain an index value of 1-12. Hysterectomy was defined as a positive response to the question: "Have you had a hysterectomy, including a partial hysterectomy, that is, surgery to remove uterus or womb," excluding women who had an oophorectomy in the past. Faecal incontinence was defined as at least monthly leakage of flatus, solid, liquid or mucus stool.²⁰ Women with a positive response to, "Do you

TABLE 1 Demographics and women's health factors

	Pre-Menopause (N = 1233)		Post-Menopause (N = 1031)		P value
	N	% (95% CI)	N	% (95% CI)	
Age (years)					
Mean	1233	35.6 (34.9-36.3)	1031	66.0 (65.1-66.9)	<0.0001
Race/Ethnicity					
Caucasian	560	63.8 (55.6-72.0)	579	80.3 (75.2-85.4)	<0.0001
African American	210	12.7 (10.1-15.4)	176	9.8 (7.6-11.9)	
Hispanics	387	15.9 (9.6-22.2)	247	6.4 (2.4-10.5)	
Other-including multi-racial	76	7.5 (5.3-9.7)	29	3.5 (1.9-5.1)	
Education					
<High school	268	15.2 (13.2-17.3)	313	20.1 (15.6-24.6)	0.0009
High school or GED	259	20.1 (17.4-22.8)	260	27.5 (24.1-31.0)	
>High school	706	64.7 (61.1-68.3)	458	52.4 (47.7-57.0)	
Family poverty income ratio					
<2	618	38.2 (34.5-41.9)	433	32.2 (28.1-36.4)	0.0141
≥2	526	61.8 (58.1-65.5)	500	67.8 (63.6-71.9)	
Number of medications					
Mean (number of medications per day)	1233	1.1 (1.0-1.3)	1031	3.7 (3.5-3.9)	<0.0001
Bowel habits					
Chronic constipation	180	13.1 (9.7-16.4)	190	17.8 (15.6-19.9)	0.0007
Normal	966	81.1 (77.9-84.2)	733	73.6 (70.5-76.7)	
Chronic diarrhoea	87	5.9 (5.1-6.7)	108	8.7 (6.9-10.4)	
Birth control					
No	1055	84.0 (50.5-58.3)	1031	100	<0.0001
Yes	178	16.0 (11.8-19.8)	0	0	
Hormone replacement therapy					
No	1229	99.3 (98.9-99.7)	979	93.5 (90.7-96.3)	<0.0001
Yes	4	0.7 (0.3-1.1)	52	6.5 (3.7-9.3)	
Urinary incontinence					
No	1109	90.6 (88.5-92.8)	727	70.9 (66.6-75.2)	<0.0001
Yes	124	9.4 (7.2-11.5)	300	29.1 (24.8-33.4)	
Faecal incontinence					
No	700	55.7 (51.6-59.8)	466	44.5 (40.4-48.6)	0.0022
Yes	530	44.3 (40.2-48.4)	563	55.5 (51.4-59.6)	
Prolapse					
No	1206	98.5 (97.8-99.3)	976	96.2 (94.5-98.0)	0.0123
Yes	27	1.5 (0.7-2.2)	51	3.8 (2.0-5.5)	
History of vaginal delivery					
No	233	24.6 (21.7-27.5)	88	10.5 (7.7-13.3)	<0.0001
Yes	708	75.4 (72.5-78.3)	858	89.5 (86.7-92.3)	
History of caesarean section					
No	306	55.7 (51.1-60.3)	278	69.7 (64.6-74.8)	0.0008
Yes	281	44.3 (39.7-48.9)	119	30.3 (25.2-35.4)	
Hysterectomy alone					
No	1187	96.0 (94.5-97.4)	854	83.2 (80.1-86.4)	<0.0001
Yes	46	4.0 (2.6-5.5)	177	16.8 (13.6-19.9)	

experience bulging or something falling out you can see or feel in the vaginal area” were defined as symptomatic pelvic organ prolapse.

2.5 | Statistics

The differences between pre- and postmenopausal women were first evaluated for statistical significance using chi-squared analysis, Fisher's exact test and Student's *t*-test where appropriate. Variables were then included in log-binomial models that provided mutually adjusted estimates of the RRs of co-variables for CC and CD. Unadjusted regression was performed to determine the association between individual variables and either CC or CD. Subsequent multivariate analysis, including only variables with $P < 0.10$ in univariate analysis, was done to discern the impact of individual variables by accounting for other variables. Adjusted RRs were evaluated for statistical significance against a value of 1.0. All confidence intervals (CIs) reported were 95% CI and $P < 0.05$ were considered statistically significant. All estimates, standard errors and association measures were calculated using sampling weights accounting for the complex survey design of NHANES. A Taylor linearisation approach was used to calculate 95% CIs for the estimated occurrence. All statistical analyses were performed using STATA statistical software version 14.2.

