Gluten Free Diet

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1 Introduction

For regulatory purposes gluten is defined as 'the protein fraction from wheat, barley, rye, oats or their crossbred varieties and derivatives that is insoluble in water and 0.5 M NaCl [1]. However, there are a varied range of definitions for gluten in the literature that have been developed from different perspectives. Cereal grain proteins, including gluten, have been classically defined according to their solubility according Osborne classification. Osborne classified the storage proteins into groups on the basis of their extraction and solubility in water (albumins), dilute saline (globulins), alcohol ether mixtures (prolamins), and dilute acid or alkali (glutelins) [2].

In the case of wheat, the storage proteins from the gluten fraction are important because of their properties are largely responsible for the ability to use wheat flour to make bread and other products. The wheat grain can be divided into two main groups: gliadins and glutenins. Gliadins are subdivided into four groups on the basis of mobility at low pH in gel electrophoresis (α-, β-, ϒ-, ω-gliadins in order of decreasing mobility). Glutenins are divided into two groups according to their molecular weight: high molecular weight glutenin subunits (HMW-GS) and low molecular weight glutenin subunits (LMW-GS). We can also find homolog gluten genes in rye and barley [3–5].

Glutenins and gliadins are widely studied due to their contribution to the quality of the end-product of bakery and pasta goods, including the rheological characteristics of dough made from wheat flour. However, besides the importance of gluten proteins in food quality, the gluten has a direct impact on the human health

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by triggering wheat related food disorders such as celiac disease (CD). Indeed, currently, the only effective therapy for CD is a strict lifelong gluten-free diet (GFD). This means the elimination of products containing wheat, rye and barley [6].

Although conceptually simple, following a GFD presents significant challenges and many barriers to compliance that have impact on life quality of patients. It can be exceedingly difficult to completely avoid gluten-containing foods, and adherence to a GFD is estimated to be only 45–80% [7]. Comprehensive understanding of the factors associated with optimal GFD adherence is needed to develop strategies and resources to assist individuals with CD maintain a GFD.

On the other hand, a GFD has been the most popular elimination diet for more than a decade. The evidence indicates that the number of people on a GFD is constantly increasing, not only among people with gluten-related disorders, because it is associated with being healthier [8]. However, some epidemiological studies indicate nutritional imbalances for people following GFD. They refer both to macronutrients and micronutrients including minerals [9]. Therefore, it is extremely important to educate the patients in how to follow a GFD not only avoiding gluten, but also combining foods in a healthy way. The gluten-free diet must be safe and healthy.

2 Gluten-Free Diet

The GFD pattern is the only treatment for CD, gluten sensitivity and wheat allergies. However, to ensure accurate test results it is imperative that the patient does not initiate a GFD until a final diagnosis is obtained. Once the diagnosis is reached, then the GFD should be implemented.

The basis of GFD is to remove all food products that contain wheat, rye and barley. In Table 1, we can find the naturally gluten-free foods, foods and products that naturally have no gluten but they may have been contaminated during processing and finally, those gluten containing foods and products.

2.1 Healthy Gluten-Free Diet and Nutritional Deficiencies

Recently, GFD has been associated with being healthier. However, epidemiological studies indicate nutritional imbalances for people following GFD, referring both to macronutrients and micronutrients including minerals [9].

This is an important issue because affects directly to the nutritional status of CD patients. Furthermore, the nutritional condition depends on the length of time the disease is active, the extent of intestinal inflammation, the degree of malabsorption, and dietary intake [10].

