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Original Article

Gluten-free diets in athletes

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Abstract
Gluten is the structural protein component of the grains wheat, rye and barley, and it is the basis for a variety of food products consumed throughout the world. Gluten proteins, major determinants of the bread-making quality of wheat, are related to several digestive disorders, and celiac disease is the most studied of these pathologies. Health effects of gluten have received increasing attention both in medical research and popular media, and remain highly controversial. People with diagnosed coeliac disease require a lifelong strictly gluten-free diet. In addition to celiac disease patients, it has been hypothesized that a substantial proportion of the population may be gluten intolerant (non-celiac gluten sensitivity), and could benefit from reducing gluten in their diet. However, clinical evidence for the existence of such conditions and other purported adverse health effects of gluten remain inconsistent. Nevertheless, there is growing popular perception that gluten-freefoods are healthier, and in recent years, there has been a dramatic increase in demand and consumption of gluten-free foods in many Western countries. Adherence to a gluten-free diet for non-celiac athletes has become increasingly popular. In this narrative review, the effects of gluten-free diet are discussed, and its impact on health and sports performance in athletes is examined. A gluten-free diet among many athletes does not result from evidence-based practice, and in the majority of cases is not based on medical rationale and may be driven by perception that gluten removal provides health benefits and an ergogenic edge in non-celiac athletes. Actually, athletes with inadequate energy intake and/or who exclude certain foods or food groups may not meet sports nutrition guidelines for key nutrients, and as a result, athletes could have at increased risk for musculoskeletal injuries, iron-deficiency anemia, hormonal imbalances, and immune suppression.
Keywords: Gluten free diet, nutrition, sport, athletes, celiac disease.

Introduction

Wheat is one of the most important cereals in the world. Although starch is the major component of grains (60–75%), the proteins (9–18%) are essential for bread-making quality. According to their functionality, wheat grain proteins are divided into two types: gluten and non-gluten proteins. About twenty per cent of the total proteins correspond to non-gluten proteins, comprising albumins and globulins, which have metabolic and structural functions. In contrast, gluten proteins represent about 80% of the total and they are mainly responsible for the rheological properties of the dough. The gluten proteins, also called prolamins given their high content of the amino acids proline and glutamine, include gliadins and glutenins, comprising high molecular weight glutenin subunits and low molecular weight glutenin subunits (García-Molina et al, 2019) (**Figure 1**). Wheat is associated with pathologies such as celiac disease (CD), non-coeliac wheat sensitivity, and allergies (Sapone etal, 2011).

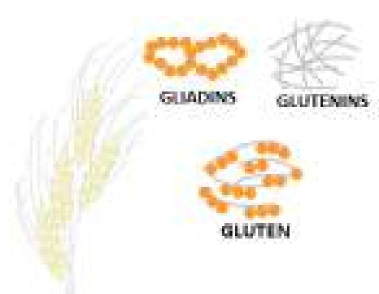

Figure 1. Components of the gluten

Gluten is the structural protein component of the grains wheat, rye and barley, and itis the basis for a variety of flour- and wheat-derived food products consumed throughout the world. Possibly, the introduction of gluten-containing grains, which occurred about 10,000 years ago with the advent of agriculture, represented a

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"mistake of evolution" that created the conditions for human diseases related to gluten exposure (Vici et al, 2016).

The reaction to gluten is mediated by T-cell activation in the gastrointestinal mucosa. However, in wheat allergy, it is the cross-linking of immunoglobulin E by repeat sequences in gluten peptides (for example, Ser-Gln-Gln-Gln-(Gln-)Pro-Pro-Phe) that triggers the release of chemical mediators, such as histamine, from basophils and mast cells.