3 | RESULTS

A total of 2264 women participating in NHANES 2009-2010 were eligible for analysis (Figure 1). These women were categorised into

pre- ($n = 1233$) and post-menopause ($n = 1031$). Among these, 180 premenopausal and 190 post-menopausal women reported CC (score of 1 or 2 on BSFS or frequent laxative use), and 87 premenopausal and 108 postmenopausal women reported CD (score of 6-7 without frequent laxative use). Demographic characteristics of the pre- and post-menopausal groups are shown in Table 1. Post-menopausal women were more likely to report history of vaginal delivery compared to pre-menopausal women, whereas premenopausal women were more likely to report history of caesarean section compared to post-menopausal women. Table S1 provides further details of lifestyle, diet and chronic medical factors. There was no difference in fibre, liquid, protein or fat intake between the pre- and post-menopausal groups. Overall, post-menopausal women had an increase in both CC and CD in comparison to pre-menopausal women (18.43% vs 14.60%; 10.48% vs 7.06%) (Figure 2). After adjusting for factors known to be associated with bowel habits such as age, diet, depression, etc. menopausal status was no longer associated with CC or CD (Table S2).

3.1 | Bowel habits and menopause status

3.1.1 | Pre-menopause

None of the women's health factors were associated with risk of CC in the pre-menopause group on univariable or multivariable analyses (Table 2). However, other non-female specific factors including Caucasian race and daily medications were associated with CC in this group. Regarding CD, urinary incontinence ($P = 0.012$) and history of hysterectomy ($P = 0.028$) were both associated with increased risk

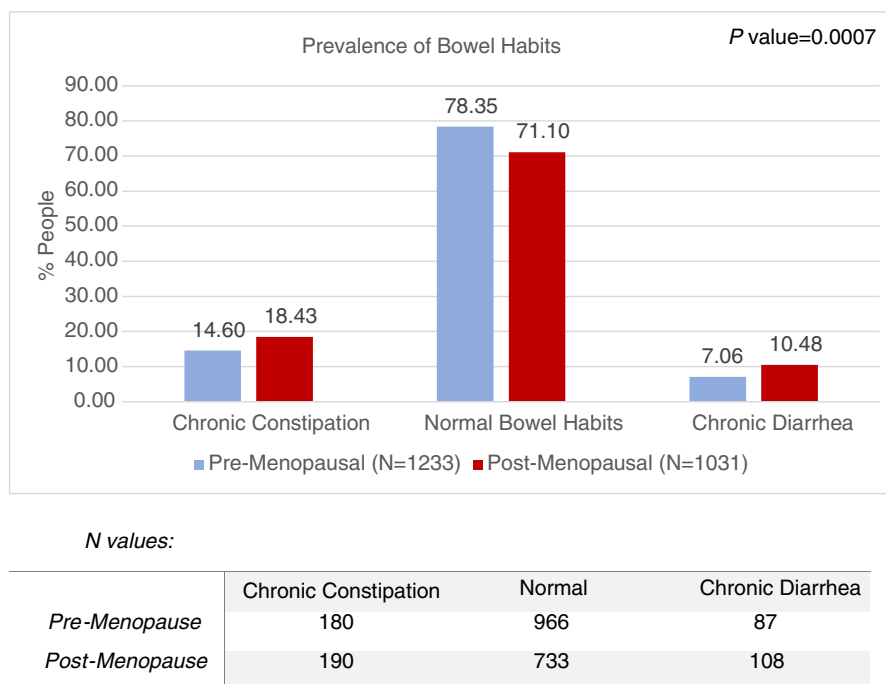


FIGURE 2 Bowel habit distribution in pre and post-menopausal women. In the pre-menopause group, 180 women reported CC and 87 reported CD. In the post-menopause group, 190 women reported CC and 108 reported CD

TABLE 2 Unadjusted and adjusted analyses of factors associated with chronic constipation in pre- and post-menopausal women

