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ORIGINAL CONTRIBUTION

Gluten-free-rendered products contribute to imbalanced diets in children and adolescents with celiac disease

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Abstract

Purpose As well as adhering to the safe limit for gluten intake, a suitable gluten-free (GF) diet must also be nutritionally balanced. However, malnutrition has been observed in the population with celiac disease (CD). This is even more important in the case of children and adolescents, whose GF diet must also ensure their proper growth. The aim of the present study was to assess the diet quality of children and adolescents with CD to attain optimal nutritional status, determining the most relevant factors that affect a balanced diet.

Methods Eighty-three children and adolescents with CD (9.2 ± 3.8 years) took part in the study. Height, weight and body composition were measured. An analysis of energy consumption and of the macronutrient distribution of their diet was carried out. Adherence to Mediterranean diet by KIDMED index was analyzed, and energy and nutrients intake.

Results The diet of participants was not balanced, containing more fat and less carbohydrate than recommended. Most children and adolescents revealed adequate body mass index and suitable body fat percentage. Two-thirds of them showed moderate or poor KIDMED index, the case of girls being remarkable. When the GF diet, containing GF-rendered foodstuffs, was compared to a similar type of diet but substituting GF products with their analogs containing gluten, important nutritional differences were revealed.

Conclusions Even though celiac children and adolescents' diet is unhealthy due to its inappropriate dietary pattern, following a diet based on GF products raises extra difficulty in complying with the nutritional recommendations.

Keywords Gluten-free products · Celiac disease · Dietary unbalance · KIDMED index · Children · Adolescents

Introduction

Celiac disease (CD) is a permanent, autoimmune disorder that causes a reaction to gluten, which is found in wheat, barley, rye and oats [1]. CD has become one of the most common food-related chronic intestinal diseases among children in Europe and the USA [2]. Its estimated prevalence in European children is 1% (1/71 in Spanish children) and it is more frequent among girls [3, 4].

At present, the gluten-free (GF) diet is the only treatment available for CD which achieves a resolution of symptoms for the majority of patients. For instance, CD pathogenesis leads to a malabsorption syndrome which implies some nutritional deficiencies [5–7], and following the GF diet could correct these deficiencies to guarantee good nutritional health. Apart from maintaining the safe limit of gluten intake, a suitable GF diet must also be nutritionally balanced; it must cover all energy and nutrient requirements to

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prevent deficiencies and ensure a healthy life. This is even more the case for children and/or adolescents, whose GF diet must also allow appropriate growth [8, 9].

An inadequate dietary pattern is a common problem in Western countries that also affects patients with CD. Nutritional deficiencies have been observed in all age ranges of the population with CD [10]. Patients with CD restricted to a GF diet have to exclude gluten-containing grains and foods such as bread, flour, pasta, breakfast cereals and bakery products from their diet. These products are a major source of energy, protein and carbohydrates but also contain micronutrients, such as iron, zinc, calcium, magnesium and group B vitamins [10–12].

However, all age-range patients with CD tend to consume refined GF cereal products, which do not have the same nutritional composition as their unrefined analogs [13]. Previously, we reported differences in energy, macronutrient, sodium, salt and cholesterol content between some GF-rendered and gluten-containing foodstuffs [14]. Moreover, wheat flour products are usually enriched, and thus, GF cereal products often do not contain the same levels of micronutrients, such as thiamine, riboflavin, niacin, folate, vitamin D calcium and iron [10, 15, 16].

In dietary assessment studies carried out in children following a GF diet, imbalanced dietary intakes have been observed, due to a reduced energy intake with a decreased intake of complex carbohydrate and subsequent higher protein and fat consumption [17–21]. Furthermore, low intake of micronutrients has been also described [18, 20, 22–24]. Consequently, children with CD can commonly develop complications such as anemia, related to an insufficient intake of iron and folic acid, and disorders affecting the bone health, associated to a lack of calcium and vitamin D [8, 25, 26]. Nevertheless, it remains worthwhile to evaluate the possible contribution of specific GF foodstuffs to nutrient balance in children and adolescents with CD following a GF diet.