Celiac disease is the most studied of wheat pathologies, a complex inflammatory disorder; the environment and several genes contribute to disease development. . It is a prevalent syndrome (affecting 1 in 200 Caucasian individuals); it is an autoimmune disorder that occurs in genetically predisposed individuals, triggered by gluten proteins from wheat (gliadins and glutenins), rye (secalins), barley (hordeins), oats (avenins), and also, all hybrids in which any of the toxic cereals are involved. Patients with active coeliac disease have IgA and IgG antibodies that are specific for the auto antigen tissue transglutaminase. In CD, the immunologic response to gluten peptides causes histological abnormalities in the small intestine, such as villous atrophy, which reduce the functional capacity of the intestine. A clinically relevant consequence is malabsorption resulting in an increased risk for nutritional deficiencies. These deficiencies can contribute to clinically important comorbidities such as anemia, osteoporosis and depression(Sollid, 2002).Nutritional deficiencies do not only play a role at the time of diagnosis, but also during treatment with a gluten-free diet (Kreutz et al, 2020; Motti et al, 2018; Meccariello et al, 2020).

The disease enters complete remission when gluten is eliminated from the diet: the only treatment for coeliac patients and all the other wheat pathologies is a**gluten-free diet**(GFD) for life. Strict adherence to a GFD results in complete recovery of the intestinal mucosa and its absorptive function. The elimination of gluten from the diet improves villous architecture and reduces the number of intraepithelial lymphocytes. However, a GFD is difficult to follow because gluten is an additive widely used in the food industry, appearing in products which originally do not contain gluten such as meat, fish and many other foodstuffs. In addition, nutritionally gluten-free products could be less healthy because they are made with high amounts of fat and sugar to achieve a texture resembling the typical and unique wheat viscoelastic properties (Kreutz et al, 2020). Therefore, GF-diet may lead to possible nutrient unbalance resulting in improper nutritional quality of diet.

A gluten-free diet requires the complete exclusion of gluten, then food products from wheat, rye, barley, oats, spelt, kamut or their hybridized strains (**Figure 2**). It comprises only naturally gluten-free (GF) food products (e.g., legumes, fruit and vegetables, unprocessed meat, fish, eggs and dairy products) and/or substitutes of wheat-based foods, specially manufactured without gluten or having a gluten content lower than 20 ppm, as per European legislation (Melini&Melini, 2019). GFD is a clinical necessity for 5% to 10% of the general population for health purposes. However, general population market reports indicate that the adoption of a GFD has far exceeded the requirement for clinical populations, with GFD uptake exploding among non-celiac athletic populations as well (Lis et al, 2015).

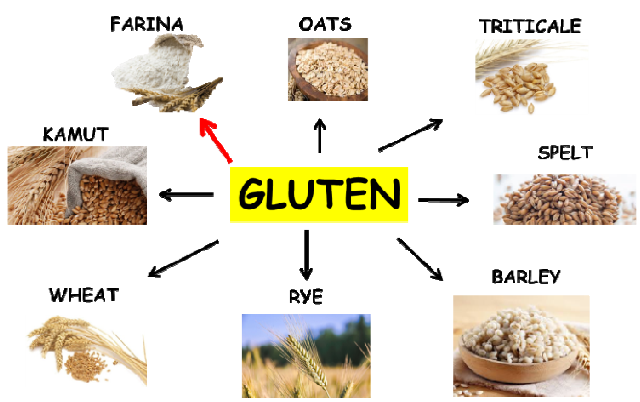

Figure.2 Types of cereals containing gluten

Achieving the highest performance during training and competition, improving and accelerating recovery, achieving and maintaining an optimal body weight and physical condition, and minimizing the risk of injury and illness are key issues in contemporary athletes. Different fields of scientific knowledge have addressed all these issues, including the field of nutrition, where specific recommendations have been developed for athletes. Optimizing nutrition in combination with exercise is considered an established, effective ergogenic practice for athletic performance.

