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# The Efficacy of a Diet Low in Fermentable Oligosaccharides, Disaccharides, Monosaccharides, and Polyols (FODMAPs) in the Treatment of Irritable Bowel Syndrome

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# THE EFFICACY OF A DIET LOW IN FERMENTABLE OLIGOSACCHARIDES, DISACCHARIDES, MONOSACCHARIDES, AND POLYOLS (FODMAPs) IN THE TREATMENT OF IRRITABLE BOWEL SYNDROME

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## ABSTRACT

This paper reviews the efficacy of the low-FODMAP (Fermentable Oligosaccharides, Disaccharides, Monosaccharides, and Polyols) diet in treating the symptoms associated with irritable bowel syndrome (IBS). Since IBS has a wide range of etiologies and symptoms, it is often difficult to treat. A large majority of patients report their symptoms being associated with their diet. Researchers have shown that specific components of food, FODMAPs, may play a role in exacerbating symptoms. In this literary review, the physiological effects and the efficacy of the low-FODMAP diet was explored using current literature. In conclusion, the low-FODMAP diet may be an efficacious treatment option for those diagnosed with IBS.



**Key Words**: Irritable bowel syndrome, FODMAPs, Gastrointestinal



## Appreciation

I would like to thank my faculty mentor, Heather Rasmussen, for guiding me through the process of writing this thesis. Her expertise in gastrointestinal health the low-FODMAP diet has been beyond helpful in focusing my research and writing. I could not have imagined having a better advisor and mentor to assist me in completing my Honor's thesis.

## INTRODUCTION

Irritable bowel syndrome (IBS) is a debilitating condition that affects about 10% of the world's population (Pletikosić Tončić & Tkalčić, 2017). It is the most common gastrointestinal condition. This condition does not stem from one single cause but may be diagnosed by a cluster of symptoms originating in the colon (Chey, Kurlander, & Eswaran, 2015). In this sense, IBS can be classified as a functional gastrointestinal disorder (FGID). Although symptoms of IBS have been noted for centuries, the grouping of these symptoms into a condition (IBS) has only taken place over the past 30-40 years (Drossman, 2016).

### Prevalence

In North America alone, the prevalence of IBS is 12% of the population. South America has the highest prevalence of the condition at 21%. Irritable bowel syndrome is more common among women than in men, and women report more abdominal pain and constipation, while men report more diarrhea (Chey et al., 2015). Irritable bowel syndrome is, on average, diagnosed in more people under age 50 (Altobelli, Del Negro, Angeletti, & Latella, 2017). Up to 88% of those diagnosed with IBS will seek treatment (Koloski, Talley, & Boyce, 2001). Both direct and indirect expenditures for IBS in the U.S. total over $20 billion (Agarwal & Spiegel, 2011).

## Characteristics and Causes of IBS

Three main types of IBS are diagnosed – diarrhea (IBS-D), constipation (IBS-C), and both/mixed (IBS-M) (Chey et al., 2015). These three altered bowel habits are usually accompanied by abdominal pain. Depending on the person, the symptoms may disrupt quality of life and cause serious, debilitating pain. Many IBS patients report being forced to abstain from daily activities and work due to their condition (Moayyedi et al., 2017). Irritable bowel syndrome symptoms can be categorized as mild, moderate, or severe, with up to 50% of IBS patients reporting their symptoms as severe (Harris & Baffy, 2017).

Although the cause of IBS is mainly unknown, many elements are thought to play a role in its pathogenesis. These can be related to genetics, hormones, psychological factors, diet, or gastrointestinal (GI) motility (Harris & Baffy, 2017). In the GI tract, symptoms are thought to stem from enteric infection, abnormal brain-gut interaction, and altered gut flora (Chen, Kim, Zhang, Du, & Dai, 2018).

The gut microbiome appears to play an important role in the presence of IBS. Quantitative measures show altered microbiota in patients with IBS when compared to healthy controls (Harris & Baffy, 2017). In healthy individuals, the gut microbiome plays an important role in immunity and digestion. Certain fibers, called prebiotics, provide food for gut bacteria to help them flourish and provide diversity. When there is an imbalance of certain species of gut microbes, the altered microbiota composition can lead to excessive fermentation of prebiotics; causing gas, bloating, and altered bowel habits. Other times, the overall number of microbes can diminish due to things like excessive use of antibiotics or altered dietary habits.

