

The role of fiber supplementation in the treatment of irritable bowel syndrome: a systematic review and meta-analysis

Neeraja Nagarajan^{a,b,*}, Amanda Morden^{a,*}, Danielle Bischof^{a,b}, Elizabeth A. King^{a,b}, Martin Kosztowski^a, Elizabeth C. Wick^b and Ellen M. Stein^c

Irritable bowel syndrome (IBS) is a functional bowel disorder associated with a wide variety of clinical symptoms. The use of fiber in treatment of IBS is well established, but recent reviews have shown conflicting evidence. The aim of our review was to study the effects of fiber (soluble and insoluble) on the symptoms of IBS. Medline, EMBASE, Cochrane Central, CINAHL, LILACS, and ClinicalTrials.gov were searched for appropriate studies. Two reviewers screened the title/abstract and full text against the inclusion criterion – that is, randomized control trials/crossover studies that compare fiber with placebo for its effect on IBS in an outpatient setting. Independent double data extraction was performed across multiple fields. An assessment of the risk of bias and tests for heterogeneity were carried out, along with a meta-analysis of the outcomes of interest. The search yielded 4199 unique records; 121 were selected after title/abstract screening and 22 after full screening. There was moderate clinical, methodological, and statistical heterogeneity across studies, with a moderate risk of bias. Overall, there was a significant improvement in global assessment of symptoms among those randomized to fiber [risk ratio: 1.27; 95% confidence interval (CI): 1.05–1.54]. Soluble fiber improved assessment of symptoms (risk ratio 1.49; 95% CI: 1.09–2.03), as well as the abdominal pain score (mean difference: –1.84; 95% CI: –2.72 to –0.97), with insoluble fiber not showing improvement in any outcome. Soluble fiber appears to improve symptoms of IBS, whereas there is no evidence for recommending insoluble fiber for IBS. *Eur J Gastroenterol Hepatol* 27:1002–1010

Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.

Background

Irritable bowel syndrome (IBS) is a functional gastrointestinal (GI) disorder that is characterized by chronic abdominal pain (AP), discomfort, and altered bowel habits [1–3]. There are a wide range of contributing factors influencing the development of IBS in individuals including genetic factors, altered colonic motility, abnormal brain activation, serotonin dysfunction, inflammation of the GI tract, abnormal intestinal flora, visceral hypersensitivity, and psychological factors [4]. IBS is a common GI condition with a worldwide prevalence of 10–15% [2,3,5] and a higher prevalence among women [6].

IBS is a chronic disorder, with the majority of patients first treated in the primary care setting [1,7–9]. There are a number of well-described criteria for the diagnosis of IBS,

including the Kruis, Manning, and Rome I, II, and III criteria [10–12], of which only Rome criteria have been validated [13]. Most general physicians still rely on patient-reported symptoms to make the diagnosis [14–16]. Therapeutic management of IBS is focused on control of symptoms with fiber, antispasmodics, and commonly used antidepressants [17]. Fiber is used for its effect on stool consistency and transit time [9,18]. Methods of increasing fiber intake include modifying the patient's diet to include more fiber-containing foods, as well as supplementing the diet with fiber supplements [9,19,20]. Both soluble and insoluble fibers have been studied for their effect on IBS [21–24].

Previous reviews on fiber use in IBS have shown conflicting results [25–27]. Most reviews have ranged from reporting no change compared with placebo to marginal differences depending on the type of fiber used [9,17,28]. The purpose of this review was to systematically assess the effect of fiber on the symptoms of IBS, taking into consideration trials that have been reported since the last systematic review addressing the topic was published.

Methods

The protocol for the review was registered with PROSPERO, an international prospective registry of systematic reviews [29]. There were no deviations from the protocol.

European Journal of Gastroenterology & Hepatology 2015, 27:1002–1010

Keywords: fiber supplementation, functional bowel disease, irritable bowel syndrome

^aJohns Hopkins Bloomberg School of Public Health, Departments of ^bSurgery and ^cMedicine, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA

Correspondence to Ellen M. Stein, Gastroenterology and Hepatology, 600 N. Wolfe St., The Johns Hopkins University School of Medicine, Baltimore, MD 21287, USA Tel: +410 550 1324; fax: +410 614 8799; e-mail: estein6@jhmi.edu

*Neeraja Nagarajan and Amanda Morden contributed equally to the writing of this article.

Received 6 April 2015 **Accepted** 27 May 2015

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (www.eurojgh.com).

Data sources and searches

Medline, EMBASE, CINAHL, LILACS, and Cochrane CENTRAL were searched using controlled vocabulary and related keywords/synonyms. The databases were searched for IBS (population), fiber supplementation (exposure), and a randomized control trial (RCT) hedge (human trials; see Appendix A, Supplemental digital content 1, <http://links.lww.com/EJGH/A45> for the complete search strategy, dates, and number of citations). Clinicaltrials.gov and ICTRP were searched to locate trials that were underway and had not yet been published. Web of Science and Google Scholar were utilized to screen the citations and references for each of the included studies. Conference proceedings of the American Gastroenterology Association, the American Society for Parenteral and Enteral Nutrition, and the *American Journal of Gastroenterology* were also searched to locate relevant articles.

Study selection

Included in this review were RCTs, and quasirandomized and crossover studies. The review included participants over 14 years of age who were diagnosed before the intervention on the basis of physician opinion or clinical criteria (Manning, Kruis, or Rome I, II, or III). Studies were included only if they were conducted in an outpatient setting and if they compared supplementary dietary fiber (soluble and insoluble) with placebo or no treatment. They were excluded if they had adjunctive interventions along with fiber. Studies with multiple arms were included, but data were analyzed only from the fiber and placebo arms. Studies with a minimum treatment period of 2 weeks were included, and the minimum time from treatment to assessment of outcomes was 2 weeks. There was no restriction on the maximum time for treatment.

There were no restrictions on the basis of country of origin, language, number of participants, or time since publication. During the full-text screening, studies were excluded if they were non-English. There was no restriction on the basis of maximum age, sex, ethnicity, comorbidities, or severity of symptoms before treatment.

