


# Within- and Between-Subject Variation in Dietary Intake of Fermentable Oligo-, Di-, Monosaccharides, and Polyols Among Patients with Irritable Bowel Syndrome

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## Abstract

**Background:** A diet low in fermentable carbohydrates, fermentable oligo-, di-, monosaccharides, and polyols (FODMAPs) is a promising treatment option for patients with irritable bowel syndrome (IBS). In order to correctly estimate and study the intake of FODMAPs, information about within- and between-subject variations in intakes is needed, but is currently lacking.

**Objectives:** The aim was to characterize the variation in FODMAP intake among patients with IBS and to calculate how many days of observations are required to capture absolute intakes as well as to rank individuals.

**Methods:** Food intake was recorded during 4 consecutive days, and intakes of energy and FODMAPs were calculated. The coefficient of variation within subjects ( $CV_w$ ), coefficient of variation between subjects ( $CV_b$ ), number of days required to estimate an individual's intake, and number of observations required to correctly rank individuals into quartiles of consumption were calculated.

**Results:** Diet records were provided from 151 women and 46 men with IBS. The reported mean energy intake was  $2039 \pm 502$  kcal among women and  $2385 \pm 573$  kcal among men, and the median FODMAP intakes were 18.7 g (range 3.7–73.4) and 22.8 g (range 3.6–165.7), respectively. The ratio of  $CV_w/CV_b$  for total FODMAP intake was 0.83 for women and 0.67 for men, and below 1 for all FODMAPs. To capture intake of FODMAPs at the individual level, 19 d of observations are required. Ranking individuals within a group would require 2–6 d of observations.

**Conclusion:** There is more variation between subjects than within subjects regarding FODMAP intake. To correctly estimate an individual's absolute intake of FODMAPs, the number of days of diet records required exceeds what is reasonable for a participant to accomplish. However, ranking individuals into quartiles of FODMAP consumption can be achieved using a 4-d food record. This trial was registered at [www.clinicaltrials.gov](http://www.clinicaltrials.gov) as NCT02107625 and NCT01252550. *Curr Dev Nutr* 2018;3:nzy101.

## Introduction

Over the years, the various dietary assessment methods available have been recognized as having errors, both random and systematic, that can seriously affect the interpretation of nutritional studies (1, 2), although, if we manage to minimize the random and systematic errors, the remaining measured variability is a representation of the true variability in nutrient intake (3, 4). Humans differ from each other in their daily food intake, but we also vary within individuals. The within-subject variation is a measure of the true day-to-day variation in the dietary intake



**Keywords:** irritable bowel syndrome, fermentable carbohydrates, FODMAP, variation, dietary assessment, dietary intake

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Abbreviations:  $CV_b$ , coefficient of variation between subjects;  $CV_w$ , coefficient of variation within subjects; FODMAPs, fermentable oligo-, di-, monosaccharides, and polyols; GI, gastrointestinal; GOS, galacto-oligosaccharide; IBS, irritable bowel syndrome.

of a subject, and it includes variations across days of the week, seasonal variations in food intake, and variety compared with monotony in the food choices of an individual (4–8). Considerations of within-subject variation are particularly important when the aim is to rank individuals within a group, or when data on usual intakes are compared with biochemical or clinical parameters at the individual level in correlation or regression analyses (9). Unfortunately, for most nutrients, there is more variability in nutrient intakes within subjects than between subjects, which makes both ranking of individuals and assessing absolute intakes of an individual cumbersome.

Irritable bowel syndrome (IBS) is one of the most common gastrointestinal (GI) disorders worldwide, characterized by recurrent abdominal pain and altered bowel movements (10, 11). Even though the etiology and pathophysiology of IBS are only partly understood, most patients report an onset or worsening of symptoms in conjunction with food intake (12, 13). In recent years, a diet low in fermentable carbohydrates, fermentable oligo-, di-, monosaccharides, and polyols (FODMAPs) has gained interest in the management of IBS symptoms (14). Many studies have reported adequate symptom relief in a large share of patients after treatment with a low-FODMAP diet (15), and the treatment seems to be at least as effective as traditional IBS dietary advice (16–18). However, the intake patterns of FODMAPs in this patient group are still unclear (e.g., types, amounts, and variability in FODMAPs consumed), and whether all patients with IBS benefit from reducing their FODMAP intake is unknown.

