The association among diet, dietary fiber, and bowel preparation at colonoscopy CME

Anna M. Leszczynski, MD,[1,*] Kristin L. MacArthur, MD,[1,*] Kerrie P. Nelson, PhD,[2] Samuel A. Schueler, MD,[3] Paula A. Quatromoni, DSc, MS, RD,[4] Brian C. Jacobson, MD, MPH[1,3]

Boston, Massachusetts, USA

Background and Aims: Pre-colonoscopy dietary restrictions vary widely and lack evidence-based guidance. We investigated whether fiber and various other foods/macronutrients consumed during the 3 days before colonoscopy are associated with bowel preparation quality.

Methods: This was a prospective observational study among patients scheduled for outpatient colonoscopy. Patients received instructions including split-dose polyethylene glycol, avoidance of vegetables/beans 2 days before colonoscopy, and a clear liquid diet the day before colonoscopy. Two 24-hour dietary recall interviews and 1 patient-recorded food log measured dietary intake on the 3 days before colonoscopy. The Nutrition Data System for Research was used to estimate dietary exposures. Our primary outcome was the quality of bowel preparation measured by the Boston Bowel Preparation Scale (BBPS).

Results: We enrolled 201 patients from November 2015 to September 2016 with complete data for 168. The mean age was 59 years (standard deviation, 7 years), and 90% of colonoscopies were conducted for screening/surveillance. Only 17% and 77% of patients complied with diet restrictions 2 and 1 day(s) before colonoscopy, respectively. We found no association between foods consumed 2 and 3 days before colonoscopy and BBPS scores. However, BPPS was positively associated with intake of gelatin, and inversely associated with intake of red meat, poultry, and vegetables on the day before colonoscopy.

Conclusions: Our findings support recent guidelines encouraging unrestricted diets >1 day before colonoscopy if using a split-dose bowel regimen. Furthermore, we found no evidence to restrict dietary fiber 1 day before colonoscopy. We also found evidence to promote consumption of gelatin and avoidance of red meat, poultry, and vegetables 1 day before colonoscopy. (Gastrointest Endosc 2018;88:685-94.)

INTRODUCTION

Despite maximizing liquid purgatives (eg, use of "split-dose" regimens), inadequate bowel preparation has been reported in 10% to 25% of colonoscopies.[1–4] This may hinder the identification of colonic lesions, result in longer procedure times, and necessitate repeat examinations at foreshortened intervals.[2,3,5–7] In addition to the liquid purgative, patients are also instructed to limit their diet in the days preceding colonoscopy. Although several studies have examined various types of laxative regimens, minimal data are available regarding specific food intake before

Abbreviations: BBPS, Boston Bowel Preparation Scale; BMI, body mass index; CLD, clear liquid diet; IQR, interquartile range; NDSR, Nutrition Data System for Research; SD, standard deviation.

DISCLOSURE: *Dr Jacobson has acted as a consultant for MOTUS GI and Remedy Partners. All other authors disclosed no financial relationships relevant to this publication. Supported by NIH/NIDDK R21DK105476.*

See CME section; p. 745.

*Drs Leszczynski and MacArthur contributed equally to this article.

0016-5107/$36.00
https://doi.org/10.1016/j.gie.2018.06.034

Received April 9, 2018. Accepted June 26, 2018.

Current affiliations: Section of Gastroenterology, Boston University Medical Center, Boston, Massachusetts, USA (1), Department of Biostatistics, Boston University, Boston, Massachusetts, USA (2), Department of Internal Medicine, Boston University Medical Center, Boston, Massachusetts, USA (3), College of Health & Rehabilitation Sciences: Sargent College, Boston University, Boston, Massachusetts, USA (4).

Reprint requests: Anna Leszczynski, MD, 85 East Concord Street, Room 7721, Boston, MA 02118.

If you would like to chat with an author of this article, you may contact Dr Jacobson at Brian.Jacobson@bmc.org.

colonoscopy and the effect diet has upon bowel preparation. The American Society for Gastrointestinal Endoscopy advises that patients should limit their diet to clear liquids at least 1 day before colonoscopy,[8] whereas some experts have recommended liberalizing dietary restrictions before colonoscopy.[9–13]

A survey of pre-colonoscopy patient instructions from 201 endoscopy units nationwide found that diet instructions varied greatly.[14] Although 91% of endoscopy units requested a clear liquid diet (CLD) for the day before colonoscopy, 9% offered patients either low-residue or normal diets. Two-thirds of endoscopy units recommended avoidance of nuts, seeds, pulp, and fiber, and 84% recommended avoidance of dairy products. The timing of when to cease consumption of specific foods was also not standardized. For example, instructions indicating when to avoid nuts, seeds, pulp, and fiber ranged from 1 to 10 days (median, 3 days) before the colonoscopy. Yet it remains unknown exactly which dietary components affect bowel preparation in a clinically significant manner. These non-standardized dietary restrictions place inconsistent constraints on patients and may result in decreased patient satisfaction with the procedure and perhaps decreased compliance with the preparation.

A recent guideline on bowel cleansing released by the Multi-Society Task Force on Colorectal Cancer explicitly expressed concern with the paucity of data regarding the impact of diet on bowel preparation.[1] The guideline's authors were reluctant to make specific dietary recommendations, stating: "Pending additional study, colonoscopists should carefully evaluate any compromise in efficacy if dietary flexibility is allowed." Moreover, with an estimated 11 to 14 million colonoscopies performed annually in the United States,[15–17] if specific dietary restrictions are indeed necessary to ensure maximizing the endoscopist's ability to detect malignant or pre-malignant lesions, then identification of optimal instructions becomes an important public health endeavor.

We therefore conducted a study designed to provide data to scientifically inform "dietary flexibility" and determine whether fiber, in addition to other dietary components, consumed in the days leading up to colonoscopy are associated with bowel cleanliness during the procedure.

