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Research Article

Use of a Food Frequency Questionnaire for the Estimation of Gut Microbiota Composition Based on Dietary Patterns and Its Association with Irritable Bowel Syndrome Symptoms in the Lebanese Adult Population: A Cross-Sectional Study

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Gut microbiome analysis is costly and poses a significant challenge for determining the gut microbiota composition to facilitate the adoption of personalized nutritional interventions. Emerging evidence suggests dysbiosis as a contributor to irritable bowel syndrome (IBS), but the results remain uncertain. Moreover, IBS prevalence is becoming a public health problem in the adult Lebanese population. This study aimed at estimating the gut microbiota's composition using a Food Frequency Questionnaire (FFQ) and exploring its correlation with IBS among Lebanese adults. A cross-sectional study was conducted for 388 adults during the summer 2023. An online questionnaire collected information about sociodemographic characteristics, anthropometric measures, health status, and dietary habits through a semiquantitative FFQ. We observed the influence of Western diet among the three patterns that were identified. Participants were clustered into two groups based on their estimated (poor or good) microbiota composition, EPMC and EGMC, respectively. We observed a significant inverse relationship between IBS symptoms and EGMC. Participants experiencing IBS symptoms were less likely to exhibit a good gut microbiota compared to those without any IBS symptoms (AOR = 0.614, 95% CI (0.402–0.937), $P = 0.024$), and a higher adherence to the Mediterranean diet was significantly associated with lower odds of having IBS symptoms (AOR = 0.786, 95% CI (0.635–0.973), $P = 0.027$). Our study revealed a dietary shift toward a more Westernized pattern among Lebanese adults who experienced symptoms of IBS. FFQ may be used to estimate the gut microbiota to provide customized nutritional therapy for patients suffering from IBS.

1. Introduction

The gut microbiota is a complex, dynamic, and diverse ecosystem that contains thousands of microorganisms, such as bacteria, yeasts, and viruses that are distributed in over 50 phyla [1]. The gut microbiota has gained attention in recent years because of advances in science and sequencing technologies. This has resulted in discoveries about its function and significance in the body in terms of health and disease [2]. The two main phyla present in the human gut microbiota are *Firmicutes* and *Bacteroidetes*, which make up to 90% of its composition, followed by *Proteobacteria*, *Actinobacteria*, and *Verrucomicrobia* [3]. The human gut microbiota has a vital role in the body; it regulates digestion and helps in the absorption and fermentation of many nutrients and metabolites [4]. It has an immune function by inhibiting the growth of pathogenic bacteria and preventing their invasion [5]. The Firmicutes/Bacteroidetes (F/B) ratio, which is the connection between the two main phyla, has been associated to several noncommunicable diseases (NCDs) including cardiovascular diseases (CVD), type 2 diabetes (T2D), and irritable bowel syndrome (IBS). As a result, the management and prevention of these various diseases through diet or other therapeutic methods are increasingly turning to the gut flora [6].

IBS is a functional disorder of the gastrointestinal tract that affects more than 11% of the global population, making it one of the most prevalent health conditions worldwide [7]. The typical symptoms involve alterations in bowel habits such as diarrhea, constipation, or a combination of both, along with persistent abdominal pain and discomfort that occur at least once per week for 3 months [8]. While the precise cause of IBS remains not fully explained, it is widely accepted as a complex condition with multiple contributing factors, involving both environmental and host elements, with diet playing a significant role [9]. Researches showed that individuals with IBS exhibit distinct differences in their gut microbiota compared to those without the condition [10–13]. Specifically, IBS has been associated with dysbiosis of the gut microbiota, characterized by an elevated presence of *Firmicutes* and *Proteobacteria* in the gut, coupled with a diminished level of *Bifidobacterium* when compared to healthy individuals [14]. Additionally, IBS patients tend to have a reduced abundance of butyrate-producing bacteria, which can compromise intestinal permeability and contribute to symptoms [15]. Several other studies [16–20] have also demonstrated a different gut microbiota diversity among IBS patients, indicating a higher level of *Firmicutes* and lower *Bacteroidetes* with a higher F/B ratio (approximately 1.2–3.5 folds) compared to healthy subjects.

Differences in dietary intake correlate with changes in health status and human microbiota. "Western diet" (WD) is a modern dietary pattern characterized by a high intake of energy-dense and nutrient-poor foods such as red meat, processed meat, added sugar, salt, prepackaged foods, food additives, refined grains, high-sugar drinks and sweets, fried foods, candies, and fast foods [21, 22]. The WD is also characterized by low consumption of nutrient-dense food such as fruits, vegetables, legumes, whole grains, and healthy fats like olive oil and nuts, which are essential for the human body in providing its needs in vitamins, minerals, dietary fiber, and phytochemicals [21]. In contrast, adhering to the Mediterranean diet (MD) is healthful because of its high daily intake of plant-based foods including nonrefined cereals, fruits, vegetables, legumes, seeds, and nuts; moderate consumption of omega-3 fatty acids abundant in olive oil and fatty fishes, chicken, and dairy products along with low-to-moderate consumption of red wine [23]. This healthy dietary pattern high in fiber, mono- and polyunsaturated fatty acids, and antioxidants may be responsible for the lower risk of developing IBS and a variety of NCDs, including colorectal cancer, CVDs, and metabolic disorders [24, 25]. It has also been shown that MD has a beneficial effect on the gut microbiota due to the wide variety of bioactive substances present in its different food groups, known as polyphenols, which act as substrates and contribute to a positive modification of the gut microbiota [26]. Finally and much less documented than MD and WD, the Prudent diet (PD) is commonly regarded as a healthier dietary option than the WD although not offering all the health benefits provided by the MD. The main recommendations to adhere to the PD are to limit all sources of foods rich in cholesterol such as eggs, organ meats, lamb, pork, and beef while encouraging the intake of white meat (chicken and fish). Skimmed milk and low-fat dairy products can be consumed daily along with an increased intake of complex carbohydrates such as bulgur, quinoa, rice, and whole-grain bread. PD adherence also encourages the consumption of a diverse selection of fruits, vegetables, and herbs rich in vitamins and minerals [27,[28].

Given that dietary habits have emerged as key influencers of gut microbiota composition [29], the need to explore different dietary patterns in the context of IBS is noteworthy. Studying the impact of varied diets on the gut microbiota is essential for the understanding of how dietary factors contribute to dysbiosis and, consequently, influence the onset and progression of IBS. Noting that, in Lebanon, there has been a shift in the population's eating habits toward a more Westernized diet, which is concerning given the detrimental effects such diets have on the gut microbiota and IBS [30]. Moreover, Yazbeck et al. [31] revealed in a recent study done in Lebanon in 2023, an on-table increase in the prevalence of undiagnosed IBS reaching 46.8% which surpasses the findings from a prior study in 2017, which indicated a prevalence of 20.1% among the Lebanese adult population [32].