An imbalance of gut bacteria has also been shown to contribute to the incidence of anxiety or depression and may be involved in the processing of emotions and coping with stress. This gives rise to the concept of not only a gut-brain connection, but also a gut-brain-microbiota axis that can determine one's overall state of health (Moser, Fournier, & Peter, 2018). Diagnoses of IBS can be associated with comorbidities such as fibromyalgia and depression due to this connection (Harris & Baffy, 2017). Chronic stress as well as previous traumas have also been associated with incidence of IBS (Nelms, Sucher, & Lacey, 2016).

Altered gut microbiota, in terms of the pathogenesis of IBS, may be the result of small intestinal bacterial overgrowth (SIBO). SIBO is the result of bacteria, normally in the large intestine, becoming established in the small intestine. This overgrowth causes symptoms indicative of IBS. Physicians may test for SIBO in the process of diagnosing IBS due to its occurrence in over one-third of IBS patients. Common diagnostic tools for SIBO include a lactulose or glucose breath test, where an individual ingests these simple carbohydrates that the bacteria will then ferment and produce hydrogen gas. The concentration of this gas is then measured, with higher amounts of hydrogen production indicative of SIBO. If diagnosed, patients would then be prescribed an antibiotic that kills off the bacterial overgrowth in the small intestine in hopes of IBS symptom relief (Chen et al., 2018).

In addition to SIBO, additional potential causes of IBS symptoms are visceral hypersensitivity, altered motility, inflammation, increased permeability of the intestines, and abnormal brain function (Corsetti, Van Oudenhove, & Tack, 2014). The pathophysiology of these etiologies is complex, as it may vary from person to

person. Altered motility may be the result of abnormalities in the connection of the gut to the enteric nervous system. Serotonin plays a role in stimulating muscle contraction and relaxation along the GI tract. It has been shown that some individuals with IBS have abnormal levels of serotonin, which could play a role in motility issues. Visceral hypersensitivity is an increased response to stimuli that is experienced by those with IBS that is not reported in controls. This can present as pain, urgency, or abnormal bowel habits. Mucosal permeability may result from any of the previously discussed etiologies and usually causes inflammation and abdominal pain (Nelms et al., 2016).

**Diagnostic Tools**

One of the most widely used set of criteria for diagnosing IBS is the Rome criteria. Most recently, the Rome IV was released and is used as the most up-to-date diagnostic tool. The diagnostic process outlined in the Rome criteria divides patients into categories based on where the symptoms originate within the GI tract. The Rome IV criteria for the diagnosis of IBS includes abdominal pain that occurs, on average, at least once a week for three months. The abdominal pain is usually associated with two or more of the following symptoms: defecation, change in stool frequency, and change in appearance of stool. A new and interesting addition to the Rome IV criteria compared to the Rome III criteria is that functional GI disorders are now categorized as disorders of gut-brain interaction. These can be related to motility disturbance, visceral hypersensitivity, altered mucosal and immune

function, altered gut microbiota, and altered central nervous system processing (Tack & Drossman, 2017).

### IBS Treatment Options

After diagnosis of IBS using Rome IV criteria, a gastroenterologist will recommend a treatment plan that may include medication and lifestyle changes, including diet and exercise. The medication will vary depending on the type of IBS one has, whether it's predominantly constipation or diarrhea, and how much pain is experienced. Selective serotonin reuptake inhibitors (SSRIs), which are a type of antidepressant, may be prescribed to help with abdominal pain but may cause constipation in some patients, depending on the type and dose. Antidiarrheal agents are usually prescribed to those experiencing IBS-D. Antispasmodics may be prescribed to slow the natural movement of the gut so the patient will not experience pain from intestinal cramping (Varjú et al., 2017). Over-the-counter medications like laxatives may also be prescribed if constipation is the primary concern. Taking polyethylene glycol in the form of a dissolvable powder is a common laxative used. The registered dietitian nutritionist (RDN) or doctor may also recommend fiber supplements to help provide stool bulk for diarrhea-predominant IBS and soften the stool for constipation-dominant IBS. These supplements often come in the form of a dissolvable powder made with fibers such as psyllium or wheat dextrin.

Lifestyle changes may come in the form of diet and exercise or just changing a daily routine. Some practitioners recommend establishing a set daily routine that

provides enough time to go to the bathroom in the morning and having set times to take supplements or medications. Regular exercise has been shown to improve IBS symptoms and promote regular stool excretion. Stress can be a major component in the severity of IBS symptoms. Patients are advised to find ways to manage their stress in their day-to-day lives and at work. Living a fast-paced, hectic lifestyle may make symptoms worse, which will result in a reduction of overall quality of life.