In this context, the aim of the present study was to assess the dietary quality of children and adolescents with CD to seek an optimal nutritional status by determining the most relevant factor that affects their balanced diet. Here, we report the influence of GF-rendered products on the achievement of a balance diet in children and adolescents with CD.

Materials and methods

Participants and procedure

"Gluten free-diet and Food Safety" is a prospective SUSFOOD (SUStainable FOOD production and consumption) study conducted in the Basque Country (Spain). Eighty-three patients with CD (♀, $n = 53$; ♂, $n = 30$) from 3 to 18 years of age (mean age ± SD, 9.2 ± 3.8) took part in the present study. They were recruited during 2011 and 2013 from three regions of the Basque Country in the north of Spain (Araba, 16.9% of participants; Gipuzkoa, 55.4%; and Bizkaia, 27.7%) in collaboration with the Association of Basque patients with CD. All participants followed a GF diet for at least 1 year and claimed to be in remission from clinical symptoms. Exclusion criteria included history of chronic diseases such as cardiovascular disease, diabetes, hyperthyroidism/hypothyroidism, hypercholesterolemia, hypertriglyceridemia or high blood pressure levels, and other digestive pathologies which need specific dietetic advice as well as a lack of motivation to participate in the study. Written informed consent was obtained from legal tutors, after receiving information about the survey, for all participants. This study was approved by the Ethical Committee of the University of the Basque Country (CEISH/76/2011 and CEISH/194M/2013).

Anthropometric measurements

Anthropometric measurements were collected by trained nutritionists. Body weight (± 10 g) was measured after voiding using a digital integrating scale (SECA 760). Height was measured to the nearest 5 mm using a stadiometer (SECA 220). Body mass index (BMI) was calculated from weight and height (kg/m^2). Sex- and age- independent BMI standard deviation scores were calculated using z-values for BMI, calculated via the LMS method by Cole et al. (2000) [27]. Thinness and overweight were defined according to age- and sex-standardized BMI cut-off points based on national and international databases [27–30].

Fat mass, energy expenditure and physical activity

For all subjects, fat mass percentage was estimated with a direct segmental multiple-frequency bioelectrical impedance analysis method (Inbody 230; Biospace, Seoul, Korea). Participants were controlled to void urinary bladder after a fast > 1.5 h to the experiment. Two skin electrodes were placed on the feet and two electrodes on the hands. According to the standard procedure, whole-body resistance and reactance were measured.

Weight, height and age were used to calculate individual energy expenditure according to the Harris–Benedict formula. Standard activity-level value was applied.

Physical activity (PA) fulfilling was assessed by World Health Organization recommendation (> 60 min/day of moderate to vigorous activities) [31].

Dietary assessment

Dietary intake was assessed using 3 days 24-h food recalls (24HR), two on weekdays and one at the weekend, and a 136-item food frequency questionnaire (FFQ). The FFQ was specifically developed for people with CD from validated FFQ for general population [32–34]. Participants were requested to include the name and brand of the consumed GF foodstuffs. Trained nutritionists–dieticians kept the records for participants, who were accompanied by their parents. Food portions and amounts were determined by the three-pass method, which included a quick list, a detailed description review, and visual aids. In this last case, printed food models, plates, glasses, spoons as wells as household measures or albums of portion photographs were used [35]. Children and adolescents over 12 years self-reported the FFQ and 24HR, whereas parents' assistance was needed for younger children. Energy and nutrient intakes were calculated by means of the nutritional software program "Alimentación y Salud" (AyS, Software, Tandem Innova, Inc.). Dietary reference intakes (DRI) for Spanish population issued by the Spanish Societies of Nutrition, Feeding and Dietetics (FESNAD) in 2010 were taken as references for the interpretation of the 24HR [36]. Macronutrient energy distribution of patients with CD was compared to non-celiac children and adolescents of the same region as well as to the recommended percentage in a balanced diet [37, 38]. In the case of FFQ, Spanish Society of Community Nutrition (SENC) recommendations were used for the correct interpretation of the results [39].

The composition of specific GF products for patients with CD was retrieved from the product labels and added into the food composition database of the program before calculations, as in previous studies [14]. As GF product labels did not indicate micronutrient content, Missbach et al. GF product database was used for vitamin and mineral estimation [40].