When planning surveys, it is essential to know the number of days required for subjects to record their diets, in order to obtain results that are sufficiently accurate for the purposes of the study. To date, no information on the variation in FODMAP intake among patients with IBS has been published. Therefore, to be able to plan and perform surveys of FODMAP intake accurately in patients with IBS, the aim of this study was to characterize the within- and between-subject variation in FODMAP intake in individuals with IBS. We also calculated the number of days required per subject to estimate an individual's nutrient intake (with a given accuracy) and the number of days required to correctly rank individuals into quartiles of FODMAP consumption.

## Materials and Methods

### Study population

The current study is based on dietary data assessed at baseline from 2 clinical studies performed at our specialized unit for functional GI disorders at the Sahlgrenska University Hospital, Gothenburg, Sweden. The first study was aimed at characterizing pathophysiologic traits of IBS ( $n = 184$ ) performed in 2010–2012 (19–21), and the second study was a randomized controlled dietary intervention trial in 75 patients with IBS conducted in 2013, with the aim of comparing 2 dietary regimes in the management of IBS symptoms (16). The same inclusion criteria were used in both studies, i.e., women and men >18 years of age diagnosed with IBS according to the Rome III criteria (22). Patients were excluded if they had other GI diseases explaining their symptoms, other serious chronic diseases, severe psychiatric diseases, or alcohol abuse, were taking probiotic supplements, were pregnant, had abnormal results on standard screening laboratory tests, or were unable to respond reliably to questionnaires in Swedish. At the baseline visit, the IBS

diagnosis was confirmed, the IBS subtype according to the Rome III criteria was determined (22), and all subjects completed a questionnaire to assess current IBS symptom severity (IBS Severity Scoring System) (23). In the dietary intervention trial, only subjects with moderate to severe symptoms (i.e., IBS Severity Scoring System >175) were eligible for enrollment. Moreover, the highest educational level (elementary school, high school, or university studies) of the subject was requested. Both studies were approved by the Regional Ethical Review Board in Gothenburg, Sweden, and all study subjects provided written informed consent before any study-related procedures were initiated.

### Diet record and calculation of energy and nutrient intake

The diet record was performed as described by Böhn et al. (16). In short, all subjects completed a paper-based diet record, in which all foods and drinks consumed during 4 consecutive days (Wednesday to Saturday) were reported. Oral and written instructions were given to the patients on how to complete the diet record, and they were instructed to maintain their regular diet during the recording days. The time of consumption and type of food consumed were noted and quantified in grams or by using household utensils or number of slices, for example. The cooking method and food labeling were noted where applicable. All diet records were entered into a special version of the software Dietist XP 3.1 (Kostdata.se) that calculates the energy and nutrient composition of foods. The software was linked to a food-composition table provided by the National Food Agency in Sweden, and to a Swedish database with FODMAP content, developed in house (by one of the authors, TL) and used by us in previous publications (16, 24). The database contained information about fructose, fructan, lactose, galacto-oligosaccharide (GOS), and polyol content (g/100 g) from published sources (methodology paper submitted; personal communication with Therese Liljebo). All diet records were entered into the software by a trained dietitian.

Excess fructose was calculated by using data for fructose and total monosaccharide content from the diet records. Glucose and fructose are the dominating monosaccharides in foods, and if the glucose content was higher than the fructose content, a value of 0 was denoted for excess fructose (for each separate meal). Intakes of nutrients were first summarized for each meal, and thereafter these were summarized into intakes per day and finally presented as the mean intake of all 4 d. A cutoff for energy intake was set so that subjects reporting energy levels below 800 kcal/d or exceeding 4500 kcal/d were excluded, in order to remove reports with implausible habitual intake. No subjects exceeded these limits. For reported intake of FODMAPs, outliers were defined as those exceeding mean  $\pm 4$  SD.

### Statistical analysis

Results for the study population are presented for men and women separately. Mean  $\pm$  SD and median (range) values are presented for continuous variables, and numbers (percentage) are presented for categorical variables. Comparisons between groups were performed using a 2-sided *t*-test for equal means for continuous, normally distributed variables, and Mann–Whitney *U*-test for non-normally distributed variables. Comparisons of means between more than 2 groups were performed by ANOVA. Two-tailed *P* values of <0.05 were considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0.0 (IBM Corp.).