Diet is a key factor in reducing IBS-related symptoms. A total of 70% of those who are diagnosed claim that specific foods trigger their symptoms (Altobelli et al., 2017). The Academy of Nutrition and Dietetics (Academy) recommends drinking plenty of fluids, eating high fiber foods throughout the day, and avoiding certain foods such as alcohol, coffee, sugar alcohols, or carbonated drinks. It is also recommended that eating small meals or snacks regularly throughout the day will help prevent the digestive system from being overloaded at any one meal (Wolfram, 2017). In addition, the goals of treating IBS as outlined in the Academy's Nutrition Care Manual®, include the following: normalize eating patterns and ensure adequacy of all nutrients; adjust diet for identified food allergies and intolerances; reduce lactose, if lactose-intolerant; avoid sorbitol, xylitol and mannitol; avoid gas-forming foods; consider use of prebiotics and probiotics. In addition to these goals, the Academy supports specifically using a low-FODMAP diet for 6-8 weeks with consistent follow-up with a RDN ("FODMAP Diet," 2015).

## LOW-FODMAP DIET

Over time, scientists have recognized that specific categories of foods that contain short-chain carbohydrates may not be absorbed as well as others. Around the 1960s, lactose intolerance was credited as being the cause of some symptoms of diarrhea; therefore, lactose-free diets became a recommended diet for those with IBS-D. During the 1980s, people with fructose malabsorption were found to have symptoms of IBS and benefitted from following a diet low in fructose-containing foods. Next, oligosaccharides were found to cause similar symptoms in clinical studies because of their function as prebiotic fibers within the gut. Polyols were also found to induce discomfort in those with IBS, usually consumed in the form of sugar alcohols used as sweeteners (Gibson, 2017a).

These earlier observations of food groups that aggravate IBS symptoms has lead more recently to the grouping of these foods high in fermentable oligosaccharides, disaccharides, monosaccharides, and polyols (FODMAPs) at Monash University in Australia. Gibson, a gastroenterologist, and Muir, a biochemist, chemically analyzed common foods to determine how much of the short-chain carbohydrates, aka FODMAPs, were in each food (Spiller, 2016). This eventually led to the use of the low-FODMAP diet with IBS patients in medical and dietetic practices. The small particle size of these carbohydrates makes them highly osmotic, drawing water into the colon and creating IBS symptoms (Harvie et al., 2017). FODMAPs have also been shown to cause immune activation, triggering low-grade inflammation that plays a role in the manifestation of IBS symptoms (Maagaard et al., 2016). The scientists at Monash found that a western diet contains high amounts

of FODMAPs commonly found in wheat, onions, garlic, fruits, and dairy products. The first placebo-controlled study of the diet in 2014 showed significant improvements in IBS symptoms when a patient was prescribed a diet low in FODMAPs in comparison to a typical Australian diet (Halmos, Power, Shepherd, Gibson, & Muir, 2014).

### FODMAP Categories

There are five categories of food specified within the low-FODMAP diet that correspond to the short-chain carbohydrate that is predominant within each group. These categories are fructose, lactose, fructans, galactans, and polyols (Borghini, Donato, Alvaro, & Picarelli, 2017). The term FODMAPs comes from the grouping of these carbohydrates according to their chain length. High FODMAP foods trigger IBS symptoms when the bacteria in the large intestine feed on these carbohydrates and contribute to increased water secretion and/or gas production (Mansueto, Seidita, D'Alcamo, & Carroccio, 2015). This is caused by the lack of luminal enzymes that can break the glycosidic bonds present on many of these short-chain carbohydrates, causing them to be fermented by the gut microbiota (Borghini et al., 2017). The luminal distention that often occurs, along with visceral hypersensitivity, can contribute to the abdominal pain experienced by most IBS suffers (Mansueto et al., 2015). Table 1 shows the categories of FODMAPS and examples of foods within each category that contain high or low amounts.

Fructose, a monosaccharide, is found in many fruits and sweetened drinks. It has the smallest carbohydrate structure out of all the FODMAPs, making it

osmotically active. This can result in the pulling of water into the intestinal lumen, contributing to abdominal pain and diarrhea when eaten in large amounts. Diets that are high in fructose can also cause excess gas production and bloating as a result (Barrett, 2017).

