Examining the increased prevalence of food hypersensitivities

by

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Abstract

The prevalence of reported food hypersensitivities has been increasing among both adults and children in the United States. Data that accurately reflect the prevalence of food hypersensitivities are limited due to diagnostic challenges, potentially leading to increased use of non-validated testing procedures. The current review examines food hypersensitivities, focusing on the validity of diagnostic methods, the effects of food processing on allergenicity, and the impact of health literacy in reporting food hypersensitivities. We further consider how increases in food hypersensitivities influence federal and educational institutional policies, industry practices, and affected individuals as well as those around them. Advancements in food processing techniques have influenced the allergenicity of proteins within common allergenic foods. In addition, health literacy may be a barrier to public understanding of health information, including information related to food hypersensitivities. The increase in the prevalence of food hypersensitivities impacts nationwide policies and practices through new federal regulations such as the FASTER Act, impacting accommodations in educational facilities, increasing the market for allergen-free products, and expanding manufacturer labeling. Ultimately, these changes may affect individuals with food hypersensitivities including increased food avoidance and economic burdens. Future studies are necessary to determine whether alternative food hypersensitivity testing can be utilized to positively identify food hypersensitivities and what effect processing has on the allergenicity of certain foods. Similarly, future research is required to assess the impact of the increased prevalence of food hypersensitivities on federal and educational institutional policies, industry practices, and individuals diagnosed with food hypersensitivities as well as those around them.

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Abbreviations	Definitions
FAs	food allergies
FIs	food intolerances
FHs	food hypersensitivities
DBPCFC	double-blind placebo-controlled food challenges
IgG	immunoglobulin G
NIH	National Institutes of Health
FASTER	Food Allergy Safety, Treatment, Education and Research
SFAs	school food authorities
GI	gastrointestinal
IgE	immunoglobulin E
AAAAI	American Association of Allergy, Asthma, and Immunology
MRT	Mediator Release Test
ALCAT	Antigen Leukocyte Cellular Antibody Test
AND	Academy of Nutrition and Dietetics
RDN	registered dietitian nutritionist
IBS	irritable bowel syndrome
FODMAP	fermented oligosaccharides, disaccharides, monosaccharides, and polyols
AGEs	advanced glycation end products
FALCPA	Food Allergen Labeling and Consumer Protection Act
FDA	Food and Drug Administration
GFD	gluten-free diet
I$	international dollars

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Introduction

Food allergies affect one in 13 children (Gupta et al., 2018) and one in 10 adults (Gupta et al., 2019) in the United States, with prevalence data increasing by 50% between 1997–2011 (Jackson, 2013). In recent years, there has been a proliferation of not only food allergies (FAs), but also food intolerances (FIs). FAs are immunologic responses to food allergens while FIs are non-immunologic reactions. Food hypersensitivities (FHs) is the overarching term used to describe both food allergies and food intolerances. True prevalence data on FHs are limited due to diagnostic challenges, making it difficult for researchers to know whether the reported rise in prevalence is due to true increases, an increase in non-validated diagnostic testing, or increases in consumer attention on FHs (Turnbull et al., 2015). In fact, self-reported rates of FIs may be up to 10 times greater than the true prevalence established by gold standard food allergy testing, i.e., double-blind placebo-controlled food challenges (DBPCFC) (Turner & Kemp, 2012). The recent increase in self-reported food allergies may also be associated with the increased opportunity for self-diagnosis with newly available and convenient non-validated allergy tests, which can be ordered online through retail distribution stores and clinicians (Hammond & Lieberman, 2018). Currently there are no known cures for FHs and their wide array of symptoms, leading to an increased consumer demand for alternative treatments and solutions (Bird, Lack, et al., 2015). One such emerging option is serum immunoglobulin G (IgG) direct-to-consumer blood testing, which may lead to inaccurate and potentially harmful results (Bird et al., 2015-a). Tests report serum IgG levels in response to multiple foods, claiming that removal of foods eliciting high IgG levels can lead to improvement in symptoms (Hammond & Lieberman, 2018). Yet, many of these tests have not undergone rigorous, blinded trials, or where they have, results have not been shown to accurately predict presence of allergies (Hammond & Lieberman, 2018).