**TABLE 1** Demographic and clinical data among women and men with irritable bowel syndrome participating in the study<sup>1</sup>

	Women N = 151			Men N = 46		
	Values	Median	Range	Values	Median	Range
Age, y	37 ± 14.5	33	18, 68	37 ± 13.5	32	18, 66
Weight, kg	65 ± 12.3	62	43, 135	82 ± 11.7	80	66, 115.0
Height, cm	167 ± 6.4	167	151, 185	181 ± 5.9	181	168, 198
BMI, kg/m <sup>2</sup>	23.1 ± 3.8	22.4	16.0, 43.1	24.8 ± 3.4	24.6	18.6, 34.0
IBS-Severity Scoring System, score	308 ± 86.2	317	63, 490	279 ± 76.2	274	82, 459
IBS-Severity Scoring System, severity						
Mild < 175	10 (6.6)	—	—	4 (8.9)	—	—
Moderate 176–300	55 (36.4)	—	—	22 (48.9)	—	—
Severe > 300	86 (57.0)	—	—	19 (42.2)	—	—
IBS subtype						
IBS with constipation	36 (24.8)	—	—	8 (17.8)	—	—
IBS with diarrhea	40 (27.6)	—	—	14 (31.1)	—	—
Mixed type IBS	33 (22.8)	—	—	13 (28.9)	—	—
Unsubtyped IBS	36 (24.8)	—	—	10 (22.2)	—	—
Education						
Elementary	6 (4.2)	—	—	2 (4.7)	—	—
High school	50 (34.7)	—	—	17 (39.5)	—	—
University	88 (61.1)	—	—	24 (55.8)	—	—

<sup>1</sup>Values are means ± SDs or *n* (%) unless otherwise indicated. IBS, irritable bowel syndrome.

### Within- and between-subject variation

Calculation of the within-subject variation (intraindividual) in nutrient intake, expressed as the coefficient of variation within subjects ( $CV_w$ ), was calculated based on SD as follows (3, 25, 26):  $SD / \text{individual mean intake} \times 100$ . This represents the individual day-to-day variation in nutrient intake as a percentage.

The group mean within-subject variation (pooled  $CV_w$ ), was calculated as:  $\Sigma CV_w / n$ .

Calculation of the between-subject variation (interindividual) in nutrient intake, expressed as the coefficient of variation between subjects ( $CV_b$ ), was calculated as:  $SD_b / \text{mean group intake} \times 100$ . This represents the mean variation in nutrient intake between subjects, as a percentage.

### Ranking individuals within a group

The number of days required to rank individuals by food or nutrient intake was calculated from the ratio of the within- and between-subject variance in nutrient intakes. If the  $CV_b$  increases relative to the  $CV_w$ , fewer days of observations would be needed to distinguish low from high consumers. The equation used was as follows (9, 27, 28):

$$n = \left[ r^2 / (1 - r^2) \right] \times (s_w^2 / s_b^2)$$

where  $n$  is the number of days required,  $r$  is the unobservable correlation between the observed and true mean intakes of individuals over the period of observations (here, we used  $r = 0.85$ , which would give 72% correctly classified into quartiles of intake;  $r = 0.90$ , which would give 77% correctly classified into quartiles of intakes; and  $r = 0.95$ , which would give 84% correctly classified into quartiles of intakes [9]) and  $s_w^2$  and  $s_b^2$  are the observed within- and between-subject variances, respectively.

### Assessing usual intake in an individual

The number of days required per subject to estimate an individual's nutrient intake with a precision of  $\pm 20\%$  of their true mean, 95% of the time, was calculated as (3, 29):

$$n = (Z_\alpha CV_w / D_0)^2$$

where  $n$  is the number of days required per subject,  $Z_\alpha$  is the normal deviate for the percentage of times the measured value should be within a specified limit (e.g., 1.96),  $CV_w$  is the within-subject coefficient of variation, and  $D_0$  is the specified precision of long-term intake as a percentage (here 20).