Table 1. FODMAP categories and examples of high-FODMAP foods and low-FODMAP alternatives within each category

| **Fructose** | | **Lactose** | |
|---|---|---|---|
| High-Fructose | Alternatives | High-Lactose | Alternatives |
| Watermelon | Blueberries* | Ricotta cheese | Hard cheeses (cheddar, swiss, mozzarella) |
| High-fructose corn syrup | Maple syrup | Cow's milk | Lactose-free cow's milk or almond milk |
| Mangoes | Strawberries* | Yogurt | Lactose-free yogurt |
| Apples | Pineapple* | Ice cream | Lactose-free ice cream |
| Honey | White sugar | Cottage cheese | Lactose-free cottage cheese |
| Rum | Vodka | Cream cheese | Lactose-free cream cheese |
| **Polyols** | | **Fructans** | |
| High-Polyol | Alternatives | High-Fructan | Alternatives |
| Cauliflower | ¼ Celery stalk | Wheat | Rice |
| Mushrooms | Oyster mushrooms | Rye | Oats |
| Blackberries | Cantaloupe | Barley | Quinoa |
| Sorbitol** | White sugar | Garlic | Oil infused with garlic |
| Mannitol** | Brown sugar | Onions | Scallions (green part only) |
| Xylitol** | Stevia | Pistachios | Almonds* |
| **Galactans (GOS)** | | | |
| High-GOS | | Alternatives | |
| Mature soybeans (soy milk, soy flour) | | ¼ cup Chickpeas | |
| Black beans | | 1 cup Edamame | |
| Navy beans | | ½ cup Lentils | |
| Kidney beans | | Tofu (firm) | |
| Cashews | | Pumpkin seeds | |
| Pistachios | | Sunflower seeds | |

*Limit to one serving per meal
**Sweeteners commonly used in products labeled as low-carb or sugar-free
(Information obtained from Scarlata, 2017a and Scarlata, 2017b)

Foods that contain fructose in excess of glucose are known to cause more symptoms than foods containing both in equal ratios or glucose in excess of fructose. This is because glucose can promote the uptake of fructose through pathways in the small intestine (Mahan & Raymond, 2017). Previously, fructose malabsorption was thought to largely contribute to IBS symptoms, but it has recently been found that there is only a relatively small amount malabsorbed. Fructose can contribute to IBS symptoms even if it isn't malabsorbed. The slow rate of absorption across the length of the small intestine has an osmotic effect, regardless if the fructose has been completely absorbed or not (Barrett, 2017).

Lactose is a disaccharide that is found in all dairy products in varying amounts. Lactose intolerance affects 30-50 million people in the U.S. and is due to a deficiency in the enzyme lactase (Butler, 2018). This deficiency can cause symptoms similar to IBS, like bloating, abdominal pain, and diarrhea. These deficiencies often come in the form of primary or secondary lactase deficiency. Primary deficiency is the reduction of the activity of the lactase enzyme. Secondary lactase deficiency results from diseases of the GI tract, such as celiac disease or gastroenteritis, condition that reduce lactase activity (Nanayakkara, Skidmore, O'Brien, Wilkinson, & Gearry, 2016).

Fructans are oligosaccharides that are found in high quantities in a variety of different foods. All humans lack the hydrolases needed to break down these carbohydrates, allowing the fructans to reach the large intestine where they are fermented by microbiota, often causing abdominal bloating and gas. In those with IBS, these symptoms can be exacerbated in comparison to a normal, healthy

individual (Shepherd, Parker, Muir, & Gibson, 2008). Galactans or galacto-oligosaccharides (GOS) are another type of oligosaccharide and are found in most legumes in high amounts. As with fructans, humans do not contain hydrolases required to completely digest galactans in the gut. Therefore, bloating and gas also frequently occur after a meal high in galactans in certain individuals (Shepherd et al., 2008).

Polyols are a unique group within FODMAPs. They do not form a typical carbohydrate structure, but are instead classified as sugar alcohols that made by the catalytic hydrogenation of carbohydrates (Lenhart & Chey, 2017). Polyols tend to produce a laxative effect when eaten in excess, causing symptoms indicative of IBS-D.

**FODMAP Elimination Phase**

Before starting a low FODMAP diet, a patient should have a diagnosis of IBS from a licensed practitioner or GI specialist. This ensures that all other GI diseases or disorders are ruled out. In individuals that have other GI diseases, a different dietary approach may need to be taken. One example of the importance of the correct diagnoses is in the case of celiac disease. If a patient who was not yet diagnosed with celiac disease started the FODMAP diet based on their symptoms, they may experience a positive outcome as the low-FODMAP diet excludes most foods with gluten. The negative outcomes of this misdiagnosis would possibly be nutritional deficiencies from the restrictive nature of the diet. In other misdiagnoses, using the diet as a sole treatment protocol could also induce

nutritional deficiencies, worsening of symptoms, and exclusion of a more effective treatment (Barrett, 2017).