Chronic constipation	Pre-Menopause				Post-Menopause			
	Unadjusted		Adjusted for age		Unadjusted		Adjusted for age	
	RR (95% CI)	P value	RR (95% CI)	P value	RR (95% CI)	P value	RR (95% CI)	P value
Age (decades)	0.99 (0.83-1.18)	0.932			1.45 (1.20-1.74)	0.001 ^a	1.28 (0.83-1.98)	0.236
Caucasian	0.62 (0.39-0.98)	0.042	0.58 (0.36-0.93)	0.027	1.31 (0.83-2.05)	0.223		
Higher education	0.67 (0.46-0.97)	0.036	0.72 (0.48-1.06)	0.092	1.08 (0.70-1.67)	0.726		
Living above poverty income	0.74 (0.42-1.29)	0.265			0.90 (0.63-1.28)	0.539		
Obese BMI	1.03 (0.66-1.61)	0.900			0.72 (0.47-1.10)	0.118		
Daily medications	1.12 (1.02-1.23)	0.019	1.13 (1.01-1.25)	0.028	1.13 (1.04-1.22)	0.005	1.19 (1.10-1.28)	<0.0001
Feeling down, depressed, hopeless	1.94 (0.99-3.81)	0.053	1.56 (0.71-3.43)	0.246	1.22 (0.49-3.03)	0.655		
Birth controls	1.12 (0.62-2.03)	0.695			1.17 (0.65-2.11)	0.572		
Urinary incontinence	1.82 (0.81-4.09)	0.136			1.23 (0.78-1.95)	0.355		
Faecal incontinence	1.30 (0.73-2.29)	0.349			1.10 (0.84-1.44)	0.447		
Prolapse	1.43 (0.47-4.33)	0.504			1.39 (0.60-3.19)	0.419		
Hx of vaginal delivery	0.82 (0.51-1.33)	0.404			1.32 (0.57-3.02)	0.495		
Hx of c-section	1.11 (0.61-2.01)	0.712			0.48 (0.22-1.05)	0.066	0.48 (0.20-1.18)	0.105
Hysterectomy	1.45 (0.53-3.94)	0.448			0.93 (0.67-1.29)	0.644		
Vigorous physical activity	0.86 (0.40-1.86)	0.690			0.52 (0.22-1.24)	0.130		
Heavy/moderate alcohol drinker	1.51 (0.74-3.06)	0.234			0.45 (0.19-1.08)	0.070	0.40 (0.07-2.38)	0.292
High caffeine intake	1.23 (0.56-2.71)	0.590			0.91 (0.46-1.79)	0.773		
Frequent milk drinker	1.41 (0.95-2.08)	0.080	1.57 (1.05-2.34)	0.029	1.57 (1.15-2.14)	0.007	1.48 (0.79-2.78)	0.208
Highest quartile fibre intake	0.69 (0.41-1.16)	0.146			0.86 (0.40-1.84)	0.681		
Highest quartile liquid intake	1.23 (0.84-1.80)	0.269			0.76 (0.45-1.29)	0.284		
Highest quartile carbohydrates intake	1.10 (0.62-1.95)	0.734			1.26 (0.69-2.30)	0.431		
Highest quartile sugar intake	1.51 (1.10-2.06)	0.013	1.40 (0.97-2.01)	0.067	1.25 (0.66-2.39)	0.470		
Highest quartile protein intake	0.92 (0.46-1.83)	0.797			0.71 (0.42-1.20)	0.185		
Highest quartile fat intake	0.85 (0.47-1.55)	0.584			0.58 (0.22-1.54)	0.255		

of CD in pre-menopausal women in univariable analysis, but were no longer significant in adjusted analysis (Table 3). Association of other demographic, medical, dietary and psychological factors with bowel habits are shown on Tables 2 and 3.

3.1.2 | Post-menopause

Similar to the pre-menopause group, none of the women's health factors were associated with risk of CC (Table 2). Vaginal delivery

TABLE 3 Unadjusted and adjusted analyses of factors associated with chronic diarrhoea in pre- and post-menopausal women