In this study, we aimed to estimate the gut microbiota's composition based on the food group intake from a Food Frequency Questionnaire (FFQ) and its correlation with IBS among the Lebanese adult population by addressing the following objectives by:

(1) Evaluating the dietary patterns of the participants based on a FFQ component analysis;
(2) Profiling the estimated gut microbiota's composition based on the dietary patterns; and
(3) Investigating the relationship between dietary patterns, gut microbiota composition, and IBS symptoms.

2. Materials and Methods

2.1. Study Design, Participants, and Sample Size. This cross-sectional study consisted of an online questionnaire shared via social media platforms using the snowball effect for recruiting participants [31] between May 2023 and July 2023 in Lebanon. To be eligible for participation, the respondents had to be Lebanese residents of both genders, aging from 20 to 70 years old. Participants with any immune disease or people who had taken antibiotics or corticosteroids in the last 3 months, in addition to those who had done chemotherapy in the last 6 months and pregnant women, were excluded. The minimal sample size to ensure representativeness was calculated using Epi Info^{TM}, a statistical software developed by Centers for Diseases Control and Prevention (CDC), with a margin of error of 5%, an expected frequency of 50%, design effect and cluster equal to 1. The minimum sample size was 384. Before filling out the questionnaire, mandatory informed consent was obtained for each participant. Participants who did not meet the inclusion criteria or who did not fully complete the questionnaire were subsequently excluded from the study. Ultimately, 388 participants were included in the survey.

2.2. Questionnaire. Through a Google Form, an online self-administered survey made of 84 questions in English, was developed and consisted of six parts and divided as follows:

Part 1 involved the qualifications for participation (pregnancy, age range, residency in Lebanon, intake of antibiotics or corticosteroids, chemotherapy treatment, presence of any anti-inflammatory disease such as Crohn's disease or ulcerative colitis). Part 2 included a question related to sociodemographic information (gender, age, governorate of residence, and ethnicity). The respondents were asked to choose their weight and height from a drop-down list in Part 3. Part 4 included the smoking habits of the participants. Part 5 included questions on the preexisting health conditions of the participants, such as CVDs (arrhythmia, atherosclerosis, coronary heart disease, hypertension), T2D, and IBS symptoms (diarrhoea, cramping, constipation, bloating, and indigestion within the past 3 months). Finally, part 6 included an FFQ that consisted of 64 semiquantitative questions covering six food groups from the MD to assess dietary intake over the last 6 months at different frequencies (never, less than 3 times per month, 1–2 times per week, 3–6 times per week, every day, at least once per day). The food group "vegetables" included the consumption of asparagus, artichokes, broccoli, cauliflower, bell pepper, chicory, cucumbers, eggplants, zucchini); group "fruits" (apples, apricots, avocado, berries, mango, peach, pomegranate, melon, watermelon, etc.), group "animal and plant source of proteins" (red meat, chicken, fish, eggs, chickpeas, lentils, beans, etc.), group "grains" (barley, oat, whole grains, rice, quinoa, etc.), group "dairy" (milk, cheese, yoghurt), group "herbs and spices" (pepper, ginger, cinnamon, oregano, parsley, mint, basil, thyme, etc.), and group "beverages" (chamomile, anise, green and black tea, coffee) in addition to questions about the intake of seeds, olive oil, and red wine.

2.3. Data Processing

2.3.1. Principal Component Analysis. Before proceeding to PCA, all food item variables from each of the vegetable, fruit, and beverage food groups were transformed into three single variables labeled "Vegetables," "Fruits," and "Beverages," respectively. The remaining food items were left uncategorized and treated separately. The correlation between all food items was assessed using the Kaiser–Meyer–Olkin (KMO) with a value >0.6 considered adequacy and Bartlett's chi-square test of sphericity, with a $P < 0.05$ considered as significant. Varimax rotation was utilized to extract particular factors, considering eigenvalues >1 and the percentage contribution of variance >5%. For each extracted factor, loaded food components with a factor loading of more than 0.3 were retained and used to compute factor scores. Extracted factors 1, 2, and 3 corresponding to participants dietary patterns, and according to their high positive loading for specific food components, were labeled MD, PD, and WD, respectively according to previous studies [21–23, 27, 28].

2.3.2. Cluster Analysis. Scores were transformed into z scores used in the K-mean cluster analysis to distribute the participants into different clusters corresponding to their estimated gut microbiota composition (EGMC). Convergence was achieved after fifteen iterations, and two clusters were identified, indicating two EGMCs. Each participant was assigned to any of the two groups referred to as EPGM (estimated poor gut microbiota) and EGGM (estimated good gut microbiota) based on their EGMC.

2.3.3. Body Mass Index. The BMI was calculated using the formula of total body weight (kg) divided by the square of height (m) that was designed for people aged 20–70 [33] to allow a classification into four subgroups according to the World Health Organization standards: underweight (BMI below 18.5 kg/m^2), normal weight (BMI between 18.5 and 24.9 kg/m^2), overweight (BMI between 25 and 29.9 kg/m^2), and obese (BMI more than or equal to 30 kg/m^2) [34].

2.4. Statistical Analysis. The statistical tests used in this study were analyzed using the IBM SPSS (Statistical Package for Social Sciences) software, version 23 (IBM Inc, Chicago, IL, USA). Before analysis, the normal sample distribution was verified by the Kolmogorov–Smirnov test. A descriptive analysis was conducted using frequencies and percentages for categorical variables. Various statistical analyses, including Pearson's chi-square, Fisher's exact test, and independent t test, were employed to uncover correlations between the EGMC and other factors such as sociodemographic characteristics, anthropometric measures, and health status. To perform logistic regression, participants were dichotomized into binary variables; the BMI variable was computed as "low BMI" including underweight and normal weight and "high BMI" including overweight and obesity. IBS symptoms or CVD were merged into outcome variables "Yes" and "No" depending on the occurrence of the disease. Smoking habits were dichotomized into "Yes" for smokers and "No" for nonsmokers. The age of the participants was dichotomized into "20–45" and "46–70." Multiple regression analysis was conducted to estimate the covariates that exhibit significant correlations with the EGMC and IBS symptoms and the corresponding unadjusted and adjusted odds ratios (ORs) along with a 95% confidence interval (CI) [35, 36]. P value < 0.05 was considered statistically significant.

