Eur J Nutr
DOI 10.1007/s00394-015-0922-1

ORIGINAL CONTRIBUTION

Does a diet low in FODMAPs reduce symptoms associated with functional gastrointestinal disorders? A comprehensive systematic review and meta-analysis

Abigail Marsh[1] · Enid M. Eslick[1] · Guy D. Eslick[1]

Received: 23 March 2015 / Accepted: 4 May 2015

Abstract
Background Functional gastrointestinal symptoms such as abdominal pain, bloating, distension, constipation, diarrhea and flatulence have been noted in patients with irritable bowel syndrome (IBS) or inflammatory bowel disease (IBD). The diversity of symptoms has meant that finding an effective treatment has been challenging with most treatments alleviating only the primary symptom. A novel treatment option for IBS and IBD currently generating much excitement is the low fermentable, oligo-, di-, mono-saccharides and polyol (FODMAP) diet. The aim of this meta-analysis was to determine the evidence of the efficacy of such a diet in the treatment of functional gastrointestinal symptoms.
Methods Electronic databases were searched through to March 2015 to identify relevant studies. Pooled odds ratios (ORs) and 95 % confidence intervals were calculated for the effect of a low FODMAP diet on the reduction in IBS [Symptoms Severity Score (SSS)] score and increase in IBS quality of life (QOL) score for both randomized clinical trials (RCTs) and non-randomized interventions using a random-effects model.
Results Six RCTs and 16 non-randomized interventions were included in the analysis. There was a significant decrease in IBS SSS scores for those individuals on a low FODMAP diet in both the RCTs (OR 0.44, 95 % CI 0.25–0.76; $I^2 = 35.52$, $p = 0.00$) and non-randomized interventions (OR 0.03, 95 % CI 0.01–0.2; $I^2 = 69.1$, $p = 0.02$). In addition, there was a significant improvement in the IBS-QOL score for RCTs (OR 1.84, 95 % CI 1.12–3.03; $I^2 = 0.00$, $p = 0.39$) and for non-randomized interventions (OR 3.18, 95 % CI 1.60–6.31; $I^2 = 0.00$, $p = 0.89$). Further, following a low FODMAP diet was found to significantly reduce symptom severity for abdominal pain (OR 1.81, 95 % CI 1.13–2.88; $I^2 = 0.00$, $p = 0.56$), bloating (OR 1.75, 95 % CI 1.07–2.87; $I^2 = 0.00$, $p = 0.45$) and overall symptoms (OR 1.81, 95 % CI 1.11–2.95; $I^2 = 0.00$, $p = 0.4$) in the RCTs. In the non-randomized interventions similar findings were observed.
Conclusion The present meta-analysis supports the efficacy of a low FODMAP diet in the treatment of functional gastrointestinal symptoms. Further research should ensure studies include dietary adherence, and more studies looking at greater number of patients and long-term adherence to a low FODMAP diet need to be conducted.

Keywords FODMAP · Diet · Functional gastrointestinal disorders · FGID · Symptoms · Meta-analysis

Introduction

Functional gastrointestinal symptoms such as abdominal pain, bloating (distension), constipation, diarrhea and flatulence (gas) have been noted in patients with irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD). IBS is the most common diagnosis made by gastroenterologists [1] and affects between 7 and 15 % of the population [2, 3]. The condition is characterized by recurrent episodes of functional gastrointestinal symptoms when anatomical abnormalities and inflammation have been excluded. The pathophysiological mechanisms underlying IBS are not clearly understood [4] and are thought to result from a

✉ Guy D. Eslick
eslickg@med.usyd.edu.au

[1] The Whiteley-Martin Research Centre, Discipline of Surgery, The University of Sydney, Nepean Hospital, Level 3, Clinical Building, Penrith, NSW 2751, Australia

Published online: 17 May 2015

combination of altered gut microbiota, visceral hypersensitivity, changes in gastrointestinal motility and low-grade inflammation [5].

Diet has been shown to play an integral role in triggering symptoms with approximately 60 % of IBS patients claiming that certain foods exacerbate their symptoms [2]. Due to the diversity of symptoms present in IBS, pharmacological treatments vary widely and drugs often only target the primary symptom, when a multitude of symptoms are present, and therefore are often inadequate [6]. This has led to the investigation of dietary therapies as treatment options. However, clinical trials of high fiber diets, thought to be a palpable way to improve bowel function, have not been shown to yield significant benefits over placebo [7]. Similarly, elimination-type diets to remove specific food triggers, most commonly dairy, wheat, caffeine and fructose [8], have had anecdotal success, but few have had been supported with scientific vitality, partially due to the challenging nature of conducting dietary trials [9]. Furthermore, IBS patients who restrict certain foods such as citrus, dairy, fiber or alcohol which they consider to worsen their symptoms, often only find negligible symptom improvements as foods are a complex matrix of macronutrients, hydrates, fermentable carbohydrates and other compounds and identifying the component causing functional gastrointestinal symptoms is often problematic [14].

A diet developed for the management of functional symptoms associated with IBS is the low fermentable oligosaccharides, disaccharides, monosaccharides, and polyol (FODMAP) diet. FODMAP is a collective term that includes fructose in excess of glucose (pears and apples), oligosaccharides including fructans (wheat and onion), galacto-oligosaccharides (legumes) and sugar polyols such as sorbitol and mannitol (stone fruits and artificial sweeteners), and lactose in patients which it is malabsorbed [10]. There is a considerable interest in this diet as FODMAP intake, specifically fructose, has increased in Western diets over the past three decades owing to increased availability of fruits and concentrated fruit juices and the extensive use of high fructose corn syrup in a wide variety of processed foods and beverages ranging from soft drinks, to yoghurts and breads [11].

