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Original article

Detection of FODMAP Intolerances and Symptom Improvement Following Dietary Intervention in Patients from Northwestern Mexico

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Abstract

Introduction: Fermentable oligo-, di-, monosaccharides, and polyols (FODMAP) are associated with gastrointestinal symptoms in patients with gut-brain interaction disorders, negatively impacting quality of life if left untreated. **Objectives:** To identify FODMAP intolerances in patients from Northwestern Mexico referred by gastroenterologists and to design low-FODMAP diets to alleviate their symptoms. **Methods:** A single-group quasi-experimental study was conducted, including breath hydrogen tests to detect small intestinal bacterial overgrowth and intolerances to lactose, fructose, sorbitol, and fructans. Personalized low-FODMAP diets were designed to manage symptoms. Symptoms were assessed at baseline and post-intervention using a 100-mm visual analog scale, and 24-hour dietary recalls were applied. **Results:** Of the 36 patients recruited, 21 (mean age: 35.9 years) completed the study, with 42% diagnosed with irritable bowel syndrome (IBS). At baseline, 92% reported abdominal bloating (mean severity: 6.5 ± 2.4) and flatulence (5.6 ± 2.8). Other reported symptoms included nausea (31%), reflux (28%), anxiety or stress (22%), and insomnia or irritability (17%). Intolerances were observed in 39% for lactose, 33% for fructose, 56% for sorbitol, and 61% for fructans. Following the dietary intervention, severity of abdominal bloating, abdominal pain, borborygmi, diarrhea, constipation, and flatulence decreased significantly ($p \leq 0.05$). Energy and macronutrient intake remained stable throughout the study, whereas FODMAP intake decreased markedly. **Conclusion:** A low-FODMAP dietary intervention tailored to pre-identified specific intolerances effectively reduced patients' gastrointestinal symptoms.

Keywords

Breath test, irritable bowel syndrome, food intolerance, FODMAP diet.

INTRODUCTION

Currently, Mexicans, like many other populations, alongside the stress of modern life, follow poor dietary patterns low in fiber that include ultra-processed foods with various additives[1]. Concurrently, an increase in the prevalence of disorders of gut-brain interaction (DGBI) is observed, which manifest with recurrent and persistent symptoms affecting up to 40% of the world's population[2,3]. Although the pathogenesis of these disorders is not well understood, continuous exposure to ultra-processed, low-fiber foods could promote dysbiosis and disruption of intestinal homeostasis, contributing to the exacerbation of associated symptoms[4,5].

Patients with DGBI often present with intolerance to fermentable oligo-, di-, monosaccharides and polyols (FODMAPs), which are found in various foods, either naturally in fruits and vegetables or as additives in processed products. Consequently, a low-FODMAP diet is recommended to alleviate symptoms such as abdominal bloating, gas, diarrhea, and abdominal pain[6]. A food is considered low in FODMAPs when it contains minimal

amounts of fermentable carbohydrates in a standard serving size. For their classification, specific threshold values have been established for each type of FODMAP, based on clinical evidence regarding the amount that typically triggers digestive symptoms in individuals with irritable bowel syndrome[7].

Some years ago, diagnosing FODMAP intolerance required the use of a very restrictive diet. Each type of food was reintroduced over prolonged periods to identify those causing symptoms through a trial-and-error process[8]. Now, the hydrogen/methane breath test, a reliable and validated technique to measure hydrogen or methane produced after ingesting a carbohydrate, is a useful tool for detecting FODMAP intolerance[9]. This test is neither costly nor invasive and can be accessible to the general population. Once intolerance is identified, a low-FODMAP diet is recommended, excluding foods containing the trigger carbohydrates to alleviate gastrointestinal symptoms[6,8].

The objective of this study was to detect lactose, fructose, sorbitol, and fructan intolerance using hydrogen breath tests, following analysis for small intestinal bacterial overgrowth (SIBO), and to recommend a short-term, personalized treatment with a low-FODMAP diet.

MATERIALS AND METHODS

A prospective quasi-experimental study (before and after in the same group, without including a control group) was conducted in patients with DGBI from Northwestern Mexico. The independent variable was the treatment based on a personalized low-FODMAP diet, according to pre-detected intolerances. The dependent variable was the set of gastrointestinal symptoms. Secondary variables were sex, age, and diet. The study consisted of two periods of one month each. In the first period, hydrogen breath tests were performed, subjecting each patient to a maximum of two tests per week, on different days. In the second period, a nutritionist gave participants dietary recommendations to follow a low-FODMAP diet according to the breath test results.