Preparation and processing methods of allergenic foods may play an additional role in the type and severity of allergic reactions. As the advancement of food technology and development of food processing methods continue to evolve it is important to note that most foods containing established allergenic ingredients are processed at least minimally before they are consumed (Wüthrich, 2005). Processing influences allergenicity by changing the composition of proteins within the structure of foods by inducing the unfolding, aggregation, cross-linking, oxidation, and glycosylation of proteins within food (Maleki, 2004). Currently, there are no published studies assessing the relationship between processed foods and FHs, but a recent retrospective cohort study showed a positive association between ultra-processed food consumption and the allergic disease of asthma in a dose-response manner (Melo et al., 2018).

Other factors potentially contributing to misunderstanding of FAs and FIs are low levels health literacy in addition to poor readability and quality of health information circulating website domains. Poor scientific health literacy in the United States may contribute to inability to decipher the degree to which information is valid and helpful, as compared to what may be potentially misleading and potentially harmful. According to the 2003 National Assessment of Adult Literacy, 53% of Americans ages 16 and older obtained intermediate health literacy, 22% had basic health literacy, and 14% fell below basic levels of health literacy (Kutner et al., 2006). Poor health literacy may be compounded by inadequate readability and quality of patient education materials. The National Institutes of Health (NIH) recommends that patient education materials should have a readability no greater than a 6^{th}-grade level (Hersh et al., 2015) yet most credible and publicly available basic nutrition information is at an 8th–10th grade reading level (Hill-Briggs & Smith, 2008). Similarly, a systematic review of research assessing quality health information for consumers on the internet found that over half of the studies concluded health information to be problematic (Zhang et al., 2015). Another third of the studies found that information varied across website domains (Zhang et al., 2015). Poor quality of health information may increase the circulation of misinformation across domains, impacting health-related decisions and potentially leading consumers to make decisions that ultimately lead to harmful outcomes.

Nevertheless, increases in food hypersensitivity prevalence may have profound impacts on federal and educational institutional policies and industry practices. The Food Allergy Safety, Treatment, Education and Research (FASTER) Act H.R. 1202, S. 578 (ref. 2) signed into federal law on April 26th, 2021, aims to establish a higher priority on food allergy research and mandates that sesame be added to the list of allergens required to be identified on all food labels (Scott, 2021). The other 'big 8' allergens required to be identified on food labels include cow's milk, hen's eggs, peanuts, tree nuts, soy, wheat, shellfish, and fish. (Hefle et al., 1996). Changes in legislation drive food providers to increase accommodations, such as educational institutions and food manufacturers. For example, school food authorities (SFAs) in elementary and secondary schools must provide accommodations for students with disabilities, which include allergies and intolerances (Fiore, 2020). Similarly, the consumer demand for allergen-free foods incentivizes food manufactures to fulfill these requests through creation of new supplements or foods. This has been observed by increased yearly sales of allergen-free products in supermarkets from $210.6 million in 2008 to $276.4 million in 2010, an increase of 31% over the two-year span (Maier, 2010).

Finally, FHs can consequently impact individuals and those around them in a variety of ways. For instance, FAs can involve life-threatening anaphylactic reactions in severe cases requiring lifestyle changes for the affected individual as well as those around them (Food

Allergy, 2021). Increased physical, psychological, social, and economic burdens are also associated with FHs (De Petrillo et al., 2021). For example, caregivers of children with allergies have increased out-of-pocket costs reaching $5.5 billion annually, with 31% coming from the cost of allergen-free foods alone (Gupta et al., 2013). With the aforementioned information in mind, the objective of the current review was to examine food hypersensitivities focusing on the validity of diagnostic methods, the effects of food processing on allergenicity, and the impact of health literacy in reporting food hypersensitivities. We further consider how increases in food hypersensitivities influence federal and educational institutional policies, industry practices, and affected individuals as well as those around them.

Methodology

Searches for relevant studies were conducted in the published literature indexed in PubMed and Google Scholar. Randomized controlled trials, clinical trials, systematic reviews, reviews, and epidemiological studies were included. Searches were limited to human studies and were completed between June of 2021 and January of 2022. Relevant studies for inclusion were obtained using a variety of search terms including "Food Hypersensitivity/diagnosis"[MeSH] OR "Food Hypersensitivity/pathology"[MeSH] OR "Food Hypersensitivity/statistics and numerical data"[MeSH]. Additional searches were performed including "food hypersensitivity" [MeSH] AND one or more of the additional terms: "IgG testing", "prevalence", "food processing", and "health literacy". Additionally, references from included papers were manually searched for additional studies. The Mintel Reports were also examined for recent consumer reports on food hypersensitivities within the United States.