	Pre-Menopause			Post-Menopause		
	Unadjusted		Adjusted for age	Unadjusted		Adjusted for age
	RR (95% CI)	P value	RR (95% CI)	RR (95% CI)	P value	P value
Age (decades)	1.10 (0.91-1.34)	0.291		1.29 (0.92-1.80)	0.129	
Caucasian	0.55 (0.34-0.89)	0.018	0.71 (0.37-1.38)	0.53 (0.30-0.96)	0.038	0.56 (0.29-1.07)
Higher education	0.31 (0.18-0.52)	<0.0001	0.38 (0.20-0.73)	0.38 (0.22-0.68)	0.003	0.37 (0.19-0.72)
Living above poverty income	0.49 (0.31-0.78)	0.005	0.94 (0.57-1.53)	0.70 (0.33-1.48)	0.325	
Obese BMI	3.30 (1.98-5.49)	<0.0001	2.48 (1.46-4.22)	2.84 (1.19-6.79)	0.022	2.54 (0.90-7.22)
Daily medications	1.17 (1.05-1.30)	0.005	1.08 (1.00-1.17)	1.09 (1.02-1.16)	0.018	1.06 (0.96-1.17)
Feeling down, depressed, hopeless	2.74 (1.41-5.34)	0.005	1.43 (0.84-2.43)	2.49 (1.41-4.38)	0.004	1.82 (0.91-3.64)
Birth controls	1.29 (0.57-2.90)	0.520				
Hormone replacement therapy				0.83 (0.29-2.36)	0.709	
Urinary incontinence	2.92 (1.32-6.49)	0.012	2.05 (0.79-5.33)	1.42 (0.97-2.07)	0.067	0.99 (0.56-1.76)
Faecal incontinence	1.10 (0.66-1.85)	0.701		1.34 (0.72-2.50)	0.330	
Prolapse	1.09 (0.23-5.19)	0.909		0.69 (0.20-2.38)	0.534	
Hx of vaginal delivery	0.79 (0.35-1.80)	0.557		5.91 (1.28-27.24)	0.025	4.16 (0.80-21.50)
Hx of c-section	1.14 (0.35-1.80)	0.745		0.82 (0.36-1.85)	0.612	
Hysterectomy	2.69 (1.13-6.43)	0.028	1.42 (0.52-3.91)	1.00 (0.39-2.56)	0.994	
Vigorous physical activity	1.27 (0.58-2.79)	0.526		1.58 (0.56-4.42)	0.363	
Heavy/moderate alcohol drinker	1.77 (0.65-4.84)	0.247		0.50 (0.17-1.45)	0.189	
High caffeine intake	1.00 (0.31-3.23)	0.993		1.27 (0.32-5.00)	0.712	
Frequent milk drinker	1.07 (0.58-1.98)	0.807		0.71 (0.44-1.13)	0.139	
Highest quartile fibre intake	0.88 (0.42-1.84)	0.710		0.35 (0.18-0.69)	0.004	0.43 (0.20-0.89)
Highest quartile liquid intake	1.54 (0.83-2.85)	0.157		0.62 (0.31-1.24)	0.163	
Highest quartile carbohydrates intake	2.26 (1.18-4.33)	0.018	1.74 (0.53-5.77)	1.57 (0.75-3.26)	0.213	
Highest quartile sugar intake	1.89 (0.98-3.67)	0.058	1.02 (0.40-2.63)	1.09 (0.55-2.17)	0.786	
Highest quartile protein intake	1.60 (0.94-2.74)	0.080	1.22 (0.54-2.75)	1.22 (0.80-1.88)	0.335	
Highest quartile fat intake	1.40 (0.78-2.49)	0.239		1.88 (1.06-3.32)	0.033	3.02 (1.46-6.27)

($P = 0.025$) was associated with increased risk of CD in univariable but not multivariable analysis (Table 2). Association of other demographic, medical, dietary and psychological factors with bowel habits are shown in Tables 2 and 3.

4 | DISCUSSION

To the best of our knowledge, this is the first study to analyse the effects of women's health factors (deliveries, hysterectomy, incontinence, prolapse, OCPs and HRT) on bowel habits in a large, nationally representative cohort of US women. Post-menopausal women were more likely to experience CC and CD compared to pre-menopausal women, but when adjusted for other factors that influence bowel habits, menopausal status did not increase the risk of CC or CD. Furthermore, when evaluating pre- and post-menopausal women individually, women's health factors were not predictive of CC or CD.

Female sex hormones, namely oestrogen and progesterone, fluctuate during the menstrual cycle and decrease after menopause. Consistent with previous studies, ours found a higher rate of altered bowel habits in post-menopausal women compared to pre-menopausal women.^{11,21} However, in contrast to other studies, we were able to control for confounding factors, including women's health factors, that are suspected to contribute to altered bowel habits. After controlling for these factors, menopause status was no longer associated with altered bowel habits, suggesting the increase rate in altered bowel habits in post-menopausal women is driven by other factors.

In our study, use of OCPs or HRT was not associated with CC or CD. This finding is consistent with existing studies showing no changes in colon transit for pre-menopausal women on or off OCPs, no change in transit during the luteal and follicular phases of menstruation (which are associated with fluctuating levels of oestrogen and progesterone), and no change in transit for post-menopausal women receiving HRT or withdrawn from HRT (either oestradiol or combined oestradiol-progesterone).^{7,10} These studies were limited by small numbers and lack of data on dietary, medical and psychological factors. However, through NHANES, we have been able to control for comorbidities as well as dietary habits.