Participants and Data Recording

A non-probabilistic, purposive sampling method was carried out. Patients referred by gastroenterologists were invited to participate. The study objective and general protocol were explained to them. Those who agreed to participate signed an informed consent form, and their clinical data were recorded. Individuals with celiac disease or small intestinal bacterial overgrowth were excluded, as were patients who had taken antibiotics or undergone a colonoscopy in the last four weeks. Before treatment with the low-FODMAP diet, a 24-hour dietary recall was applied to assess food intake. The severity of gastrointestinal symptoms was also assessed: abdominal pain, abdominal bloating, diarrhea, constipation, gas, borborygmi, and others, using a 100 mm visual analog scale (VAS), with values of 0 (none), 4 (moderate), and 10 (intense)[10].

Hydrogen Breath Tests

Hydrogen breath tests were performed according to the method of Gasbarrini et al.[11]. Patients were instructed the day before the test to avoid consuming alcohol, carbonated beverages, and high-fiber foods. On the day of the examination, they were asked to present after a 12-hour fast and with good oral hygiene. Additionally, they were asked not to engage in sports activity at least one hour before the test because hyperventilation decreases the concentration of exhaled hydrogen, which can compromise diagnostic accuracy. During the test, they were only allowed to drink water.

Initially, SIBO detection was performed with a 65 g dose of glucose (Quintron©, Milwaukee, Wisconsin, USA). Patients with a positive result were referred to a gastroenterologist for treatment and excluded from the study. Patients with a negative result continued with the tests to identify intolerances. For lactose, 25 g (Quintron©) were administered; for fructose, 45 g of agave syrup (Unicornio©, Guadalajara, Mexico), containing 25 g of fructose, were administered. For sorbitol, 10 g (Quintron©) were given, and for fructans, 17.5 g of agave inulin (Unicornio©), containing 8 g of fructans, were given. All doses were dissolved in 250 mL of purified water for administration. Tests were performed with a minimum washout period of three days between them.

In each test, baseline breath samples (in duplicate) were taken before dosing. After administering the corresponding dose (lactose, fructose, sorbitol, or fructans), breath samples (in duplicate) were taken every 20 minutes during the first hour and then every 30 minutes until reaching three hours. During the tests, patients recorded their symptoms using the 100 mm VAS. Upon completion, the hydrogen concentration of the baseline and post-dose samples was measured in a pre-calibrated MicroLyzer mod CM-2 gas chromatograph (Quintron©) using 102 parts per million (ppm) hydrogen (QuinGas, Quintron©). The test was considered positive when an increase of ≥20 ppm of hydrogen compared to the baseline value was obtained.

Breath test interpretation was performed according to Amieva-Balmori et al.[12]. *Malabsorption* was defined as a positive test (H2 ≥20 ppm) without gastrointestinal symptoms, and *intolerance* was defined as a positive test accompanied by symptoms. The test was normal when it was negative (H2 <20 ppm) without symptoms. *Visceral hypersensitivity* was considered when the hydrogen concentra-

tion did not exceed 20 ppm, but during the test, the patient presented new (not habitual) symptoms or experienced ≥2 symptoms with moderate or greater severity (VAS ≥4), suggesting an exaggerated response of the enteric nervous system to the test carbohydrate[13].

Dietary Counseling and Recommendations

Dietary counseling was provided by a nutritionist in weekly 30-50 minute sessions for one month. Patients received individualized diets according to their breath test results. They also received nutritional education based on the Mexican official standard NOM-043-SSA2-2012 "Basic health services, promotion and education for healthy eating"[14] and beverage consumption recommendations[15]. They were trained to measure food portions using the palm of their hand or kitchen utensils. The importance of checking the nutritional labeling of foods and identifying ingredients high in FODMAPs was explained to them using food label samples.

Patients who completed the protocol were advised to avoid high-FODMAP foods for two weeks, then reintroduce them during the following two weeks in small quantities to prevent symptoms and gradually increase the amount based on their tolerance. To help them comply with the dietary recommendations, they were given printed materials, including a list of high and low FODMAP foods, a shopping list, and a seven-day menu with low-FODMAP foods and meals (1320-1504 kcal/day).