## Results

### Subjects

Of all 198 subjects with complete food records, 1 male subject was excluded due to reporting a mean FODMAP intake of 166 g/d (exceeding the  $\pm 4$  SD limit). Hence, a total of 151 women and 46 men were included in the analyses. Demographic and clinical data are presented in Table 1. The group mean BMI was within the normal range for both women and men. Subgroups of IBS were evenly distributed for both men and women. However, most women reported having severe IBS symptoms (57%), whereas the majority of men reported moderate symptoms (50%). Sixty-one percent of women and 56% of men had a university education.

### Variation in energy and macronutrient intakes

In Table 2, the mean and median intakes of energy, macronutrients, and FODMAPs are presented. For each nutrient, the  $CV_w$  and  $CV_b$  are presented as a percentage. The ratio of  $CV_w / CV_b$  was thereafter

**TABLE 2** Mean daily energy, nutrient and fermentable oligo-, di-, monosaccharides, and polyols intake and the coefficients of variation among women and men with irritable bowel syndrome<sup>1</sup>

	Women N = 151					Men N = 46				
	Mean ± SD	Median	CV <sub>w</sub>	CV <sub>b</sub>	Ratio of CVs (CV <sub>w</sub> /CV <sub>b</sub> )	Mean ± SD	Median	CV <sub>w</sub>	CV <sub>b</sub>	Ratio of CVs (CV <sub>w</sub> /CV <sub>b</sub> )
Energy, kcal	2039 ± 502	2002	23.8	24.6	0.97	2385 ± 573	2424	22.4	24.0	0.93
Protein, g	82 ± 21	81.63	25.6	25.0	1.02	102 ± 40	99	22.8	39.0	0.58
Fat, g	87 ± 28	84.03	33.0	31.9	1.04	95 ± 30	92	32.2	32.2	1.00
SFA, g	33.8 ± 13.7	30.5	37.3	40.7	0.92	36.2 ± 16.3	35.9	38.5	45.2	0.85
MUFA, g	30.6 ± 10.0	30.0	38.6	32.8	1.18	34.8 ± 13.7	34.9	39.0	39.3	0.99
PUFA, g	12.7 ± 5.8	11.7	45.1	45.6	0.99	35.9 ± 12.4	14.3	36.4	34.6	1.05
Carbohydrates, g	205 ± 67	202	26.3	32.5	0.81	247 ± 79	253	28.2	32.1	0.88
Monosaccharides, g	29.1 ± 15.2	26.5	43.0	52.3	0.82	29.9 ± 16.4	29.4	50.8	54.9	0.93
Glucose, g	19.5 ± 7.6	15.5	30.3	38.9	0.78	17.9 ± 11.3	14.8	58.4	63.3	0.92
Dietary fiber, g	17.1 ± 8.7	18.7	48.4	50.7	0.95	20.5 ± 7.7	19.1	30.5	37.6	0.81
Alcohol, g	8.8 ± 10.3	6.7	151.1	117.1	1.29	13.2 ± 15.3	8.7	131.3	116.2	1.13
Total fermentable oligo-, di-, monosaccharides, and polyols, g	20.0 ± 11.0	18.7	45.7	54.9	0.83	23.1 ± 14.5	22.8	42.0	62.8	0.67
Galacto-oligosaccharides, g	0.5 ± 0.4	0.4	72.8	89.6	0.81	0.6 ± 0.5	0.5	74.2	84.8	0.87
Fructans, g	2.4 ± 1.2	2.2	46.9	51.9	0.90	2.8 ± 1.7	2.3	44.5	58.9	0.76
Polyols, g	1.1 ± 1.4	0.6	107.5	124.8	0.86	1.0 ± 1.6	0.3	120.4	168.4	0.71
Lactose, g	10.4 ± 7.8	8.9	67.4	74.9	0.90	11.9 ± 10.5	10.2	74.2	88.0	0.84
Fructose, g	13.6 ± 9.1	12.0	54.3	67.0	0.81	14.3 ± 9.9	12.2	58.3	69.4	0.84
Excess fructose, g	5.6 ± 6.1	4.2	104.9	109.5	0.96	6.8 ± 7.4	5.5	100.7	108.3	0.93

<sup>1</sup>CV<sub>b</sub>, coefficient of variation between subjects; CV<sub>w</sub>, coefficient of variation within subjects.

calculated. Values <1 represent more variation between subjects than within subjects.