METHODS

This was a prospective observational study of patients scheduled for outpatient colonoscopy at Boston Medical Center, a safety-net academic medical center in Boston. The study was approved by our Institutional Review Board and funded by the National Institute of Diabetes and Digestive and Kidney Diseases.

Research team members called patients aged 50 years and older scheduled for colonoscopy from November 2015 to September 2016. Exclusion criteria included non-English speakers, previous bowel surgery, inability to complete a food diary/conduct a dietary interview by telephone, inability to tolerate a regular diet, and participation in another colonoscopy-related research study. Patients who provided verbal consent were mailed an information packet including the hospital's standard preparation instructions, which advise no dietary restrictions 3 days before colonoscopy (referred to here as day −3), avoidance of vegetables and beans 2 days before colonoscopy (day −2), and use of 4 L of split-dose polyethylene glycol with a CLD the day before colonoscopy (day −1). No specific instructions were given for the volume of clear liquids to consume. The packet also included instructions for participants to keep a 24-hour food record of all foods and beverages consumed on day −2, a sample completed food record, and a booklet picturing a variety of food-specific portions. A timeline depicting study components was also included in the pre-colonoscopy packet (Fig. 1).

On the morning of day −2, nutrition research staff conducted a scripted, 24-hour dietary recall interview by telephone. The multiple pass approach (ie, collect a list of consumed foods/beverages; probe for foods forgotten; collect time of consumption; probe for preparation details and portion sizes of food/beverages consumed; review for completeness) was used to elicit details on all foods and beverages consumed by patients on day −3. Patients were also instructed on how to complete the 1-day, prospective food record to self-report their intake on day −2. Patients were enrolled in the study after successfully completing the phone interview. Participants then independently completed the prospective detailed food diary for the remainder of day −2. On presentation to our endoscopy unit on the day of their colonoscopy, the research assistant administered a structured 24-hour dietary recall interview to capture all foods and beverages consumed on day −1, the intended clear liquid day. Next, the research assistant reviewed the day −2 participant-recorded food log, probing for details where needed to increase the accuracy of the self-report. Demographics and other patient information were also collected in a pre-procedure questionnaire and supplemented, when needed, via chart review. Participants received a $25 incentive if they completed all 3 dietary assessments.

Colonoscopies were observed by a study team physician who recorded procedure-related factors, including amount of fluid used for lavage, amount of fluid suctioned from the colon, colonoscope insertion and withdrawal times, and presence of polyps. The endoscopist was blinded to the dietary intake data. Our primary endpoint was the Boston Bowel Preparation Scale (BBPS) score as determined by the endoscopist, with bowel cleanliness determined for each segment of the colon after all washing was completed. With the BBPS, a higher score indicates a cleaner colon, and the range of scores is 0 to 9.[18,19]

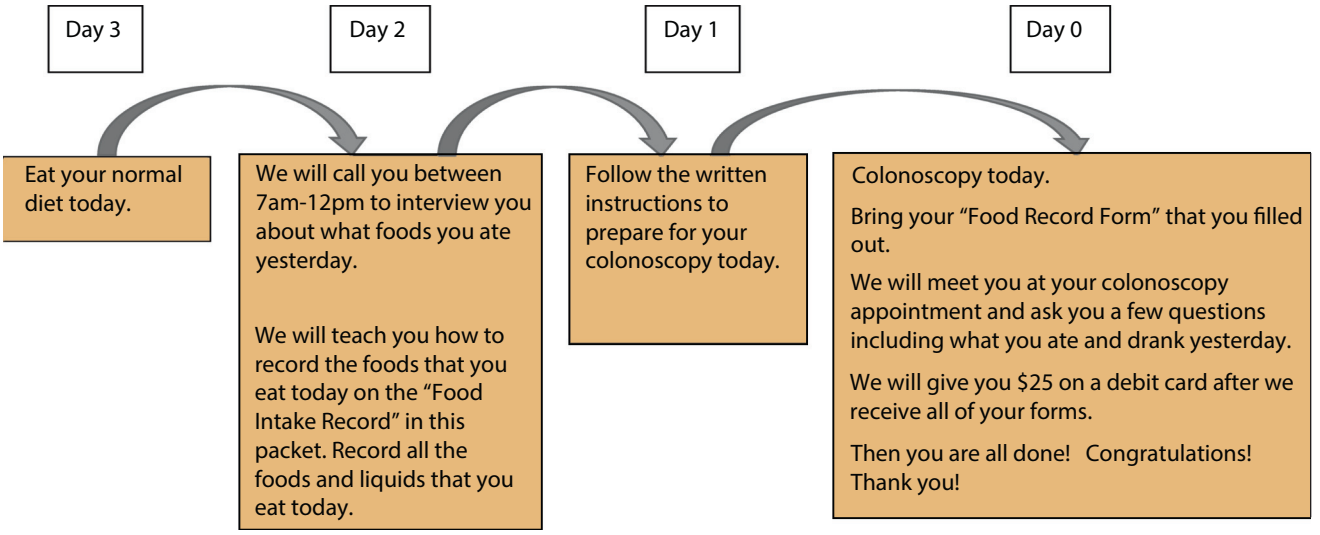

Figure 1. Study design flowchart. Instructions provided to participants outlining the study details and timeline.

Secondary endpoints included BBPS segment scores for the right, transverse, and left side of the colon (each segment score 0-3).

Dietary recalls and food records were coded using the Nutrition Data System for Research (NDSR, from the Nutrition Coordinating Center at the University of Minnesota), a research tool used to analyze dietary data, producing estimates of food and nutrient intake.[20] The NDSR database includes commodity and brand-name foods commonly consumed in the United States; it is updated annually to reflect changes in the marketplace.[21] The database contains over 18,000 foods and is widely used in research. Compliance with day −2 restriction of vegetables and legumes and with day −1 CLD guidelines was determined objectively based on reported dietary data, not on patients' self-assessment of compliance.