Athletes experience regular cycles of physiological stress accompanied by transient inflammation, oxidative stress (D'Angelo & Rosa, 2020) and immune perturbations. Oxidative stress is a condition, which has been observed during ageing, under certain pathological conditions (D'Angelo et al, 2012; D'Angelo et al, 2013), and a number of studies have revealed that it is also related to contractile activity (D'Angelo & Rosa, 2020). Nutritional support has the potential to partially mitigate the exercise-induced changes without interfering with the signaling activities necessary for training adaptations. Every professional sport athlete and nearly every amateur frequently comes across some sort of advertisement, touting the salubrious activities of nutraceuticals in sport. Among nutraceuticals related foods, polyphenols (D'Angelo, 2020; D'Angelo & Rosa, 2020a) and omega 3 fatty acids are among the most convincing. Particularly, polyphenols are phytochemicals, which can act as pro-oxidant (D'Angelo et al, 2019a; Martino et al, 2018; D'Angelo et al, 2017; D'Angelo et al, 2012a; Boccellino et al, 2020) or anti-oxidant (D'Angelo et al, 2009; Zappia et al, 2010; D'Angelo &Sammartino 2015; del Monaco et al, 2015; Vuoso et al, 2020; D'Angelo et al., 2020a; Boccellino& D'Angelo, 2020) effects. They could enhance the pro-inflammatory and pro-oxidant circulating environment that is evident in response to the exercise.

In addition to nutraceuticals (D'Angelo & Tafuri, 2020; D'Angelo &Cusano, 2020, D'Angelo et al, 2019), special diets, as **gluten-free diet**, have grown in popularity among athletes related to the belief that they confer health and weight management benefits compared to a more typical diet. Athletes who exclude certain foods or food groups may not meet sports nutrition guidelines for key nutrients such as carbohydrates, protein, essential fatty acids, calcium, iron, vitamin D, and the B-vitamins. As a result, athletes are at increased risk for musculoskeletal injuries, iron-deficiency anemia, menstrual disturbances, hormonal imbalances, and immune suppression.

In this narrative review, the effects of GFD are discussed, and its impact on health and sports performance in athletes is examined.

Material and Methods

The databases PubMed and Web of Science were consulted. The combined keywordswere: "gluten-free", "diet", "inflammation", "oxidative stress", and "exercise performance". The search was carried out on January, 2010-June, 2020.

Results

A questionnaire-based study investigated the frequency, perceptions and beliefs surrounding GFDs. It found that in 942 non-celiac athletes, over 40% reported following a GFD at least 50% of the time (Lis et al, 2014). Startlingly, this group of non-celiac athletes mostly relied on self-diagnosis of a gluten-related disorder and subsequent self-treatment with a GFD (Liset al, 2014).

Non-celiac athlete populations adopt a GFD in the belief that it is not only healthier and augments weight loss, but it will also decrease gastro-intestinal (GI) distress and systemic inflammation and improve psychological well-being and athletic performance (Lis et al, 2014). The rise in GFD uptake may be further influenced by advertising campaigns around the medical necessity and health benefits, whereas athlete testimonies support the idea that this diet might provide an ergogenic performance edge. Although there is one study showing improved glucose metabolism and reduced obesity with gluten elimination in no celiac rodents, there is no scientific evidence to date that shows a GFD positively influences elements of health or performance in nonclinical populations.

Athletes believe that GFD adherence increases conscientiousness of eating a healthy and balanced diet (Lis et al, 2014). However, adopting a GFD without appropriate nutrition counseling may be associated with increased expense (+242%), inadequate intake of B vitamins, fiber and iron, as well as compromised gut health through reduced beneficial gut bacteria populations. Shepherd and Gibson (Shepherd & Gibson, 2013) suggest that the inadequacies found in a GFD may be linked to dietary gluten-free food choices rather than the diet itself, which all need to be considered before adopting such a diet (Liset al, 2015).

Halson and Martin summarized the "belief effect," which suggests that the belief in an intervention can contribute a 1% to 3% improvement in performance regardless if it actually has ergogenic mechanisms (Halson& Martin, 2013). A study has shown a current belief in the performance-enhancing effects of gluten removal (Liset al, 2014).Through effective double-blinding, non-celiac athletes and researchers were unable to differentiate each diet and time trial performance was similar between trials. Accordingly, other physiologic parameters such as heart rate, power, and cadence were not significantly different between diets. It is pertinent to note that in undiagnosed celiac disease or gluten-related clinical conditions, dietary gluten removal would potentially yield a performance benefit through exhibited improvement in biochemical measures and GI symptoms; however, to our knowledge, no published data yet exist to support this.