When a diagnosis has been made, the next step is for the patient to work closely with a RDN to discuss the fundamentals of the low-FODMAP diet and develop a plan to implement the diet that addresses the patient's specific needs. This can be done in either a group setting or a one-on-one counseling session (Barrett, 2017). The RDN will walk the patient through all the steps of the diet: elimination, re-challenging, and a personalized, long-term diet. Working with a RDN will ensure that the patient's nutritional needs are met while developing a long-term diet that the patient can follow to gain control of their symptoms.

The elimination phase usually lasts 3-4 weeks depending on the patient and the degree of symptom control. This phase can last up to 6 weeks if symptoms still persist after 4 weeks. If the patient has determined that the symptoms usually present with their IBS are sufficiently lower in severity during the elimination phase, then they can move on to the re-challenging phase. If symptoms do not improve or contraindications are present within the elimination phase, then moving on to re-challenge the foods is not recommended, and other forms of treatment should be considered. This does not mean that the low-FODMAP diet will not help this patient in the future, but other etiologies of IBS should be examined before focusing on diet. For example, someone with high levels of stress may need to focus on reducing their stress levels before the low-FODMAP diet can truly work.

In the elimination phase, all foods containing high levels of FODMAPs in a single serving are eliminated, and the portion sizes of other moderate-FODMAP

foods are smaller and spread out during the day. RDNs can help a patient develop a meal plan and show them which foods they can include in their diet. The RDN is integral in ensuring nutritional adequacy during this phase and weight maintenance, if desired. Although this phase restricts a long list of foods, there is still variety included in the allowed food list (See Table 1).

Each MyPlate food group (dairy, protein, fruits, vegetables, and grains) can be included in some way during the elimination phase. The protein group can be considered the least restrictive on this diet as a good portion of foods in this group contain very little, if any, carbohydrates and fibers. Meat and eggs are virtually FODMAP-free, while some nuts can be eaten in small quantities. All legumes and some nuts are not allowed during this phase because of their high fructan content (Scarlata, 2017a). Although all dairy foods contain lactose, many low-lactose and lactose-free dairy foods and non-dairy alternatives can be enjoyed during elimination.

Most of the components of the grain group during elimination need to be gluten-free (GF) to keep wheat out of the diet. However, this does not mean the patient has to be completely GF. Slow-leavened breads such as sourdough wheat or spelt breads have been deemed low-FODMAP. It is best to check with a RDN to receive recommendations on brands that are suitable for a low-FODMAP diet (Scarlata, 2017b).

The fruit and vegetable groups contain the highest variety of different FODMAPs and therefore may be the most difficult to restrict. The vegetable group contains foods high in polyols, fructans, GOS, and fructose. The biggest culprits in

the American diet are onions and garlic. Due to its use in many processed foods and spice mixtures, the patient may have to cook most meals at home in order to avoid fructans. For example, beef alone is low-FODMAP, but it may be seasoned with garlic and onion powder when eating out at a restaurant. It is important for the RDN to teach their clients how to read ingredient lists to make the elimination phase successful. All fruits contain fructose in differing levels. However some fruits contain fructose above the cutoff values for the low-FODMAP elimination diet. Some of these fruits also contain high amounts of polyols, fructans, and GOS. Since the low-FODMAP fruits contain moderate amounts of fructose, close attention needs to be given to the serving size. Usually, ½ -1 cup is safe depending on the fruit.

Other food components that do not fall into a food group category include drinks, sweeteners, and other food additives. Sugar alcohols are high-FODMAP sweeteners used in foods such as sugar-free gum, sugar-free candy, and low-carb protein shakes or bars. These compounds are notorious for causing diarrhea due to their osmotic activity in the gut. Certain teas are high in fructans/GOS and can cause bloating and flatulence. These include oolong, chamomile, and fennel teas. Alcohol can be a big culprit of IBS symptoms. During the elimination diet, up to one beer (12 oz), one glass of wine (4 oz), or one ounce of liquor can be enjoyed per sitting. Rum is high in FODMAPs and needs to be eliminated during this phase. Other food additives to look out for are carob (usually found in vegan chocolate chips), chicory root extract, and inulin, and it is important to read labels carefully to avoid these ingredients as many "health foods" such as gluten-free products, vegan foods, and protein shakes/bars contain these additives. Just because the product is GF doesn't

mean it's low-FODMAP. If symptoms appear to improve in any way, it is time to move on to the re-challenge phase of the diet (Scarlata, 2017a).