Table 1 Sources of gluten

Gluten-containing grains and their derivatives	Foods that may contain gluten[a]	Naturally gluten-free foods[b]
• Wheat and derivatives: *triticale*, *durum*, emmer, semolina, spelt, farina, farro, graham, KAMUT® khorasan wheat, einkorn wheat • Wheat starch that has not been processed to remove the presence of gluten to below the limit 20 ppm • Rye • Barley • Malt in various forms including: malted barley flour, malted milk or milkshakes, malt extract, malt syrup, malt flavouring, malt vinegar • Brewer's Yeast All products with those ingredients are **not** allowed for CD people	• **Processed lunch meats, friednuts, sauces** • **Energy bars and granola bars** —some bars may contain wheat as an ingredient, and most use oats that are not gluten-free • **French fries:** risk in the batter containing wheat flour or cross-contact from fryers • **Potato chips** seasonings: could contain malt vinegar or wheat starch • **Candy and Candy bars** • **Ready to eat soups**—pay special attention to cream-based soups, which have flour as a thickener. Many soups also contain barley • **Multi-grain or artisan tortilla chips or tortillas** that are not entirely corn-based (specify in the ingredient list) may contain a wheat • **Salad dressings and marinades** • **Starch or dextrin** without specify the origin of starch: if found on meat product • **Brown rice syrup**—may be made with barley traces • **Meat substitutes** made with seitan such as vegetarian burgers, vegetarian sausage, imitation meat or fish derivatives (bacon, seafood) • **Soy sauce** without specify that is gluten-free • **Self-basting poultry and eggs served at restaurants** or bars–some restaurants put pancake batter in their scrambled eggs and omelettes	• Rice, cassava, corn (maize) • Soy • Tubercles: potato, tapioca, yucca • Beans • Sorghum, quinoa, millet, buckwheat groats, amaranth • Arrowroot • Teff • Chia • Gluten-free oats certificated • Nut flours • Natural nuts, seeds and oils • Fresh meat, fish and eggs • Dairy • Fresh fruits and vegetables • Legumes

[a]These foods must be verified by reading the label or checking with the manufacturer and/or kitchen staff

[b]Although these foods are naturally gluten free, it is necessary to check always the labels of manufacturing products

For that reason, it is extremely important to monitor nutritional status and diet at the time of diagnosis and during follow-up. Some studies have revealed that deficiencies in iron, calcium, zinc, vitamin B12, vitamin D and folate are by far the most common nutritional inadequacies claimed for newly diagnosed celiac patients, whereas macronutrient inadequacies are rarely identified at diagnosis. On the other hand, after a while following the gluten-free diet, the most important nutritional deficiencies are: iron, calcium, selenium, zinc, magnesium, vitamin B and B12, excess of fat and simple sugar intake and poor fibre consumption [11, 12].

We have considered that most of the vitamin and mineral deficiencies are consequence of the villous atrophy in the small intestine, because their absorption occurs mainly in different sections of the intestine. But after start the GFD and when the gut recovers, some of these deficiencies are solved.

However, the nutritional deficiencies after several years of GFD are due to an unhealthy diet in the most cases. In general, an inadequate macronutrient intake has been associated above all with the fact that CD patients are focusing on the avoidance of gluten and often leaving back the importance of nutritional quality of the choice.

The poor intake of fibre is associated with the necessity of the avoidance of several kinds of foods naturally rich in fibre (i.e. grain) and the low content of fibre of GF products that are usually made with starches and/or refined flours. As is well known, a consumption of adequate amounts of dietary fibre is related to potential health benefits such as prevention of obesity, diabetes, cardiovascular diseases and various cancers. So, it is important to encourage CD patients to review their fibre consumption [13].

Concerning micronutrients, deficiencies of some vitamins and minerals may persist and this required a particular attention to the quality of the GFD, especially those implicated in crucial metabolic functions. Calcium and vitamin D deficiencies can lead to osteopenia and osteoporosis and may cause growth problems and difficulties in peak bone mass achievement in young patients. But this deficiency also are important in elderly CD people because it results in a lowered mineral density and increased bone fracture risk [14, 15]. The zinc deficiency can affect protein synthesis and leads to growth arrest, whereas magnesium deficiency can compromise the metabolism of proteins, nucleic acids, glucose, fats, and transmembrane transportation. We should control blood levels of these minerals [12, 16]. Finally, iron deficiency anaemia and vitamin B12 deficiency, are among of the most common extra-intestinal manifestations of CD patients. Although in most patients this is reversed after starting a gluten-free diet, we should monitor regularly, especially in vegan and vegetarian CD patients [9, 10].