Statistical methods

For power considerations, a sample size of 160 participants was required to be able to detect a minimum linear slope of 0.15 between daily fiber intake in the days leading up to the colonoscopy and the BBPS score based on a 2-sided hypothesis test at a 5% significance level and a minimum of 80% power. This means that if at least a mild positive linear slope exists between fiber and bowel cleanliness as measured by BBPS, then our study would be sufficiently large to detect this association.

Spearman correlation coefficients were used to measure the association between dietary variables and BBPS scores because BBPS scores are measured on an ordinal scale. Multivariate linear regressions were conducted in an exploratory manner to investigate the association between each dietary component and BBPS scores and adjust for possible confounders, including age, gender, body mass index (BMI), and race/ethnicity. To assess whether participation in the study itself was independently associated with BBPS scores, we compared total BBPS scores from all patients who underwent outpatient colonoscopies in our endoscopy unit during the same time as our study cohort. All statistical analyses were conducted using the software package R (R Foundation for Statistical Computing, Vienna, Austria).[22]

RESULTS

We identified 1889 patients aged 50 years or older scheduled for outpatient colonoscopy between November 2015 and August 2016. We successfully engaged 711 patients by telephone and enrolled 204 participants (see Fig. 2 for the flow of potential participants through the enrollment process, and their reasons for exclusion when applicable). Among those enrolled, 168 completed their colonoscopy, contributed all 3 days of dietary data, and constituted our final cohort for analysis. Patient demographics are shown in Table 1. The mean age of the patients was 59.3 years (standard deviation [SD], ± 6.8 years); 60% were female, 53% were self-identified as black, and 61% of the colonoscopies were performed for colorectal cancer screening. Although our protocol excluded non-English speakers, 16% considered English to be their secondary language, and nearly 8% of participants had lived in the United States for 10 years or less. Twenty-seven percent of participants had received a bachelor's or graduate degree, and 58% had previously undergone at least 1 colonoscopy.

Despite receiving printed instructions and verbal reminders from our patient navigators, only 28 patients (17%) complied with the dietary restriction to eliminate vegetables and beans 2 days before colonoscopy (day −2). Higher, although not universal, compliance

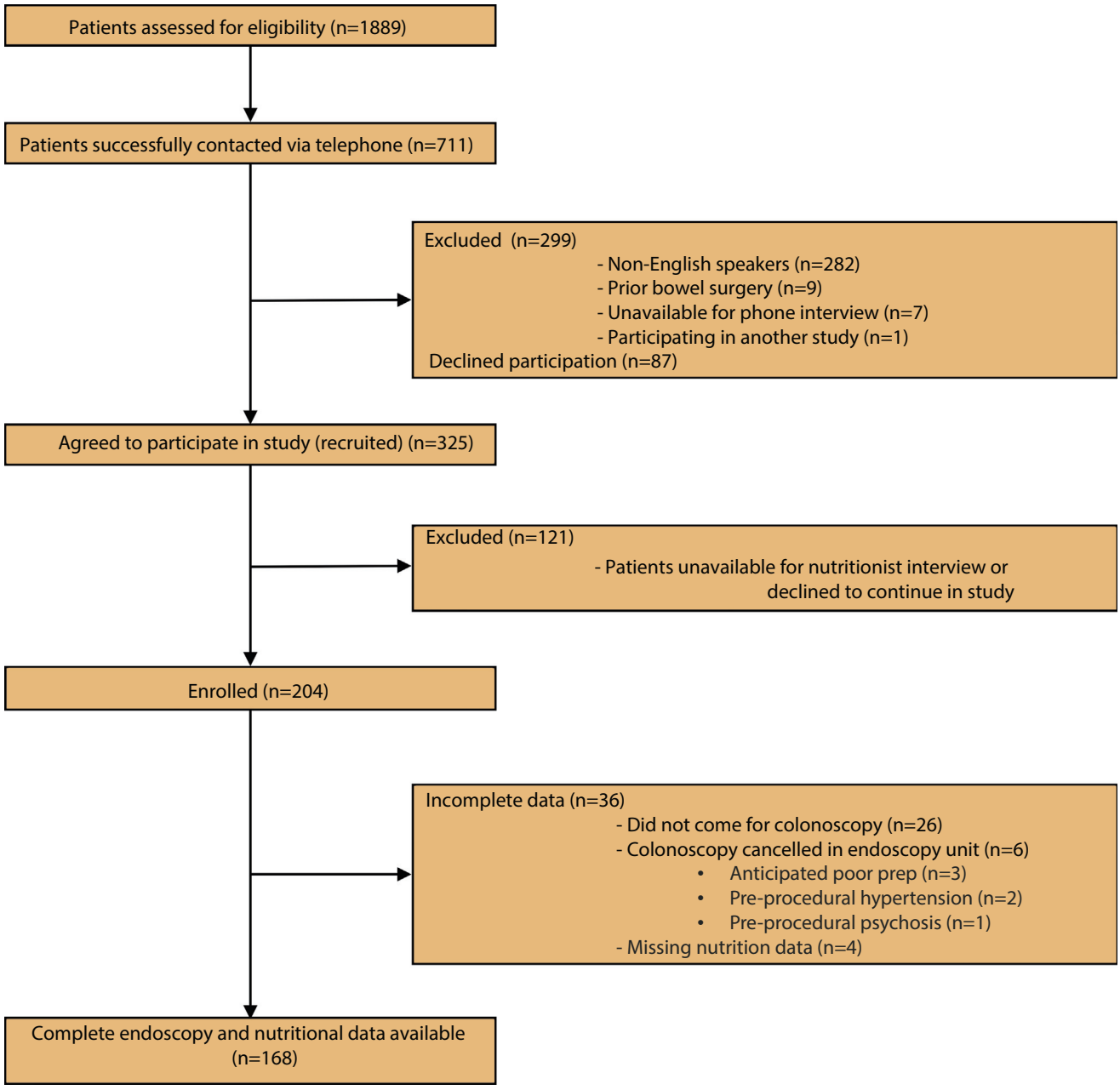

Figure 2. Patient enrollment process. CONSORT diagram of participant selection, recruitment, enrollment, and reasons for ineligibility.