The low FODMAP diet was developed based on the poor absorption of the short-chain carbohydrates in the small intestine which causes gas production and increases intestinal osmolality due to their rapid fermentation and osmotic action. This has been shown in a study in ileostomates revealing a high FODMAP diet increased the fermentable load and volume of liquid delivered to the proximal colon [12]. Further, breath hydrogen analysis of those with IBS and healthy controls has accentuated the fermentative effects of these carbohydrates with a high FODMAP diet increasing breath hydrogen across the day reflective of fermentation patterns occurring in the large intestine [13]. Therefore, reducing the fermentable load and liquid volume delivered to the colon, through following a low FODMAP diet, reduces gas production thus reduces luminal distension subsequently providing GI symptom relief for IBS sufferers [14]. The low FODMAP diet is still a novel area of research with increasing evidence suggesting its worth in the treatment of IBS [15]. The aim of the current study was to collect all available data to construct the first meta-analysis on the efficacy of a low FODMAP diet in the treatment of functional gastrointestinal symptoms.

Methods

Study protocol

We followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines [16]. A systematic search of the databases MEDLINE (from 1950), PubMed (from 1946), EMBASE (from 1949), Web of Science (from 1990) and Google Scholar databases to the March 24 , 2015, was conducted to identify relevant articles. The search used the terms 'FODMAP' OR 'FODMAPS' OR 'Fermentable, poorly absorbed, short-chain carbohydrates,' OR 'Fermentable oligosaccharides, disaccharides, monosaccharides and polyols,' which were searched as text word and as exploded medical subject headings where possible. The reference lists of relevant articles were also searched for appropriate studies. No language restrictions were used in either the search or study selection.

Study selection

We included studies that met the following inclusion criteria: (1) studies that measured the IBS SSS (symptoms severity score) or IBS-QOL (quality of life) pre- and post-intervention (AND/OR), and stated the number of patients with specific IBS symptom improvements post-intervention; (2) subjects who were classified as having IBS by Rome II criteria, Rome III criteria and NICE criteria, or had IBD; and (3) an internal comparison was used when calculating the risk estimate for RCTs.

Data extraction

The data extraction was performed using a standardized data extraction form, collecting information on the publication year, study design, country, number of cases, number of controls, total sample size, age range, percentage of females, IBS classification, exclusion criteria, the percentage of study population with fructose or lactose

malabsorption, how the low FODMAP diet was administered and dietary adherence if given. IBS SSS and IBS-QOL scores, SD pre- and post-intervention and number of patients who improved in any of the functional symptoms of IBS were collected to calculate the risk estimates, event rates and confidence intervals. Authors were contacted in regard to missing data or study queries. Quality of the studies was assessed using the Jadad scale for reporting RCTs.

Statistical analysis

Pooled odds ratios and 95 % confidence intervals were calculated for the effect of a low FODMAP diet on the reduction in IBS SSS score and increase in IBS-QOL score for both the RCTs and non-randomized interventions. Pooled odds ratios and 95 % confidence intervals were calculated for the effect of a low FODMAP diet on the number of patients with improved functional symptoms (overall, abdominal pain and bloating), and events ratios and 95 % confidence intervals were calculated for patients with improved functional symptoms (overall, abdominal pain, bloating, flatulence, diarrhea, constipation and energy levels) for the non-randomized interventions using a random-effects model [17]. We tested heterogeneity using the I^2 statistic, which represents the percentage of the total variability across studies which is due to heterogeneity. I^2 values of 25, 50 and 75 % corresponded to low, moderate and high degrees of heterogeneity, respectively [18]. We quantified publication bias using the Egger's regression model [19], with the effect of bias assessed using the fail-safe number method. The fail-safe number was the number of studies that we would need to have missed for our observed result to be nullified to statistical non-significance at the $p < 0.05$ level. Publication bias is generally regarded as a concern if the fail-safe number is less than 5n + 10, with n being the number of studies included in the meta-analysis [20]. All analyses were performed with Comprehensive Meta-analysis (version 2.0), Biostat, Englewood, NJ (2005).

Results

Study characteristics

The literature searches identified 334 articles for evaluation. Title and abstract screening excluded 148 duplicates and 130 studies due to non-human or non-original research. After full text screening, 38 articles were excluded for various reasons: two studies looked at a low FODMAP diet administered through eternal nutrition, two studies looked at the effect of a low FODMAP diet on ileostomates, three studies looked at healthy participants following a low FODMAP diet and the remaining studies were excluded if improvement in functional gastrointestinal symptoms or IBS SSS or IBS-QOL scores was not analyzed and if the diet was only low in a specific FODMAP such as fructose. This left eight RCTs; however, one had to be excluded as the author did not produce the required data in time, and another was excluded as the same patient cohort was used from a prior RCT and 20 non-randomized interventions, four of which were excluded as authors failed to respond with the requested data suitable for our analysis (Fig. 1). Characteristics of included studies are outlined in Table 1; it should be noted that not all studies (RCTs and non-randomized interventions) contained data on all variables analyzed.

Symptom response

The analysis looked at the number of patients who recorded improvement in the predominant functional gastrointestinal symptoms associated with IBS after commencing a low FODMAP diet compared with controls. The greatest improvement in specific functional symptoms in the RCTs was seen for abdominal pain (OR 1.81, 95 % CI 1.13–2.88; $I^2 = 0.00$, $p = 0.56$) (Fig. 2) and abdominal bloating (OR 1.75, 95 % CI 1.07–2.87; $I^2 = 0.00$, $p = 0.45$) (Fig. 3). Overall, the low FODMAP diet was shown to provide greatest benefit in the relief of gastrointestinal symptoms overall (OR 1.81, 95 % CI 1.11–2.95; $I^2 = 0.00$, $p = 0.40$) (Fig. 4).

In the non-randomized interventions, the most substantial improvement in individual gastrointestinal symptoms occurred for abdominal bloating (ER 0.77, 95 % CI 0.67–0.85; $I^2 = 74.05$, $p < 0.001$), followed by flatulence (ER 0.76, 95 % CI 0.64–0.84; $I^2 = 73.01$, $p = 0.001$), abdominal pain (ER 0.71, 95 % CI 0.59–0.80; $I^2 = 72.05$, $p < 0.001$), diarrhea (ER 0.70, 95 % CI 0.52–0.84; $I^2 = 73.02$, $p = 0.001$), nausea (ER 0.65, 95 % CI 0.46–0.63; $I^2 = 73.44$, $p = 0.001$) and constipation (ER 0.44, 95 % CI 0.27–0.63; $I^2 = 68.25$, $p = 0.01$). Overall, symptom improvement was very high (ER 0.80, 95 % CI 0.72–0.86; $I^2 = 57.88$, $p = 0.01$). Consequently, there was also an increase in energy levels (ER 0.61, 95 % CI 0.35–0.81; $I^2 = 87.48$, $p < 0.001$).