Lastly, regarding macronutrients there are disagreements among studies mainly related with protein, sugars and fat intake. But anyway, what is clear is that, following all this evidence, from the practical point of view the nutritional recommendation to CD patients for following a healthy and balance GFD should be:

1. **The basis of your diet should be naturally gluten-free foods**: fruits, vegetables, meat, fish, eggs, sugar free dairy, whole grains, gluten free starches and flours, legumes, nuts, seeds and oils.
2. Eat at least **3 daily portions of fruits**
3. Eat at least **2 daily portions of vegetables**, and try to choose one of them the raw version.
4. Choose **gluten-free whole grains**
5. **Pseudocereals** such as amaranth, buckwheat, and quinoa are good sources of vitamins, minerals, healthy fats and fibre.
6. **Use the Healthy Eating Plate** developed by the Harvard School of Public Health, as a guide for creating healthy, balanced meals, whether served at the table or packed in a lunch box
7. **Try to avoid specific gluten-free products with high amounts** of added sugar, refined flours and saturated fats.

In Table 2, we can see a general example of a healthy gluten-free menu, with the main gluten-free food groups distributed.

Table 2 Example of a healthy gluten free menu

	Breakfast	Lunch	Dinner
Monday	Overnight chia seed pudding with Greek yoghurt	Meat with vegetables and fruit (desert)	Fish with quinoa salad and fruit
Tuesday	Gluten-free cereals with milk and nuts	Legumes with vegetables and fruit (desert)	Egg with vegetables and fruit
Wednesday	Gluten-free toast with avocado and an egg	Fish with vegetables, potatoes and fruit (desert)	Meat with vegetables and fruit
Thursday	Gluten-free cereals with milk and nuts	Legumes with vegetables and fruit (desert)	Egg with salad and fruit
Friday	Fruit smoothie with gluten-free cereals	Meat with vegetables, potatoes and fruit (desert)	Fish with vegetables and fruit
Saturday	Porridge with nuts	Legumes with vegetables and fruit (desert)	Egg with vegetables and fruit
Sunday	Overnight chia seed pudding with Greek yoghurt	Rice with vegetables and fruit (desert)	Fish with quinoa salad and fruit

2.2 Oats and Gluten-Free Diet

The inclusion of oat into the GFD is still controversial. The main limitation to its use is the contamination of oat by wheat, barley, or rye. Indeed, gluten contamination of oat occurs frequently and commercially available oats are not suitable in a GFD for CD due to their routine contamination with gluten-containing cereals. Only gluten-free oat is acceptable as a foodstuff for celiac patients [17].

However, the main problem with the cultivation and processing of gluten-free oat is that oats requires sophisticated technology. The prevention of contamination of oat by wheat, rye, or barley includes to have separate fields with an appropriate distance and a natural barrier between the fields. Moreover, a field previously planted with gluten-free cereals cannot be used for oat for at least eight years. Oat fields must also be routinely inspected for contaminating cereal plants (containing prolamins immunogenic for celiac patients), and those plants have to be removed [18]. Gluten-free oat must meet the legislative criteria for gluten-free foodstuff, i.e., the content of gluten in the end-products must be less than 20 mg/kg.

In general, uncontaminated oats are safe for almost all patients with CD. A small percentage of patients with CD maybe sensitive to oats and develop symptoms or even mucosal damage. One of the most recent systematic analysis about oat safety for celiac disease patients, concludes that supplementing a GFD with oats can potentially diminish nutrient deficiency and may provide significant health and quality of life benefits as well. However, the debate regarding the safety of oats for CD patients' needs to be settled first. The authors specify that a large-scale clinical trial using the high-quality GF oats is needed to confirm the real safety of this cereal in CD patients [19].

Experts recommend to avoid the introduction of oat into a gluten-free diet for newly diagnosed celiac patients, since a strict adherence to a gluten-free and oat-free diet is required for newly diagnosed celiac patients [18, 20, 21].