A simulation of a gluten-containing diet was performed by duplicating recorded GF diets and replacing specific GF foodstuffs by their equivalent gluten-containing foods. Then a nutritional comparison between both diets was carried out. The GF products' brands were those specifically reported by patients with CD. In the case of gluten-containing products, these were available on the same shops as their GF counterparts and had the same name as well as the most similar appearance.

Diet quality was evaluated as adherence to the Mediterranean diet (MeD) by the KIDMED index (Mediterranean Diet Quality Index in children and adolescents). MeD has been widely used as an indicator of healthy dietary habits, due to its good correlation with improved glycemic control and cardiovascular health [41–43].The KIDMED index was based on principles sustaining Mediterranean dietary patterns, as well as those that could potentially impair the MeD, described elsewhere [44]. Levels of adherence were classified into three groups: poor (0–3), moderate (4–7), and high adherence (8–12) to the MeD.

Statistical analysis

Statistical analyses of results were performed using the IBM SPSS statistical program, version 23 (IBM Inc., Armonk, NY, USA). P values < 0.05 were accepted as significant.

The results for continuous variables are given as the arithmetical mean ± standard deviation (SD) and the range. The results for non-continuous variables are given as the frequency and the percentage. Normality in the distribution was assessed by Kolmogorov–Smirnov test and the homogeneity by Levene's test.

Linear regression analysis was used to examine the association of adherence to the KIDMED index (poor, moderate and high) with sex, age interval, physical activity fulfilling, province, time following GF diet and adequate weight. Variables with skewed distribution were logarithmically transformed to obtain a more symmetrical distribution.

Statistical analyses of paired means for GF diet and gluten-containing diet were performed with non-parametrical Wilcoxon's test.

Results

Anthropometric measurements

Anthropometric characteristics of the children and adolescents, stratified by age, group and gender, are shown in Table 1. Nearly 70% of the participants presented an adequate BMI, 20% were thin and there were only nine cases (11%) of overweight. None was obese. Although greater weights were observed in boys, accompanied by a tendency to higher heights, not differences in BMI values were found. Accordingly, body fat percentage was adequate in most cases. There were no differences between genders from 3 to 13 years, but at age of 14–18 body fat percentages were higher in girls than in boys, as expected.

Healthy behavior

Healthy behavior is summarized in Table 2. A low percentage of the population studied (19%) reached physical activity recommendations. By contrast, a small number of girls and boys with CD (less than 5%) followed unhealthy practices such as skipping breakfast, eating commercially baked goods or pastries at this meal or eating more than once a week in fast food restaurants.

Table 1 Anthropometric results of celiac boys and girls aged 3–18 years, stratified by age group and gender

Characteristic	3–8 years		9–13 years		14–18 years	
	Girls	Boys	Girls	Boys	Girls	Boys
n	20	14	20	11	13	5
Age (year)	5.1 ± 1.5	5.7 ± 1.4	10.2 ± 1.2	10.9 ± 1.2	15.8 ± 1.2	15 ± 0.7
Height (cm)	113 ± 11.3	118 ± 10.5	140 ± 11.1	144 ± 8	160 ± 6.0	174 ± 8.9
Weight (kg)	21.1 ± 4.5	23.0 ± 5.1	37.8 ± 9.9	37.4 ± 7.6	57.9 ± 8.2	62.7 ± 12.6*
Body fat %	16.4 ± 1.5	16.6 ± 1.4	22.5 ± 7.5	19.8 ± 10.8	25.3 ± 5.8	13.6 ± 9.2**
Body mass index						
Mean (kg/m^2)	16.4 ± 1.5	16.6 ± 1.4	18.5 ± 2.6	17.7 ± 2.6	21.2 ± 2.5	20.7 ± 3.7
Z score	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.2	1.0 ± 0.2	1.0 ± 0.2	1.0 ± 0.2
Thinness—no. (%)	3 (15)	2 (14)	5 (25)	4 (36)	2 (13)	1 (20)
Adequate weight—no. (%)	15 (75)	10 (72)	13 (65)	7 (64)	9 (74)	3 (60)
Overweight—no. (%)	2 (10)	2 (14)	2 (10)	0 (0)	2 (13)	1 (20)