High-intensity exercise can reduce the integrity of the GI barrier. A primary mechanism causing GI distress during exercise is gut ischemia, resulting from the redistribution of blood from the splanchnic area to tissue with increasing exercise intensities. Recurrent GI stress and injury may create an environment resulting in greater susceptibility to adverse reactions to common dietary triggers. Increased epithelial injury also permits translocation of endotoxins across the gut barrier and into circulation, potentially contributing to increased systemic inflammatory responses. Increased plasma intestinal fatty acid binding protein (IFABP) levels are indicative of intestinal injury, known to occur under strenuous and acute exercise conditions. It is suggested that intestinal injury is a possible hindrance to training capacity, performance, and recovery through adverse GI symptoms and decreased nutrient absorption. A double-blind cross-over study found no effect of 7-days GFD on exercise performance. A short-term GFD had no overall effect on performance, symptoms, well-being, and a select indicator of intestinal injury or inflammatory markers in non-celiac endurance athletes (Liset al, 2015). An investigation found gut injury to be increased during strenuous exercise; nonetheless, gluten ingestion did not seem to augment this response before, throughout or at the end of a strenuous exercise bought.Performance and training capacity can be affected by GI distress and a decrease in performance has also been shown as a consequence of this stress. It has been reported that up to 70% of endurance athletes commonly experience GI distress during intense exercise and that many athletes believe gluten removal might reduce these symptoms. Anecdotally, a short-term GFD is adopted before competition among some endurance athletes and many athletes follow this diet intermittently. Short-term clinical interventions in patients with reported GI distress have found that in true non-celiac gluten sensitivity symptoms triggered by gluten appear within a few hours to days after ingestion. Endurance athletes predictably experience GI ischemia, which is proposed as a primary mechanism causing GI distress during exercise. GI ischemia can ultimately give rise to a cascade of responsive events including epithelial injury and both GI and systemic inflammation.

Psychological well-being is an additional factor that can be influenced by dietary intake and further affect performance and training capacity. Observational data obtained from cyclists on a range of special diets summarized that 50% of respondents following a GFD reported increased feelings of tiredness/lethargy when deviating from this diet. A 9-d dietary intervention of low carbohydrate during a period of intensified cycling has been shown to increase mood disturbances compared with a high-carbohydrate diet. Gluten does not appear to affect well-being in non-celiac athletes (Lis et al, 2015). Gibson & Muir (2013) have suggested that gluten itself may not be the sole nutrient regulating factor in the reported symptom improvement with a GFD, but that the subsequent reduction in fructans and galacto-oligosaccarides (fermentable oligo-, di- and monosaccharides and polyols; FODMAPs) associated with gluten removal may be a modulating factor. The pattern of short-term or periodic gluten avoidance common for athletes to adopt does not influence performance, GI symptoms, or well-being.

Future research with a longer duration of GFD adherence may help account for differential gut flora habituation, which could be influential on GI health, performance, and other parameters. However, such outcomes may be difficult to monitor, as during a longer intervention, training adaptations would be likely to occur that may mask any dietary influenced performance changes. Lengthier interventions are also more intrusive for the athlete, compromise dietary adherence, and challenge the ability to control and replicate training and food

A GFD eliminates cereals and products (i.e., wheat, rye, barley, spelt, triticale, kamut, and farina) that contain the wheat protein, gluten. These diets are recommended by health professionals for individuals with celiac disease or non-celiac gluten sensitivity. Lis et al. (2014)have examined the prevalence of GFDs in athletes. Athletes surveyed ranged from recreational to Olympic medalists, with approximately 66% reporting being endurance athletes. A GFD was reported to be followed by ~20% of the athletes 90%–100% of the time and by ~70% of endurance athletes >50% of the time. Athletes who adhered to a GFD >50% of the time did so based primarily on self-diagnosis (~57%) of a gluten intolerance, with a majority (~81%) reporting improvement of symptoms attributed to gluten (i.e., abdominal bloating, gas, diarrhea, and fatigue). Of these, only 9.9% had a clinical diagnosis, and 0.5% did it based on registered dietitian nutritionist (RDN).