was achieved with the CLD on day −1 (77%, n = 129). Despite objective evidence of noncompliance determined by our research team, 155 (92%) of our study participants reported no difficulty with understanding bowel preparation instructions, and 162 (96%) reported good understanding of the CLD instructions. Not surprisingly, 28% of patients reported at least some difficulty complying with the day −2 restrictions, and 43% reported difficulty complying with a CLD. In addition, 64 patients (38%) reported having to purchase specific food items in order to comply with the pre-procedure dietary instructions. More than 90% of participants drank at least three-quarters of the polyethylene glycol purgative.

Figure 3 shows the distribution of total BBPS scores among study participants. The median BBPS score was 9.0 (interquartile range [IQR], 2; mean BPPS, 7.9; SD, ±1.84) and 96% of patients had adequate bowel preparation, defined as having all 3 BBPS segment scores ≥2.[23] We calculated a median BBPS score of 7.0 (IQR, 2; mean BBPS score, 7.03; SD, ±1.49) among a comparison group of 2663 patients who underwent outpatient colonoscopy at our medical center during the same timeframe as our

TABLE 1. Demographics and baseline characteristics of study participants

Characteristic	Mean ± SD or n (%)
Patients who completed study with all data available	168
Female	100 (59.5%)
Age (years)	59.3 ± 6.8
Height (cm)	167 ± 9.4
Weight (kg)	85.4 ± 20.7
BMI (kg/m^2)	30.7 ± 7.4
Race	
White	62 (36.9)
Black	89 (53)
Asian	4 (2.4)
Native Hawaiian/Pacific Islander	1 (0.6)
American Indian	2 (1.2)
More than one race	4 (2.4)
Other	6 (3.6)
Ethnicity	
White Hispanic	8 (4.8)
Non-white Hispanic	9 (5.4)
Indication	
Screening	103 (61.3)
Surveillance	49 (29.1)
Diagnostic	16 (9.5)
Primary language	
English	142 (84.5)
Spanish	6 (3.6)
Haitian Creole	3 (1.8)
Portuguese Creole	1 (0.60)
Other	16 (9.5)
How long in the United States	
<5 years	10 (5.9)
5-10 years	3 (1.8)
>10 years	155 (92.3)
Highest level of education	
High school or less	68 (40.5)
Some college/trade school	55 (32.7)
Bachelor's degree	24 (14.3)
Graduate degree	21 (12.5)
Number of previous colonoscopies	1.5 ± 3.8
Compliant with restricted diet day −2 (no vegetables, no beans)	28 (17)
Compliant with clear liquid diet day −1	129 (77)

SD, Standard deviation; *BMI*, body mass index.

study (difference between mean BBPS scores of the 2 groups has a $P < .001$), suggesting that study participation itself was associated with bowel cleanliness.

Table 2 displays food and nutrient intake by study participants during the 3 days before colonoscopy. Results are presented in terms of the numbers of serving sizes consumed. Most nutrient intake decreased appropriately from day −3 (unrestricted diet) to day −1 (CLD), except for gelatin and water as expected. There was only a small difference in consumption of insoluble fiber comparing day −3 with day −2, consistent with the relatively low compliance observed in our study participants with vegetable/legume restriction for day −2. We also found that day −2 consumption of fruits, dairy, meat, poultry, fish, deli meats, nuts, and seeds was comparable with day −3 consumption, consistent with a lack of any self-imposed dietary restriction for those food groups. We also found no difference in compliance with a CLD depending on the time of colonoscopy (morning vs afternoon procedure).

Table 3 demonstrates the correlation between pre-colonoscopy dietary intake and both total and segmental BBPS scores. Total BBPS scores were compared with dietary data on all 3 days leading up to procedure, but segmental BBPS score were only examined in relation to day −1 intake. We found no association between total BBPS scores and any food or nutrient consumed on either day −3 or day −2. We found a positive association between total BBPS scores and consumption of gelatin and animal protein (derived in this case from gelatin) on day −1, with Spearman correlation coefficients of 0.228 ($P = .003$) and 0.115 ($P = .045$), respectively. We found an inverse association between total BBPS scores and meat consumption on day −1 with a Spearman correlation coefficient of −0.153 ($P = .048$) indicating that meat consumption may have a negative impact on bowel cleanliness (although only 4 participants [2.4%] consumed meat on day −1).

We also found positive associations between BBPS segment scores and consumption of gelatin (right and transverse colon segments) and animal protein (right side of the colon only) on day −1 (Table 3). We found significant inverse associations between BBPS segment scores and consumption of all vegetables (transverse colon), meats (transverse and left colon), and poultry (transverse colon) on day −1. Although legume consumption on day −1 also appears inversely associated with BBPS segment scores in the transverse and left side of the colon, only one study participant consumed legumes on day −1, making this result difficult to interpret. There was no association between volume of water consumed as a beverage and BBPS scores. We also examined whether there was an association between preparation adequacy (ie, BBPS ≥6 vs BBPS <6) and dietary intake on days −2 and −1, with all food groups showing no significant association. However, our study was not powered for this binary outcome, and this was performed in a purely exploratory manner.