Follow-up and Adherence to Dietary Recommendations

Patients were contacted weekly via social media, phone, or in person to resolve doubts and verify their adherence to the treatment. At the end of the month, a 24-hour food recall was applied to indirectly assess adherence to the low-FODMAP diet. The intensity of gastrointestinal symptoms was also assessed using the VAS.

Statistical Analysis

Demographic data, baseline symptoms, and symptoms during the breath tests were analyzed descriptively. The non-parametric Mann-Whitney U test was used to compare symptom severity and differences in FODMAP consumption before and after the dietary recommendations. Statistical significance was set at a p-value ≤0.05. The NCSS package version 2006 (NCSS, LLC. Kaysville, Utah, USA) was used.

Ethical Considerations

All procedures performed in this study followed the principles of the Declaration of Helsinki. The bioethics committee of our institution approved the protocol (CE/011/2018). All participants signed an informed consent form after being informed about the study, and their data were handled with strict confidentiality. Under no circumstances was patient information disclosed that would allow their identification. Their participation in the study was completely voluntary, and they could leave at any time they wished.

RESULTS

Participant Characteristics

Fifty-one subjects were invited to participate in the study, of whom 15 were not eligible (**Figure 1**). Thirty-six participants with negative SIBO tests were recruited. Subsequently, 8 patients dropped out of the study due to the duration of the tests (3 hours), lack of availability to attend appointments, or personal reasons. Of the remaining participants, 28 completed at least two intolerance tests (lactose, fructose, sorbitol, fructans). Afterwards, seven left the study for personal reasons or lack of time. Finally, 21 participants completed the protocol, which included four intolerance tests, counseling, and personalized recommendations for a low-FODMAP diet, and follow-up assessment of gastrointestinal symptoms.

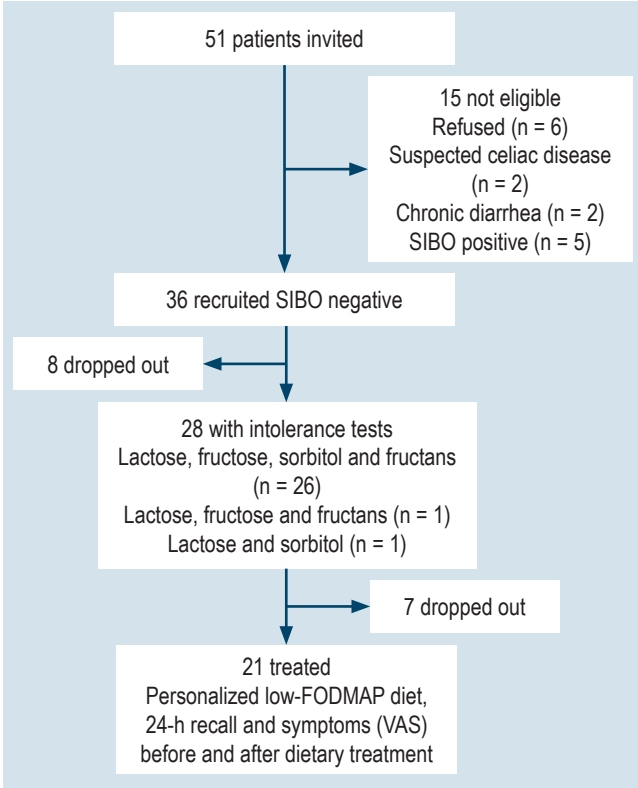

Figure 1. Participant recruitment flow diagram. Image property of the authors.

Participants were predominantly women, with a mean age of 35.9 years (**Table 1**). Forty-two percent had irritable bowel syndrome (IBS) and 8% had had SIBO months before, but symptoms persisted after a negative test. The rest had no defined diagnosis for their condition but experienced persistent gastrointestinal symptoms that worsened after eating.

Table 1. Demographic Characteristics of Participants

Variable	Recruited	Treated
Patients, n (%)	36 (100)	21 (58)
Sex, n (%)		
- Male	8 (22.2)	2 (9.5)
- Female	28 (77.8)	19 (90.5)
Age, mean (SD)	35.9 ± 17.5	36.9 ± 13.4

Data are presented as number (%) of the total group or mean ± standard deviation. SD: standard deviation. Table prepared by the authors.