Data extraction and quality assessment

Two reviewers independently screened each study on the basis of predefined inclusion and exclusion criteria. Any discordance between reviewers was adjudicated by joint consensus. The initial screening was at the title and abstract levels. The secondary screening was at the full-text level, where studies were reviewed in depth to ensure that they met all the prespecified criteria for inclusion. Data were then extracted from the selected studies and entered into a database by two independent reviewers (see Appendix B, Supplemental digital content 1, <http://links.lww.com/EJGH/A45> for each category extracted). After data extraction, differences between extracted data were assessed and resolved by group consensus. The authors were contacted for missing data. If there was no response, we treated the missing data as random. Data were then entered into RevMan 5.0 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen) [30] by one data extractor and checked for discrepancies by the other

data extractor. Two reviewers independently performed assessments of the risk of bias in each study and the group-discussed discrepancies between reviewers. The checklist was adapted from the Cochrane Handbook Version 5.1.0 [31].

Data synthesis and analysis

Clinical and methodological heterogeneities were assessed and noted in our qualitative synthesis. Statistical heterogeneity was assessed in terms of I^2 . A funnel plot was created to visually assess the potential for publication bias.

The primary outcome of interest was Global Assessment of IBS Symptoms (GAS), measured as a dichotomous outcome (improved or not improved). The secondary outcomes under study were IBS-symptom severity score (IBS-SSS), IBS-quality of life (IBS-QOL), and abdominal pain score (APS) as continuous outcomes, measured by a change in the mean score in the different treatment groups; AP was also measured as a dichotomous outcome (improved or not improved). Adverse effects reported in individual studies were noted and further analyzed for trends. The proportion of participants completing the trial in each of the two groups was also compared.

We reported risk ratio (RR) for outcomes that were dichotomous (GAS, AP). For continuous outcomes, we reported the mean difference and conducted a *t*-test (APS, IBS-SSS, IBS-QOL). Standard mean differences were used if different methods were used in the different studies included. Completion of the trial was reported as an RR.

A meta-analysis was carried out with a random effects model, as studies varied on many clinical, methodological, and statistical characteristics. The meta-analysis was carried out using an intention-to-treat analysis. χ^2 -Tests, as well as forest plots, were used to assess the level of overlap between the studies. A subgroup analysis was carried out for soluble versus insoluble fiber. A sensitivity analysis was carried out for studies with a low risk of bias across all domains, and for only RCTs. A per-protocol analysis was also undertaken as a sensitivity analysis.

Results

Search results

Medline, EMBASE, Cochrane CENTRAL, CINAHL, LILACS, and ClinicalTrials.gov were searched on 16 September 2014 at 16:00 h (see Appendix A, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>, for detailed search strategy). A total of 866 studies were identified from PubMed, 3206 from EMBASE, 185 from Cochrane CENTRAL, 182 from CINAHL, 734 from LILACS, and two from ClinicalTrials.gov. The American Gastroenterology Association yielded 1280 studies; the American Society for Parenteral and Enteral Nutrition, 36 studies; and the *American Journal of Gastroenterology*, 656 studies. The studies were combined and the duplicates were removed to give 4199 unique studies (see Fig. 1 for PRISMA flow chart). At the title and abstract screening, 121 studies were selected for further evaluation. At the level of full-article review, the results were further narrowed down to 22 [1,21–24,32–48] unique studies.

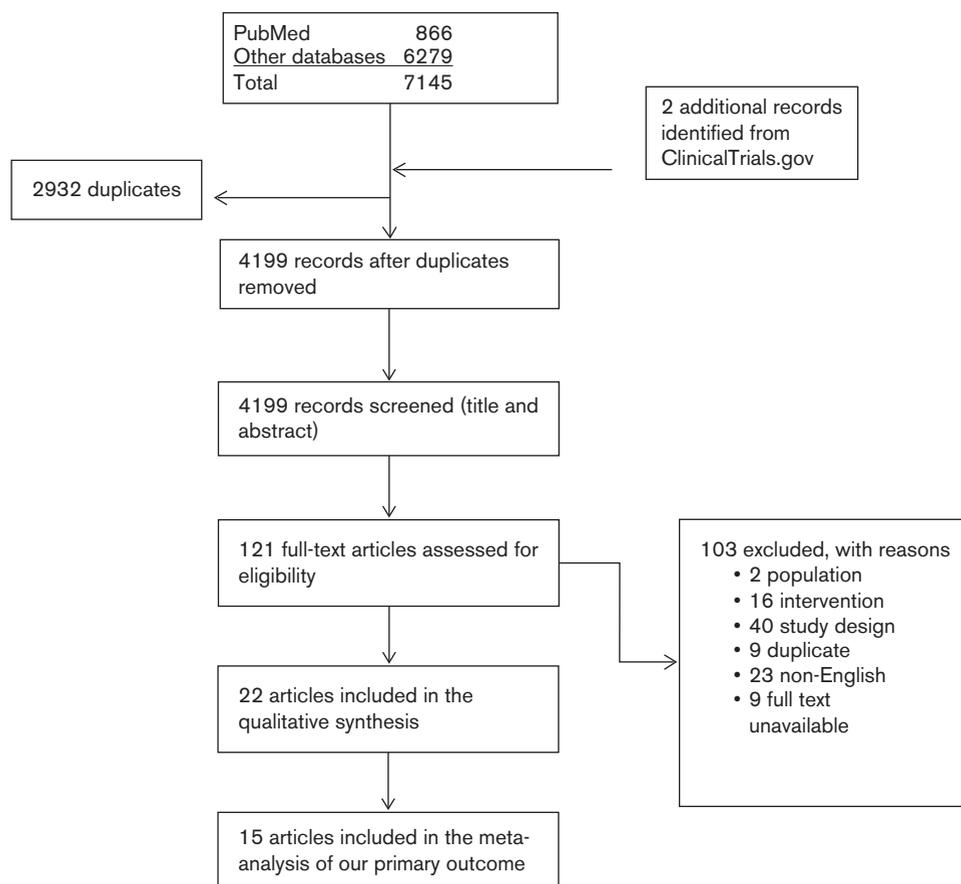


Fig. 1. PRISMA flowchart for included studies.

Qualitative analysis

The review included 11 studies [1,21–23,32–37,48] examining the effect of soluble fiber on IBS and 12 studies [1,24,38–47] assessing insoluble fiber (Table 1). One study [1] assessed the effect of both soluble and insoluble fibers on IBS. The included studies were published between 1976 and 2013 and were conducted in eight countries: UK: 10, India: 4, USA: 2, Denmark: 2, Netherlands: 1, Spain: 1, Germany: 1, Australia: 1 (Table 1). Fourteen studies were randomized control trials [1,21,32,33,35–37,40–44,46,48], whereas eight were crossover studies [22–24,34,38,39,45,47].