It also important to highlight that the recent evidence indicates gluten-free oats only should be introduce in patients with clinical remission, without symptoms and negative serology and, during the introduction, celiac patients should be under medical supervision due to individual susceptibility too. Although the dietary oat (without contamination with gliadins) is tolerated by the majority of celiac patients, the individual sensitivity to oat cannot be excluded [20].

The current recommendation of the European Society for the Study of Celiac Disease regarding the introduction of oats in the GFD is that "*Oats are safely tolerated by the majority of CD patients; its introduction into the diet should be cautious and patients should be monitored for possible adverse reaction*". (Strong recommendation, moderate level of evidence) [22].

2.3 *Pseudocereals in Gluten-Free Diet*

Pseudocereals (amaranth, quinoa and buckwheat) are composed mainly of albumins and globulins and contain very little or no storage prolamin proteins, which are toxic for CD patients; thus, they are good substitutes for cereal in GF foods.

Also, they have an interesting nutritional value as compared with wheat and different important GF flour. All pseudocereals have more calcium, magnesium and iron than wheat. As we have mentioned, these are one of the most compromised micronutrients the diet of GFD [23].

Amaranth has a nutritional value better than that of any other vegetable and much higher amounts of fibre, protein and minerals than any other GF grain as well as important amino acids such as lysine, arginine, tryptophan, and sulphur-containing amino acids Moreover, some food industries have used this ingredient to enrich cereal-based foods, including GF pasta [24].

Quinoa is a good complement for legumes (low amounts of methionine and cysteine) because its protein is rich in lysine, methionine, and cysteine. In addition, quinoa is a good source of Vitamin E and B-group vitamins and has high levels of calcium, iron, and phosphorous. It also has a suitable fatty acid composition and low amylase contents, this particularity is necessary to have a high shear in extrusion cooking, so quinoa could be used for several gluten-free products [24–26].

Buckwheat has a low glycaemic index which is beneficial for lowering blood pressure and control cholesterol levels. It has been demonstrated that the replacement of cornstarch with buckwheat flour in GF bread and GF crackers showed to have a positive effect on the texture and leads to products with acceptable sensory qualities. Buckwheat and quinoa breads have a higher volume than other kinds of GF breads [24, 27].

Apart from these pseudocereals it is important to highlight the nutritional value of other minor cereals used as alternative to gluten containing cereals: sorghum, teff, millet and wild rice. In recent analyses, these cereals have demonstrated to have a good nutritional profile, mainly in those nutrients which CD patients have deficiencies. Finally, the authors concluded that it is possible to use the combined mix of these flours in order to improve the nutritional value of cereal-based gluten-free products [28].

3 Gluten-Free Products

3.1 *Gluten Free Products Regulation*

The gluten-free products (GFP) are regulated by two European Commission Regulation: The Regulation (EU) Nº 828/2014 which entered into force on 20 July 2016. This Regulation lays down harmonized requirements for the provision of

information to consumers on the absence or reduced presence of gluten in food. More specifically, this legislation sets out the conditions under which foods may be labelled as "gluten-free" or "very-low gluten". This new regulation repealed the previous one: Commission Regulation (EC) No 41/2009.

The other is Regulation (EU) Nº 1169/2011 which lays down rules requiring the mandatory labelling for all foods of ingredients such as gluten-containing ingredients, with a scientifically proven allergenic or intolerance effect. In order to ensure clarity and consistency, it was considered that all the rules applying to gluten should be set by the same piece of legislation and, for this reason, Regulation (EU) No 609/2013 established that Regulation (EU) No 1169/2011 should also be the framework for the rules related to information on the absence of gluten in food [29].

The Crossed Grain Trademark

The Crossed Grain Trademark is registered and protected across the European Union, Switzerland, Norway, Croatia, Montenegro, Serbia and Bosnia Herzegovina developed by the Association of European Celiac Societies (AOECS).