IBS SSS score

The pooled OR in both RCTs and non-randomized interventions showed a positive association between a low FODMAP diet and a significant decrease in IBS SSS score means (OR 0.44, 95 % CI 0.25–0.76; $I^2 = 35.52$, $p = 0.20$) (Fig. 5) and 0.04 (95 % CI 0.00–0.38; $I^2 = 76.05$, $p = 0.01$), respectively.

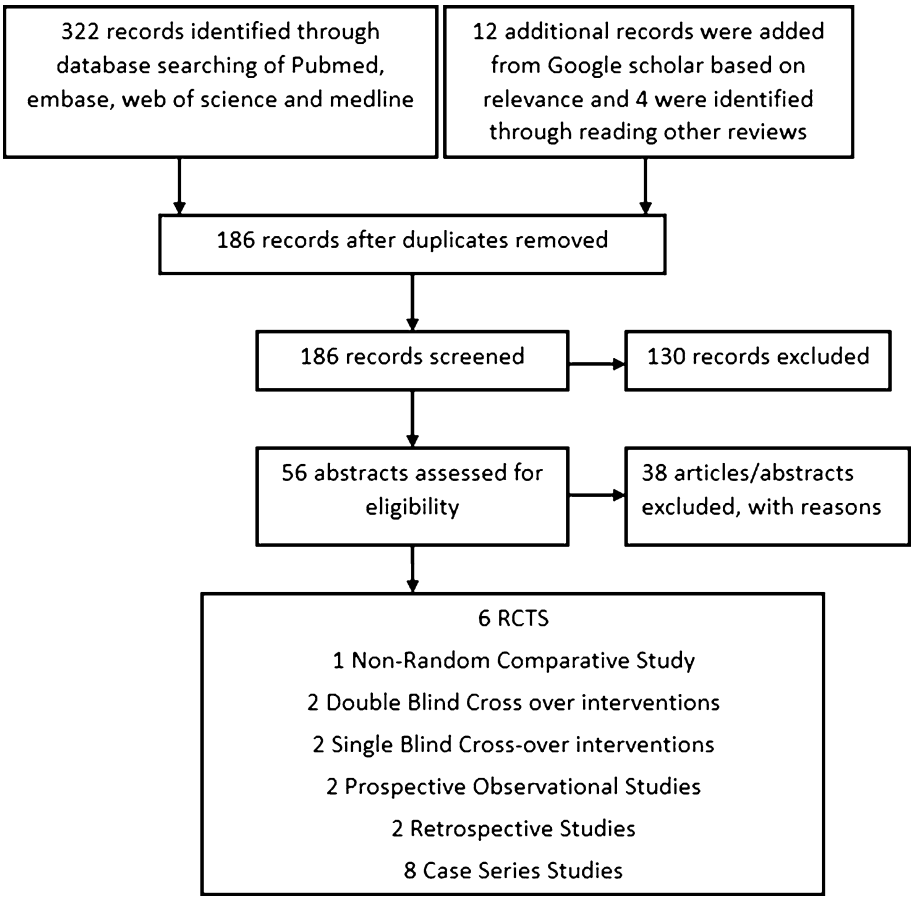

Fig. 1 Flow diagram of systematic literature search

IBS-QOL score

The IBS-QOL yielded a significant improvement post low FODMAP intervention with RCTs (OR 1.84, 95 % CI 1.12–3.03; $I^2 = 0.00$, $p = 0.39$). The non-randomized interventions were also significant (OR 2.64, 95 % CI 1.47–4.75; $I^2 = 0.00$, $p = 0.92$). Moreover, in the non-randomized interventions, the mental IBS-QOL was specifically analyzed in three studies and was higher than the overall IBS-QOL score (OR 3.18, 95 % CI 1.60–6.31; $I^2 = 0.00$, $p = 0.89$).

Publication bias

There was no evidence of publication bias based on Egger's regression analysis ($p = 0.11$).

Discussion

The present meta-analysis shows that adherence to a low FODMAP diet leads to the overall improvement of functional symptoms associated with IBS and IBD as well as a significant improvement in symptom severity and quality of life scores compared to IBS patients following a normal Western diet. To our knowledge, this is the first meta-analysis assessing the efficacy of a low FODMAP diet in the treatment of functional gastrointestinal symptoms associated with IBS or IBD.

Validated biomarkers allowing objective measures of predominant symptoms of IBS such as abdominal pain and bloating have yet to be established [41]. Consequently, patient reported outcomes; IBS SSS score, IBS-QOL score and improvement in the number of patients with the predominant functional and overall symptoms of IBS are relied on to evaluate symptom improvement. Pooling comparable data on functional symptoms from the different studies was challenging as not all studies provided the data required for the meta-analysis.