The mean energy intake was 2039 ± 502 kcal among women and 2385 ± 573 kcal among men. For women, CV<sub>w</sub>/CV<sub>b</sub> was >1 for protein and fat, meaning that there was a larger variation within subjects than between subjects. For men, the ratio for protein was 0.58, indicating a small variation within subjects and a large variation between subjects. For alcohol intake, the variation was large both within and between subjects, ranging from 116.2% (between subjects, men) to 151.1% (within subjects, women). The variation in micronutrient intakes is shown in **Supplemental Table 1**.

### FODMAP intake and variation

The reported median total FODMAP intake was 18.7 g (range 3.7–73.4) for women and 22.8 g (range 3.6–63.2) for men, ( $P = 0.16$ ) (**Table 2**). Intake of FODMAPs was positively skewed, and the mean FODMAP intake of all 4 quartiles for both sexes is shown in **Table 3**. Total intakes of FODMAPs did not differ between women and men in energy adjusted amounts, 9.96 g/1000 kcal and 10.36 g/1000 kcal ( $P = 0.70$ ), respectively.

When comparing the reported intakes of FODMAPs at the group level during the various reporting days, the amounts did not differ across the 4 d (**Figure 1**). Lactose contributed to >53% of the total intake in FODMAPs, excess fructose 27%, fructans 12%, polyols 5%, and GOS the least amount, 3%.

For total FODMAP intake, the CV<sub>w</sub> was 45.7 and 42.0 for women and men, respectively. The CV<sub>w</sub>/CV<sub>b</sub> was <1 for all FODMAPs, with a ratio for total FODMAP intake of 0.83 for women and 0.67 for men.

### Number of days required for ranking individuals within a group

For energy and macronutrients, approximately 3–5 d of recording would be required from each subject to be able to rank individuals into quartiles of consumption with an accuracy of  $r = 0.90$  between the observed and true intake (**Table 4**). Because there are larger variations between subjects than within subjects regarding FODMAP intake, only 2–3 d would be required to rank individuals with the same level of accuracy, and 3–6 d would increase the precision to  $r = 0.95$ . A correlation coefficient of 0.95 would give 84% of the subjects correctly classified into quartiles of consumption and less than 1% of the subjects misclassified into the opposite extreme quartile. The number of days required to rank individuals into quartiles of micronutrient intake is shown in **Supplemental Table 2**.

### Number of days required to estimate true mean intake

The numbers of replicate days (with dietary recalls or records) needed to estimate the true mean intakes at the individual level, at different levels of precision, are listed in **Table 5**. The values are presented for women and men separately, and for the whole group combined. To maintain a precision of ±10% of the true energy intake, it would require 21 replicate recording days. Intake of FODMAP would require 77–415 replicate days, if the study population consisted of both women and men. If a precision of ±20% is accepted, 7 replicate days of recording would be sufficient to estimate intake of energy, protein, and carbohydrates. Total FODMAP intake would require 19 replicate days, and polyols and excess fructose would require >100 replicate days of recordings for each individual. The numbers of replicate days to capture micronutrient intakes are provided in **Supplemental Table 2**.

**TABLE 3** Mean daily intake of fermentable oligo-, di-, monosaccharides, and polyols among women and men with irritable bowel syndrome, expressed as g/1000 kcal and as mean quartile intake.<sup>1</sup>

	Women N = 151					Men N = 46				
	EA	q1	q2	q3	q4	EA	q1	q2	q3	q4
Total fermentable oligo-, di-, monosaccharides, and polyols, g	9.96 ± 5.14	8.57	15.46	21.71	34.86	10.36 ± 7.26	6.79	17.70	26.30	43.67
Galacto-oligosaccharides, g	0.25 ± 0.23	0.11	0.29	0.52	1.08	0.29 ± 0.30	0.17	0.40	0.62	1.37
Fructans, g	1.16 ± 0.51	1.14	1.85	2.56	4.12	1.23 ± 0.78	1.35	2.12	2.90	5.26
Polyols, g	0.58 ± 0.69	0.10	0.37	0.98	3.19	0.41 ± 0.73	0.09	0.26	0.60	2.93
Lactose, g	5.20 ± 3.85	2.70	6.63	10.88	21.55	5.76 ± 6.88	1.06	6.48	14.41	27.38
Fructose, g	6.70 ± 4.28	4.54	9.53	14.32	26.19	5.72 ± 3.45	4.15	9.72	15.08	27.60
Excess fructose, g	2.78 ± 2.92	0.82	3.08	5.50	13.15	2.68 ± 2.38	0.65	3.28	7.29	15.91

<sup>1</sup>EA, energy adjusted; q, quartile.