This trademark can be licenced only for multiple ingredient and/or processed products or when there is a high risk of contamination. For example, fresh fruit and vegetables cannot be licenced as they are naturally gluten-free; but fruit bars or buckwheat flour can be licenced as they have undergone a process which may hold a risk for gluten contamination.

This symbol is recognized by CD patients in Europe and is particularly important when the consumer is unsure on the gluten status of a product, or whilst travelling and unable to understand the language in which the label is displayed. It is a quality and safety guarantee as all producers wishing to use it must conform to high and safe standards of production.

The use of this trademark protected symbol is strictly monitored by AOECS and its Member societies [30].

3.2 Challenges of Gluten Free Products

Gluten Functionality and Replacement Strategies

One of the main challenges is the gluten functionality. The gluten protein fraction displays unique structure building properties that are used in food processing because gluten in wheat flour forms a three-dimensional protein network upon proper hydration and mixing. These network-forming properties are used in baking applications to form viscoelastic dough matrices. In addition, gluten functionality in food includes water binding and viscosity yielding, which make gluten a widely used food additive. For that reason, the replacement of gluten as a vital ingredient in numerous food products is not straightforward. Different ingredients and processing techniques have been investigated to date. However, the quality of gluten-free products is often not comparable to gluten-containing products [4, 31].

There are a lot of trials which have attempted to imitate the cohesiveness and elasticity of a gluten-containing dough using a wide range of alternative raw ingredients and/or additives. The most studied gluten-replacing combinations with acceptable quality effects have been: starches, gluten-free flours of cereals/pseudocereals, hydrocolloids, and proteins with enzymes and emulsifiers [31].

Cost

One of the main challenges of GFP is the cost. The GF commercial foods are more expensive as compare with their gluten-containing counterparts (GCC). One of the most recent studies concluded that the cost of GF products was significantly more expensive than their wheat-based counterparts for all ten product categories which include staple foods; (bread, cereals, pastas), snack foods; (crackers, pretzels, cookies), and convenience foods (waffles, pizza, macaroni, and cheesecake). The overall cost of GF products was 183% more expensive than their wheat-based counterparts. The largest difference between GF and wheat-based products was for crackers (snack food category) which were 270% more expensive [32]. Previous studies have shown similar results between 150 and 200% more expensive GFP as compared with their counterparts [33–35].

Although, the cost GF products has been declined over the past 10 years, it remains significantly higher than their wheat-based counterparts.

Nutritional Value of Gluten-Free Products

It is well-known that overall the nutritional profile of GFP is associated with a lower content of protein as compared to their (GCC). The lower protein content of GFP is the result of the ingredients used in the formulation such as cornstarch, corn flour and rice flour that naturally have a high carbohydrate and low-protein content. This is unlikely to be a problem because of the high protein intake in general population, and this deficiency can be easily covered by the consumption of other gluten-free products: eggs, meat, fish, legumes and dairy [36–39].

However, regarding other macronutrients such as fibre, saturated fatty acids and added sugars there are controversial results. Some studies found significant differences in these ingredients in all GFP and others only found differences in few food groups (bread and biscuits). But in general, the main studies agree on two main points: (1) In GFP different kinds of fats are frequently added to the GF dough so as to replace the texture given by the network that gluten forms and also to enhance flavour and acceptance. (2) The main ingredients used in the formulation of most GFP are corn flour and rice flour, ingredients which are made of up to 70–80% of amylopectin, a glucose polymer, which results in a high glycaemic index, related to the risk of metabolic syndrome [35–47].

Additionally, the main limitation of all these studies is that the authors only analyze products from their own countries and from specific brands available there, so their results cannot be generalized to other countries and we should be cautious with the interpretation. Other important limitation is most of the studies only investigate about macronutrients. Few data are currently available regarding the vitamin content of GF products, despite nutritional deficiencies emerging from

analysis of the nutritional status of CD patients on a GFD. So, it is necessary that vitamin and mineral content in GF food products should be investigated in order to evaluate the necessity for fortification of GF products. The use of alternative ingredients, such as pseudocereals and legumes, should be also considered in order to improve the protein profile of GF products [12].