Values are means + standard deviation (SD); *n* number of subjects. Asterisks represent significant difference between boys and girls: *$P < 0.05$; **$P < 0.01$

Table 2 Dietary habits of study sample according to the KIDMED index

	All	Girls	Boys
n	83	53	30
Healthy behavior following			
PA recommendation (%)	19.3	17.0	23.0
Skips breakfast (%)	3.6	3.8	3.3
Dairy product for breakfast (%)	95.2	98.1	90.0
Two yogurts and/or some cheese daily (%)	30.1	32.1	26.7
Cereal or cereal product for breakfast (%)	92.8	92.5	93.3
Pasta or rice almost daily (≥ 5/week) (%)	20.5	9.6	10.8
Fresh or cooked vegetables daily (%)	25.3	20.8	33.3
Fresh or cooked vegetables daily—no. (%)	1.2	1.9	0
Fruit or fruit juice daily (%)	86.8	90.0	88.0
Second serving of fruit daily (%)	50.6	50.9	50.0
Regular fish consumption (≥ 2–3/week) (%)	84.3	83.0	86.7
More than 1/week fast food (hamburger) restaurant (%)	3.6	5.7	0.0
Pulses > 1/week (%)	94	90.6	100
Regular nut consumption (≥ 2–3/week) (%)	27.7	28.3	26.7
Use of olive oil at home (%)	90.4	92.5	86.7
Sweets and candy several times a day (%)	7.2	7.5	6.7
Commercially baked goods or pastries for breakfast (%)	1.2	0.0	3.3
KIDMED index (0–16)	6.8 ± 1.6	6.6 ± 1.6	7.0 ± 1.5
KIDMED index (%)			
Poor (≤ 3)	2.4	3.8	0.0
Moderate (4–7)	63.9	44.6	19.3
High (≥ 8)	33.7	26.4	46.7
Gluten-free habits			
Time following GF diet (years)	6.43 ± 4.18	6.56 ± 4.53	6.20 ± 3.54
Energy intake from GF-rendered foods (Kcal)	478 ± 186	487 ± 161	463 ± 227
Percentage of daily total energy intake	24.3%	23.8%	24.3%

Values are mean ± SD or percentages

GF Gluten-free, *PA* physical activity

Although almost all children and adolescents with CD introduced cereal products into their breakfast, only 33% of the participants ate the minimum of four recommended servings per day of cereals (recommendation, 4–6 portion/day). Along similar lines, around 21% of them ate pasta or rice almost daily. Moreover, two out of ten patients with CD consumed a very small amount of cereals (fewer than two servings). Notwithstanding, grains and cereal derivatives provided 27% of energy intake, GF-rendered cereals being the main contributors (24% of total energy intake) (Table 2).

The vast majority of the participants, 86%, did not reach vegetable consumption recommendations (2 portions/day). While the consumption of only one fruit or fruit juice daily was extended among patients with CD, nearly half of them ate the second serving of fruit daily (recommendation, 2–3 portion/day).

With respect to animal origin food, 73% of participants included two or more servings daily of milk or dairy products (recommendation, 2–4 portion/day). However, two out of ten children and adolescents with CD consumed more than four servings/day. Meat and meat product consumption was excessive in 64% of participants (recommendation, 4 portion/week), whereas almost 50% of them reached the weekly recommended amount of fish (3–5 portions/week) and 42% that of eggs (4 portions/week). Animal origin food provided 32% of total energy intake: 14% from milk and dairy products and 18% from meat and meat products, fish and eggs.

Eight out of ten participants included two or more portions of pulses per week (recommendation, 2–4 portion/week). By contrast, regular nut consumption was covered by merely 28% of the sample studied. Regarding other energy sources such as vegetable oils, sugar, chocolate and pastries, most participants consumed them correctly.

KIDMED index

The average of diet quality index, KIDMED index, was 6.8, and was higher for boys than girls (Table 2). While 47% of boys with CD demonstrated high adherence to MeD, only 25% of girls reached this goal. Table 3 represents linear regression statistics, showing the positive association of KIDMED interval (poor, moderate and high) with sex and adequate weight.