In multivariate analyses of individual foods adjusted for age, gender, BMI, and race/ethnicity, day −1 consumption

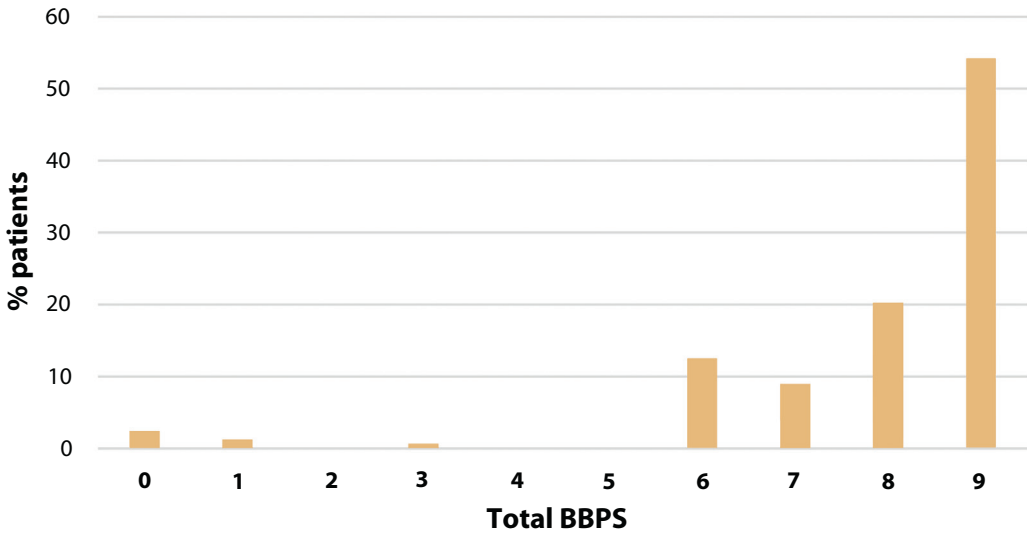

Figure 3. Distribution of Boston Bowel Preparation Scale (BBPS) scores. Frequency of observed total BBPS scores among participants.

of meat and gelatin were each significantly associated with total BBPS scores (Table 4). However, in a secondary analysis that included both of those foods simultaneously, only day −1 gelatin consumption remained significantly associated with total BBPS scores.

We also found that total BBPS scores were inversely associated with increasing volume of water used for intraprocedure colonic lavage and quantity of effluent fluid suctioned from the colon (Spearman correlation coefficients, −0.205; $P = .008$ and −0.249, $P = .001$, respectively). However, we did not find an association between procedure time and BBPS score (Spearman correlation coefficient, −0.033, $P = .675$), nor between consumption of any food or nutrient group and total procedure time. We found that consumption of dairy and poultry were each positively associated with the amount of fluid suctioned from the colon (Spearman correlation coefficients, 0.245, $P = .001$ and 0.162, $P = .037$, respectively).

DISCUSSION

In this observational study, we explored the relationship between dietary intake during the 3 days before colonoscopy and subsequent bowel cleanliness during the procedure as measured by the BBPS. Our findings provide much-needed support for current guidelines,[1,24] indicating no need for patients to alter their diet except on the day before colonoscopy, because only dietary intake on that day correlated with BBPS scores. We found that in the 24 hours before colonoscopy, consumption of gelatin and animal protein (reflecting gelatin intake) were associated with improved bowel cleanliness, whereas consumption of meat, poultry, vegetables, and whole grains were associated with worse bowel cleanliness. We had insufficient evidence that dietary fiber was associated with bowel preparation quality based on our sample size of enrolled patients.

Current guidelines suggest use of a full liquid to low-residue diet on the day before colonoscopy.[1] However, it is noted that this is a "weak" recommendation, with "moderate-quality" evidence according to the authors. Our findings therefore provide important additional evidence to support the current, more liberalized dietary guidelines. We also found that although most of our patients reported a good understanding of dietary and purgative instructions, fewer than 20% fully adhered to our restrictions against vegetables and beans 2 days before colonoscopy and ~75% fully adhered to a CLD the day before colonoscopy. Significant percentages of patients indicated difficulty complying with dietary restrictions, and many reported having to make food purchases to enable compliance.

Previous studies have examined the effects of pre-colonoscopy diet on bowel cleanliness. Stolpman and colleagues[25] compared bowel preparation quality in patients allowed a low-residue diet for breakfast and lunch the day before colonoscopy versus those on a CLD. They found that 96.5% of patients had BBPS scores ≥6. Those patients on a low-residue diet had noninferior bowel cleanliness compared with those on a CLD (mean BBPS scores, 8 vs 8.2, respectively), with similar polyp detection rates. Interestingly, patient tolerance of their preparation process did not differ between the 2 groups. In another study, Soweid and colleagues[26] evaluated the efficacy and tolerability of a polyethylene glycol-based preparation in patients who were randomized to either a fiber-free diet or a CLD. Both groups were given instructions indicating acceptable food options. The authors found that patients

TABLE 2. Food and nutrient intake levels (mean ± SD) on days leading up to colonoscopy (n = 168)