The IBS symptoms severity score (IBS SSS) validated in 1997 by Francis et al. [42] provides a measure of the overall severity of IBS. The IBS SSS questionnaire contains five questions that measure, on a 100-point visual analogue scale (VAS), the severity of abdominal pain, frequency of abdominal pain, abdominal bloating, bowel habit dissatisfaction and interference with quality of life. A theoretical range of 0–500 is established from equal contributions of all five components with a higher score indicating more

Table 1 Characteristics of the FODMAP studies included in the meta-analysis

Reference	Country	Study duration	Total case/controls or cohort size	IBS classification	Age range or mean age (SD)	Number of females (%)
Randomized control trials						
Staudacher et al. [21]	Australia	4 weeks	19/22	Rome III criteria	18–65	66
Pedersen et al. [22]	Denmark	6 weeks	44/45	Rome III criteria	20–70	75
Pedersen et al. [23]	Denmark	6 weeks	34/37	Rome III criteria	18–74	73
Harvie et al. [24]	New Zealand		23/27	Rome III criteria		
Halmos et al. [25]	Australia	3 weeks	30/8	Rome III criteria	23–60	74
Bohn et al. [55]	Sweden	4 weeks	32/33	Rome III criteria	19–68	83
Non-random comparative study						
Staudaucher et al. [26]	UK	9 months	43/39	NICE criteria	18–65	71
Double blind cross-over intervention						
Biesierkierski et al. [27]	Australia	5 weeks	37	Rome III criteria	24–61	84
Chumpitazi et al. [28]	USA	2 days	33	Pediatric Rome III criteria	7–17	67
Single blind cross-over intervention						
Pendersen et al. [29]	Denmark	12 weeks (0–6 control: 6–12 intervention)	19	Rome III criteria	18–74	74
Prospective observational study						
de Roest [30]	New Zealand	Av 15.7 months	90	IBS patients	45 (14.95)	84.4
Huaman et al. [15]	Spain	2 months	30	Rome III criteria	39 (12)	80
Case series						
Zubek et al. [31]	UK	4–12 weeks	21	Rome III criteria		
Mcgeoch et al. [32]	UK	35 months	46	Rome III criteria	38.3 (12.8)	76
O'Meara et al. [33]	Ireland	8 weeks	27	IBS patients		
Ones et al. [34]	Norway	6 weeks	23	Rome III criteria		87
Van Meegan [35]	Norway	6 weeks	12	IBD patients in remission	23–57	75
Chevillat et al. [36]	Switzerland		20	Rome III criteria	42	85
Zanini et al.[37]	Italy	8 weeks	16	Rome III criteria	41 (12)	93.7
Joyce et al. [38]	UK	6 weeks	37	IBD patients with Functional Bowel Disorder	39	63
Mazzawi et al. [39]	Norway	Median 4 months	17	Rome III criteria	20–45	70
Retrospective study						
Gearry et al. [40]	Australia	Av 17 months	70	Rome III criteria	18–72	54

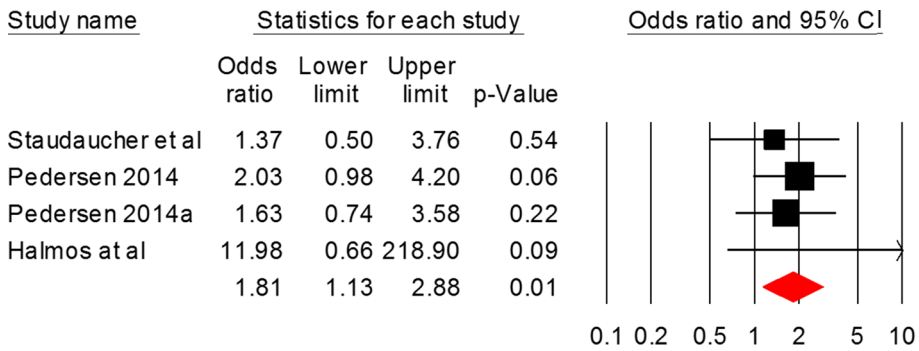

Fig. 2 Pooled odds ratios and 95 % CI for severity of abdominal pain obtained from RCTs

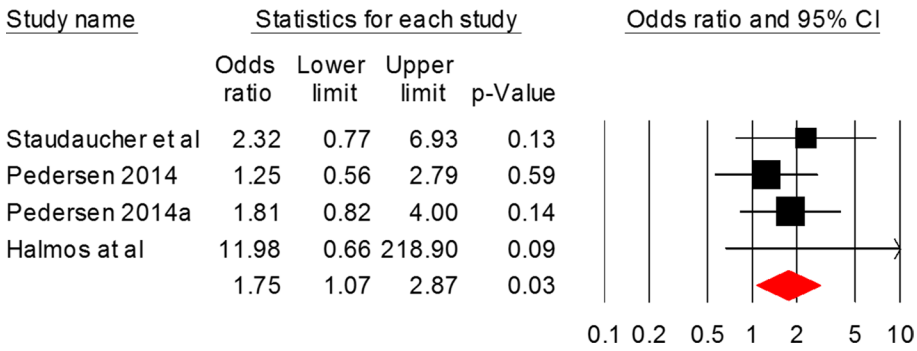

Fig. 3 Pooled odds ratios and 95 % CI for severity of bloating obtained from RCTs