Overall, there were 1299 participants in the studies included in the systematic review. Patient ages ranged from 15 to 78 years. Only five studies [1,32,33,42,45] provided details on the type of IBS that the patients had; among the 621 patients in those studies, 37.8% has IBS-C, 35.1% had IBS-M, and 27.1% had IBS-D.

Of the 11 studies using soluble fiber as the intervention, seven used psyllium/isphagula, and one each used linseed, calcium polycarbophil, Metamucil, and methylcellulose (Table 1). Among the 12 studies that randomized insoluble fiber, nine used wheat bran, and one each used corn fiber, vegetable fiber, and cereal/fruit fiber (Table 1). There was a broad range of doses administered for the fiber group, from 4.1 to 40 g/day (Table 1). The duration of therapy ranged from 3 to 16 weeks (Table 1). A variety of outcomes were assessed in the included studies, including

GAS, IBS-SSS, IBS-QOL, APS, AP, bowel movement characteristics, and measures of depression (Table 1).

Included studies spanned five decades, with the earliest study from 1977 [43] and the latest from 2013 [33]. Studies from 2000 onward [1,32,33,44] were all pure RCTs, and tended to have low risk of bias compared with studies published before 2000 (Table 1 and Appendix C, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). In addition, all four studies from 2000 onward used Rome III criteria to include patients with IBS, whereas earlier studies used clinical symptoms and/or other criteria.

Assessment of risk of bias

There was moderate heterogeneity of risk across the included studies (Fig. 2 and Appendix C, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). The vast majority of studies did not report how random sequence generation or allocation concealment was completed. This resulted in an unclear risk of bias for these domains in the majority of studies. This could have resulted in significant selection bias. There was a low risk of bias for blinding of participants in 50% of the studies; in the remaining studies, the participants were not blinded or the manuscript did not state whether the participants were blinded. There was a low risk of bias for blinding of outcome assessment in around 70% of the studies; in the remaining studies, the manuscript did not state whether outcome assessors had been blinded. The lack of blinding

Table 1. Study characteristics

Reference	Country	Method	Participants (n)	Diagnosis	Intervention	Dose (g/day)	Duration (weeks)	Outcomes
Soluble fiber								
Bijkerk <i>et al.</i> [1]	Netherlands	RCT	275	Rome III	Psyllium	10	12	(1) GAS, (2) IBS-SSS, (3) APS, (4) IBS-QOL
Cockerell <i>et al.</i> [32]	UK	RCT	40	Rome III	Linseed	24	4	(1) IBS-SSS
Everitt <i>et al.</i> [33]	UK	RCT	92	Rome III	Methylcellulose	Unclear	6	(1) GAS, (2) IBS-SSS, (3) IBS-QOL, (4) Hospital Anxiety and Depression Scale, (5) patient enablement score
Golecha <i>et al.</i> [34]	India	Crossover	26	Clinical	Isphagula	Unclear	3 each	(1) GAS
Jalilhat and Kurian [23]	India	Crossover	20	Clinical	Isphagula husk	30	4 each	(1) GAS
Longstreth <i>et al.</i> [21]	USA	RCT	77	Clinical	Metamucil	19.2	8	(1) GAS, (2) APS, (3) bowel movements, (4) GAS, (5) interference of symptoms on functioning
Nayak <i>et al.</i> [35]	India	RCT	30	Manning	Isphagula	20	8	(1) IBS-SSS, (2) APS, (3) bowel movement, (4) stool consistency, (5) mucus in stool, (6) incomplete evacuation, (7) propagated contractions as recorded by rectosigmoid manometry
Nigam <i>et al.</i> [48]	India	RCT	168	Clinical	Isphagula	Unclear	12	(1) GAS
Prior and Whonwell [36]	UK	RCT	80	Clinical	Isphagula	10.8	12	(1) GAS
Ritchie and Truelove [37]	UK	RCT	24	Clinical	Isphagula	7	12	(1) GAS
Toskes <i>et al.</i> [22]	USA	Crossover	28	Clinical	Calcium polycarbophil	6	12	(1) Stool frequency/consistency/ease, (2) nausea, (3) AP, (4) bloating, (5) GAS
Insoluble fiber								
Arffmann <i>et al.</i> [38]	Denmark	Crossover	20	Clinical	Wheat bran	30	6 each	(1) AP, (2) fecal mass, (3) recovery of ingested markers, (4) distention score, (5) rumbling score
Bijkerk <i>et al.</i> [1]	Netherlands	RCT	275	Rome III	Wheat bran	10	12	(1) GAS, (2) IBS-SSS, (3) APS, (4) IBS-QOL
Cann <i>et al.</i> [24]	UK	Crossover	38	Clinical	Wheat bran	10-30	4 each	(1) Frequency and consistency of stools, (2) urgency, (3) pain, (4) distension
Cook <i>et al.</i> [39]	Australia	Crossover	14	Clinical	Corn cookie	20	12 each	(1) IBS-SSS, (2) APS, (3) pain frequency, (4) pain duration, (5) stool frequency, (6) additional symptoms
Diaz-Rubio <i>et al.</i> [40]	Spain	RCT	34	Clinical	Vegetable fiber	39.13	12	(1) AP, (2) bowel movements
Fowle <i>et al.</i> [41]	UK	RCT	49	Clinical	Cereal and fruit tablet	4.1	12	(1) GAS, (2) urgency to defecation, (3) constipation (4) AP, (5) relief of pain at defecation, (6) mucus in stool, (7) distention, (8) flatulence or borborygmi, (9) incomplete evacuation, (10) depression score
Kruis <i>et al.</i> [42]	Germany	RCT	120	Clinical	Wheat bran	15	16	(1) GAS
Lucey <i>et al.</i> [47]	UK	Crossover	44	Manning	Wheat bran	12.8	12	(1) Total symptom score, (2) stool weight
Manning <i>et al.</i> [43]	UK	RCT	26	Clinical	Wheat bran	20	6	(1) GAS, (2) AP
Rees <i>et al.</i> [44]	UK	RCT	28	Rome III	Wheat bran	10-20	8-12	(1) GAS, (2) APS, (3) stool weight, (4) gut transit time, (5) bowel movement, (6) distention
Snook and Shepherd [45]	UK	Crossover	80	Kruis	Wheat bran	40	7	(1) GAS, (2) AP, (3) bloating
Softoff <i>et al.</i> [46]	Denmark	RCT	59	Clinical	Wheat bran	30	6	(1) GAS, (2) bowel movements, (3) consistency/frequency, (4) pain, (5) borborygmi, (6) distention, (7) laxative use

AP, abdominal pain; APS, abdominal pain score; GAS, Global Assessment of IBS Symptoms; IBS-QOL, irritable bowel syndrome-quality of life; IBS-SSS, irritable bowel syndrome-symptom severity score; RCT, randomized controlled trials.