Table 3 Lineal regression coefficients (β) and standard errors (SE) considering the associations of KIDMED index interval with sex, age interval, physical activity fulfilling, province, time following gluten-free diet and adequate weight

	β	SE	P
Sex	0.31	0.13	0.02
Age interval (3–8, 9–13, 14–18)	0.13	0.12	NS
PA fulfilling	− 0.03	0.16	NS
Province	− 0.05	0.08	NS
Adequate weight	0.38	0.13	< 0.01
Time following GF diet[a]	− 0.26	0.24	NS

Normal weigh consideration was determined by Orbegozo cut-off values and physical activity (PA) fulfilling by World Health Organization recommendation [30, 31]

[a]Analysis was performed with log-transformed data

Dietary intakes

The energy intake of children with CD was under their estimated energy expenditure (supplementary Fig. 1). They reached, on average, around 80% of recommended energy.

As in the case of non-celiac children and adolescents, the diet of patients with CD was not balanced, containing more fat (39.6%) and less carbohydrate (45.4%) than recommended by the European Food Safety Authority (EFSA) (supplementary Fig. 2) [38]. Protein intake was around 17%. As far as micronutrients were concerned, a low percentage (< 10%) of participants showed insufficient intakes of thiamin, riboflavin, vitamin B6 and B12, as well as niacin, phosphorus, and magnesium (supplementary Fig. 3). By contrast, more than 2/3 of participants did not reach recommendations for vitamin D, and over half of them did not fulfill the recommendations for folic acid and calcium, nor about 1/4 those for iron (supplementary Fig. 3).

In the present research, the amount of calories coming from GF-rendered foods supposed 24% of the total energy intake. Therefore, it was very important to analyze the potential impact of these products on dietary imbalance. For this purpose, diets containing GF-rendered foodstuffs (the ones reported by the participants) were compared to similar diets but substituting those foodstuffs with analog gluten-containing products. Diet composition was significantly changed, providing more protein and carbohydrate and less fat content in the gluten-containing one (Table 4). With regard to fatty acids, higher contents in polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA) and lower saturated fatty acids (SFA) were observed (Table 4). The micronutrient comparison of GF diet against gluten-containing diet indicated higher levels of vitamin E, zinc, potassium and calcium consumption, but lower of vitamin A, thiamine, riboflavin, niacin, vitamin B6, vitamin B12, folate, biotin, vitamin D, pantothenate, magnesium, sodium, iron, cupper, iodine, chlorine, manganese and selenium intake (Table 5).

Discussion

It has been previously demonstrated that diets followed by adults with CD can lead to imbalances in their macronutrient intake and to vitamin and mineral deficiencies [5, 45–47].

Table 4 Energy and macronutrient intake comparison between the following gluten-free and gluten-containing diet

	Gluten-free diet		Gluten-containing diet		*P*
	Mean	SD	Mean	SD	
Energy (Kcal/d)	1952	344	1979	438	NS
Protein (g/d)	*79.8*	*17.0*	*83.5*	*17.2*	*<0.001*
%	*16.7*	*2.6*	*17.4*	*2.4*	*<0.001*
Fat (g/d)	*86.2*	*19.6*	*83.2*	*19.5*	*<0.001*
%	*40.1*	*5.9*	*38.9*	*5.0*	*<0.001*
MUFA (g/d)	*31.1*	*8.9*	*33.1*	*9.1*	*<0.001*
%	*46.9*	*6.0*	*48.3*	*5.3*	*<0.001*
PUFA (g/d)	*8.2*	*4.0*	*9.4*	*4.3*	*<0.001*
%	*12.2*	*4.2*	*13.6*	*4.2*	*<0.001*
SFA (g/d)	*27.1*	*7.9*	*25.9*	*7.4*	*0.002*
%	*40.9*	*6.6*	*37.9*	*5.9*	*<0.001*
Carbohydrate (g/d)	*219.0*	*47.1*	*223.2*	*42.2*	*<0.001*
%	*42.6*	*6.4*	*43.8*	*5.4*	*<0.001*

In italic, nutrients with significance level $P<0.05$

Kcal/d kilocalories/day, *g/d* grams/day, *MUFA* monounsaturated fatty acids, *NS* not significance, *PUFA* polyunsaturated fatty acids, *SD* standard deviation, *SFA* saturated fatty acids