3. Results

3.1. Sociodemographic and Health Characteristics of Participants. A total of 563 responses were collected, of which 175 were excluded for incomplete questionnaires or exclusion criteria. As shown in Table 1, of the 388 participants who were retained in the present study, 133 were males and 255 were females, with a mean age of 32.6 ± 12.1. A large majority (74.74%) of the respondents were from the Middle East, and about half (48.71%) declared not smoking. Most of them, 92.79% and 97.79%, reported not having cardiovascular diseases or diabetes, respectively. Less than half (45.88%) of them experienced IBS symptoms. The mean average BMI of more than half of the participants was normal (24.3 ± 4.16). However, most of the males, 48.12%, were classified as overweight, while in contrast, the majority of females (70.59%) were classified as having a normal BMI.

3.2. Food Group Consumption. The semiquantitative FFQ analysis for the consumption of food items among the respondents for each of the five food groups—vegetables, fruits, proteins, grains, and seed–herb–beverage–olive oil—is shown

Table 1: Sociodemographic and health characteristics of the participants by gender ($N = 388$).

Characteristics	Total ($N = 388$)	Male ($N = 133$)	Female ($N = 255$)	P value
Age in years	32.62 (12.1)	33.79 (13.74)	32.01 (11.13)	0.17*
Governorate of residence				
Akkar	0 (0)	0 (0)	0 (0)	
Baalbek–Hermel	3 (0.77)	1 (0.75)	2 (0.78)	
Beirut	67 (17.27)	33 (24.81)	34 (13.33)	
Beqaa	10 (2.58)	2 (1.51)	8 (3.14)	
Mount Lebanon	280 (72.16)	82 (61.65)	198 (77.65)	**0.002#**
Nabatiyeh	0 (0)	0 (0)	0 (0)	
North Lebanon	26 (6.7)	15 (11.28)	11 (4.32)	
South Lebanon	2 (0.52)	0 (0)	2 (0.78)	
Ethnicity				
Middle Eastern	290 (74.74)	98 (73.68)	192 (75.3)	
American Indian or Alaska Native	0 (0)	0 (0)	0 (0)	
Asian	33 (8.5)	12 (9.02)	21 (8.23)	
African American	2 (0.52)	0 (0)	2 (0.78)	0.458#
Hispanic or Latino	2 (0.52)	2 (1.51)	0 (0)	
Native Hawaiian or Pacific Islander	1 (0.26)	0 (0)	1 (0.39)	
White	60 (15.46)	21 (15.79)	39 (15.3)	
Anthropometrics				
BMI (kg/m²)	24.34 (4.16)	26.14 (4.3)	23.41 (3.76)	**<0.0001***
BMI classification				
Underweight	17 (4.38)	6 (4.5)	11 (4.31)	
Normal Weight	224 (57.73)	44 (33.1)	180 (70.59)	**<0.0001#**
Overweight	111 (28.61)	64 (48.12)	47 (18.43)	
Obese	36 (9.28)	19 (14.28)	17 (6.67)	
Smoking habits				
Tobacco cigarettes	59 (15.2)	31 (23.31)	28 (10.98)	
Shisha	67 (17.27)	14 (10.53)	53 (20.78)	
E-cigarettes mods	53 (13.67)	27 (20.29)	26 (10.2)	**<0.0001#**
Dual smoker of any of the above	20 (5.15)	13 (9.77)	7 (2.75)	
Not smoking	189 (48.71)	48 (36.1)	141 (55.29)	
Cardiovascular diseases				
Arrythmias	3 (0.77)	1 (0.75)	2 (0.79)	
Atherosclerosis	1 (0.26)	1 (0.75)	0 (0)	
Coronary heart disease	3 (0.77)	2 (1.5)	1 (0.39)	
Heart failure	0 (0)	0 (0)	0 (0)	**<0.0001#**
Hypertension	21 (5.41)	16 (12.03)	5 (1.96)	
None	360 (92.79)	113 (84.97)	247 (96.86)	
Type 2 diabetes				
Yes	8 (2.06)	3 (2.25)	5 (1.96)	1
No	380 (97.94)	130 (97.75)	250 (98.04)	
Irritable bowel syndrome symptoms				
Yes	178 (45.88)	39 (29.32)	139 (54.51)	**<0.0001#**
No	210 (54.12)	94 (70.68)	116 (45.49)	

BMI, body mass index; numbers in bold indicate significant P values (<0.05).*P value: independent t test. #P value: Pearson's chi-square test and Fisher exact test with more than 20% of expected counts less than 5 (smoking habits, cardiovascular diseases, and type 2 diabetes).

in Table 2. More than half of the participants had a low consumption of vegetables during the last 6 months. The majority of participants showed very low intake of broccoli, cauliflower, cabbage, radishes, kale, bell pepper, eggplants, green peas, mushrooms, cooked pumpkin, cooked spinach, and cooked okra (less than three times a month to never in the last 6 months). Conversely, participants demonstrated a higher focus on the intake of cucumbers, lettuce, and fresh tomatoes, with a consumption of three to six times per week in the last 6 months. The consumption of fruits was generally low among participants. A majority reported consuming apples, apricots, avocado, berries, oranges, dates, dried fruits, grapes,

Table 2: Semi quantitative FFQ analysis of the food item components consumption from the six food groups of participants ($N = 388$).