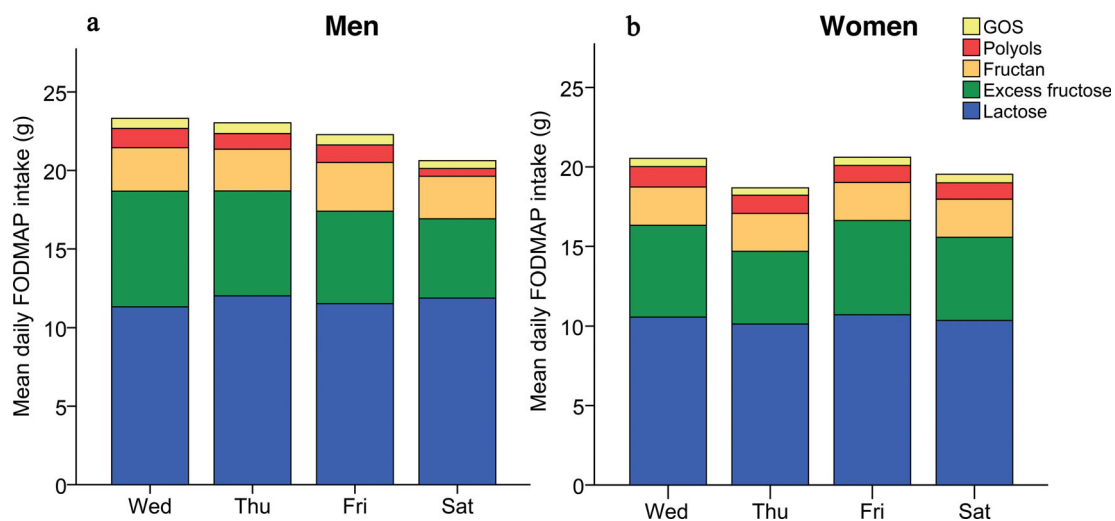
## Discussion

This is the first study to characterize intake patterns of FODMAPs among patients with IBS. Our results show that lactose contributes most to the total FODMAP intake in Swedish patients and that for each group of FODMAPs, there is more variation between subjects than within subjects. At the group level, there is little variation across the various days of the week. Ranking individuals into quartiles of FODMAP intake can be achieved with good precision using a few days of observations. However, if the objective is to capture intake at the individual level, a good level of precision would not be obtainable using a reasonable number of days of food records.

The coefficients of variation in energy and macronutrients were similar to, or slightly lower than, those from previous research in healthy adults (30–32). This might be a consequence of a high prevalence of perceived food intolerance in patients with IBS (12, 13), which likely leads to exclusion of certain food items. There is evidence that manipulation of the diet is the primary behavioral avenue for women to manage their IBS symptoms (33). This could potentially lead to a

more homogenous eating pattern within subjects and, consequently, a relatively larger variation between subjects. The large discrepancy in protein intake in men may be partly explained by the fact that some diets, e.g., vegetarian or vegan diets, usually contain less protein (34) and that several diets advocate a larger proportion of protein intake. There were evidently a few men who had adapted to a diet with a high protein intake and the discrepancies between low and high consumers of protein were more striking among men than among women. The largest variation was seen for alcohol intake, which is very much in line with previous research, and this emphasizes the difficulty in capturing alcohol intake at the individual level using only a few days of replicate recordings (35).

The coefficient of variation in FODMAP intake within subjects was relatively high compared with that for macronutrients, and more similar to that of dietary fibers and sugars. This similarity was expected, because foods that contain FODMAPs are mainly starchy vegetables, fruits, and dairy products (36). Even if there was a high variation within subjects, the discrepancy between subjects was even larger. This explains why only a few recording days would be sufficient to rank



**FIGURE 1** Distribution in reported intake of FODMAPs for (a) women and (b) men during Wednesday to Saturday. No difference in FODMAP intake at the group level was seen during the 4 recording days,  $P = 0.55$  for women and  $P = 0.86$  for men. FODMAP, fermentable oligo-, di-, monosaccharides, and polyols; GOS, galacto-oligosaccharides.