A GFD can put an athlete at risk for low intakes of protein and micronutrient deficiencies (i.e., B-vitamins, calcium, vitamin D, iron, and potassium). Thus, athletes should determine if a GFD is medically warranted by consulting with a RDN who is part of their health care team (Cialdella-Kam, 2016). A GFD is prescribed for those with celiac disease or non-celiac gluten sensitivity. The impact of a GFD on body weight is equivocal. In both normal and overweight celiac patients who adhered to a strict GFD for 2 years, weight gain was observed. Conversely, a GFD has also been associated with improved BMI (i.e., weight gain in underweight and weight loss in overweight patients) in celiac patients. Research is lacking on the impact of a GFD on body mass and composition in athletes (Cialdella-Kam, 2016).

Nutrient deficiency in those consuming GFDs has not been well examined. Kulai and Rashid (2014) examined the nutritional adequacy of gluten-free food products available in Canadian stores. Mean protein content of gluten-free products was lower for both bread (mean difference = 4 g/100 g of bread) and pasta (mean difference = 5.8 g/100 g of pasta) vs. regular products. Additionally, gluten-free breads contained less iron and more total fat than regular bread; however, saturated fat did not differ. For pasta, gluten-free products had higher carbohydrate content and lower fiber, sugar, iron and folate content (Kulai& Rashid, 2014). In addition, the price (per 100 g of product) was ~1.6-folds higher for gluten-free products compared to regular products. Similarly, Wu et al.(2015) and Mishbach et al. (2015) compared the nutrient content of gluten-free to gluten-containing food products in Australia and Austria, respectively. Mean protein content was lower in gluten-free product vs. regular products. However, there were no differences in total energy, total carbohydrates or sugars, total or saturated fat, or sodium levels. Contrary to Kulai and Rashid (2014), mean fiber content was higher in gluten-free pasta and bread but lower in ready-to-eat cereals vs. gluten-containing Australian products and no different in Austrian products. In addition, iron content did not differ in Austrian products (Missbach et al, 2015), but Wu et al (Wu et al, 2015) did not report the iron content of their gluten-free products. In conclusion, gluten-free products are costlier and have lower protein content than regular products, with mixed findings on differences in iron and fiber content of these foods.

Lis et al. (2015) have examined the impact of GFDs on exercise performance in a double-blind, placebo-controlled, crossover design study. Non-celiac cyclists followed either a GFD or regular diet for seven days. No observed difference was found in time trial performance (i.e., 15 min cycling time trial after completion of 45 min steady state cycling at 75% peak power), inflammatory response, GI symptoms, or overall well-being. Thus, for the non-celiac athlete, GFD may not confer any advantages in sport performance. Athletes without a diagnosed condition should consult a RDN to discuss the pros and cons of such a diet and to ensure both energy and nutrient needs for sports performance are met (Lis et al, 2015)

The rationale behind why many athletes follow gluten-free diets is basically to ease unappealing digestive symptoms during competition. Improved digestion leads to improved absorption of nutrients, which can then translate into improved performance. Based on anecdotal evidence, it appears that there is potential for improved performance in athletes who eat a gluten-free diet even if they are not diagnosed with an allergy or celiac disease.

Myths and truths about gluten

The manufacturing of GF products is challenging, as gluten contributes vital structural, rheological, and organoleptic properties to bread and pasta. Currently, no direct substitute for gluten is available and a combination of refined unfortified cereal flours (e.g., maize and rice), hydrocolloids (e.g., hydroxypropyl methylcellulose) and proteins (e.g., egg white) are used to make GF products, which are often unpalatable. There is inadequate evidence on the impact these foods have on the health of consumers; however, studies have demonstrated a strong impact of a GF diet on diet-related quality of life, affecting in particular their ability to eat socially and outside the home.