Food groups/food items	Never, n (%)	<3 times per month, n (%)	1–2 times per week, n (%)	3–6 times per week, n (%)	Everyday, n (%)	At least once per day, n (%)
Vegetables						
Artichokes	159 (41)	216 (56)	13 (3)	0 (0)	0 (0)	0 (0)
Asparagus	211 (54)	169 (44)	8 (2)	0 (0)	0 (0)	0 (0)
Cruciferous[$]	43 (11.08)	174 (44.85)	125 (32.22)	32 (8.25)	7 (1.8)	7 (1.8)
Beat juice	270 (69.59)	77 (19.85)	25 (6.44)	11 (2.84)	4 (1.03)	1 (0.26)
Bell pepper	65 (16.75)	173 (44.59)	116 (29.9)	27 (6.96)	5 (1.29)	2 (0.52)
Carrots, celery	35 (9.02)	166 (42.78)	141 (36.34)	29 (7.47)	16 (4.12)	1 (0.26)
Chicory	239 (61.6)	117 (30.15)	26 (6.7)	4 (1.03)	2 (1)	0 (0)
Cucumbers	10 (2.58)	46 (11.86)	112 (28.87)	118 (30.41)	90 (23.2)	12 (3.09)
Eggplants	83 (21.39)	196 (50.52)	80 (20.62)	23 (5.93)	5 (1.29)	1 (0.26)
Onions [#]	9 (2.32)	39 (10.05)	85 (21.91)	127 (32.73)	113 (29.12)	15 (3.87)
Green peas	54 (13.92)	222 (57.22)	97 (25)	13 (3.35)	1 (0.26)	1 (0.26)
Lettuce	4 (1.03)	54 (13.92)	117 (30.15)	141 (36.34)	66 (17.01)	6 (1.55)
Mushrooms	50 (12.89)	180 (46.39)	119 (30.67)	32 (8.25)	7 (1.8)	0 (0)
Cooked okra	217 (55.93)	150 (38.66)	14 (3.61)	4 (1.03)	2 (0.52)	1 (0.26)
Potato**	12 (3.09)	110 (28.35)	186 (47.94)	69 (17.78)	11 (2.84)	0 (0)
Cooked pumpkin	223 (57.47)	144 (37.11)	14 (3.61)	6 (1.55)	0 (0)	1 (0.26)
Cooked spinach	97 (25)	256 (65.98)	28 (7.22)	6 (1.55)	0 (0)	1 (0.26)
Sweet potato**	157 (40.46)	159 (40.98)	53 (13.66)	12 (3.09)	7 (1.8)	0 (0)
Fresh tomatoes	14 (3.61)	30 (7.73)	103 (26.55)	126 (32.47)	101 (26.03)	14 (3.61)
Zucchini	94 (24.23)	204 (52.58)	75 (19.33)	11 (2.84)	2 (0.52)	2 (0.52)
Fruits						
Apples	35 (9.02)	138 (35.57)	130 (33.51)	54 (13.92)	25 (6.44)	6 (1.55)
Apricots	107 (27.58)	207 (53.35)	49 (12.63)	19 (4.9)	3 (0.77)	3 (0.77)
Avocado	57 (14.69)	180 (46.39)	107 (27.58)	32 (8.25)	11 (2.84)	1 (0.26)
Bananas	21 (5.41)	74 (19.07)	127 (32.73)	90 (23.2)	72 (18.56)	4 (1.03)
Berries*	65 (16.75)	195 (50.26)	86 (22.16)	36 (9.28)	6 (1.55)	0 (0)
Cherries	110 (28.35)	198 (51.03)	58 (14.95)	15 (3.87)	7 (1.8)	0 (0)
Citrus[&]	35 (9.02)	146 (37.63)	137 (35.31)	42 (10.82)	24 (6.19)	4 (1.03)
Dates	101 (26.03)	143 (36.86)	68 (17.53)	36 (9.28)	31 (7.99)	9 (2.32)
Dried fruits	137 (35.31)	159 (40.98)	50 (12.89)	28 (7.22)	9 (2.32)	5 (1.29)
Figs	187 (48.20)	162 (41.75)	29 (7.47)	9 (2.32)	0 (0)	1 (0.26)
Grapes	110 (28.35)	196 (50.52)	58 (14.95)	21 (5.41)	3 (0.77)	0 (0)
Kiwi	123 (31.7)	191 (49.23)	46 (11.86)	20 (5.15)	6 (1.55)	2 (0.52)
Lemon	12 (3.09)	85 (21.91)	101 (26.03)	98 (25.26)	86 (22.16)	6 (1.55)
Mango	128 (32.99)	208 (53.61)	37 (9.54)	11 (2.84)	4 (1.03)	0 (0)
Melon	128 (32.99)	176 (45.36)	61 (15.72)	14 (3.61)	8 (2.06)	1 (0.26)
Peaches	105 (27.06)	186 (47.94)	63 (16.24)	25 (6.44)	9 (2.32)	0 (0)
Pomegranate	121 (31.19)	201 (51.8)	39 (10.05)	19 (4.9)	8 (2.06)	0 (0)
Pineapple	139 (35.82)	203 (52.32)	34 (8.76)	7 (1.8)	5 (1.29)	0 (0)
Plums	184 (47.42)	156 (40.21)	40 (10.31)	6 (1.55)	1 (0.26)	1 (0.26)
Watermelon	103 (26.55)	153 (39.43)	87 (22.42)	28 (7.22)	12 (3.09)	5 (1.29)

Table 2: Continued.

Food groups/food items	Never, *n* (%)	<3 times per month, *n* (%)	1–2 times per week, *n* (%)	3–6 times per week, *n* (%)	Everyday, *n* (%)	At least once per day, *n* (%)
Proteins						
Fish	35 (9.02)	210 (54.12)	124 (31.96)	17 (4.38)	1 (0.26)	1 (0.26)
Red meat	15 (3.87)	72 (18.56)	178 (45.88)	101 (26.03)	19 (4.9)	3 (0.77)
Eggs	18 (4.64)	82 (21.13)	197 (50.77)	73 (18.81)	15 (3.87)	3 (0.77)
Chicken	5 (1.29)	35 (9.02)	171 (44.07)	152 (39.18)	24 (6.19)	1 (0.26)
Organ meat	146 (51.23)	162 (56.84)	64 (22.46)	14 (4.91)	2 (0.7)	0 (0)
Processed meat	74 (25.96)	161 (56.49)	110 (38.6)	36 (12.63)	7 (2.46)	0 (0)
Chickpeas	58 (14.95)	181 (46.65)	127 (32.73)	17 (4.38)	5 (1.29)	0 (0)
Lentils	33 (8.51)	172 (44.33)	167 (43.04)	12 (3.09)	3 (0.77)	1 (0.26)
Beans	45 (11.6)	192 (49.48)	127 (32.73)	22 (5.67)	2 (0.52)	0 (0)
Soy bean	231 (59.54)	113 (29.12)	35 (9.02)	7 (1.8)	2 (0.52)	0 (0)
Nuts	29 (7.47)	132 (34.02)	129 (33.25)	50 (12.89)	41 (10.57)	7 (1.8)
Grains and dairy						
Barley, oat, whole grain bread	68 (17.53)	106 (27.32)	81 (20.88)	68 (17.53)	59 (15.21)	6 (1.55)
Bulgur, quinoa, rice	12 (3.09)	80 (20.62)	171 (44.07)	99 (25.52)	22 (5.67)	4 (1.03)
Milk or cheese	4 (1.03)	37 (9.54)	95 (24.48)	111 (28.61)	132 (34.02)	9 (2.32)
Yogurt	20 (5.15)	114 (29.38)	157 (40.46)	64 (16.49)	31 (7.99)	2 (0.52)
Seeds, herbs, beverages, and olive oil						
Mixture of spices and herbs	7 (1.8)	43 (11.08)	86 (22.16)	91 (23.45)	149 (38.4)	12 (3.09)
Fresh herbs[†]	18 (4.64)	71 (18.3)	133 (34.28)	85 (21.91)	76 (19.59)	5 (1.29)
Anise	141 (36.34)	130 (33.51)	73 (18.81)	28 (7.22)	14 (3.61)	2 (0.52)
Green or black tea	55 (14.18)	130 (33.51)	108 (27.84)	51 (13.14)	41 (10.57)	3 (0.77)
Chamomile	139 (35.82)	134 (34.54)	78 (20.1)	25 (6.44)	11 (2.84)	1 (0.26)
Coffee	40 (10.31)	35 (9.02)	30 (7.73)	26 (6.7)	196 (50.52)	61 (15.72)
Seeds	127 (32.73)	145 (37.37)	71 (18.3)	31 (7.99)	13 (3.35)	1 (0.26)
Olive oil	4 (1.03)	21 (5.41)	68 (17.53)	109 (28.09)	170 (43.81)	16 (4.12)
Red wine	104 (26.8)	185 (47.68)	72 (18.56)	18 (4.64)	7 (1.8)	2 (0.52)