Gynaecologic surgery has also been linked with altered bowel habits in women.^{22,23} Disruption of the pelvic floor anatomy, changes to pelvic floor physiology or nerve injury in the pelvic plexus have been cited as possible mechanisms leading to constipation. However, this is not a consistent finding, with some studies failing to show this association.²⁴⁻²⁶ In our study, 9.8% women underwent hysterectomy but we did not find hysterectomy to be a predictor of altered bowel habits at a population level. Our findings lend further support to the lack of association between hysterectomy and CC in women.

In addition to gynaecologic surgery, pelvic organ prolapse has been associated with CC in case-controlled studies.²⁷⁻³⁰ Most of these studies have been restricted to small cohorts in specialty clinics, with contradictory findings. One study observed a four-fold increased odds of constipation in women with prolapse, but

findings were partially explained by lower fibre intake compared to controls.²² Other studies have refuted this association, with no evidence of altered bowel habits with prolapse.^{31,32} In our study, pelvic organ prolapse (as well as urinary and faecal incontinence) was included in the bowel habits model for CC and CD as a surrogate for pelvic floor dysfunction. We similarly found that prolapse was not associated with an increased the risk of either CC or CD in pre- or post-menopausal women. However, we acknowledge the limitations of our definition of prolapse as this was based on a self-reported question "Do you experience bulging or something falling out you can see or feel in the vaginal area?" rather than physical exam findings. It is possible that earlier stages of prolapse may be missed by our definition and may underestimate an association with CC.

Vaginal births and c-sections were included in the analysis given the increased risk of pelvic floor disorders and GI symptoms after delivery. Multiple proposed mechanisms of this association have been described previously. Studies have focused primarily on development of urinary or faecal incontinence, but few have evaluated delivery mode and risk of CC or CD. Furthermore, the results are also conflicting: a study of Australian women found no difference in vaginal vs c-section births and development of CC up to 18 months postpartum,³³ but another study of Turkish women found increased risk of CC with mode of delivery after adjusting for age and parity.³⁴ In the current study, vaginal births and c-sections did not increase the risk of development of CD or CC.

While our study did not show an association between women's health factors and CC or CD, we did find that other factors were predictive of CC and CD. Regarding CC, we found that an increase in daily medications was a predictor of CC in both pre- and post-menopausal groups. Daily medications may be a surrogate for other comorbidities, which may increase the risk of constipation. While NHANES reports medication classes, the number of participants taking each medication was too small to report. Regarding CD, similar to a prior NHANES study,² we found that higher education was negatively correlated with CD in whereas obesity was positively correlated with CD in both pre-menopausal women. Lastly, fibre intake was negatively correlated with CD in post-menopausal women, which could be because women with diarrhoea are more likely to avoid excess fibre.

There were several limitations to this study. Data collected were entirely based on self-reported menstrual patterns. To make the classification of pre- and post-menopausal groups as consistent as possible, we excluded women who would be considered peri-menopausal and were therefore unable to examine the effects of peri-menopause on bowel habits. This may have excluded patients who experience significant hormonal changes and diminished the hormonal effects observed in the study. Furthermore, one of our aims was to evaluate the impact of hysterectomy on CD and CC. NHANES does not specify hysterectomy type (vaginal or abdominal), which has been suggested previously as a possible predictor of CC in a small study.²³ Lastly, NHANES does not assess for abdominal pain (ie in IBS). There is an urgent need for

future studies to assess the role of women's health factors in IBS. As inherent to large databases, questions regarding stool consistency are subject to recall bias and limited in regard to fluctuation across time. However, our study has many strengths. Our analysis is based on a large, nationally representative population with detailed factors known to affect bowel habits including demographics, diet and lifestyle.^{2,17,18}

In summary, in a representative US population of women, menopausal status, reproductive and pelvic floor factors were not shown to influence the risk of CC or CD when accounting for other bowel related characteristics such as diet, medication use and lifestyle.

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AUTHORSHIP

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Author contributions: Judy Nee, Sophie Brigstocke, Johanna Iturrino provided study concept and design. Judy Nee, Sophie Brigstocke, Sarah Ballou provided analysis and interpretation of data, Sarah Ballou, Shuji Mitsuhashi, Prashant Singh provided statistical analyses. Sophie Brigstocke, Sarah Ballou, Rafla Hassan, Johanna Iturrino, Carsten Langhol, Shuji Mitsuhashi, Judy Nee, Vikram Rangan drafted the manuscript. All authors have approved the final version of this manuscript.

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Peer Review

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in NHANES at <https://www.cdc.gov/nchs/nhanes/index.htm>. These data were derived from the following resources available in the public domain: URLs] <https://www.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx?BeginYear=2009>

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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