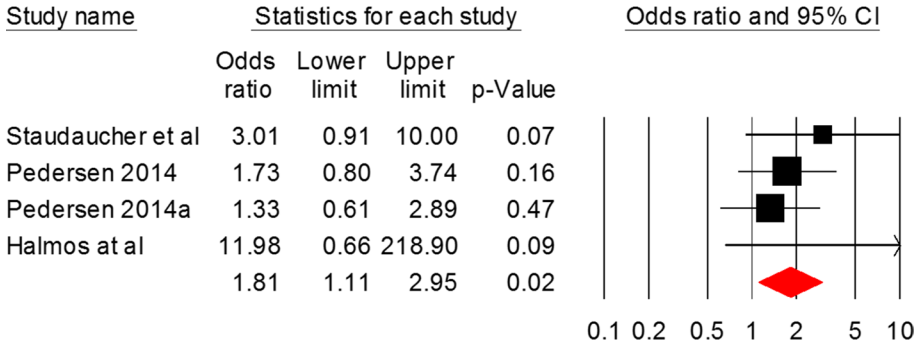

Fig. 4 Pooled odds ratios and 95 % CI for overall symptom severity score

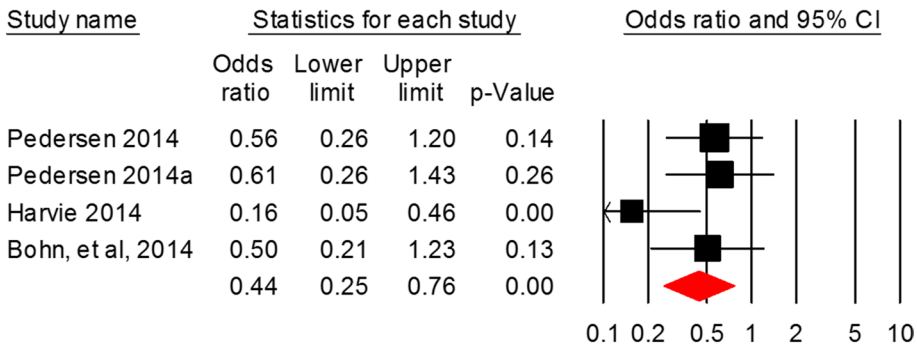

Fig. 5 Pooled odds ratio and 95 % CI for IBS SSS means

severe symptoms and a decrease of 50 points correlating with an improvement in clinical symptoms [42]. In patients with mild IBS, classified by an IBS SSS score of less than 175, the IBS SSS score may fail to detect improvements in IBS symptoms [42]. This did not affect our results as all patients at baseline had an IBS SSS score of greater than 232 (moderate IBS). In the RCTs, there was a mean average decrease in IBS SSS score of 122.64 after following the low FODMAP diet therefore highlighting that there was a significant improvement in clinical symptoms associated with IBS. Interestingly, among the control group, there was a mean drop in IBS SSS score of 69.46 suggesting that these patients also benefited in a reduction in clinical symptoms. This could be due to a patients being more conscientious of what they ate over the study period as they may have felt under scrutiny. Moreover, the single negative study we found showed IBS patients following a low FODMAP diet, and those receiving traditional dietary advice for IBS management both correlated with a decrease in IBS SSS scores; however, there was no significant difference in association with the respective diets. This suggests that any dietary measures IBS sufferers take, may offer symptomatic improvement depending on the individual. Among the non-randomized interventions, there was a mean decrease in IBS score of 118.7 showing a strong association between a low FODMAP diet and an improvement in clinical symptoms of IBS.

The IBS-QOL was validated in 1998 by Patrick et al. [43] as a conceptually valid self-administered questionnaire with highly reproducible results for assessing the perceived quality of life for individuals with IBS [43]. The IBS-QOL contains 41 descriptive IBS-specific quality of life items and uses a 5-point Likert response scale to determine how accurately the statement describes the responders feeling.

Meaningful clinical improvement is seen by a change in IBS-QOL score greater than 14 [44]. In the RCTs, the average difference in IBS-QOL means was 9.6, and in the non-randomized interventions, there was an average improvement of 10.5 suggesting holistically a clinically significant improvement did not occur. However, compared to the control group in the RCTs where the mean increase in score was 0.4, it is evident that there is a significant improvement in IBS-QOL score. Additional time may be necessary for clinically significant improvements in quality of life for IBS patients to manifest after following a low FODMAP diet.

The low FODMAP diet resulted in statistically and clinically significant improvements in all functional symptoms; however, the symptom with the least improvement was constipation. Constipation has long been associated with a low fiber intake, and a typical low FODMAP diet can often be lacking in fiber content. However, a recent meta-analysis on the effect of fiber on constipation in adults found there was low evidence on the importance of a high fiber diet in treating constipation with only 44 % of RCTs demonstrating a significant increase in stool frequency and only two studies showing fiber-enhanced stool consistency [45]. Another study reported that patients with IBS type symptoms eat a higher FODMAP diet, but there was no association with level of fiber intake suggesting that modifying FODMAP intake may alter spectrum of IBS symptoms; however, there is no need to modify dietary fiber [46]. Therefore, further research is required to look at potential treatment for constipation in those with IBS that can be used in conjunction with a low FODMAP diet such as linaclotide which has been shown to improve constipation in a recent RCT [48].

Abdominal pain and bloating are often reported as the most troublesome and frequent symptoms among IBS sufferers [52, 53] with abdominal bloating occurring in 96 % of individuals with IBS [54]. Therefore, it is evident that a low FODMAP diet is likely to be of benefit to the majority of IBS sufferers and potentially cause relief of the most problematic symptoms. All the participants of the RCTs fulfilled Rome III criteria for diagnosing IBS, thus standardizing the results [47]. In the non-randomized intervention studies, we did not implement such a strict selection criteria enabling us to evaluate more data. However, 63 % of studies selected IBS patients fulfilling Rome III criteria, one study reported on IBS patients fulfilling the NICE criteria, one on IBS patients fulfilling Rome II criteria one study on IBS patients fulfilling pediatric Rome III criteria, while two studies reported on IBD patients and two studies reported on IBS patients and did not specify how they were classified. IBD patients were not excluded from the non-randomized interventions as IBD patients in studies were noted as having IBS symptoms consistent with that of Rome III criteria. Chumpitazi et al. [28] assessed IBS patients aged 7–17 years, and in this population, there was a significantly smaller improvement in abdominal pain than for adults. This appears to be the first study looking at the efficacy of a low FODMAP diet in the treatment of IBS in children; thus, further research is required to determine whether this diet is suitable for children.

The majority of studies did not provide information on IBS subclassification: diarrhea predominant (IBS-D), constipation predominant (IBS-D), those with both diarrhea and constipation (IBS-M) and those with neither diarrhea nor constipation (IBS-U) [25]. Despite constipation as such not showing a significant improvement, it is important to recognize that a low FODMAP diet is still of benefit to those with IBS-C as regardless of classification, the severity of IBS is determined by the associated functional symptoms such as abdominal pain and bloating. Studies have shown that there is no difference in IBS SSS or IBS-QOL scores based on functional bowel diagnosis [42, 44]. Further, improvements in specific IBS functional symptoms would not have been affected by IBS subtype as participants were required to have the symptom prior to dietary intervention to yield an improvement and thus be included in the analysis. Therefore, in the context of the current meta-analysis, IBS subclassification should not have factored in our results.