Anyway, it is recommendable to highlight the importance of basing the GFD in natural gluten-free foods and choose minimally processed products. And this is also recommendable for general population: not to abuse of processed products with high amounts of low-quality fats, added sugars and refined grains. And the recommendation is the same for the gluten-free and gluten-containing food industry: a reduction of fat, carbohydrate, sugars and sodium should become a priority for manufacturing products [48].

4 Cross Contamination

Cross contamination occurs when a gluten-free or food product is exposed by either direct or indirect contact with a gluten-containing ingredient or food—making it unsafe for people with celiac disease to eat.

However, it is almost impossible to maintain a diet with a zero-gluten content because gluten contamination is very common in food and may contain undetectable amounts of gluten proteins. Currently, the maximum level of gluten contamination (expressed as parts per million, ppm) that can be tolerated in products that are marketed for the treatment of CD is 20 ppm [1]. Nevertheless, the relation between the intestinal damage induced by trace intakes of gluten and the long-term complications of CD remains to be elucidated, but the most acceptable dangerous amount established is that as little as 50 mg gluten can damage the architecture of the small intestine in patients being treated for CD [49].

The cross contamination can be a source of stress and anxiety for people and, although a gluten-free diet has become easier to follow with the proliferation of gluten-free products and increasing options available, eating out and risk of contamination is still one of the main challenges of CD people.

For that reason, it is recommendable to provide specific and basic procedures for gluten-free food preparation to avoid the cross contamination at home and out of home [30].

Basic recommendations at home:

- Store gluten-free and gluten-containing foods separately and labelled clearly, especially if removed from original packaging.
- Have dedicated butters and spreads for gluten-free use
- Clean surfaces after preparing foods containing gluten as well as chopping boards, knives and other cooking utensils used in food preparation.
- Have a separate toaster or use a clean sandwich press/grill.

- Use separate water in a clean pot for cooking or re-heating gluten-free pasta. Use a separate colander for gluten-free pasta or drain it first.
- Do not dust meats or fish or cake tins with gluten-containing flour prior to cooking
- Wash hands before handling gluten-free food, especially after preparation of other food.
- Clean oil should be used when deep frying. If sharing with family, make sure the gluten-free item is fried first and then fry the gluten-containing items.

Basic recommendations out of home:

- Keep a few gluten-free snacks at work, in the car or handbag for any time of day
- Speaking to the restaurant or host prior to the event
- If appropriate, offer to help with the meal, either by bringing a gluten-free dish to share, or with preparation and serving.
- Discuss the menu and suggest gluten-free alternatives, such as brands of gluten-free sauce or stock
- If the holiday involves a flight, try to pre-arrange a gluten-free meal
- When eating out explain the situation to waiting staff and ask them if they can check the ingredients of dishes with the chef.

5 Adherence to Gluten Free Diet

Complete gluten withdrawal in patients diagnosed with CD has been shown to lead to normalization of intestinal atrophy, disappearance of the symptoms as well as improvement in the majority of related problems including osteoporosis and osteopenia, anaemia, risk of malignancy, gastrointestinal symptoms and in several studies, psychological well-being and quality of life [50–58]. However, despite the proven benefits of the GFD, it can be exceedingly difficult to completely avoid gluten-containing foods, and adherence to a GFD is estimated to be only 45–80% [7]. Generally, better dietary adherence is achieved (in 90–95%of cases), on average in the paediatric population, or in those people whose disease is diagnosed in early childhood [13]. For that reason, it is necessary to have a comprehensive understanding of the factors associated with optimal GFD adherence to develop strategies and resources to assist individuals with CD to maintain a GFD.

Physicians and dietician involved in the management of CD should insist strongly to their patients that compliance with the GFD is fundamental and is the cornerstone of the success of this treatment. They need to explain this concept convincingly to the patients, as well as the main features of the GFD, with the greatest possible clarity and simplicity at the time of diagnosis: strict adherence to the diet includes careful monitoring of ingredients, food preparation, and reading of labels will help avoid any potential cross contact and unintentional ingestion of gluten.