	Day −3: unrestricted diet	Day −2: restricted diet*	Day −1: clear liquid diet†
Foods (servings)			
All vegetables	2.12 ± 2.17	1.45 ± 1.60	0.09 ± 0.57
Green vegetables	0.53 ± 1.27	0.19 ± 0.58	0.01 ± 0.06
Legumes	0.18 ± 0.71	0.045 ± 0.19	0.003 ± 0.04
Citrus fruits	0.49 ± 1.53	0.39 ± 1.35	0.08 ± 0.45
Other fruits‡	1.13 ± 1.96	1.51 ± 2.56	1.43 ± 3.24
Dairy foods	1.37 ± 1.68	1.38 ± 1.59	0.05 ± 0.23
Meats	1.26 ± 2.29	1.11 ± 2.00	0.02 ± 0.15
Poultry	2.17 ± 3.26	2.21 ± 3.32	0.12 ± 0.86
Fish	0.66 ± 1.80	0.75 ± 1.78	0.06 ± 0.51
Deli meats	0.76 ± 1.99	0.56 ± 1.03	0.04 ± 0.36
Whole-grain foods	1.06 ± 2.15	1.07 + 1.77	0.082 + 0.48
Nuts and seeds	0.90 ± 3.11	0.67 ± 2.04	0.01 ± 0.18
Popcorn	0.05 ± 0.38	0.02 ± 0.21	0.00 ± 0.00
Water as a beverage	4.19 ± 4.60	4.72 ± 6.06	12.96 ± 5.96
Gelatin	0.03 ± 0.31	0.06 ± 0.45	1.27 ± 2.66
Nutrients (g)			
Soluble fiber	5.07 ± 3.58	5.02 ± 3.83	0.87 ± 1.64
Insoluble fiber	10.85 ± 9.94	9.56 ± 6.95	1.01 ± 2.57
Total fat	64.21 ± 45.03	57.96 ± 38.66	4.12 ± 8.75
Solid fat	28.15 ± 24.36	26.50 ± 22.70	2.04 ± 5.53
Total carbohydrate	185.00 ± 110.40	193.60 ± 105.87	91.17 ± 87.11
Animal protein	47.37 ± 32.67	47.81 ± 36.05	4.85 ± 9.80

*Participants were instructed to "stop eating vegetables and beans" and to drink at least 8 glasses of water 2 days before the procedure.
†Participants were instructed to "follow a strict clear liquid diet; to not eat any food or thick liquids."
‡Includes 100% fruit juice.

assigned to the fiber-free diet drank more preparation, had superior bowel cleanliness, and reported fewer side effects. However, the study's 33% rate of "unsatisfactory" bowel preparations is high compared with guidelines, which suggest an inadequacy rate of no more than 15%, making the results difficult to generalize.[1] In addition, the authors did not determine whether patients randomized to a fiber-free diet versus CLD actually adhered to these recommendations because no dietary recall was performed. Sipe and colleagues[27] also examined the effects of a low-residue diet on bowel preparation by providing patients with a handout with details of low-residue food options for breakfast, lunch, and a snack the day before colonoscopy and comparing BBPS scores between these patients and those adhering to a CLD. They found mean preparation scores were not different in either segmental or total scores (total BBPS 8.03 vs 7.89 in low-residue vs CLD groups, $P = .81$). Patient satisfaction with both bowel preparation and diet was significantly higher in the low-residue diet group. However, dietary recall was limited, with patients indicating the foods they ate from a pre-printed list.

Our study differed from those of previous authors in several important ways. First, we did not assign our patients specific food recommendations. They were given dietary restrictions for the 48 hours before colonoscopy but were free to eat whatever they liked within those restrictions. Therefore, their dietary habits more closely resembled real-world experiences, enabling us to study the impact of patients' personal choices on bowel preparation. We also applied a rigorous methodology for collecting, coding, and processing food intake data using standardized interview and coding protocols administered by trained research assistants using the NDSR database. We also examined patients' perception of compliance with pre-colonoscopy guidelines but then compared this with their food records to assess for objective evidence of compliance. We found a discordance between patients' stated compliance rates and their actual food intake. This may be related to low health literacy or the way we communicate with our patients, which typically consists of listing excluded food groups but giving few examples of acceptable choices.

In a subgroup analysis of bowel segments (transverse, right, and left), we found certain foods were correlated with total BBPS scores, but other foods and nutrients were correlated with bowel cleanliness only for particular

TABLE 3. Correlation between pre-colonoscopy dietary intake and total/segmental BBPS scores (n = 168)

	Spearman (*P* value)					
	Total BBPS			Right BBPS	Transverse BBPS	Left BBPS
	Day −3	Day −2	Day −1	Day −1	Day −1	Day −1
Foods (servings)						
All vegetables	0.111 (.154)	0.04 (.607)	−0.102 (.187)	−0.08 (.302)	−0.161 (.038)	−0.086 (.266)
Green vegetables	0.09 (.247)	−0.113 (.143)	−0.112 (.148)	−0.124 (.11)	−0.053 (.493)	−0.068 (.385)
Legumes	0.061 (.434)	0.034 (.665)	NA*	NA*	NA*	NA*
Citrus fruit	0.034 (.658)	−0.009 (.905)	−0.04 (.609)	−0.016 (.838)	−0.048 (.536)	−0.08 (.306)
Other fruit	0.003 (.973)	0.041 (.601)	−0.082 (.289)	−0.097 (.212)	−0.071 (.358)	−0.058 (.452)
Dairy	−0.013 (.866)	0.042 (.589)	0.019 (.809)	−0.005 (.944)	−0.025 (.746)	0.035 (.65)
Meat	0.004 (.959)	−0.066 (.395)	−0.153 (.048)	−0.13 (.092)	−0.182 (.018)	−0.206 (.007)
Poultry	0.000 (.996)	−0.006 (.941)	−0.108 (.164)	−0.109 (.16)	−0.168 (.029)	−0.129 (.096)
Fish	−0.047 (.547)	0.132 (.088)	−0.01 (.893)	0.022 (.781)	−0.019 (.81)	0.071 (.358)
Deli meat	0.049 (.531)	0.028 (.723)	0.096 (.218)	0.088 (.255)	0.065 (.403)	0.058 (.455)
Whole-grain foods	0.031 (.686)	0.001 (.957)	−0.166 (.031)	−0.166 (.031)	−0.233 (.002)	−0.125 (.106)
Nuts/seeds	0.028 (.719)	0.045 (.559)	−0.042 (.589)	0.062 (.423)	−0.122 (.116)	0.041 (.598)
Popcorn	−0.031 (.694)	0.018 (.821)	NA*	NA*	NA*	NA*
Water as a beverage	0.041 (.595)	−0.072 (.355)	−0.073 (.345)	−0.028 (.719)	−0.066 (.394)	−0.084 (.281)
Gelatin	0.067 (.385)	0.028 (.715)	0.228 (.003)	0.252 (.001)	0.194 (.012)	0.148 (.056)
Nutrients (g)						
Soluble fiber	0.049 (.532)	−0.009 (.905)	−0.043 (.583)	0.005 (.948)	−0.093 (.23)	−0.101 (.193)
Insoluble fiber	0.077 (.318)	0.012 (.878)	−0.056 (.472)	−0.038 (.622)	−0.104 (.178)	−0.045 (.567)
Total fat	−0.011 (.89)	0.101 (.194)	0.01 (.895)	−0.029 (.71)	−0.035 (.655)	0.055 (.475)
Solid fat	−0.025 (.745)	−0.032 (.681)	0.093 (.232)	0.101 (.193)	0.03 (.704)	0.065 (.402)
Total carbohydrates	0.034 (.658)	0.002 (.98)	0.033 (.668)	0.069 (.375)	0.015 (.843)	0.034 (.661)
Animal protein	−0.029 (.714)	0.003 (.967)	0.115 (.045)	0.189 (.014)	0.078 (.314)	0.098 (.208)