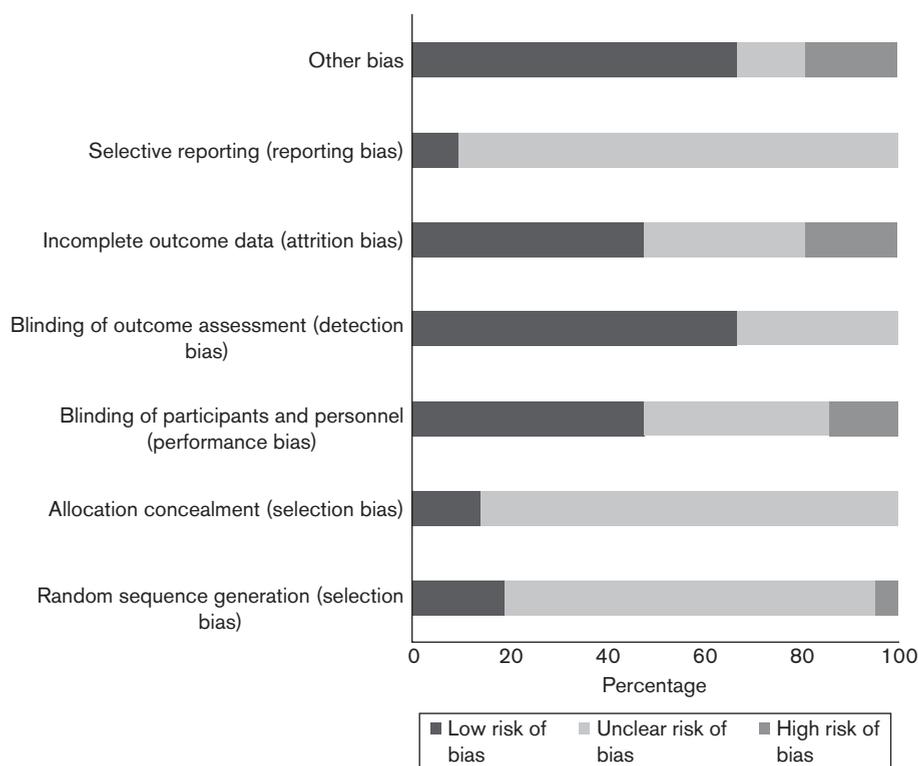


Fig. 2. Assessment of risk of bias in the included studies.

may have resulted in information bias. There was high or unclear risk of incomplete outcome data in 50% of the studies: this was because of unbalanced loss to follow-up between groups, very high attrition rates, and lack of reporting of reasons for attrition in the manuscript. This may have resulted in analysis bias in the study. In the majority of studies, the risk of reporting bias due to selective reporting was unclear as the original protocol to identify the pre-stated primary and secondary outcomes was unavailable. Four studies had high risks of other biases: these were due to clinical and methodological issues (i.e. other medications were prescribed for IBS as needed, timing of outcome assessment varied between patients in the same study, inclusion criteria were overly restrictive). For the purposes of our planned sensitivity analysis, only two studies had low risk of bias across all domains (Fig. 2 and Appendix C, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>).

Primary outcome

Global assessment of symptoms – dichotomous

Fifteen studies [1,21,23,32–34,36,37,41,43–48] involved GAS and were included in a meta-analysis (Fig. 3). There were 1048 patients included in the meta-analysis of primary outcome. Overall, a statistically significant improvement in GAS was found among patients randomized to fiber compared with those randomized to placebo [RR: 1.27; 95% confidence interval (CI): 1.05–1.54]. Statistical heterogeneity was low for this outcome; I^2 -value was 43%.

Secondary outcomes

Abdominal pain – dichotomous

Three studies [36,42,43] assessed AP as a dichotomous outcome (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). There were a total of 186 patients in the studies that reported AP. Overall, no significant difference in AP was found between those receiving fiber versus placebo (RR: 0.85; 95% CI: 0.68–1.06). Statistical heterogeneity was low for this outcome; I^2 -value was 39%.

Irritable bowel syndrome-symptom severity score – continuous

Six studies [1,22,33,35,39,41] reported on the effect of fiber on IBS-SSS (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). The included studies had 581 patients. One study that assessed soluble fiber [22] and one that assessed both soluble and insoluble [1] fibers did not report an SD; hence, they could not be included in the analysis. Heterogeneity ($I^2 = 91%$) was too high to carry out a meta-analysis.

Irritable bowel syndrome-quality of life – continuous

Two studies [1,33] assessed the effect of fiber on IBS-QOL (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). There were 460 patients included in the studies that reported IBS-QOL. Unfortunately, the study [1] that assessed IBS-QOL with regard to both soluble and insoluble fibers did not report an SD and hence, we could not carry out a meta-analysis. The remaining study [33] reported no significant difference in