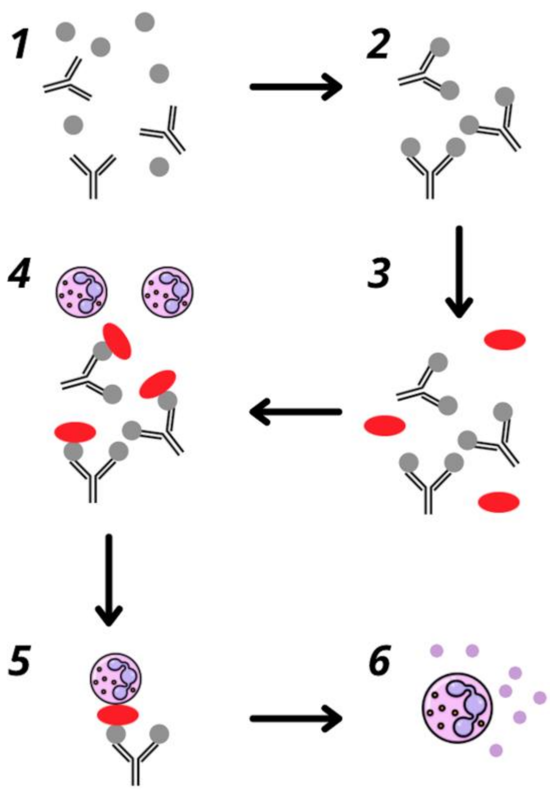
Discussion

Background on food hypersensitivities

The terms food hypersensitivity, allergy, and intolerance have been collectively used to describe FAs. Food hypersensitivities (FHs) comprise both food allergies and food intolerances. Immune mediated reactions to proteins within certain foods are characterized as FAs with symptoms ranging from swelling, itching, and gastrointestinal (GI) discomfort, to life-threatening responses like anaphylaxis (Mullin et al., 2010). Reactions occur rapidly and result from an immunoglobulin E (IgE) modulated response. Produced by the immune system, IgE antibodies cross link with mast cells to trigger degranulation and the release of histamine and other mediators that increase inflammation in the body (Bird, Lack, et al., 2015). Non-immune mediated responses to proteins within food are characterized as FIs with heterogenous symptoms ranging from fatigue, swelling in joints and muscles, to skin reactions, GI distress, and disorientation. Symptoms of FIs are rarely life-threatening and are associated with IgG antibodies. Responses associated with IgG antibodies are potentially considered natural as IgG antibodies comprise approximately 75% of the total immunoglobulins within the blood (Mullin et al., 2010). Allergenic water-soluble glycoproteins cause most FIs. The glycoproteins initiate an allergic response after they bind to serum antibodies and are not broken down by enzymes within the GI tract. This may lead to the absorption of allergenic antigens in their intact form. When allergenic proteins are absorbed, an immune response is triggered by IgE and IgG antibodies binding to food particles, which forms immune complexes and trigger an allergenic response (van Wijk & Knippels, 2007). Although still not fully understood, the mechanistic rationale for FIs is that when foods are not fully digested and absorbed, remnants are recognized as foreign substances (Lin et al., 2019). The immune response increases inflammation and degranulation of white blood cells to release mediators and trigger symptoms from antibody-antigen binding (Figure 1) (Lin et al., 2019; Mullin et al., 2010). Mediators that are secreted include but are not limited to histamine, prostaglandins, and leukotrienes. They stimulate inflammation, pain, chemotaxis, and other bodily reactions similar to the antibody-antigen binding found in FAs (Lepski & Brockmeyer, 2013; Mullin et al., 2010).

Figure 1.

Food Intolerance Reaction Mechanism



Note.

1. Free circulating antibodies and antigens
2. Antibodies and antigens combine to form immune complexes

3. Immune complexes activate when foreign proteins are present
4. Activated immune complexes recruit white blood cells to the area
5. Immune complexes and white blood cells attach to foreign proteins
6. Immune complexes trigger white blood cells to degranulate and release mediators into the cell. Mediators released include but are not limited to histamine, chemotactic factors, cytotoxic proteins, proteases, etc.