BBPS, Boston Bowel Preparation Scale.
*Insufficient data owing to a single participant consuming legumes and no participants consuming popcorn.

TABLE 4. Multivariate linear regression analysis of food intake on day −1 and resulting BBPS (n = 168)

Dietary component	Estimate	Standard error	*T* value	*P* value
Total animal protein (g)*	−0.009307	0.015295	−0.608	.544
Total meat*	−0.07830	0.03352	−2.336	.0207
Total poultry*	−0.009898	0.005941	−1.666	.0977
Gelatin*	0.002553	0.001166	2.189	.0301
Gelatin†	0.002377	0.001155	2.058	.0412

BBPS, Boston Bowel Preparation Scale.
*Controlled for age, gender, body mass index, race, and ethnicity.
†Controlled for age, gender, body mass index, race, ethnicity, and meat intake.

segments of the colon. It is likely this represents limited power for specific foods and bowel segments, because it seems implausible that certain foods only have an impact on bowel cleanliness in some segments. Moreover, multivariate analysis controlling for age, gender, BMI, race and ethnicity, and total meat intake on the day before colonoscopy was associated with worse bowel preparation, whereas gelatin's association with better preparations persisted. We postulate that gelatin's association with improved bowel cleanliness reflects simply that it is a marker of compliance with a CLD. Likewise, the positive association of animal protein with improved bowel cleanliness (whereas meat consumption had an inverse association) likely reflects the large quantity of animal protein present in gelatin products.

Our study had several strengths, including racial and ethnic diversity among our study participants, making our results generalizable to a broad range of patients;

use of a standardized dietary data collection protocol that minimized exposure measurement error; use of a standardized, reliable bowel preparation rating scale (BBPS), which minimized outcome measurement errors; and use of a robust nutritional data analysis program. Nonetheless, we acknowledge certain limitations. We did not specifically inquire of the 23% of study participants why they failed to comply with the CLD. More than 40% of our patients reported that complying with a CLD was "difficult" or "very difficult," although almost all reported no difficulty understanding the instructions for a CLD. Nearly 40% also reported having to buy food specifically to follow our dietary restrictions, which may have been a factor in noncompliance. Although we had sufficient power to detect differences in BBPS scores based on typical dietary variation between patients, our subgroup analyses should be taken as exploratory. In addition, our nearly 96% bowel preparation adequacy rate exceeds those reported in many studies.[28] However, we found a similar rate of adequate preparation among non-study patients at our institution undergoing colonoscopy during the same period as our study. In addition, previously published data from our institution showed similar historical rates of adequate bowel preparation.[29] Our comparison group's mean BBPS scores were lower than those of study participants (7.0 vs 7.9, $P < .001$), yet both of these values indicate adequate bowel preparation and therefore likely have minimal clinical significance. However, the difference between groups does suggest that participation in the study was independently associated with bowel preparation. This may reflect selection bias, but does not invalidate the correlations observed between diet and bowel cleanliness. Moreover, the high adequacy rate despite large numbers of patients who failed to comply with dietary instructions provides further evidence that restrictive diets are not required to achieve adequate bowel preparation. We had very small numbers of patients with comorbidities/medications that may have an impact on bowel preparation, limiting our ability to explore interactions between diet and these conditions. Finally, although we found statistically significant correlations between specific foods and BBPS scores, these were generally weak correlations. However, we consider this an important message about our findings; namely that restrictive diets in the days leading to colonoscopy are not supported by strong associations between what people eat and their bowel cleanliness. We recognize that diet restrictions will likely persist and therefore consider our results to be a much-needed addition to the literature to provide at least some evidence-based rationale if one does want to impose dietary restrictions.

In summary, our study supports current guidelines to only restrict diet 1 day before colonoscopy, to avoid high-residue foods, and to freely include the use of gelatin and other clear liquids on the day before colonoscopy. We found no evidence that dietary fiber was associated with bowel preparation quality. Restrictive, multi-day dietary instructions appear confusing and inconvenient to patients without providing significant impact on bowel preparation quality or procedure time.