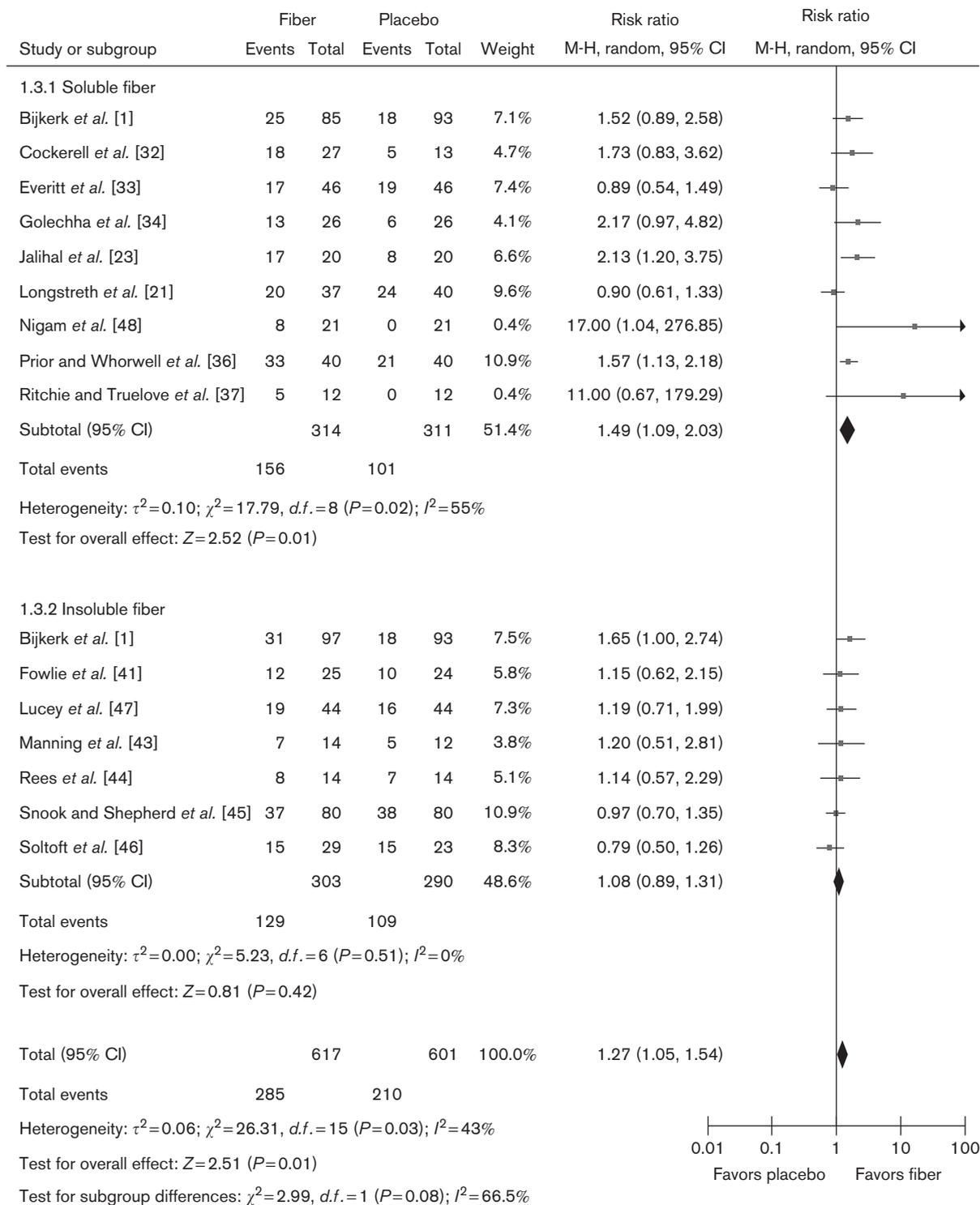


Fig. 3. Forest plot for meta-analysis of Global Assessment of IBS Symptoms (GAS).

IBS-QOL after fiber use (mean difference: - 3.90; 95% CI: - 10.21 to 2.41).

Abdominal pain score – continuous

Eight studies [1,21,35,38–41,44] assessed the effect of fiber use on APS (Appendix D, Supplemental digital

content 1, <http://links.lww.com/EJGH/A45>). A total of 620 patients were included in the studies that assessed APS. Unfortunately, one study that assessed soluble fiber [21], one that assessed insoluble fiber [44], and one that assessed both [1] did not report SDs and hence could not be combined in a meta-analysis. The heterogeneity was too high ($I^2=93\%$) to carry out a meta-analysis.

Adverse effects

No serious adverse effects were reported. The studies reported a variety of minor adverse effects, including diarrhea, constipation, nausea and vomiting, dysphagia, backache, fatigue, flatulence, heartburn, pelvic pain, joint pain, etc. Twenty-one studies [1,21–24,26,32–39,41–43,45–48] reported the number of dropouts in their study, which was 1265 patients in total (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). No significant difference was observed between fiber and placebo arms in the number of patients completing the trial (RR: 1.00; 95% CI: 0.98–1.03), and the heterogeneity between the studies was low ($I^2 = 0\%$).

Subgroup analysis

The decision to carry out a subgroup analysis of soluble and insoluble fiber made a priori as the mechanism of action of soluble fiber is different from that of insoluble fiber. For the primary outcome of GAS (Fig. 3), there was an improvement in GAS among patients (RR: 1.49; 95% CI: 1.09–2.03) who received soluble fiber [1,21,23,32–34,36,37,48], but not among patients (RR: 1.08; 95% CI: 0.89–1.31) who received insoluble fiber [1,41,43–46].

The one study that reported AP associated with the use of soluble fiber [36] did not report a significant difference between the two groups (RR: 0.89; 95% CI: 0.75–1.05). Two studies reported AP associated with the use of insoluble fiber [42,43], but the heterogeneity was too high ($I^2 = 67\%$) to carry out a meta-analysis (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). Four studies on soluble fiber [1,22,33,35], and three on insoluble fiber [1,39,41] look at their effect on IBS-SSS (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>), unfortunately the heterogeneity among the studies assessing soluble fiber ($I^2 = 96\%$) and insoluble fiber ($I^2 = 76\%$) was too high to carry out a meta-analysis. One study assessed the effect of soluble fiber [33] and one assessed the effects of both types of fibers [1] on IBS-QOL (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). As the study [1] reporting IBS-QOL for both types of fiber did not report an SD, we were unable to carry out a meta-analysis of the outcome. The effect of soluble fiber on IBS-QOL was not significantly different than that of placebo in the one study [33] (mean difference: -3.90 ; 95% CI: -10.21 to 2.41). Three studies reported change in APS for soluble fiber [1,21,35], and six studies for insoluble fiber [1,38–41,44] (Appendix D, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). For soluble fiber, there was a significant decrease in pain, as measured by APS, reported by the one [35] included study (mean difference: -1.84 ; CI: -2.74 to -0.97). A meta-analysis was not carried out for insoluble fiber because of high heterogeneity ($I^2 = 94\%$).

Sensitivity analysis

To evaluate the effect of the studies with high or unknown risk of bias on the results, a sensitivity analysis was carried out on the outcome of global symptoms measured by GAS including only the two studies that reported low risk of bias across all subcategories [1,33] (Appendix E, Supplemental digital content 1, <http://links.lww.com/>

[EJGH/A45](http://links.lww.com/EJGH/A45)). The relative risk of improvement in global symptoms was 1.16 (95% CI: 0.68–1.96). This result is similar in magnitude to the result obtained from all of our studies, albeit statistically not significant.