Table 5 Micronutrient intake comparison between the following gluten-free and gluten-containing diet

	Gluten-free diet		Gluten-containing diet		*P*
	Mean	SD	Mean	SD	
Vitamin A (µg/d)	*555*	*224*	*602*	*231*	*<0.001*
Thiamin (mg/d)	*1.3*	*0.4*	*1.4*	*0.5*	*<0.001*
Riboflavin (mg/d)	*1.6*	*0.4*	*1.8*	*0.5*	*<0.001*
Vitamin B6 (mg/d)	*1.6*	*0.4*	*1.9*	*0.5*	*<0.001*
Vitamin B12 (µg/d)	*5.9*	*2.9*	*6.8*	*3.1*	*<0.001*
Vitamin C (mg/d)	89.6	46.0	92.2	48.1	0.9
Vitamin D (µg/d)	*3.3*	*3.5*	*3.8*	*3.3*	*<0.001*
Vitamin E (mg/d)	*10.4*	*3.9*	*9.6*	*3.4*	*<0.001*
Niacin (mg/d)	*21.2*	*5.6*	*23.7*	*6.2*	*<0.001*
Pantothenate (mg/d)	*4.1*	*1.1*	*4.6*	*1.4*	*<0.001*
Biotin (µg/d)	*4.2*	*2.3*	*4.3*	*2.3*	*<0.001*
Folate (µg/d)	*186*	*76*	*233*	*88*	*<0.001*
Sodium (mg/d)	*1819*	*529*	*1932*	*533*	*<0.001*
Potassium (mg/d)	*2788*	*585*	*2747*	*565*	*0.001*
Calcium (mg/d)	*900*	*217*	*887*	*219*	*0.007*
Phosphorus (mg/d)	1297	287	1298	285	0.7
Magnesium (mg/d)	242	66	279	66	<0.001
Iron (mg/d)	12.2	3.3	13.9	4.1	<0.001
Zinc (mg/d)	15.1	13.3	8.7	2.6	<0.001
Iodine (µg/d)	63.0	28.6	66.8	29.3	<0.001
Copper (mg/d)	0.5	0.3	0.7	0.3	<0.001
Chlorine (mg/d)	697	322	1118	518	<0.001
Manganese (mg/d)	76.3	67.4	77.1	67.1	<0.001
Selenium (µg/d)	36.9	17.6	52.0	20.2	<0.001