### Re-challenging

Re-challenging involves trying the foods that have been removed during the elimination phase in varying amounts and at different times to pinpoint what FODMAP groups one can tolerate and in what amounts. The goal of this phase is to expand the diet to the highest degree while maintaining symptom control (C. Tuck & Barrett, 2017). After one finds which foods can be tolerated, a personalized low-FODMAP diet that is tailored to long-term dietary needs is implemented. This entire phase involves a lot of self-monitoring of symptoms and noting exact triggers (Martin, 2016).

The re-challenge phase is important, especially for those able to tolerate certain categories of FODMAP-containing foods, and thus needing to use a modified version of the low-FODMAP diet long-term. Restricting all high-FODMAP foods long term may lead to nutritional deficiencies and a change in the diversity of the gut microbiota; thus, identifying which categories can be tolerated will liberalize the diet and reduce this risk. Although the foods taken out during the elimination phase have been determined to cause IBS symptoms in some individuals, they still have healthful qualities and may be tolerated in smaller amounts (C. Tuck & Barrett, 2017).

At the start of the re-challenging stage, a RDN or doctor will ask that the patient not change any of their other daily habits outside of their diet to be able to

identify if it is the removal of FODMAP-containing foods that is affecting symptoms. There are many other strict protocols one must follow in order to make the results as accurate as possible. The patient must continue to follow a low-FODMAP diet throughout the re-challenge phase and only challenge foods during the specific time frame outlined with the specific FODMAP group. The patient will test different portions within each FODMAP group three days in a row and then go back on the elimination diet for a washout period (Martin, 2016). It is very important to test each FODMAP group separately because of their different physiological effects on the gastrointestinal tract. If symptoms experienced are severe during one portion on the three-day period, then the patient can stop the re-challenge of that particular group, note the symptoms, and start the washout period (C. Tuck & Barrett, 2017).

This phase can consist of 5-10 re-challenges, with each one taking about a week to complete. During the three-day testing period, portion sizes of the FODMAP group will increase each day followed by a three-day washout period. The washout period ensures that there is no carryover effect from one type of FODMAP when moving on to another group to re-challenge. The washout period may need to be longer depending on the severity of the symptoms experienced during the re-challenge. The small, medium, and large portion sizes tested over a three-day re-challenge depend on the food being tested. An example of a small, medium, and large portion size of garlic is ¼ of a clove, ½ of a clove, and 1 whole clove, respectively (Martin, 2016). Close guidance by a RDN is necessary to understand the exact portion sizes to be tested for each food during each phase.

Since there are only five different groups of FODMAPs but up to 10 re-challenges, some of the group can be split into subgroups or combination groups depending on how many different types of foods are in each one. It is key to test the 5 main FODMAP groups first, without any foods that are in multiple categories. This will help pinpoint which groups the individual can or cannot tolerate. For example, some fruits, such as apples, contain both fructose and sorbitol, which is a polyol. After testing the five main FODMAPs alone, the patient can include combination groups, where foods with multiple FODMAPs would be tested to see if the combination of specific FODMAPs together would induce symptoms differently than they would produce separately. For example, a group that includes foods with both fructose and sorbitol could be tested with apples and pears because they contain high amounts of both FODMAPs (C. Tuck & Barrett, 2017). Another way to test foods is to challenge different food groups within each FODMAP. The fructans group is a good example of a group that would be able to be separated into subgroups of fruits, vegetables, and grains. This could be beneficial for a patient who is very sensitive to fructans. If different food groups within the fructans category resulted in dissimilar symptoms, then the patient might be able to include some sources of fructans in their diet in their personalized low-FODMAP diet (Martin, 2016).

### Personalized Low-FODMAP Diet

After the re-challenge phase, the patient will be able to tailor a long-term dietary pattern that is easy for them to follow and will limit IBS symptoms. Based on the symptom presence and severity produced by FODMAP-containing foods, the

patient may not have to completely avoid any foods. It is very important that the patient records all symptoms experienced during re-challenges and the exact portion sizes. Small amounts of offending foods can often be consumed when the patient is cognizant of all FODMAPs consumed within a day. They key of maintaining the low-FODMAP diet long-term, without nutritional deficiencies, is to incorporate low-FODMAP foods from all food groups. Using the U.S. dietary guidelines as described through MyPlate is a helpful tool to keep variety in the diet. It is important for a patient to check in with a RDN on a regular basis to maintain meal patterns that are nutritionally adequate.