Analysis carried out on only the 10 RCTs [1,21,32,33,36,37,41,43,44,46] and not the crossover studies also showed similar results (RR: 1.21; 95% CI: 0.99–1.49; Appendix E, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). All the included studies were also analyzed as per protocol (Appendix E, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>), and this showed a statistically significant improvement with fiber overall (RR: 1.24; 95% CI: 1.04–1.47) and more specifically with soluble fiber (RR: 1.45; 95% CI: 1.14–1.83).

Publication bias

The funnel plot of the IBS-GAS was a symmetrical plot, suggesting no significant publication bias (Appendix F, Supplemental digital content 1, <http://links.lww.com/EJGH/A45>). The two studies [37,48] that did not report any events in the placebo group were small studies that only contributed 0.8% of the weight for the analysis (Fig. 3).

Discussion

In our systematic review and analysis of the literature, we found 22 randomized controlled and randomized crossover trials that examined the role of supplemental fiber in improving the symptoms of IBS. Supplemental fiber use in patients with IBS led to an improvement in global symptoms (RR: 1.27; 95% CI: 1.05–1.54). To demonstrate improvement in GAS for one IBS patient, 8.7 patients would be needed to be treated with fiber [number needed to treat (NNT) for the outcome GAS was 8.7 (95% CI: 5.8–16.8)]. In the subgroup analyses, treatment with soluble fiber resulted in an improvement in GAS (RR: 1.49; 95% CI: 1.09–2.03) and a reduction in APS (standard mean difference -1.84 ; 95% CI: -2.72 to -0.97). To improve global symptoms for one patient with IBS about six patients would be needed to be treated with soluble fiber [NNT for GAS in soluble fiber was 5.8 (95% CI: 4.0–10.4)]. Insoluble fiber did not appear to have an effect on any of the outcomes studied; hence, insoluble fiber would not be recommended. The mechanism by which fiber helps alleviate the symptoms of IBS is not fully elucidated. Some studies have suggested that by altering intestinal transit time, fiber relieves symptoms of IBS [49,50]. Whereas insoluble fiber increases stool volume, soluble fiber may undergo further enzyme digestion by microbiota and promote an increase in the percentage of short-chain fatty acids in stool [9,51,52]. An increase in the production of healthy short-chain fatty acids in stool can aid in the nourishment of the colonic mucosa and improve mucus production. There is some suggestion in a recent study of further action in decreasing inflammation at the cellular level, but this is under current investigation. There were no severe adverse events seen in any of the studies included. Minor side effects were reported, including GI disturbances, which were a result of the mechanism of action of soluble and insoluble fibers.

Strengths and limitations of the systematic review

This systematic review is the most up to date and complete review of the literature on the role of fiber in IBS. Recent meta-analyses carried out by Cochrane [17] and the American College of Gastroenterology in 2014 [27] utilized excellent methodology but offered differing results. Bijkerk *et al.* [9] and Moayyedi *et al.* [27] found that fiber was effective in global relief of IBS symptoms, with only soluble fiber showing improvement in a subgroup analysis. The 2011 Cochrane review [17] found no improvement in symptoms with fiber, for both soluble and insoluble fibers. In the interim, higher quality randomized controlled trials with large populations, compared with previous studies, have become available [32,33]. Incorporating these new data, the current meta-analysis is the largest to date on the subject of fiber use in IBS. The variability in results may also have arisen from patient factors; different subsets of patients, IBS-C versus IBS-D, may respond differently to the same treatment strategy. The Cochrane review [17] and the study by Moayyedi *et al.* [27] had slightly different search and selection criteria, allowing them to include some studies with low fiber comparison arms [53–55], which was outside the parameters of this current review that focused on only placebo or no treatment comparison arms. The decision to only include studies with placebo as a comparison group was made to be able to discern the effect of fiber alone on IBS without the confounding effects of other treatments and/or doses of fiber. Our study and other studies [9,17] analyzed the GAS as RR of improvement, whereas Moayyedi *et al.* [27] reported the GAS as RR of no improvement. The Cochrane review [17] included pure RCT and crossover studies. Our study also included both but incorporated a sensitivity analysis to show that crossover studies did not change our final results. The differences between our study and previous studies lend strength to our results and analysis and, more importantly, they provide a path for future research into the role of fiber in the management of IBS.

There were several limitations to this systematic review. There was significant potential for the introduction of publication bias at the full-text screening level: among the articles selected for full-text review, 23 were in languages other than English and full text was unavailable for nine articles. The included studies that utilized a crossover design presented significant methodological challenges: for the majority of these studies the outcomes were not separated on the basis of the order of treatment, and it was unclear whether the washout period allowed patients to truly return to baseline. In addition, there were a number of studies that had missing data, for which the authors were contacted. A number of studies were excluded from the analysis of IBS-SSS, IBS-QOL, and APS because the SD of the treatment difference was not available. In addition, the overall risk of bias was unclear for most of the studies included. Finally, although we were able to assess for heterogeneity of our results according to the class of fiber (soluble vs. insoluble) for our primary outcome, the small populations within the specific subtypes of fiber, the duration of treatment, and the dosages were too heterogeneous to carry out subgroup analyses. We were also unable to study the effect of fiber on specific subtypes of IBS, as only five studies reported the type of IBS in the

study participants, and no study was dedicated to studying patients with one particular subtype of IBS. Thus, although IBS patients may benefit from soluble fiber, the review was unable to formally evaluate the IBS type that best benefits and the preferred type of soluble fiber, treatment duration, or dose.

Conclusion

Fiber, especially soluble fiber, appears to have a role in improving the symptoms of IBS and appears to have a low risk of harm. The soluble fiber interventions reviewed included those on psyllium/isphagula (nine trials evaluated), linseed, calcium polycarbophyl, Metamucil, and methylcellulose. A reasonable clinical approach might be to advise IBS patients to include small amounts of soluble fiber into their diet gradually over the course of a few weeks. If symptoms improve, then the therapy might be continued. If symptoms do not improve, with an NNT of around 6 for soluble fiber, then quickly moving on to the next therapy may be helpful. More research, including large, high-quality, randomized controlled studies, is needed to identify specific types of fibers, doses of fiber, duration of fiber supplementation, and which patients would benefit best from fiber supplementation. Insoluble fiber does not appear to have any benefits compared with placebo and cannot be recommended for the management of IBS on the basis of the results of this meta-analysis.