Study duration of the RCTs varied potentially acting as cofounding factor within the results. RCT duration ranged from 3 to 6 weeks; the majority of research suggests that the greatest difference in severity of overall gastrointestinal symptoms occurs within 7 days of adherence to the low FODMAP after which symptom severity scores remain almost constant [25, 27]. This improvement is likely to be attributed to primarily osmotic and motility changes [13]. Staudacher et al. [21] suggest that it may take up to 8 weeks for symptom response to appear if dietary-mediated changes to gut microbiota induced by a low FODMAP diet are the cause of the improvement. There is an absence of RCTs looking at the effects of long adherence to a low FODMAP diet; thus, further research in this area would be beneficial. The follow-up of the non-randomized interventions ranged from 2 days to 35 months which may account for a greater diversity of results. However, there was only one study that lasted only 2 days, and that study only contained data on abdominal pain. The other studies ranged from 5 weeks to 35 months, and there did not appear to be any correlation with duration of study and IBS symptom improvement.

Quality assessment of the RCTs yielded mixed results. Single-blinded studies occurred for four out of six studies, and two of the RCTs provided no information on randomization techniques, and dropouts were not given. There was no statically significant heterogeneity in the RCTs;

however, there was large heterogeneity (I^2 value) in the non-randomized interventions; the heterogeneity in the non-randomized interventions may be due to duration of studies or differences in adherence to the low FODMAP diet and the extent to which FODMAP intake was reduced. In the non-randomized interventions, there appeared to be a trend in the studies which provided the FODMAP meals [25, 27, 28] having greater adherence (>95 %) than those where dietary advice was provided by a dietician (average adherence 78 %). The determination of adherence in itself is hard to determine as if it was gauged by the participants opinion on how well they adhered to the diet responder bias should be accounted for. Our meta-analysis could not make a link between adherence to diet, FODMAP intake and improvement in symptom due to the lack of studies providing adherence figures and numerical quantities of FODMAPs ingested.

The low FODMAP diet is a relatively novel area of research with the majority of studies focusing on the effects of a low FODMAP diet on IBS symptoms published in the last five years. As such, we deemed it necessary to include both abstracts and peer-reviewed papers to gain adequate data to statistically analyze the effect of following a low FODMAP diet on IBS symptoms. The validity of non-peer-reviewed data can be questionable which presented a weakness to the study; however, we aimed to control for this by contacting the authors of all abstracts for further information regarding data figures and study protocol. It should also be noted that the control used in the RCTs varied between studies. Some looked at the benefits of a low FODMAP diet in comparison with the IBS sufferer's regular diet, while other studies compared the low FODMAP diet to standard dietary advice given to IBS patients. The study undertaken by Bohn et al. compared the Low FODMAP diet with standard dietary advice which can potentially explain the negative findings as such advice has some correlation with a low FODMAP diet. However, other studies have shown significant benefits of the low FODMAP diet over standard dietary advice [15, 24, 26, 39], suggesting the worth of the low FODMAP diet. Further research should be directed at determining the value of the low FODMAP diet over traditional methods used in IBS treatment.

This meta-analysis provides strong evidence to support the efficacy of a low FODMAP diet in reducing functional gastrointestinal symptoms associated with IBS. The low FODMAP diet is dependent upon access to accurate food composition data. This can be challenging as FODMAP content varies among varieties, climates, seasons, brands, the ripeness of foods and cooking methods, and many foods have not yet been analyzed for their FODMAP content [49]. As such, universal guidelines cannot be accurately developed and each nation needs to undertake their own food analysis to determine FODMAP content. Geary et al. [40] found that 64 % patients following a low FODMAP diet believed that the diet cost more; however, 61 % of patients found it easy to find low FODMAP foods in their local supermarket. On a scale of 0 = easy to 10 = impossible on how hard it had been to implement diet, the median response was 3 (SD 2.9 range 0–10) suggesting that the diet is relatively straightforward diet to follow. It should be noted that this was an Australian study, and thus, the ease of implementing the diet in other countries may differ. Further, the introduction of the Monash University low FODMAP Diet smartphone app based upon detailed and ongoing food analysis provides accessible visual guidance on low FODMAP substitutes for food assisting with the ease in which the diet can be followed.

More research is required looking at the long-term adherence as a low FODMAP diet may have a detrimental effect on gut microbiota shown in a study done by Staudacher et al. The study demonstrated that a low FODMAP diet significantly reduces luminal bifidobacteria after 4 weeks and suggests the use of a pre- or probiotic for those following the low FODMAP diet in the long term [50]. A recent study by Halmos et al. [14] has also urged caution when following the low FODMAP diet for an extended period of time with study results showing that a low FODMAP diet reduces total bacteria but had no effect on relative abundance of bacteria putatively associated with colonic health. Therefore, it has been recommended that the diet should not be put forward for asymptomatic population, and FODMAPs should only be restricted to a level of adequate symptom control to exercise benefits of a higher FODMAP intake on gut bacteria [14]. However, holistically the Low FODMAP diet is a nutritionally adequate diet if the appropriate dietary counseling is provided. In contrast to other dietary restrictions, the low FODMAP diet allows the patients to consume foods from each of the core food groups, therefore, minimizing the effect on nutrition adequacy when appropriately implemented [51]. The overall evidence now supports that a low FODMAP diet can now be implemented as one of the key treatment strategies in managing IBS patients.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Russo MW, Gaynes BN, Drossman DA (1999) A national survey of practice patterns of gastroenterologists with comparison to the past two decades. J Clin Gastroenterol 29(339):43
2. Brandt LJ, Chey WD, Foxx-Orenstein AE, Schiller LR, Schoenfeld PS, Spiegel BM, Talley NJ, Quigley EM (2009) An evidence-based position statement on the management of irritable bowel syndrome. Am J Gastroenterol 104:S1–S35