**TABLE 4** Number of days of observation required for ranking individuals into quartiles of consumption of energy and nutrients, including fermentable oligo-, di-, monosaccharides, and polyols.<sup>1</sup>

	Number of days of observations to achieve precision of $r = 0.85$ <sup>2</sup>			Number of days of observations to achieve precision of $r = 0.90$ <sup>3</sup>			Number of days of observations to achieve precision of $r = 0.95$ <sup>4</sup>		
	All	Women	Men	All	Women	Men	All	Women	Men
Energy, kcal	2	2	2	4	4	4	8	8	8
Protein, g	2	3	1	3	4	2	6	9	4
Fat, g	3	3	2	4	4	4	9	10	9
SFA, g	2	2	2	4	4	4	8	8	8
MUFA, g	3	4	3	5	6	5	11	13	10
PUFA, g	2	3	2	4	4	4	9	9	8
Carbohydrates, g	2	2	2	3	3	3	6	6	6
Monosaccharides, g	2	2	2	3	3	3	6	6	6
Glucose, g	2	2	2	3	3	3	7	7	6
Dietary fiber, g	2	2	2	3	2	3	5	5	6
Alcohol, g	3	3	2	5	5	4	10	12	8
Total fermentable oligo-, di-, monosaccharides and polyols, g	1	2	1	2	3	2	5	6	4
Galacto-oligosaccharides, g	2	2	2	3	3	3	6	6	7
Fructans, g	2	2	1	3	3	2	6	7	5
Polyols, g	1	2	1	2	3	1	4	6	2
Lactose, g	1	1	1	2	2	1	4	5	3
Fructose, g	1	1	2	2	2	3	5	5	6
Excess fructose, g	2	2	1	3	3	2	5	6	5

<sup>1</sup> $r$  is the unobservable correlation between the observed and true mean intakes of individuals over the period of observations.

<sup>2</sup> $r = 0.85$  would give 72% correctly classified into quartiles of intake.

<sup>3</sup> $r = 0.90$  would give 77% correctly classified into quartiles of intakes.

<sup>4</sup> $r = 0.95$  would give 84% correctly classified into quartiles of intakes.

individuals into quartiles of FODMAP consumption with a good level of accuracy, because it would be easy to distinguish between low and high consumers, although the large within-subject variation in FODMAP intake makes it difficult to assess the habitual FODMAP intake at the individual level. It would not be possible to maintain a precision

of  $\pm 10\%$  of true long-term intake for the selected nutrients. Even if a precision of  $\pm 20\%$  were acceptable, it would be difficult to capture FODMAP intake with such precision at the individual level using food records or 24-h recalls, because 19 d of observations would probably lead to a poorer quality in the registrations as the quality of the dietary

**TABLE 5** Number of days of observation required for capturing intake of energy and nutrients, including fermentable oligo-, di-, monosaccharides, and polyols, at the individual level with given precision.

	Number of days of observations to capture $\pm 10\%$ of true mean intake 95% CI			Number of days of observations to capture $\pm 20\%$ of true mean intake 95% CI			Number of days of observations to capture $\pm 30\%$ of true mean intake 95% CI		
	All	Women	Men	All	Women	Men	All	Women	Men
Energy, kcal	21	22	19	5	5	5	2	2	2
Protein, g	24	25	20	6	6	5	3	3	2
Fat, g	41	42	40	10	10	10	5	5	4
SFA, g	55	54	58	14	13	15	6	6	6
MUFA, g	56	57	51	14	14	13	6	6	6
PUFA, g	74	78	61	19	20	15	8	9	7
Carbohydrates, g	27	26	30	7	7	8	3	3	3
Monosaccharides, g	77	71	99	19	18	25	9	8	11
Glucose, g	99	90	131	25	22	33	11	10	15
Dietary fiber, g	35	35	36	9	9	9	4	4	4
Alcohol, g	828	877	662	207	219	165	92	97	74
Total fermentable oligo-, di-, monosaccharides, and polyols, g	77	80	68	19	20	17	9	9	8
Galacto-oligosaccharides, g	205	204	212	51	51	53	23	23	24
Fructans, g	83	85	76	21	21	19	9	9	8
Polyols, g	470	444	557	117	111	139	52	49	62
Lactose, g	183	174	212	46	44	53	20	19	24
Fructose, g	117	113	131	29	28	33	13	13	15
Excess fructose, g	415	423	390	104	106	97	46	47	43