DRI, FESNAD: A vitamin (µg/d): 400 for 3–5 y, 450 for 6–9 y, 600 for 10–13 y, 600 for 14–18 y ♀, 800 for 14–18 y ♂. Thiamin (mg/d): 0.7 for 4–5 y, 0.8 for 6–9 y, 0.9 for 10–13 y ♀, 1 for 10–13 y ♂, 1 for 14–18 y ♀, 1.2 for 14–18 y ♂. Riboflavin (mg/d): 0.9 for 4–5 y, 1.1 for 6–9 y, 1.2 for 10–18 ♀, 1.3 for 10–13 y ♂, 1.5 for 14–18 y ♂. Vitamin B6 (mg/d): 0.9 for 4–5 y, 1 for 6–9 y, 1.1 for 10–13 y ♀, 1.2 for 10–13 y ♂, 1.3 for 14–18 y ♀, 1.4 for 14–18 y ♂. Vitamin B12 (µg/d): 1.1 for 4–5 y, 1.2 for 6–9 y, 1.8 for 10–13 y, 2 for 14–18 y. Vitamin C (mg/d): 45 for 4–9 y, 50 for 10–13 y, 60 for 14–18 y. Vitamin D (µg/d): 5 for 4–18 y. Vitamin E (mg/d): 7 for 4–9 y, 11 for 10–13 y, 15 for 14–18 y. Niacin (mg/d): 11 for 4–5 y, 12 for 6–9 y, 13 for 10–13 y ♀, 14 for 14–18 y ♀, 15 for 10–18 y ♂. Pantothenate (mg/d): 3 for 4–9 y, 4 for 10–13 y, 5 for 14–18 y. Biotin (µg/d): 12 for 4–9 y, 20 for 10–13 y, 25 for 14–18 y. Folic Acid (µg/d): 150 for 4–5 y, 200 for 6–9 y, 250 for 10–13 y, 300 for 14–18 y. Sodium (mg/d): 1200 for 4–9 y, 1500 for 10–18 y. Potassium (mg/d): 1100 for 4–5 y, 2000 for 6–9 y, 2900 for 10–13 y ♀, 3100 for 14–18 y ♀, 3100 for 10–18 y ♂. Calcium (mg/d): 700 for 4–5 y, 800 for 6–9 y, 1100 for 10–13 y, 1000 for 14–18 y. Phosphorus (mg/d): 500 for 4–5 y, 600 for 6–9 y, 900 for 10–13 y, 800 for 14–18 y. Magnesium (mg/d): 120 for 4–5 y, 170 for 6–9 y, 250 for 10–13 y ♀, 280 for 10–13 y ♂, 300 for 14–18 y ♀, 350 for 14–18 y ♂. Iron (mg/d): 8 for 3–5 y, 9 for 6–9 y, 12 for 10–13 y ♂, 11 for 14–18 y ♂, 15 for 10–18 y ♀. Zinc (mg/d): 6 for 4–5 y, 6.5 for 6–9 y, 8 for 10–13 y, 8 for 14–18 y ♀, 11 for 14–18 y ♂. Iodine (µg/d): 90 for 4–5 y, 120 for 6–9 y, 130 for 10–13 y ♀, 135 for 10–13 y ♂, 150 for 14–18 y. Copper (mg/d): 0.6 for 4–5 y, 0.7 for 6–9 y, 1 for 10–18 y. Chlorine (mg/d): 1900 for 4–9 y, 2300 for 10–18 y. Manganese (mg/d): 1.5 for 4–9 y, 1.6 for 10–13 y ♀, 1.9 for 10–13 y ♂, 1.67 for 14–18 y♀, 2.2 for 14–18 y ♂. Selenium (µg/d):

Therefore, it could be suggested that patients with CD tend to develop nutrition-related pathologies such as hypercholesterolemia, osteoporosis or anemia [25, 26, 46]. This matter gains even more importance in children or adolescents with CD, who often have suboptimal nutritional status at the time of diagnosis [8] and should meet all nutrient intake recommendations to ensure their growth and development.

With similar data to those observed in adult celiac studies, children and adolescents from the present study followed an unbalanced diet (excessive fat, insufficient carbohydrate). However, most participants revealed adequate BMI and body fat percentage. Furthermore, a lower BMI than those reported for Spanish children and adolescents was observed. National research studies in adolescents found a prevalence of overweight, including obesity, of 25.7% in boys and 19.1% in girls [48], whereas its prevalence in children reached 26.7% in boys and 25.7% in girls [49]. By contrast, 11% of young people with CD were overweight with no differences in gender. Even though authors such as Babio et al. did not find differences in BMI values between celiac and non-celiac adolescents, other studies have indicated that children on a GF diet have lower weight, height and BMI compared to age- and sex-matched controls [50, 51].

Dietary pattern is one of the main factors that could explain the observed unbalanced intakes of macronutrients, as well as deficiencies in mineral and vitamins. For this reason, we assessed the adherence to the MeD by KIDMED index to evaluate the adequacy of the healthy behavior

Table 5 (continued)

20 for 3–5 y, 25 for 6–9 y, 35 for 10–13 y, 45 for 14–18 y ♀, 50 for 14–18 y ♂

In italic, nutrients with significance level $P < 0.05$

NS not significant, *SD* standard deviation, *DRI* dietary reference intake, *FESNAD* Federation of Spanish Societies of Nutrition and Dietetics, *mg/d* milligrams/day, *µg/d* micrograms/day, *y* years

♀, girls; ♂, boys

-dietary and lifestyle- of children and adolescents with CD [42, 52].