[*]Blueberries, blackberries, cranberries, raspberries, strawberries; [$]broccoli, cauliflower, cabbage, radishes, kale; [#]green onions, white onions, garlic; [&]orange, mandarin, clementine, grapefruit; [†]parsley, mint, thyme, basil, arugula; [**]boiled, baked, or mashed.

Table 3: Pattern loading of the three factors solutions after varimax rotation.

Food items	Extracted factors		
	1	2	3
Vegetables	0.750	—	—
Fruits	0.722	—	—
Nuts	0.633	—	—
Beans	0.612	—	—
Seeds	0.610	—	—
Chickpeas	0.604	—	—
Soy bean	0.591	−0.434	—
Lentils	0.577	—	—
Fish	0.534	—	—
Beverages	0.492	0.363	—
Barley, oat, whole grain bread	0.365	0.344	—
Mixture of spices and herbs	—	0.748	—
Parsley, mint, thyme, basil, arugula	—	0.661	—
Olive oil	—	0.643	—
Milk and cheese	—	0.522	0.338
Yogurt	0.431	0.464	—
Bulgur, quinoa, rice	—	0.428	0.301
Red meat	—	—	0.746
Chicken	—	—	0.745
Processed meat	—	—	0.670
Organ meat	—	—	0.543
Eggs	—	—	0.322

Total variance explained by the three factors is 44%.

kiwi, mango, melon, peaches, pomegranate, pineapple, and watermelon less than three times per month in the last 6 months. Regarding protein consumption, a significant portion of the participants reported consuming fish less than three times per month (54.12%) in the last 6 months. On the contrary, there was a greater emphasis on the intake of red meat, eggs, and chicken, with 45.88%, 50.77%, and 44.07% reporting consumption one to two times per week, respectively. In terms of milk or cheese consumption, a significant number of participants reported daily intake (34.02%). Yogurt consumption was predominantly 1–2 times per week (40.46%), with a smaller percentage reporting less than three times per month (29.38%). Participants had a high usage of a mixture of spices and herbs in their cooking; 38.4% reported daily consumption, with an additional 23.45% having an intake of 3–6 times per week. In terms of beverages, consumption of anise and chamomile was generally low, with 36.34% and 35.82%, respectively, reporting never consuming them in the last 6 months. Green or black tea consumption was slightly higher, with the majority reporting consumption less than three times per month (33.51%), followed by 1–2 times per week (27.84%). However, coffee consumption was prevalent among participants, with half reporting daily intake (50.52%) and an additional 15.72% having at least one consumption per day. The majority consumed seeds and red wine less than three times per month (37.37% and 47.68%, respectively), followed by those who never consumed them in the last 6 months (32.73% for seeds and 26.8% for red wine). As for olive oil, a high intake was observed, with almost half of the participants reporting daily consumption (43.81%), followed by those having it 3–6 times per week (28.09%).

3.3. Principal Component Analysis. Before proceeding to PCA, the adequacy of the correlation between all food items was assessed. The overall KMO value was measured at 0.826, and Bartlett's chi-square test of sphericity was highly significant at $P < 0.0001$ (Supplementary 2). Based on the selection criteria, three factors were extracted that accounted for 44% of the variance in the dietary intake of the respondents (Supplementary 3 and Supplementary 1). The three extracted factors/diets were classified as (1) Mediterranean diet, which was highly correlated with vegetables, fruits, nuts, beans, seeds, chickpeas, soy bean, lentils, fish, beverages, barley, oats, and whole grain bread; (2) Prudent diet, which was positively correlated with mixtures of spices and herbs, parsley, mint, thyme, basil, arugula, olive oil, milk, cheese, yogurt, along with bulgur, quinoa, and rice; (3) Western diet, which was associated with red meat, chicken, processed meat, organ meats, and eggs (Table 3 and Figure 1).

3.4. Cluster Analysis. The *K*-mean cluster analysis was done based on the participants' factor *z* scores of the three identified factors presented in Table 3 and Figure 1 above. Convergence was achieved after 15 iterations, and two clusters were identified according to their estimated gut microbiota composition (EGMC). Each participant was assigned, according to their EGMC, into two groups. As shown in Table 4, the first group was labeled EPGM for "estimated poor gut microbiota," including 244 participants (62.88%), while the second group ($n = 144$; 37.12%) was labeled EGGM for "estimated good gut microbiota." The EPGM group exhibited positive correlations with both the Prudent diet (PD) and Western diet (WD), but showed a negative correlation with the Mediterranean diet (MD). On the other hand, the EGGM group demonstrated a positive correlation with the "MD" but an inverse correlation with both the "PD" and "WD."

3.5. Characteristics of Participants Based on Their Estimated Gut Microbiota Composition. We further explored the sociodemographic, health, and lifestyle characteristics among the two groups, EPGM and EGGM.

The majority of participants among the two groups were from Mount Lebanon. The percentages of both males and females were higher in the EPGM group (66.27% and 56.39%, respectively) compared to the EGGM group (43.61% and 33.73%, respectively), although not statistically significant. Although there was a significant difference ($P = 0.009$) observed in ethnicity between the two groups, there was a weak association (Cramer's $V = 0.182$). Middle Eastern participants were higher in the poor gut microbiota group compared to the good gut microbiota (67.24% and 32.76%, respectively), followed by white people (53.33% and 46.67%, respectively) although Asian people were more present in the EGGP group compared to the EPGM one (51.52% versus 48.48%, respectively; Table 5).