REFERENCES

1. Johnson DA, Barkun AN, Cohen LB, et al. Optimizing adequacy of bowel cleansing for colonoscopy: recommendations from the U.S. Multi-Society Task Force on Colorectal Cancer. Gastrointest Endosc 2014;80:543-62.
2. Froehlich F, Wietlisbach V, Gonvers J-J, et al. Impact of colonic cleansing on quality and diagnostic yield of colonoscopy: the European Panel of Appropriateness of Gastrointestinal Endoscopy European multicenter study. Gastrointest Endosc 2005;61:378-84.
3. Harewood GC, Sharma VK, Garmo P de. Impact of colonoscopy preparation quality on detection of suspected colonic neoplasia. Gastrointest Endosc 2003;58:76-9.
4. Kazarian ES, Carreira FS, Toribara NW, et al. Colonoscopy completion in a large safety net health care system. Clin Gastroenterol Hepatol 2008;6:438-42.
5. Chokshi RV, Hovis CE, Hollander T, et al. Prevalence of missed adenomas in patients with inadequate bowel preparation on screening colonoscopy. Gastrointest Endosc 2012;75:1197-203.
6. Lebwohl B, Kastrinos F, Glick M, et al. The impact of suboptimal bowel preparation on adenoma miss rates and the factors associated with early repeat colonoscopy. Gastrointest Endosc 2011;73:1207-14.
7. Rex DK, Imperiale TF, Latinovich DR, et al. Impact of bowel preparation on efficiency and cost of colonoscopy. Am J Gastroenterol 2002;97:1696-700.
8. Wexner SD, Force T, Beck DE, et al. A consensus document on bowel preparation before colonoscopy: Prepared by a Task Force From The American Society of Colon and Rectal Surgeons (ASCRS), the American Society for Gastrointestinal Endoscopy (ASGE), and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). Gastrointest Endosc 2006;63:894-909.
9. Aoun E, Abdul-Baki H, Azar C, et al. A randomized single-blind trial of split-dose PEG-electrolyte solution without dietary restriction compared with whole dose PEG-electrolyte solution with dietary restriction for colonoscopy preparation. Gastrointest Endosc 2005;62:213-8.
10. Delegge M, Kaplan R. Efficacy of bowel preparation with the use of a prepackaged, low fibre diet with a low sodium, magnesium citrate cathartic vs. a clear liquid diet with a standard sodium phosphate cathartic. Aliment Pharmacol Ther 2005;21:1491-5.
11. Park DI, Park SH, Lee SK, et al. Efficacy of prepackaged, low residual test meals with 4L polyethylene glycol versus a clear liquid diet with 4L polyethylene glycol bowel preparation: a randomized trial. J Gastroenterol Hepatol 2009;24:988-91.
12. Stengel JZ, Jones DP. Single-dose lubiprostone along with split-dose PEG Solution without dietary restrictions for bowel cleansing prior to colonoscopy: a randomized, double-blind, placebo-controlled trial. Am J Gastroenterol 2008;103:2224-30.
13. Wu K-L, Rayner CK, Chuah S-K, et al. Impact of low-residue diet on bowel preparation for colonoscopy. Dis Colon Rectum 2011;54:107-12.
14. Ton L, Lee H, Taunk P, et al. Nationwide variability of colonoscopy preparation instructions. Dig Dis Sci 2014;59:1726-32.
15. Centers for Disease Control and Prevention (CDC). Vital signs: colorectal cancer screening test use–United States, 2012. MMWR Morb Mortal Wkly Rep 2013;62:881-8.
16. Peery AF, Dellon ES, Lund J, et al. Burden of gastrointestinal disease in the United States: 2012 update. Gastroenterology 2012;143:1179-87.e3.
17. Seeff LC, Richards TB, Shapiro JA, et al. How many endoscopies are performed for colorectal cancer screening? Results from CDC's survey of endoscopic capacity. Gastroenterology 2004;127:1670-7.

18. Lai EJ, Calderwood AH, Doros G, et al. The Boston Bowel Preparation Scale: a valid and reliable instrument for colonoscopy-oriented research. Gastrointest Endosc 2009;69:620-5.
19. Calderwood AH, Jacobson BC. Comprehensive validation of the Boston Bowel Preparation Scale. Gastrointest Endosc 2010;72:686-92.
20. Schakel SF, Sievert YA, Buzzard IM. Sources of data for developing and maintaining a nutrient database. J Am Diet Assoc 1988;88:1268-71.
21. Schakel SF. Maintaining a nutrient database in a changing marketplace: keeping pace with changing food products—a research perspective. J Food Compost Anal 2001;14:315-22.
22. R Core Team. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing; 2012. Available at: http://www.R-project.org/.
23. Calderwood AH, Schroy PC, Lieberman DA, et al. Boston Bowel Preparation Scale scores provide a standardized definition of adequate for describing bowel cleanliness. Gastrointest Endosc 2014;80:269-76.
24. Hassan C, Bretthauer M, Kaminski M, et al. Bowel preparation for colonoscopy: European Society of Gastrointestinal Endoscopy (ESGE) guideline. Endoscopy 2013;45:142-55.
25. Stolpman DR, Solem CA, Eastlick D, et al. A randomized controlled trial comparing a low-residue diet versus clear liquids for colonoscopy preparation: impact on tolerance, procedure time, and adenoma detection rate. J Clin Gastroenterol 2014;48:851-5.
26. Soweid A, Kobeissy A, Jamali F, et al. A randomized single-blind trial of standard diet versus fiber-free diet with polyethylene glycol electrolyte solution for colonoscopy preparation. Endoscopy 2010;42:633-8.
27. Sipe BW, Fischer M, Baluyut AR, et al. A low-residue diet improved patient satisfaction with split-dose oral sulfate solution without impairing colonic preparation. Gastrointest Endosc 2013;77:932-6.
28. MacArthur KL, Leszczynski AM, Jacobson BC. Enhancing bowel preparation instructions: Is the bang worth the buck, or are we stuck with the muck? Gastrointest Endosc 2017;85:98-100.
29. Calderwood AH, Mahoney EM, Jacobson BC. A plan-do-study-act approach to improving bowel preparation quality. Am J Med Qual 2017;32:194-200.