**Efficacy of the Low-FODMAP Diet**

Multiple researchers looking at the effectiveness of the low-FODMAP diet report that around 70% of IBS patients have symptom reduction (Gibson & Shepherd, 2010; Gibson, 2017c; Nanayakkara et al., 2016). Recent researchers have also shown that patients report overall improvement in quality of life when implementing the diet due to a reduction in symptom severity. The change in stool pattern and type that happens as a result of eliminating FODMAP triggers may play a role in preventing abdominal pain and distention that is experienced by many IBS sufferers (Maagaard et al., 2016).

Researchers of a recent meta-analysis looked at randomized control trials and cohort studies examining traditional diets, high-FODMAP diets, and low-FODMAP diets and their outcomes in patients. Patients who implemented a low-FODMAP diet had significant reduction in bloating and abdominal pain compared to

a traditional IBS diet and a high-FODMAP diet. However, the scientists also shed light on the fact that this does not prove that the low-FODMAP diet is a better treatment option compared to traditional IBS diets that follow the National Institute for Health and Care Excellence (NICE) guidelines in the long term. More studies are needed to look at the long-term contraindications of reducing FODMAPs (Altobelli et al., 2017).

A recent study compared the effects of a low-FODMAP diet vs a modified diet recommended by NICE on health-related quality of life (QOL), work productivity, anxiety and depression, and sleep quality. A total of 84 patients with diarrhea-predominant IBS were randomly placed into the two experimental groups and were assessed before and after the implementation of their respective diets. Patients in the low-FODMAP group had better scores on QOL, anxiety, and activity impairment when compared to the group following the NICE guidelines (S. Eswaran et al., 2017). Another study that compared the low-FODMAP diet with NICE guidelines looked at symptom control as a result of either diet. A total of 76% of patients using the low-FODMAP diet reported positive symptom control compared to 54% in the traditional diet group (H. M. Staudacher, Whelan, Irving, & Lomer, 2011). An additional study comparing these two diets gave similar results; about half of the IBS-D patients in each group reported adequate relief of symptoms. However, the low-FODMAP diet had significantly higher scores when looking at relief of individual symptoms, such as abdominal pain and bloating (S. L. Eswaran, Chey, Han-Markey, Ball, & Jackson, 2016).

When looking at individual clinical trials, it is important to note that it is almost impossible to use the "gold standard" of double-blind, prospective, placebo-controlled studies when researching the effectiveness of the low-FODMAP diet. The use of uncontrolled studies to look at efficacy of the diet can lead to bias and multiple confounding factors (Nanayakkara et al., 2016). Several key attributes of low-FODMAP intervention trials should be taken into consideration when evaluating the literature. First, the duration of clinical trials is relatively short, meaning assumptions cannot be made regarding the long-term effects the diet may have. However, because long-term elimination diets can bring ethics into question, longer studies may not be possible. Second, the number of subjects used in a study has to be considered before the degree of significance can be evaluated. The results of small studies cannot be generalized to the whole population. Finally, the criteria for selection of patients in the study needs to be standardized in some way. The Rome IV is the standardized system of IBS diagnosis that should be used to identify patients with IBS that may benefits from the FODMAP treatment plan (Gibson, 2017b).

**Low-FODMAP Diet Challenges and Concerns**

The effectiveness of the low-FODMAP diet depends heavily on evidence-based food composition data from reliable sources. Monash University in Australia provides the most complete and up-to-date list of foods and their FODMAP content. Techniques such as high-performance liquid chromatography and enzymatic hydrolysis provide accurate methods for researchers to develop food composition

lists. However, many of these lists don't take into account the variations in climates, brands, and cooking practices across the world that may affect FODMAP content. RDNs play an integral role in translating the composition data into information that the general public can understand. It is best for a patient following the diet to consult a RDN to go over food lists and develop a general meal plan to ensure nutritional adequacy and balance (C. J. Tuck, Muir, Barrett, & Gibson, 2014).

While long-term restriction of all FODMAPs is not recommended, some patients may continue to implement an elimination-type diet in fear of their symptoms returning. Avoiding FODMAPs long-term takes a large source of prebiotics out of one's diet, which are proven to have beneficial effects on the gut microbiome. These fibers, when fermented by bacteria in the gut, produce short chain fatty acids that have been shown to have positive effects on the body. Some of these fibers are fermented to make nutrients such as Vitamin K, which is necessary for the formation of blood-clotting factors (Harvie et al., 2017). It has been shown that the elimination phase commonly leads to marked alterations in the number and diversity of the gut microbiota, although more studies need to be done to determine the significance of these changes (C. Tuck & Barrett, 2017). Even adding some high-FODMAP foods back into the diet in small amounts may reduce the alterations experienced during the elimination phase. However, no research has been conducted to explore this prediction (C. Tuck & Barrett, 2017). RDNs can help a patient successfully reintroduce FODMAPs back into their diet while keeping in the mind the amount of prebiotics that are being consumed.