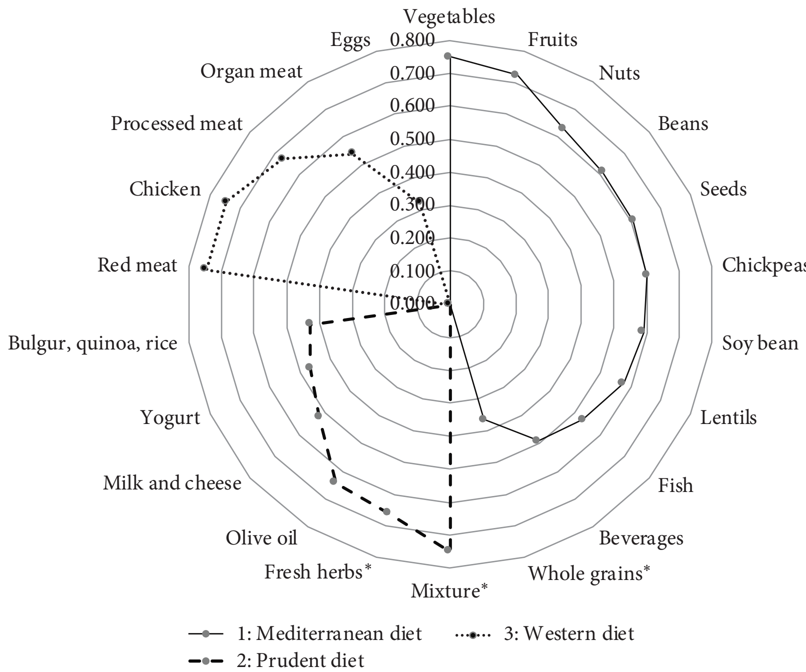

Figure 1: Web plot representing the extracted factors.

Table 4: Identified clusters of estimated good ($n = 144$) or poor ($n = 244$) gut microbiota composition.

Extracted factors (diets)	EPGM	EGGM
Factor 1 (Mediterranean diet)	−0.21791	0.36923
Factor 2 (Prudent diet)	0.56508	−0.9575
Factor 3 (Western diet)	0.19592	−0.33198

EPGM: estimated poor microbiota composition; EGGM: estimated good microbiota composition.

Nearly half of the participants in both groups were nonsmokers, with a slightly higher percentage in the EGGM group (49.3%) compared to the EPGM group (48.36%). Those who smoked shisha constituted 17.27%, with a slightly higher prevalence in the EPGM group (18.85%) compared to the EGGM group (14.58%). However, this difference was not found to be statistically significant. A large majority of participants declared having no cardiovascular disease or type 2 diabetes. However, about half of the participants declared having IBS symptoms. Participants in the EGGM group (61.11%) had a lower percentage of reported symptoms for IBS than those in the EPGM group (50%), and this difference was found to be statistically significant ($P = 0.034$) with Cramer's $V = -0.108$, indicating a weak and inverse relationship between IBS symptoms and EGMC. Finally, a majority of participants have a BMI ranging in the normal body weight category (57.73%). Among those with an estimated good gut microbiota, 61.81% were in the normal weight range, slightly exceeding the 55.33% observed in the estimated poor gut microbiota group. Overweight individuals constituted 28.61% of the total, with 30.33% in the poor gut microbiota group compared to 25.7% in the predicted good gut microbiota group. Notably, this difference was not statistically significant between the EGGM and EPGM groups ($P = 0.336$; Table 5).

To further explore predictors of gut composition, we conducted binary logistic regression using the EGMC as an outcome. The results indicated that individuals aged between 46 and 70 years were 1.83 times less likely to have a good gut microbiota compared to those aged between 20 and 45 years (OR = 0.547, 95% CI (0.301–0.992), $P = 0.047$; Supplementary 4). Additionally, participants experiencing IBS symptoms were 1.57 times less likely to have a good gut microbiota compared to those without any IBS symptoms (OR = 0.636, 95% CI (0.419–0.967), $P = 0.034$). Multiple logistic regressions were then conducted, including covariates that were statistically significant ($P < 0.05$) and eligible factors ($P < 0.2$; Supplementary 5). After adjusting for age (Model 1), the presence of IBS symptoms remained significantly associated with estimated gut microbiota composition (AOR1 = 0.614, 95% CI (0.402–0.937), $P = 0.024$), with participants having IBS symptoms being 1.62 times less likely to have a good gut microbiota composition when adjusted for age. However, after further adjustment for gender (Model 2) and for other eligible variables (Model 3), the association between IBS and gut microbiota composition was no longer present.

3.6. Irritable Bowel Syndrome Predictors. As shown in Table 6, binary logistic regressions were performed using the IBS symptoms as an outcome. The findings were that female participants were 2.888 times more likely to have IBS symptoms compared to male participants (OR = 2.888, 95% CI = (1.846–4.518), $P \leq 0.0001$). Additionally, people who were more adhering to an MD were 1.25 times less likely to have

Table 5: Sociodemographics, smoking, and health characteristics of the participants exhibiting estimated poor gut microbiota composition (EPGM; $n = 244$) and estimated good gut microbiota composition (EGGM; $n = 144$).

Characteristics	EPGM, *n* (%)	EGGM, *n* (%)	*P* value	Cramer's *V* (ϕ)
Gender				
Male	75 (56.39)	58 (43.61)	0.056*	*n/a*
Female	169 (66.27)	86 (33.73)		
Governorate of residence				
Akkar	0 (0)	0 (0)	0.116*	*n/a*
Baalbek–Hermel	3 (100)	0 (0)		
Beirut	49 (73.13)	18 (26.87)		
Beqaa	8 (80)	2 (20)		
Mount Lebanon	165 (58.93)	115 (41.07)		
Nabatiyeh	0 (0)	0 (0)		
North Lebanon	17 (65.38)	9 (34.62)		
South Lebanon	2 (100)	0 (0)		
Ethnicity				
Middle Eastern	195 (67.24)	95 (32.76)	**0.009***	0.182
American Indian or Alaska Native	0 (0)	0 (0)		
Asian	16 (48.48)	17 (51.52)		
African American	0 (0)	2 (100)		
Hispanic or Latino	1 (50)	1 (50)		
Native Hawaiian or Pacific Islander	0 (0)	1 (100)		
White	32 (53.33)	28 (46.67)		
Smoking habits				
Tobacco cigarettes	36 (14.75)	23 (15.97)	0.667	*n/a*
Shisha	46 (18.85)	21 (14.58)		
E-cigarettes mods	30 (12.3)	23 (15.97)		
Dual smoker of any of the above	14 (5.74)	6 (4.17)		
Not smoking	118 (48.36)	71 (49.31)		
Cardiovascular diseases				
Arrythmias	2 (0.82)	1 (0.7)	0.23*	*n/a*
Atherosclerosis	0 (0)	1 (0.7)		
Coronary heart disease	2 (0.82)	1 (0.7)		
Heart failure	0 (0)	0 (0)		
Hypertension	17 (6.97)	4 (2.78)		
None	223 (91.39)	137 (95.14)		
Type 2 diabetes				
Yes	5 (2.05)	3 (2.08)	1	*n/a*
No	239 (97.95)	141 (97.92)		
Irritable bowel syndrome symptoms				
Yes	122 (50)	56 (38.89)	**0.034***	-0.108
No	122 (50)	88 (61.11)		
BMI				
Underweight	9 (3.69)	8 (5.55)	0.336#	*n/a*
Normal Weight	135 (55.33)	89 (61.81)		
Overweight	74 (30.33)	37 (25.7)		
Obese	26 (10.65)	10 (6.94)		