At the start of the study, 92% of recruited patients presented with abdominal bloating and gas with a severity (VAS: 0-10) of 6.5 ± 2.4 and 5.6 ± 2.8, respectively. Eighty-six percent presented with borborygmi (4.8 ± 2.6), 83% (4.2 ± 2.6) with abdominal pain, 81% (4.3 ± 3.5) with constipation, and 61% (3.4 ± 3.1) with diarrhea. Other symptoms were nausea (31%), reflux (28%), stomach heaviness along with loss of appetite (19%), and belching (11%). Non-gastrointestinal symptoms were anxiety or stress (22%), insomnia or irritability (17%), depression (14%), dizziness (6%), and headache (6%). Most patients (33 of 36) noticed the onset or worsening of symptoms after consuming certain foods, mainly those high in FODMAPs. Other foods related to intestinal discomfort were spicy or fatty foods and irritants, such as coffee.

Hydrogen Breath Tests and Symptoms During Testing

Table 2 presents the prevalence (%) of tests positive for lactose, fructose, sorbitol, and fructans. All patients were positive for one saccharide and more than half (64%) for two or more.

Patients with positive tests showed intolerance to fructans (60.9%), sorbitol (56.5%), lactose (39.1%), and fructose (33.3%). Those with a positive result without symptoms were classified as having malabsorption. Thirteen percent had lactose malabsorption, 13% sorbitol malabsorption, 4.8% fructose malabsorption, and 4.3% fructan malabsorption. Patients with negative tests but who experienced symptoms during the test were classified as having visceral hypersensitivity. Visceral hypersensitivity was present in 21.7% for lactose, 19% for fructose, 17.4% for sorbitol, and 8.7% for fructans.

Table 2. Percentage of Positive Hydrogen Breath Tests*

Saccharide	Recruited (n = 28)	Treated (n = 21)
Lactose	14 (50.0)	12 (57.1)
Fructose	14 (50.0)	8 (38.1)
Sorbitol	19 (67.9)	14 (66.7)
Fructans	18 (64.3)	14 (66.7)

*Data are presented as number (%) of the total group. Table prepared by the authors.

Symptom and Diet Follow-up

All participants who completed the protocol expressed their satisfaction with the symptom relief provided by the low-FODMAP diet (**Figure 2**). Overall, symptom severity decreased significantly ($p \leq 0.05$), primarily abdominal bloating, gas, and borborygmi. Furthermore, they did not present other symptoms such as nausea, reflux, or non-gastrointestinal symptoms.

During follow-up, the nutritionist maintained close contact with the patients to monitor their nutritional needs. The intake of energy, macronutrients, fiber, and calcium did not vary significantly with the low-FODMAP diet (**Table 3**). In contrast, FODMAP intake decreased notably, especially for fructose and fructans ($p \leq 0.05$).

Table 3. Nutrient and FODMAP Content in Participants' Diet Before and After Dietary Recommendations

Variable	Before	After	*p*-value*
Energy, kcal/d	1879.4 ± 1154.4	1914.6 ± 970.2	0.9523
Protein, g/d	75.8 ± 35.2	102.9 ± 78.4	0.6458
Fat, g/d	77.6 ± 59.6	65.7 ± 32.3	0.6458
Carbohydrates, g/d	224.9 ± 118.2	228.9 ± 150.7	0.7342
Fiber, g/d	24.3 ± 15.8	19.6 ± 9.9	0.4116
Calcium, mg/d	778.2 ± 554.6	612.8 ± 306.9	0.4590
Lactose, g/d	3.2 ± 8.7	0.80 ± 2.39	0.0974
Fructose, g/d	12.2 ± 11.7	0.77 ± 1.39	0.0001
Sorbitol, g/d	1.1 ± 2.4	0.23 ± 0.35	0.1347
Fructans, g/d	3.9 ± 7.1	0.20 ± 0.2	0.0007

*Mann-Whitney U test ($p \leq 0.05$). Table prepared by the authors.