Most of the participants showed a moderate KIDMED index. With regard to dietary pattern, cereal consumption as well as fruit and vegetables were low in children and adolescents with CD, highlighting that the majority of participants did not fulfill recommendations (almost 50% for fruit and 86% for vegetables). By contrast, foodstuffs of animal origin, especially meat, were eaten to excess, representing on average 32% of the total calorie consumption. These data are in good accordance with those published by other authors, who observed that adolescents with CD consumed less starch and more animal products (meat, fish and eggs) than children without CD [51]. Taken together, these results could suggest that celiac children and adolescents tend to replace cereals, and in general, plant origin foods in the diet with animal products.

Data concerning PA showed that only almost 20% of participants fulfilled the WHO's recommendations (> 60 min/day of moderate to vigorous activities) [31]. Similarly, Babio et al. observed that 32% of their celiac patients were active or very active (very active being the equivalent to fulfilling WHO recommendations) [51]. As in the present study, other studies carried out among Spanish adolescents pointed out the gender difference related to PA, with significantly more boys being active than girls (32 and 17%, respectively) [53].

After introducing the GF diet, nutritional deficiencies arising from the malabsorption syndrome of CD could be corrected [8]. Nevertheless, it has been demonstrated that diets followed by patients with CD can lead to imbalances in macronutrient intake and to vitamin and mineral deficiencies [5, 45–47]. Although dietary pattern could be one explanation for malnutrition, other factors could play a role. Taking into account that several studies have revealed higher amounts of fat and lower quantities of protein, carbohydrate and several vitamins and minerals in GF products [14, 40, 54, 55], the influence of GF product composition cannot be neglected.

In the present research, GF-rendered foods provided almost a quarter of the total calorie intake, which is close to data published by others (36%) [50]. This result indicates that, first of all, GF-rendered foodstuffs play a major role in the diet of children and adolescents with CD, and second, that the impact of these products on nutritional balance compliance should be taken into account.

GF diets resulted in higher fat ingestion (especially due to saturated fat) and lower protein and carbohydrate consumption. Micronutrient intake also proved to be lower when comparing GF diets with their analogs containing gluten. Specifically, vitamin A, thiamine, riboflavin, niacin, vitamin B6, vitamin B12, folate, biotin, vitamin D, pantothenate, magnesium, sodium, iron, cupper, iodine, chlorine, manganese and selenium intakes were lower in GF diets. Other studies among children following a GF diet have suggested unhealthy diets, characterized by low intakes of complex carbohydrate and subsequent higher protein and fat intakes [17–21] as well as lower intake of folic acid, zinc, iron and magnesium [51]. It is important to point out that all the research reported evaluated the diet followed by patients with CD, and not the influence of GF-rendered products. As stated before, in the case of the present study the dietary pattern followed by young patients with CD is inappropriate. However, taken as a whole, data from the present study indicate that GF-rendered foodstuffs contribute to a higher degree of unbalance among those children and adolescents with CD.

This study has an important limitation. Since there are no food composition tables containing GF-rendered foodstuffs, information regarding their energy and macronutrient content was based on our previous research, where data provided on the GF product labels were collected in a database and used for the comparison of these products versus the ones containing gluten [14]. Unfortunately, micronutrient data are not provided in the product labels so the database provided by Missbach et al. was used for this purpose [40]. They included GF products from another European market (Germany), therefore the composition could vary slightly from ours (the Spanish market). However, we believe that it is essential to include the specific composition of GF products, to assess the real micronutrient intake of GF diet followed by children and adolescents with CD. Otherwise, it would be inaccurate to claim that a GF diet promotes inadequate micronutrient intake, as has been concluded in other studies [5, 45–47, 51].

In conclusion, the present study revealed that a relevant participant sample of children and adolescents with CD do not meet energy and nutrient recommendations and showed, on average, moderate adherence to the Mediterranean diet. Moreover, the consumption of GF-rendered foods increases the imbalances observed in energy and nutrient intakes. Thus, although GF products could guarantee the absence of gluten in the diet, following a diet based on them adds to the difficulty of reaching a nutritional balance for patients with CD, which means that specific nutritional guidelines should be put forward for this collective.

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Author contributions IL and MAB performed the anthropometric measurements and collected questionnaires. FJE and LB recruited the patients, performed anthropometric measurements and collected questionnaires. IC and ES carried out the experimental design and analyzed data. JM and AL wrote the manuscript.

Compliance with ethical standards

Conflict of interest Authors declare no conflict of interest.

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