3. Andrews EB, Eaton SC, Hollis KA, Hopkins JS, Ameen V, Hamm LR et al (2005) Prevalence and demographics of irritable bowel syndrome: results from a large web-based survey. Aliment Pharmacol Ther 22(10):935–942
4. Horwitz BJ, Fisher RS (2001) The irritable bowel syndrome. N Engl J Med 344:1846–1850
5. Anastasi JK, Capili B, Chang M (2013) Managing irritable bowel syndrome. AJN Am J Nurs 113(7):42–52
6. Brandt LJ, Chey WD, Foxx-Orenstein AE, Schiller LR, Schoenfeld PS, Spiegel BM, Talley NJ, Quigley EM (2009) American college of gastroenterology task force on irritable bowel syndrome—an evidence-based position statement on the management of irritable bowel syndrome. Am J Gastroenterol 104(Suppl 1):S1–S35
7. Eswaran S, Muir J, Chey WD (2013) Fiber and functional gastrointestinal disorders. Am J Gastroenterol 108:718–727
8. Eswaran S, Tack J, Chey WD (2011) Food: the forgotten factor in the irritable bowel syndrome. Gastroenterol Clin N Am 40(1):141–162
9. Shepherd SJ, Halmos E, Glance S (2014) The role of FODMAPs in irritable bowel syndrome. Curr Opin Clin Nutr Metab Care 17(6):605–609
10. Gibson PR, Shepherd SJ (2005) Personal view: food for thought–western lifestyle and susceptibility to Crohn's disease—the FODMAP hypothesis. Aliment Pharmacol Ther 21(12):1399–1409
11. Parker K, Salas M, Nwosu VC (2010) High fructose corn syrup: production, uses and public health concerns. Biotechnol Mol Biol Rev 5(5):71–78
12. Barrett JS, Gearry RB, Muir JG, Irving PM, Rose R, Rosella O, Haines ML, Shepherd SJ, Gibson PR (2010) Dietary poorly absorbed, short-chain carbohydrates increase delivery of water and fermentable substrates to the proximal colon. Aliment Pharmacol Ther 31(8):874
13. Ong DK, Mitchell SB, Barrett JS, Shepherd SJ, Irving PM, Biesiekierski JR et al (2010) Manipulation of dietary short chain carbohydrates alters the pattern of gas production and genesis of symptoms in irritable bowel syndrome. J Gastroenterol Hepatol 25(8):1366
14. Halmos E, Chrstopherrsen CT, Bird AR, Shepard SJ, Gibson PR, Muir JG (2015) Diets that differ in their FODMAP content alter the colonic luminal microenvironment. Gut 64(1):93–100
15. Huamán JW, Felip A, Guedea E, Jansana M, Videla S, Saperas E (2014) The diet low in fermentable carbohydrates short chain and polyols improves symptoms in patients with functional gastrointestinal disorders in Spain. Gastroenterol Hepatol 6(14):00245
16. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 151:264–269
17. DerSimonian R, Laird N (1986) Meta-analysis in clinical trials. Control Clin Trials 7:177–188
18. Higgins JPT, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analyses. BMJ Br Med J 327(7414):557–560
19. Egger M, Davey S, Schneider M, Minder C (1997) Bias in meta-analysis detected by a simple, graphical test. Br Med J 1(315):629–634
20. Orwin R (1983) A fail-safe N for effect size in meta-analysis. J Educ Stat 8:157–159
21. Staudacher HM, Lomer MCE, Anderson JL, Barrett JS, Muir JG, Irving PM, Whelan K (2012) Fermentable carbohydrate restriction reduces luminal bifidobacteria and gastrointestinal symptoms in patients with irritable bowel syndrome. J Nutr 142(8):1510
22. Pedersen N, Ankersen DV, Felding M, Vegh Z, Burisch J, Munkholm P (2014) Mo1210 low FODMAP diet reduces irritable bowel symptoms and improves quality of life in patients with inflammatory bowel disease in a randomized controlled trial. Gastroenterology 146(5):S-587
23. Pedersen N, Andersen NN, Végh Z, Jensen L, Ankersen DV, Felding M, Simonsen M, Burisch J, Munkholm (2014) Ehealth: low FODMAP diet vs Lactobacillus rhamnosus GG in irritable bowel syndrome. World J Gastroenterol WJG 20(43):16215
24. Harvie R, Schultz M, Chisholm A (2013) A reduction in FODMAP intake correlates strongly with a reduction in IBS symptoms–the FIBS study. J Gastroenterol Hepatol 28(Suppl. 3):23–693
25. Halmos EP, Power VA, Shepherd SJ, Gibson PR, Muir JG (2013) A diet low in FODMAPs reduces symptoms of irritable bowel syndrome. Gastroenterology 146(1):67
26. Staudacher HM, Whelan K, Irving PM, Lomer MCE (2011) Comparison of symptom response following advice for a diet low in fermentable carbohydrates (FODMAPs) versus standard dietary advice in patients with irritable bowel syndrome. J Hum Nutr Diet 24(5):487–495
27. Biesiekierski JR, Peters SL, Newnham ED, Rosella O, Muir JG, Gibson PR (2013) No effects of gluten in patients with self-reported non-celiac gluten sensitivity after dietary reduction of fermentable, poorly absorbed, short-chain carbohydrates. Gastroenterology 145(2):320
28. Chumpitazi BP, Tsai CM, McMeans AR, Shulman RJ (2014) A low fodmaps diet ameliorates symptoms in children with irritable bowel syndrome: a double blind, randomized crossover trial. Gastroenterology 146(5):S-144
29. Pedersen N, Vegh Z, Burisch J, Jensen L, Ankersen DV, Felding M, Simonsen M, Burisch J, Munkholm P (2014) Ehealth monitoring in irritable bowel syndrome patients treated with low fermentable oligo-, di-, mono-saccharides and polyols diet. World J Gastroenterol 20(21):6680–6684
30. Roest RH, Dobbs BR, Chapman BA, Batman B, O'Brien LA, Leeper JA, Hebblethwaite CR, Gearry RB (2013) The low FODMAP diet improves gastrointestinal symptoms in patients with irritable bowel syndrome: a prospective study. Int J Clin Pract 67(9):895–903
31. Zubek J, White R (2012) An audit investigating the efficacy of the low FODMAP diet in improving symptoms in patients with functional gastro-intestinal symptoms. Gut 61:A86–A86
32. Mcgeoch V, Blackwell V, Wigham L, Hoare JM (2014) PWE-170: an audit of clinical response in patients with Ibs treated with the low Fodmap diet at St Mary's Hospital. Gut 63(Supp 1):A199–A200
33. O'Meara C, Craig OF, Mahmud N, McKiernan S, Maccarthy F (2013) A pilot study on the introduction of a low FODMAP diet in a subgroup of symptomatic IBS patients referred by the gastroenterology service in an Irish Tertiary Referral Centre. Gut 62(Suppl 2):A3–A4
34. Ones M, Morken MH, Hatlebakk JG (2014) PP112-MON: effects of a Fodmap-restricted diet in a Scandinavian population with irritable bowel syndrome. Clin Nutr 33:S171
35. Van Megen F, Kahrs GE (2014) Effects of a FODMAP-restricted diet on irritable bowel symptoms in patients with inflammatory bowel disease. United Eur Gastroenterol J 2(Suppl 1):P0342
36. Chevillat D, Neff S, Maghdessian R, Kiss C, Maissen S (2014) P091: L'approche FODMAP améliore la symptomatologie gastro-intestinale chez les patients adultes souffrant d'un syndrome de l'intestin irritable: une étude pilote. Nutrition Clinique et Métabolisme. UEG Week 28: S116
37. Zanini B, Marullo M, Ricci C, Lanzarotto F, Lanzini A (2014) Sa1989 non celiac gluten sensitivity (NCGS) is outnumbered by FODMAPs sensitivity in patients spontaneously adhering to gluten free diet (GFD): a two stage double blind prospective study. Gastroenterology 146(5):S-348