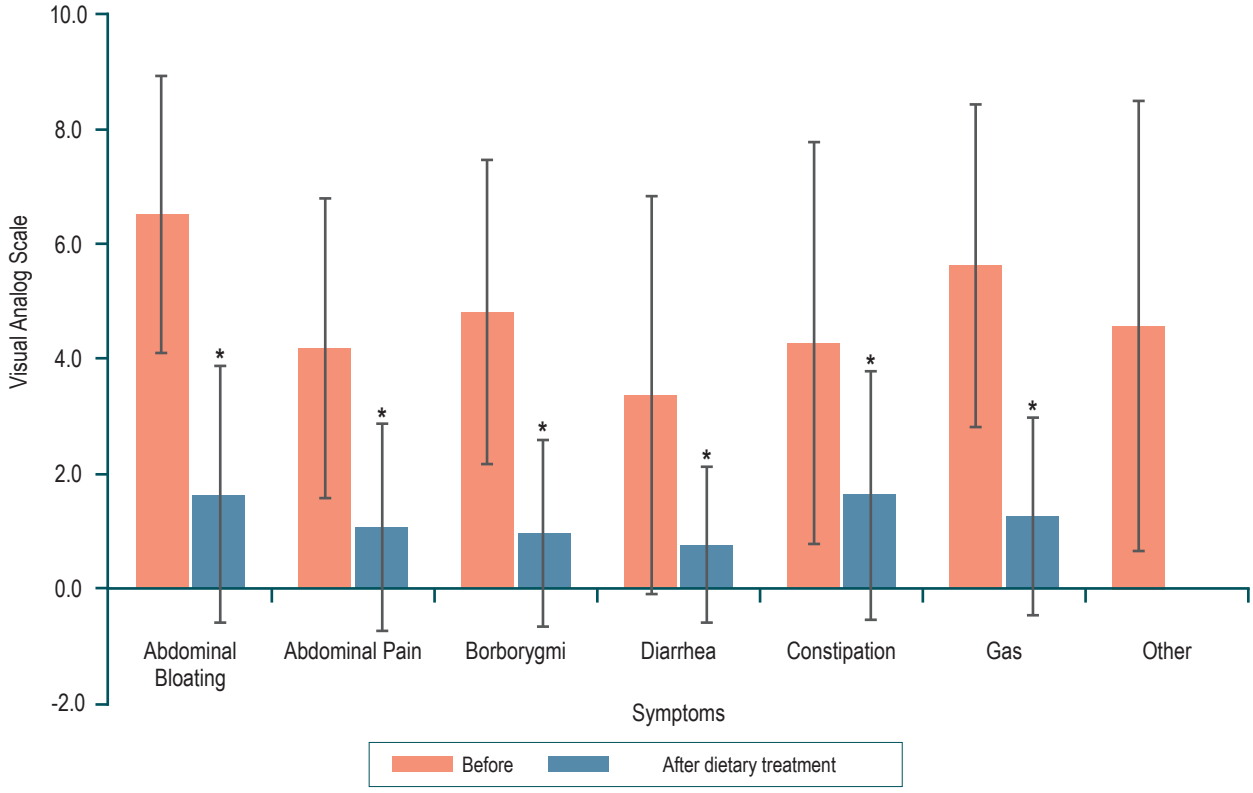

Figure 2. Changes in symptoms after dietary treatment. Values are presented as mean ± standard deviation. *Statistical significance p ≤0.05. Image property of the authors.

DISCUSSION

The initial SIBO test was essential to obtain reliable results in the intolerance tests. Abnormal bacterial growth in the small intestine can induce fermentation and gas production, leading to false positives, so it is necessary to ensure its absence to minimize this risk[16].

At the start of the study, the three most common and severe symptoms reported by our patients were abdominal bloating, gas, and borborygmi, typical in disorders of gut-brain interaction, such as IBS. Gas-related symptoms significantly impact patients' quality of life[17] and, as observed in this study, finding effective solutions to alleviate them is an important achievement[3].

Regarding non-gastrointestinal symptoms, anxiety, stress, insomnia, and irritability were the most frequently mentioned by patients. These symptoms, along with depression, dizziness, and headaches, which were also reported, are associated with disorders of gut-brain interaction, such as IBS[5,18]. Sleep disturbances, for example, could contribute to activating inflammatory cascades, as disruption of circadian rhythms is a form of biological stress[19]. Furthermore, stress affects various functions of the gastrointestinal tract, such as gastric secretion, intestinal motility, and mucosal permeability, which act as cofactors in the development of gastrointestinal symptoms[3]. Therefore, it is necessary to help patients manage stress, as it plays an important role in the pathogenesis of gastrointestinal disorders[20].