Percentages from total per subcategory are presented horizontally. n/a: not applicable. Numbers in bold indicate significant *P* values (<0.05). **P* value: Pearson's chisquare test and Fisher exact test with more than 20% of expected counts less than 5 (governorate of residence and ethnicity). #*P* value: Pearson's chi-square test and Fisher exact test with more than 20% of expected counts less than 5 (smoking habits, cardiovascular diseases, and type 2 diabetes).

IBS symptoms compared to those who were not following an MD (COR = 0.800, 95% CI (0.652–0.982), $P = 0.033$).

Multiple logistic regressions were then conducted, including covariates that were statistically significant ($P < 0.05$; (Table 7). After adjusting for age (Model 1) and further adjustment for gender (Model 2), MD remained significantly associated with the presence of IBS symptoms (AOR = 0.786, 95% CI (0.635–0.973), $P = 0.027$), with participants following

Table 6: Bivariate logistic regression analysis for the presence of IBS symptoms and independent variables.

Characteristics	COR (95% CI)	*P* value
Gender		
Male	1	**<0.0001**
Female	2.888 (1.846–4.518)	
Age range		
20–45 years old	1	0.190
46–70 years old	0.694 (0.403−1.198)	
Mediterranean diet	0.800 (0.652−0.982)	**0.033**
Prudent diet	1.129 (0.923−1.381)	0.236
Western diet	1.041 (0.852−1.271)	0.696

COR, crude odd ratio; CI, confidence interval. Numbers in bold indicate significant *P* values (<0.05).

Table 7: Multiple logistic regression analysis for IBS.

Characteristics	COR (95% CI)	*P* value	AOR1 (95% CI)	*P* value	AOR2 (95% CI)	*P* value
Mediterranean diet	0.800 (0.652−0.982)	**0.033**	0.798 (0.650−0.980)	**0.032**	0.786 (0.635−0.973)	**0.027**

COR, crude odd ratio; CI, confidence interval; AOR1, adjusted odd ratio (model 1); AOR2, further adjusted odd ratio (model 2). Numbers in bold indicate significant *P* values (<0.05); Model 1 is adjusted for age range (universal covariate); Model 2 is further adjustment for gender (universal covariate).

a MD being 1.27 times less likely to have IBS symptoms compared to those who were not following a MD.

4. Discussion

This cross-sectional study aimed at estimating the gut microbiota's composition based on the food group intake extracted from a semiquantitative FFQ and its correlation with some NCDs, specifically reported IBS symptoms. Recently, we and others have observed that a high AMD was declining in Lebanon [37, 38]. This observation, confirmed in the present study, showed a significant drop in the consumption of fruits and vegetables among participants. Indeed, more than half of them reported a frequency of less than three times per month for almost all kinds of fruit and vegetable intake. However, the consumption tends to focus more on the intake of tomatoes, garlic, onions, and lemon known to be basic components of Lebanese dishes. Our results comfort another recent previous study conducted in Lebanon, where participants exhibited a low intake of fruits and vegetables mostly due to the significant price inflation in the country [39]. We also observed that Lebanese dietary habits displayed a distinctive pattern characterized by an increase in the consumption of red meats and chicken, while fish consumption remained relatively low. This preference for red meats and poultry over fish opposes the MD's emphasis on regular fish consumption, which is considered a healthier animal protein source due to its high content of healthy fats. In addition, we have observed a higher daily intake of both dairy products and eggs, which is also an unmatched feature of the MD's recommendations that suggests limiting these food items consumption to once a week. While the MD encourages the daily inclusion of legumes, nuts, and whole grains which are considered as nutrient-rich foods, participants displayed deviation from these guidelines resulting in a lower incorporation of these foods in their daily dietary practices. This shift in the dietary intake of the Lebanese population has been observed over the past years; Nasreddine et al. [40] studied the nutrition transition among Lebanese adults between 1997 and 2008–2009, and they have observed a lower consumption of fruits, vegetables, legumes, and whole grains along with an increase in saturated fats, red meats, and chicken intake. In a recent study conducted on Lebanese adolescents residing in both urban and rural areas, the findings revealed a significant rise in the consumption of saturated fats and sugars alongside a notable preference toward Western-style diets over traditional Lebanese cuisines [41].

In line with these observations made in Lebanon during the last decade, our research has identified three major dietary patterns: MD, PD, and WD, which together explained 44% of the total variance. Naja et al. [42] have identified the WD, which included meats, poultry, processed meats, and fast foods; the PD, which consisted mainly of dairy; and the Lebanese traditional diet, which is similar to the MD, was characterized by a high intake of fruits, vegetables, and legumes. Similarly, we have previously identified two dietary patterns: PD and WD. The PD was associated with fruits, vegetables, legumes, grains, and fish, in contrast to the WD, which was characterized by fast foods and fried foods [38]. All together, these data confirmed a shift in dietary habits among Lebanese people toward a much less healthy dietary pattern that may influence the gut microbiota.

Further analysis was done to confirm the impact of "westernization" on diet and gut health through the diet-based microbiota composition. Our participants were grouped into two different clusters based on their estimated gut microbiota composition, labeled EPMC and EGMC, according to their respective dietary patterns. About two-thirds of our participants who were following WD and PD patterns fell into the EPMC group. This trend was already observed a few years ago in studies made in the Mediterranean basin. First, a Spanish study found that participants following a more westernized diet with low AMD had a "poor gut microbiota" characterized by a high *Firmicutes/Bacteroidetes*(F/B) ratio, while those adhering to a MD had a higher amount of *Bacteroidetes*, indicating better gut health [43]. Second, a study conducted in Greece showed that participants following a MD had better gut health (higher SCFA production and a lower F/B ratio) compared to those following a Westernized dietary pattern [44].