38. Joyce T, Staudacher H, Whelan K, Irving P, Lomer M (2014) PWE-092 symptom response following advice on a diet low in short-chain fermentable carbohydrates (fodmaps) for functional bowel symptoms in patients with Ibd. Gut 63(Suppl 1):A164
39. Mazzawi T, Hausken T, Gundersen D, El-Salhy M (2013) Effects of dietary guidance on the symptoms, quality of life and habitual dietary intake of patients with irritable bowel syndrome. Mol Med Rep 8(3):845–852
40. Gearry RB, Irving PM, Barrett JS, Nathan DM, Shepherd SJ, Gibson PR (2009) Reduction of dietary poorly absorbed short-chain carbohydrates (FODMAPs) improves abdominal symptoms in patients with inflammatory bowel disease—a pilot study. J Crohn's Colitis 3(1):8–14
41. Azpiroz F, Guyonnet D, Donazzolo Y, Gendre D, Tanguy J, Guarner F (2014) Digestive symptoms in healthy people and subjects with irritable bowel syndrome: validation of symptom frequency questionnaire. J Clin Gastroenterol 1
42. Francis CY, Morris J, Whorwell PJ (1997) The irritable bowel severity scoring system: a simple method of monitoring irritable bowel syndrome and its progress. Aliment Pharmacol Ther 11(2):395–402
43. Patrick DL, Drossman DA, Frederick IO, DiCesare J, Puder KL (1998) Quality of life in persons with irritable bowel syndrome: development and validation of a new measure. Dig Dis Sci 43(2):400
44. Drossman D, Morris CB, Hu Y, Toner BB, Diamant N, Whitehead WE et al (2007) Characterization of health related quality of life (HRQOL) for patients with functional bowel disorder (FBD) and its response to treatment. Am J Gastroenterol 102(7):1442–1453
45. Christodoulides S (2014) PWE-184 the effect of fibre on chronic constipation in adults: a systematic review. Gut 63(suppl 1):A206–A207
46. James SL et al (2009) FODMAP but not fibre intake is associated with IBS-like symptoms in patients with IBD. J Gastroenterol Hepatol 24:A313–A314
47. Rome F (2006) Guidelines-Rome III diagnostic criteria for functional gastrointestinal disorders. J Gastrointest Liver Dis 15(3):307–312
48. Buono JL, Tourkodimitris S, Sarocco P, Johnston JM, Carson RT (2014) Impact of linaclotide treatment on work productivity and activity impairment in adults with irritable bowel syndrome with constipation: results from 2 randomized, double-blind, placebo-controlled phase 3 trials. Am Health Drug Benefits 7(5):289
49. Muir JG, Rose R, Rosella O, Liels K, Barrett JS, Shepherd SJ et al (2009) Measurement of short-chain carbohydrates in common australian vegetables and fruits by high-performance liquid chromatography (HPLC). J Agric Food Chem 57(2):554–565
50. Staudacher HM, Lomer MCE, Anderson JL, Barrett JS, Muir JG, Irving PM et al (2010) Fermentable carbohydrate restriction reduces luminal bifidobacteria and gastrointestinal symptoms in patients with irritable bowel syndrome. J Nutr 142(8):1510
51. Tuck CJ (2014) Fermentable oligosaccharides, disaccharides, monosaccharides and polyols: role in irritable bowel syndrome. Expert Rev Gastroenterol Hepatol 8(7):819–834
52. Azpiroz F, Malagelada J (2005) Abdominal bloating. Gastroenterology 129(3):1060–1078
53. Spiegel BMR, Bolus R, Harris LA, Lucak S, Chey WD, Sayuk G et al (2010) Characterizing abdominal pain in IBS: guidance for study inclusion criteria, outcome measurement and clinical practice. Aliment Pharmacol Ther 32(9):1192
54. Houghton LA, Lea R, Agrawal A, Agrawal A, Reilly B, Whorwell PJ (2006) Relationship of abdominal bloating to distention in irritable bowel syndrome and effect of bowel habit. Gastroenterology 131(4):1003
55. Böhn L, Störsrud S, LiIjebo T, Collin L, Törnblom H, Simrén M (2014) A Multi-center, randomized, controlled, single-blind, comparative trial: low-FODMAP diet versus traditional dietary advice in IBS. United Eur Gastroenterol J 2(1S):A1–A131