data declines in relation to the number of days recorded (37). Also, with polyols and excess fructose requiring >100 replicate days of recordings for each individual, it would not be feasible to assess individual FODMAPs using diet records or recalls. If the study objective can be answered by ranking individuals into quartiles of FODMAP intake, then dietary records or repeated 24-h recalls can provide accurate data. However, to be able to capture intake of foods high in FODMAPs that are consumed less frequently (e.g., foods high in polyols, excess fructose and GOSs), dietary records or repeated 24-h recalls are not suitable. Here we suggest the use of semiquantitative food-frequency questionnaires specifically aimed at capturing intakes of FODMAP-rich foods consumed both regularly and occasionally. Still, one must bear in mind that dietary intakes assessed with food-frequency questionnaires are suitable for ranking rather than for capturing absolute intakes of individuals (38), so the challenge of assessing absolute intake levels of FODMAPs remains unsolved.

To date, most studies on FODMAP intake in relation to IBS symptoms have been intervention studies focusing on reducing the intake of FODMAPs in the diet. The efficacy has been evaluated by comparing a low-FODMAP diet to a high-FODMAP diet, or to a control diet with higher amounts of FODMAPs. These comparisons include correlation or regression analyses that do not study the relation between FODMAP intake and symptom severity at the individual level but rather compare symptom severity within groups where different amounts of FODMAPs have been consumed. In these cases, under controlled study settings, an individual's habitual FODMAP intake would probably not be of major importance for the research question. However, epidemiologic and explanatory research on whether FODMAP intake does provoke IBS symptoms is still lacking, but we need to be cautious about using the absolute FODMAP intake as an explanatory variable, because our data show that the precision in individual intake data would be low. In these cases, the use of ranking and nonparametric statistical methods would be advisable.

In our study population, the reported intake of FODMAPs did not differ between women and men, and, at a group level, was similar across the various days of the week. This indicates that group mean intake is easily obtainable using 1 or a few dietary recalls in cross-sectional studies, or in studies aiming to assess FODMAP intake at group level.

Our study population was representative for an IBS population with regard to the proportion of female/male participants, and we included a wide age range (although, as expected, the majority of participants were below the age of 50). Most men reported having moderately severe IBS symptoms, and a larger proportion of women reported severe symptoms. This is likely explained by the fact that 1 of the included studies had symptom severity as an inclusion criterion and did not recruit any patients with mild symptom severity. The span of symptoms was wide and probably responds well to a patient group seeking help at a specialized gastroenterology unit. However, we did notice a higher proportion of participants with a university degree than expected in the general Swedish population and also a lower mean BMI (39, 40). Because high BMI and low educational level are predictors of under-reporting of energy intake (41, 42), this could explain why we did not have to exclude any individuals with implausibly low energy intakes.

A strength of the current study is that we enrolled our study participants consecutively during a span of 3 years, which enabled us to capture seasonal variations in dietary intake. Because we aimed to

cover the consecutive dietary intake during both weekdays and weekend days, we were limited to covering only 4 d of the week. However, our results do not suggest any differences in FODMAP intake during weekdays or weekend days, indicating that FODMAP containing foods are eaten at random during the week. A weakness of the study is that the FODMAP database consists of a composite of different published FODMAP databases, and some local variations in FODMAP content in foods might occur that we have not been able to consider. Also, dietary intakes captured in our study might be limited to Nordic dietary habits, so whether these numbers can be applied globally remains unknown.

To conclude, this study provides a basis for planning studies aiming to assess intake of FODMAPs among individuals with IBS. The nature of the variation in dietary intake leads to a poor capability of capturing absolute intake of FODMAPs at the individual level using diet records or recalls, but is well adapted for ranking individuals within a group.

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