Acknowledgements

All authors contributed to coordinating the review, formulating the research question, considering studies for the review, data management for the review, qualitative synthesis of data, quantitative synthesis of data, and interpretation of data.

Data collection for the review: all authors contributed to selecting the database to be searched and designing the search strategies, screening the search results, organizing the retrieval of papers, screening the retrieved papers against inclusion criteria, appraising the quality of the papers, extracting data from the papers.

Undertaking and documenting searches were conducted using Cochrane CENTRAL (D.B., E.A.K.), EMBASE (A.M., N.N.), PubMed (D.B., E.A.K.), CINAHL (D.B., E.A.K.), LILACS (A.M., N.N.), Clinicaltrials.gov (M.K.), and ICTRP (M.K.). The authors would also like to thank Dr. Kay Dickersin and Dr. Ian Saldana for their valuable input.

Conflicts of interest

There are no conflicts of interest.

References

- 1 Bijkerk CJ, de Wit NJ, Muris JW, Whorwell PJ, Knottnerus JA, Hoes AW. Soluble or insoluble fibre in irritable bowel syndrome in primary care? Randomised placebo controlled trial. *BMJ* 2009; 339:b3154.
- 2 Mayer EA. Irritable bowel syndrome. *N Engl J Med* 2008; 358:1692–1699.
- 3 Drossman DA, Camilleri M, Mayer EA, Whitehead WE. AGA technical review on irritable bowel syndrome. *Gastroenterology* 2002; 123:2108–2131.