In addition to a reduced nutritional profile of GF foods, consuming a GF diet has financial and psychological effects on CD patients. The inability to purchase affordable food easily may result in CD patients experiencing higher levels of depression and increased psychological stress regarding food consumption, especially in social situations.

It is generally considered that GF foods are less nutritionally adequate than standard products, although evidence is limited. Fry et al. (2018) observed higher levels of fat, sugar and salt in UK GF foods compared to standard foods, although the study focuses solely on front-of-pack macronutrient levels. Thompson (1999) found only 9% of US GF bread products were fortified with thiamin, riboflavin, and niacin. Thompson (2000) reported iron fortification in 23% of GF breads and no fortification in US GF pasta products. Recent studies have demonstrated low intakes of micronutrients in celiac diets; this may be of particular concern in children (Allen&Orfila, 2018)

Despite tremendous growth in the consumption of gluten-free foods, there is a lack of evaluation of their nutritional profile and how they compare with non-GF foods. Wu et al (2015) have observed that relative to non-GF foods, GF products had consistently lower average protein content across all the three core food groups, in particular for pasta and breads (52 and 32% less). A substantial proportion of foods in discretionary categories carried GF labels (e.g., 87% of processed meats), and the average HSR of GF discretionary foods were not systematically superior to those of non-GF products. The consumption of GF products is unlikely to confer health benefits, unless there is clear evidence of gluten intolerance (Wu et al, 2015).

The gluten-free food market has expanded considerably, although there is limited comparative evidence for the nutritional quality and cost of GF food products. The most recent surveys on the nutritional quality of GF food products currently available on the market show key inadequacies—a low protein content and a high fat and salt content—compared to their equivalent gluten-containing products.

Most people are convinced that gluten is a "bad" component. This only applies to people with celiac disease who experience symptoms such as abdominal pain, constipation, weight loss and fatigue when consuming gluten, the Foundation for Celiac Disease points out. Recently, another condition called "gluten intolerance" has spread which is not a true allergy but also causes headache, intestinal pain and other symptoms related to gluten intake. One of the problems in excluding gluten is that in fact, foods containing gluten can be beneficial to health if you do not have a sensitivity or allergy to it. Cereals that contain gluten, such as barley and rye, are often whole grains and provide fiber, vitamins and minerals that are beneficial to the diet. Gluten-free whole grains, such as buckwheat, rice, quinoa, sorghum and oats (if they are not contaminated during growth or production) offer similar advantages; however excluding a part of cereals is not optimal for the varied diet concept. Even eating only pasta and rice is not a good choice. Varying is the right key!

Gluten-free diets do not make lose weight. In fact, it may be more difficult to eat healthy on a gluten-free diet. A study (Fry et al, 2018) suggested that fats, saturated fats, sugars and salt were found more frequently in gluten-free foods than in gluten-containing foods in the UK. To give consistency and flavor to gluten-free foods, more fats and sugars are often added. Unnecessarily removing gluten from the diet may not bring any health or weight benefit. A gluten-free diet has a rationale only for people with celiac disease (for whom it is a lifesaver) and perhaps in part for those who have a diagnosis of non-celiac gluten sensitivity. For all other people, however, it is appropriate to vary all food sources, including those with gluten. Avoiding consuming only wheat is a healthy choice, there are many beneficial cereals, varying as always is the winning choice.

Conclusions

From a diet perspective, the key nutritional concern for athletes remains meeting the energy demands of their training. Restricted-energy diets or special diets, such as gluten free diet, put an athlete at risk for low Energy Availability and associated musculoskeletal, hormonal, and other health concerns. Athletes should refer to a registered dietitian nutritionist who specializes in sport nutrition for additional guidance on implementing these diets.

Differences exist in the nutritional composition of GF and regular food. GF food is unlikely to offer healthier alternatives to regular foods, except for those who require a GF diet for medically diagnosed conditions, and it is associated with higher costs.

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