Interestingly, we found a higher prevalence of EPMC among Middle Eastern and white ethnic backgrounds. These findings confirmed that gut microbiota variation may also be influenced by racial and ethnic differences in addition to preexisting health conditions [3, 45]. Indeed, there is evidence that sociocultural and socioeconomic environments are determinants in shaping microbiota across ethnic groups. The elevated prevalence of Middle Eastern participants with a predicted poor gut microbiota may be attributed to the lower consumption of fruits, vegetables, and plant-based foods in addition to the shift from the traditional MD to a more westernized diet, as these dietary changes are recognized as important for affecting the gut microbiota composition. The majority of overweight and obese participants in our study were included in the EPGM group compared to the EGGM group, but this difference was not found to be statistically significant in contrast to previous studies that have reported a significant correlation between BMI and gut microbiota composition in overweight and obese individuals [46, 47].

Concerning the NCDs among our participants' studies, we did not find a significant correlation between T2D and EGMC. It is worth noting that numerous studies from different countries have shown a correlation between T2D and alterations in gut microbiota composition. The common observation was an increase in the F/B ratio among T2D patients compared to healthy individuals [48–52]. Our findings did not reveal this relationship, most probably because of the relatively small number of individuals with T2D in our sample. This could have limited our ability to detect statistically significant associations that could have been more evident with a larger sample size. We have observed a relatively low prevalence of CVDs among our participants. This figure stands in contrast to other findings that have indicated a high prevalence of hypertension among Lebanese adults, reaching 36.4% and a contribution of 47% to the overall mortality in the country caused by CVDs [53]. The low prevalence of various CVDs among our participants could potentially explain the absence of a correlation between CVDs and EGMC. This results differ from other studies that have observed a link between the alteration in gut microbiota composition and CVDs among individuals [54, 55]. Further research, particularly in samples with a higher prevalence of T2D and CVDs, may provide deeper insights into this relationship and its implications.

Strikingly, our results revealed a high prevalence of participants experiencing IBS symptoms (45.88%). This trend aligns with a recent study made in Lebanon that found a similar prevalence of IBS [31]. Notably, our results surpass the findings of another study that only reported a 20.1% prevalence of IBS among the Lebanese adult population [32]. The increasing rate of IBS symptoms could potentially be attributed to the switch of dietary habits within the Lebanese population, characterized by a decline in adherence to a MD and by a more Westernized approach. In our study, we have demonstrated that among the three identified dietary patterns, only the MD showed an inverse correlation with IBS symptoms. This implies that participants who adhered more closely to the MD exhibited a protective effect against experiencing IBS symptoms. Our observation agrees with findings from other studies that have suggested that low adherence to MD is associated with a high prevalence of IBS [56–59]. Furthermore, our study reported that higher IBS symptoms were significantly associated with lower odds of having a predicted good gut microbiota. Previous studies have shown a correlation between IBS and gut microbiota composition [10–12, 60]. A recent Italian study involving IBS patients and healthy participants revealed a higher F/B ratio in the IBS group, indicating a poor gut microbiota, in comparison to the healthy subjects [61]. Liu et al. [62] demonstrated significant disturbance at the genus level of the gut microbiota in participants with IBS when compared to healthy subjects. Specifically, there was a decrease in Bifidobacterium and Lactobacillus, which leads to a poor gut microbiota [62]. This significant difference in gut microbiota composition between IBS patients and healthy controls has been reported by a group of Finnish investigators. They have shown that IBS patients had a higher F/B ratio, indicating a poor gut microbiota compared to healthy subjects [11].

When evaluating the results of our research, it is important to consider certain limitations. First, the data collected from our participants was self-reported, which increases the potential for recall bias, as sometimes participants tend to answer random questions or to inaccurately estimate their dietary intake while completing the FFQ. Second, a bias effect on our results may be the use of the English language for the questionnaire. The validated FFQ used in this study was not available in Arabic. Therefore, although the English language remains widely written and spoken in Lebanon, specifically in social media literacy, Arabic-speaking people may have refrained from completing the survey due to a language barrier. Third, the rectal swab analysis required to perform sequencing for a complete gut microbiota profile could not be executed to confirm the predicted gut microbiota's composition, estimated from the dietary patterns of the participants. This was due to logistics and financial issues, as the company responsible for providing the kits was no longer in operation at the time of the study in Lebanon, and it was necessary to collect the feces sample in time to prevent bias between data survey collection and feces sample quantitative analysis. Finally, our data were obtained from an adult population aged 20–70, with less males than female included, limiting the generalization of our findings to other life cycle groups and sexes because there is evidence of changes in the gut microbiota with sex and throughout the lifespan [63, 64]. However, we were able to address our objectives and establish a significant baseline to further our research.

5. Conclusions

In conclusion, our study revealed a high prevalence of people exhibiting symptoms of IBS in Lebanon, particularly among women, raising a growing public health concern in our country. We have identified an association between IBS symptoms and EGMC among participants using FFQ. Notably, our findings demonstrated an inverse relationship between adherence to MD and the occurrence of IBS symptoms, suggesting that individuals with higher MD adherence experienced a protective effect on IBS symptoms. To the best of our knowledge, we are the first to have ascertained here that a FFQ can be used as a valuable instrument for the assessment and monitoring of the estimated gut microbiota composition in a sample of people suffering from IBS in Lebanon. To enhance the precision of future research, it is recommended to replicate this study with a larger sample size using official IBS diagnostic criteria, such as the Rome IV criteria provided by the Rome Foundation. Additionally, obtaining fecal samples from participants to analyze the gut microbiota and evaluate the alpha diversity profile would further contribute to a comprehensive understanding of the relationship between the gut microbiota and IBS. Our results can be used to develop a reliable and cost-effective instrument for the estimation of the individual gut microbiota in clinical settings and dietetic interventions, more specifically for nutritional assessment, nutritional diagnosis, and monitoring of nutritional interventions of people suffering or at risk for IBS.

Data Availability

Most of the data used to support the findings of this study are included within the article. More data are available upon reasonable request from the corresponding author.

Ethical Approval

This research study was approved on 05, April 2023 (HCR/EC 2023-009), by the Research Ethics Committee of the Higher Centre for Research at the Holy Spirit University of Kaslik.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Supplementary Materials

Supplementary 1. Scree plot of the eigenvalues of each component (forced extraction).

Supplementary 2. KMO and Bartlett's test.

Supplementary 3. Forced total variance explained.

Supplementary 4. Simple bivariate logistic regression analysis for EGMC outcome and its covariates.

Supplementary 5. Multiple logistic regression analysis for EGMC and the independent variable presence of IBS symptoms.

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