Another concern about the use of the low-FODMAP diet, especially during the elimination phase, is the nutritional deficiencies that may result from restricting a long list of foods. Although entire food groups are not withheld from the diet, it is important, but often difficult, to maintain variety during all phases to ensure that nutrient and caloric needs are being met. One study showed that more than 50% of patients were deficient in the recommended intakes of calcium and iron. However, when compared to the general population, these values were quite similar (H. Staudacher et al., 2015). In another study, reductions in fiber intake in those implementing a low-FODMAP were recorded. After these subjects introduced FODMAPs back into their diets, fiber intake increased back to pre-intervention levels (Harvie et al., 2017). More studies need to be done to examine specific nutrients that may be of concern while one this diet. When considering specific nutrient needs, the use of a RDN becomes the subject of upmost importance during all phases of the low-FODMAP diet.

Another contraindication of this diet would be its use for people with eating disorders (ED). The restrictive nature of this diet may not be suitable for those with disordered eating because it may trigger orthorexic or anorexic behaviors. The use of this diet for those with a history of ED should be justified first by a practitioner. The benefits of controlling IBS symptoms should outweigh the negative effects of triggering obsessive behaviors. Sometimes the health outcomes that come from over-restricting may actually be worse for the patient's health than the symptoms that result from IBS. Patients with orthorexia may attribute all of their symptoms to food, even though IBS is a multifactorial disease. Red flags of these ED tendencies

could be severe restriction and over-adherence to the diet, even when a certain FODMAP group has been deemed safe to consume after the re-challenge phase. In this population, a non-diet approach may need to be considered before a low-FODMAP diet is prescribed. Any IBS patient with a history of ED should first meet with a RDN to go over the best treatment options (Halmos, 2017).

Certain studies have also looked at the efficacy of FODMAP restriction in other GI diseases, in particular, inflammatory bowel disease (IBD). Implementation of the low-FODMAP diet in a research setting showed a decline in symptoms such as abdominal pain, bloating, and diarrhea, as well as improvements in stool frequency (Nanayakkara et al., 2016). One review reported that reducing FODMAP intake showed symptom reduction in 50% of patients with Crohn's disease or ulcerative colitis (Gearry et al., 2009). More studies are needed before these results can be translated into practice for GI disorders apart from IBS, but the preliminary studies are promising.

**New Findings and Future Directions**

In general, more studies need to done to support the overall effectiveness of this diet. Some aspects of the diet, such as concerns for nutrient inadequacy and ineffectiveness in certain populations, should be looked at in more detail to determine if this diet is appropriate as a first-line treatment for IBS.

Future directions in the research of FODMAPs should be to implement longer prospective trials to test the effect of the low-FODMAP diet on the composition of the colonic microbiome. However, doing so brings into question human ethics and

the possibility of adverse effects stemming from these studies. Along with studying the microbiota, there needs to be research done on the level of nutrient density that can be achieved from a personalized low-FODMAP diet in the long-term. This will determine if a long-term diet can be achieved without individualized restrictions leading to nutrient deficiencies (Halmos, n.d.).

Through more research, a standardized system of testing FODMAPs can be developed to ensure more reproducible results that can be applied to a variety of study populations (Nanayakkara et al., 2016). This would broaden the foods included on a low-FODMAP diet to use in clinical practices around the world. Addressing how the low-FODMAP diet can fit into cultures around the world would be an interesting topic in research and in clinical practice.

**Conclusion**

Overall, the low FODMAP diet is an efficacious treatment option for those with irritable bowel syndrome. In most studies, approximately three-quarters of the patients experienced symptomatic relief. Not all studies were of double-blinded design, but they represent how this diet would be implemented in a clinical setting. Through the elimination phase, re-challenge phase, and the personalized diet that follows, it is crucial for a RDN to be involved. This ensures that the patient is receiving the right amount of nutrients and not completely restricting certain food groups. If the patient were to use an elimination diet in the long-term, nutrient deficiencies and alterations in the gut microbiome could follow. A RDN can help the patient find a personalized low-FODMAP diet that addresses their unique

sensitivities and is not unnecessarily restrictive. At this time, the low-FODMAP diet has been proven to be most efficacious in the short-term, but evidence has shown it has the potential to be a nutritionally balanced option for those using it long-term.

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