It is important to consider the possible factors that contribute to gluten-free diet adherence. One of the most exhaustive studies conclude that up to thirteen factors can compromise the adherence to GFD [7]. Those significantly associated with improved adherence including: understanding of the gluten-free diet, membership of a celiac disease advocacy group, and perceived ability to maintain adherence despite travel or changes in mood or stress.

This study support others results confirm by recent studies. On the one hand, that patient associations or support groups can provide help with trying to achieve proper compliance with the diet. These associations offer detailed information about the importance of a strict GFD and answer all questions related to the characteristics of gluten-free foods and different recipes. They also organize regular meetings, during which patients can share information about CD with other patients and thereby improve compliance with their diet [59].

On the other hand, the nutritional education and the educational interventions are crucial to improve the adherence. When patients feel confident about their self-efficacy to follow the gluten-free diet, it is easier for them to adhere to the GFD.

How to Measure the Adherence to GFD

Compliance with the GFD can be evaluated through different approaches, and various health professionals, may participate or collaborate to carry this out, in line with the following study procedures:

1. Periodic control visits by an expert dietician
2. Regular consultations with a gastroenterologist/family doctor
3. Structured specific questionnaires
4. Regular control of serum antibody titres for CD
5. Serial endoscopies with duodenal biopsies
6. Determination of derived peptides from gluten, in faeces/urine

The dieticians are the health professionals best placed to assess the degree of compliance with the GFD but it also needed to have regular consultations with a gastroenterologist to measure other clinical aspects. Patients with more complex needs will require a multidisciplinary approach, including various medical specialists, to assess their associated diseases and their compliance with the GFD.

Other important tools during the follow up of CD patients are the structured short questionnaires. These are used as an alternative to consultations with a dietician to obtain a rapid assessment of the adherence to the GFD. It is easy to complete this type of questionnaire in the patient's usual clinic. Most of them have been validated and the responses are highly correlated with antibody levels and the presence of villous atrophy in duodenal biopsies and useful for monitoring [59–64].

The main limitation of these questionnaire that is important to know before choosing one is that each author group has developed and validated these tools in their own countries, considering diverse clinical contexts and ones are specific validated for children [61, 62] and others for adults [63, 64]. So, before use a

questionnaire we need to know all the variables that is considering and check if it is applicable to our patients.

Regarding the regular control of serum antibody titres for CD to measure the GFD compliance have an important limitation: antibody titres cannot identify the existence of small dietary transgressions, so its use is limited to indicating an obvious lack of compliance but is of no value for evaluating whether there is strict adherence to the GFD [59].

The utility of endoscopies with duodenal biopsies and the determination of derived peptides from gluten, in faeces and urine will be covered in depth in other chapters of this book.

Finally, one of the concepts that have emerged in the last decade with the rise of the self-efficacy and self-management of chronic diseases though the new technology is the Mobile health (mHealth). mHealth is a way to promote health by applying mobile technologies to improve health outcomes.

This has been also investigated in the impact of the adherence to GFD in CD patients. Nowadays, applications, not specifically defined as medical devices, that are dedicated to CD or gluten-free diets are available in many countries and languages. They are often offered by celiac organizations, mostly to provide information about gluten-free diets, recipes, products, stores, and restaurants. Most of these applications are focused on self-management strategies such as diet tracking, symptom journaling, meal-plan content, education, supplements, and recommended foods. Others include the option to interact among people with CD and share experiences. Recent studies have demonstrated that this type of application, developed by health professionals and celiac organizations are effective to increase the adherence to GFD. But it is extremely important to be sure that the application is reliable [65–68].

For that reason, it is recommendable to encourage CD people use applications endorsed by celiac organization and scientific associations to increase the adherence to GFD. But always remembering that applications are not a substitute for medical advice.

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