- 4 Talley NJ. A unifying hypothesis for the functional gastrointestinal disorders: really multiple diseases or one irritable gut? *Rev Gastroenterol Disord* 2006; 6:72–78.
- 5 Jones R. Treatment of irritable bowel syndrome in primary care. *BMJ* 2008; 337:a2213.
- 6 Hilliä MT, Färkkilä MA. Prevalence of irritable bowel syndrome according to different diagnostic criteria in a non-selected adult population. *Aliment Pharmacol Ther* 2004; 20:339–345.
- 7 Longstreth GF, Thompson WG, Chey WD, Houghton LA, Mearin F, Spiller RC. Functional bowel disorders. *Gastroenterology* 2006; 130:1480–1491.
- 8 Thompson WG, Heaton KW, Smyth GT, Smyth C. Irritable bowel syndrome in general practice: prevalence, characteristics, and referral. *Gut* 2000; 46:78–82.
- 9 Bijkerk CJ, Muris JW, Knottnerus JA, Hoes AW, de Wit NJ. Systematic review: the role of different types of fibre in the treatment of irritable bowel syndrome. *Aliment Pharmacol Ther* 2004; 19:245–251.
- 10 Manning AP, Thompson WG, Heaton KW, Morris AF. Towards positive diagnosis of the irritable bowel. *Br Med J* 1978; 2:653–654.
- 11 Dalton CB, Drossman DA. Diagnosis and treatment of irritable bowel syndrome. *Drugs Today (Barc)* 1998; 34:585–592.
- 12 Dogan UB, Ünal S. Krus scoring system and Manning's criteria in diagnosis of irritable bowel syndrome: is it better to use combined? *Acta Gastroenterol Belg* 1996; 59:225–228.
- 13 Ford AC, Guyatt GH, Talley NJ, Moayyedi P. Errors in the conduct of systematic reviews of pharmacological interventions for irritable bowel syndrome. *Am J Gastroenterol* 2010; 105:280–288.
- 14 Rubin G, De Wit N, Meineche-Schmidt V, Seifert B, Hall N, Hungin P. The diagnosis of IBS in primary care: consensus development using nominal group technique. *Fam Pract* 2006; 23:687–692.
- 15 Spiller R, Aziz Q, Creed F, Emmanuel A, Houghton L, Hungin P, et al. Guidelines on the irritable bowel syndrome: mechanisms and practical management. *Gut* 2007; 56:1770–1798.
- 16 Brandt LJ, Bjorkman D, Fennerty MB, Locke GR, Olden K, Peterson W, et al. Systematic review on the management of irritable bowel syndrome in North America. *Am J Gastroenterol* 2002; 97 (11 Suppl):S7–S26.
- 17 Ruepert L, Quartero AO, de Wit NJ, van der Heijden GJ, Rubin G, Muris JW. Bulking agents, antispasmodics and antidepressants for the treatment of irritable bowel syndrome. *Cochrane Database Syst Rev* 2011. CD003460.
- 18 Miller V, Lea R, Agrawal A, Whorwell PJ. Bran and irritable bowel syndrome: the primary-care perspective. *Dig Liver Dis* 2006; 38:737–740.
- 19 Paterson WG, Thompson WG, Vanner SJ, Faloon TR, Rosser WW, Birtwhistle RW, et al. Recommendations for the management of irritable bowel syndrome in family practice. IBS Consensus Conference Participants. *CMAJ* 1999; 161:154–160.
- 20 Bennett WG, Cerda JJ. Benefits of dietary fiber. Myth or medicine? *Postgrad Med* 1996; 99:153–156, 166–168, 171–172 passim.
- 21 Longstreth GF, Fox DD, Youkeles L, Forsythe AB, Wolochow DA. Psyllium therapy in the irritable bowel syndrome. A double-blind trial. *Ann Intern Med* 1981; 95:53–56.
- 22 Toskes PP, Connery KL, Ritchey TW. Calcium polycarbophil compared with placebo in irritable bowel syndrome. *Aliment Pharmacol Ther* 1993; 7:87–92.
- 23 Jalihal A, Kurian G. Ispaghula therapy in irritable bowel syndrome: improvement in overall well-being is related to reduction in bowel dissatisfaction. *J Gastroenterol Hepatol* 1990; 5:507–513.
- 24 Cann PA, Read NW, Holdsworth CD. What is the benefit of coarse wheat bran in patients with irritable bowel syndrome? *Gut* 1984; 25:168–173.
- 25 Klein KB. Controlled treatment trials in the irritable bowel syndrome: a critique. *Gastroenterology* 1988; 95:232–241.
- 26 Rees GA, Trevan M, Davies GJ. Dietary fibre modification and the symptoms of irritable bowel syndrome – a review. *J Hum Nutr Diet* 1994; 7:179–189.
- 27 Moayyedi P, Quigley EM, Lacy BE, Lembo AJ, Saito YA, Schiller LR, et al. The effect of fiber supplementation on irritable bowel syndrome: a systematic review and meta-analysis. *Am J Gastroenterol* 2014; 109:1367–1374.
- 28 Ford AC, Talley NJ, Spiegel BM, Foxx-Orenstein AE, Schiller L, Quigley EM, et al. Effect of fibre, antispasmodics, and peppermint oil in the treatment of irritable bowel syndrome: systematic review and meta-analysis. *BMJ* 2008; 337:a2313.
- 29 Nagarajan N, Morden A, Bischof D, King E, Kosztowski M, Wick E, et al. The role of dietary fibers in the treatment of irritable bowel syndrome: a systematic review and meta-analysis. *PROSPERO* 2014; CRD42014010489.
- 30 The Nordic Cochrane Centre The Cochrane Collaboration. *Review Manager (RevMan) [Computer program] Version 5.3*. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration; 2014.
- 31 Higgins J, Green S. *Cochrane handbook for systematic reviews of interventions version 5.10 [updated March 2011]*. The Cochrane Collaboration.
- 32 Cockerell KM, Watkins AS, Reeves LB, Goddard L, Lomer MC. Effects of linseeds on the symptoms of irritable bowel syndrome: a pilot randomised controlled trial. *J Hum Nutr Diet* 2012; 25:435–443.
- 33 Everitt H, Moss-Morris R, Sibelli A, Tapp L, Coleman N, Yardley L, et al. Management of irritable bowel syndrome in primary care: the results of an exploratory randomised controlled trial of mebeverine, methylcellulose, placebo and a self-management website. *BMC Gastroenterol* 2013; 13:68.
- 34 Golechha AC, Chadda VS, Chadda S, Sharma SK, Mishra SN. Role of ispaghula husk in the management of irritable bowel syndrome (a randomized double-blind crossover study). *J Assoc Physicians India* 1982; 30:353–355.
- 35 Nayak AK, Karnad DR, Abraham P, Mistry FP. Metronidazole relieves symptoms in irritable bowel syndrome: the confusion with so-called 'chronic amebiasis'. *Indian J Gastroenterol* 1997; 16:137–139.
- 36 Prior A, Whorwell PJ. Double blind study of ispaghula in irritable bowel syndrome. *Gut* 1987; 28:1510–1513.
- 37 Ritchie JA, Truelove SC. Treatment of irritable bowel syndrome with lorazepam, hyoscine butylbromide, and ispaghula husk. *Br Med J* 1979; 1:376–378.
- 38 Arffmann S, Andersen JR, Hegnhøj J, Schaffalitzky de Muckadell OB, Mogensen NB, Krag E. The effect of coarse wheat bran in the irritable bowel syndrome. A double-blind cross-over study. *Scand J Gastroenterol* 1985; 20:295–298.
- 39 Cook IJ, Irvine EJ, Campbell D, Shannon S, Reddy SN, Collins SM. Effect of dietary fiber on symptoms and rectosigmoid motility in patients with irritable bowel syndrome. A controlled, crossover study. *Gastroenterology* 1990; 98:66–72.
- 40 Diaz-Rubio M, De Onis Sanz M, Enriquez Gonzalez L, Esteban Bernaldez JM. Effects of wheat bran in the irritable bowel syndrome. *An Med Interna* 1985; 2:420–422.
- 41 Fowle S, Eastwood MA, Prescott R. Irritable bowel syndrome: assessment of psychological disturbance and its influence on the response to fibre supplementation. *J Psychosom Res* 1992; 36:175–180.
- 42 Krus W, Weinzierl M, Schüssler P, Holl J. Comparison of the therapeutic effect of wheat bran, mebeverine and placebo in patients with the irritable bowel syndrome. *Digestion* 1986; 34:196–201.
- 43 Manning AP, Heaton KW, Harvey RF. Wheat fibre and irritable bowel syndrome. A controlled trial. *Lancet* 1977; 2:417–418.
- 44 Rees G, Davies J, Thompson R, Parker M, Liepins P. Randomised-controlled trial of a fibre supplement on the symptoms of irritable bowel syndrome. *J R Soc Promot Health* 2005; 125:30–34.
- 45 Snook J, Shepherd HA. Bran supplementation in the treatment of irritable bowel syndrome. *Aliment Pharmacol Ther* 1994; 8:511–514.
- 46 Soltoff J, Krag B, Gudmand-Hoyer E, Kristensen E, Wulff HR. A double-blind trial of the effect of wheat bran on symptoms of irritable bowel syndrome. *Lancet* 1976; 1:270–272.
- 47 Lucey MR, Clark ML, Lowndes J, Dawson AM. Is bran efficacious in irritable bowel syndrome? A double blind placebo controlled crossover study. *Gut* 1987; 28:221–225.
- 48 Nigam P, Kapoor KK, Rastog CK, Kumar A, Gupta AK. Different therapeutic regimens in irritable bowel syndrome. *J Assoc Physicians India* 1984; 32:1041–1044.
- 49 Müller-Lissner S. General geriatrics and gastroenterology: constipation and faecal incontinence. *Best Pract Res Clin Gastroenterol* 2002; 16:115–133.
- 50 Spiller RC. Pharmacology of dietary fibre. *Pharmacol Ther* 1994; 62:407–427.
- 51 Eswaran S, Muir J, Chey WD. Fiber and functional gastrointestinal disorders. *Am J Gastroenterol* 2013; 108:718–727.
- 52 Tilg H, Moschen AR. Food, immunity, and the microbiome. *Gastroenterology* 2015; 148:1107–1119.
- 53 Arthurs Y, Fielding JF. Double blind trial of ispaghula/poloxamer in the irritable bowel syndrome. *Ir Med J* 1983; 76:253.
- 54 Aller R, de Luis DA, Izaola O, la Calle F, del Olmo L, Fernandez L, et al. Effects of a high-fiber diet on symptoms of irritable bowel syndrome: a randomized clinical trial. *Nutrition* 2004; 20:735–737.
- 55 Villagrasa M, Boix J, Humbert P, Quer JC. Aleatory clinical study comparing otilonium bromide with a fiber-rich diet in the treatment of irritable bowel syndrome. *Ital J Gastroenterol* 1991; 23 (8 Suppl 1):67–70.