Our patients primarily associated their symptoms with high-FODMAP foods, similar to observations in other studies[10,12,17], without knowing they had developed malabsorption or intolerance problems. Identifying the specific symptom triggers allowed for a more refined dietary treatment, which, in turn, indirectly alleviated discomfort in the intestinal mucosa. This specific dietary approach played a crucial role in symptom relief.

This study found a lower prevalence of lactose intolerance (39%) compared to others. Amieva Balmori et al.[12], for example, reported a prevalence of 44% in patients with chronic gastrointestinal symptoms. Wilder-Smith et al.[21] found an even higher prevalence (51%) in patients with functional gastrointestinal disorders (IBS, functional dyspepsia, and functional bloating). Although the prevalence of lactose intolerance in people with gastrointestinal disorders is unknown in Mexico, it is estimated to be approximately 30% in the general population[22]. Currently,

consumption of lactose-free foods is common, which could contribute to many people being unaware of their lactose intolerance condition.

Fructose intolerance in our study (33%) was similar to the 34% observed by Amieva-Balmori et al.[12], but lower than the 52% reported by Reyes-Huerta et al.[23] in Mexicans with IBS, and half the prevalence of 60% observed by Wilder-Smith et al.[21] This variability in prevalence could be attributed to factors such as microbiota composition, dietary habits, and genetics[4,6,24].

Breath tests for sorbitol and fructans are not widely recognized in clinical practice and are primarily used in research studies. However, Sia et al.[25] identified a clinically significant association between fructose and fructan "malabsorption" (determined by a positive hydrogen breath test without symptom assessment) in patients with IBS. They observed that patients with positive tests for either type of malabsorption were 1.95 times more likely to test positive for the other. Consequently, they suggest that fructan malabsorption should be suspected in patients with fructose malabsorption and vice versa.

On the other hand, our study found a high prevalence of sorbitol and fructan intolerance, particularly sorbitol, which is found naturally in fruits and juices but is also added as an artificial sweetener in highly consumed ultra-processed foods in Northwestern Mexico, in addition to being present in various hygiene and health products[4]. It is interesting to note that one of our patients identified a toothpaste containing sorbitol as the cause of their intestinal discomfort.

The categorization of breath tests with negative results but persistent symptoms was particularly useful in our view. This approach allowed for the identification of patients with probable visceral hypersensitivity. In the present study, the prevalence of visceral hypersensitivity to lactose and fructose was 22% and 19%, respectively, which is higher than the 9% found by Amieva-Balmori et al.[12] for lactose, and similar to the 16% for fructose. Considering that approximately 40% to 60% of people with disorders of gut-brain interaction present with visceral hypersensitivity[11], having a tool like this to detect it is especially valuable.

During follow-up, adherence to the nutritional recommendations, indirectly assessed via the 24-hour recall, was maintained in this study and reflected in a significant improvement in symptoms. Patients made some dietary changes, such as reducing consumption of carbonated beverages, drinking only water, cooking at home instead of buying fast food, and eating appropriate portions. When they occasionally deviated from the diet, they were able to return to it because they had already experienced symptom relief. In these cases, the changes in symptoms were small but evident.

The nutritionist's close contact with the patients during follow-up was probably a key factor in maintaining the diet, as other authors have suggested[26]. Knowing that a professional is available to help gives patients the necessary confidence to succeed. Furthermore, short periods (<6 weeks) of low-FODMAP diet intervention have shown greater adherence[27], which aligns with the four-week duration of our study: two weeks on the diet, followed by two weeks of reintroduction. Additionally, the low-FODMAP diet has been recognized to decrease fiber and calcium intake[17]. However, in our study, these reductions were not statistically significant.

The present study had some limitations. The sample size was small (n = 21) compared to other studies, and only 58% of recruited participants completed the protocol, resulting in a high dropout rate. There was no control group, so the results should be evaluated with caution. Nevertheless, the before-and-after single-group design provides some evidence of change. Likewise, although we received positive feedback from participants regarding satisfaction with symptom relief and improvements in their daily lives, we did not conduct a quality of life assessment.

CONCLUSIONS

Following a personalized low-FODMAP diet based on intolerance test results, under the supervision of a trained nutritionist, resulted in a significant reduction of gastrointestinal symptoms. These dietary modifications were essential for the relief of these symptoms, underscoring the importance of personalized nutrition in the treatment of gastrointestinal problems. Long-term studies would be useful to confirm the continuity of symptom control.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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