There has been a recent increase in prevalence of self-reported food allergies. Results from a survey of approximately 38,000 U.S. children from 2015–2016 indicated that more than 11% of parents/guardians reported that their children had food allergies; however, when compared with physician diagnosed serum IgE testing, only 7% of the total children examined tested positive for food allergies (Gupta et al., 2018). Similarly, another study of self-reported FAs indicated an increase in prevalence from 9.1% in 2001 to 13% in 2010, as compared with physician-diagnosed FAs increase from 5.3% in 2001 to 6.5% in 2010 (Verrill et al., 2015). Studies show that symptoms of suspected FAs are often inconsistent with diagnostic findings (Gupta et al., 2019; Verrill et al., 2015). More data are necessary to understand the relationship between self-reported FAs and true prevalence data.

Diagnosing food hypersensitivities

Allergy diagnosis can involve multiple testing techniques and coordination between practitioners. Diagnostic tools endorsed by the American Association of Allergy, Asthma, and Immunology (AAAAI) are oral food challenges including the double-blind placebo-controlled food challenge, skin prick testing, and serum IgE testing (Bird, Lack, et al., 2015). Decisions on which type of test performed should be based on a full and detailed medical history along with coordination among a team of healthcare providers. The gold standard of food allergy testing, DBPCFC, involves lengthy and rigorous food challenges where neither the patient nor allergist knows which allergen or placebo is being presented to the patient to confirm allergic reactions (double-blind). Other oral food challenges are typically single-blind, less laborious, but may still produce predictable results. Skin prick tests reflect the presence of IgE antibodies bound to the surface of cutaneous mast cells. These tests have a high negative predictive value where negative skin pricks indicate which FAs can be ruled out. Positive skin pricks detect the presence of IgE antibodies; however, more testing may be required to positively predict the presence of FAs. Serum IgE testing screens for high values of specific IgE levels that are associated with clinical reactivity to antigens. Values for serum IgE testing vary based on patient age, gender, race/ethnicity, as well as the last time the antigen was ingested. This test has been shown to be reliable for a limited number of allergens including egg white, cow's milk, peanut, and fish (Lack, 2008). The benefits of serum IgE testing over skin prick testing are that it can be used for patients with dermographism or those who take antihistamine medication which cannot be discontinued (Kowalski et al., 2016). Both skin prick and serum IgE testing are useful, additive tools to oral food challenges or DBPCFC testing. Advantages of skin prick and serum IgE testing over oral food challenges include availability in both primary care and allergy-related office settings, less time required, and less labor intensive, (Bird, Lack, et al., 2015).

Conflation of FAs and FIs can lead patients and parents/guardians of patients to seek diagnostic procedures, which may or may not be able to accurately detect FHs (Turnbull et al., 2015). There has been increasing interest in and use of other diagnostic testing procedures for FHs, which have not been validated nor adequately reported in the peer-reviewed scientific literature. Serum IgG testing, Mediator Release Test (MRT), and Antigen Leukocyte Cellular Antibody Test (ALCAT) are among these alternative testing techniques. Previous research has shown that up to 25% of those with self-reported FAs have undergone diagnostic testing that is not positively predictable when compared to DBPCFC (Ko et al., 2006). Many of these tests have not undergone rigorous, blinded trials and if they have, results did not accurately detect presence of allergies (Hammond & Lieberman, 2018). For example, 98% of healthy children were found to have a detectable serum IgG responses to cow's milk by the age of 2 (Siroux et al., 2017), whereas a cow's milk allergy was diagnosed in 2–3% of children undergoing oral food challenges (Gupta et al., 2011). Additionally, alternative allergen testing techniques, including direct-to-consumer testing kits, may or may not be analyzed in accredited laboratories. A recent review examined allergen testing procedures to see if laboratory results were processed in an accredited laboratory (Wong et al., 2021). Results of that review showed that only one of the 22 companies investigated possessed the correct endorsement to be accredited. The company using the accredited laboratory used AAAAI supported serum IgE testing and included a clinician in the diagnostic process (Wong et al., 2021). The most common assay used by the other 21 companies reviewed was serum IgG testing, which has become widely available for at-home use with and without practitioner recommendation and prescription (Wong et al., 2021).

Serum IgG testing and other non-validated food hypersensitivity tests

Like serum IgE testing, serum IgG testing screens for high values of specific IgG levels and can vary in patients based on demographic factors. As part of the natural immune response, IgG antibodies can procure false positive test results for FHs, thus, foods may be identified as problematic according to high test values without any clinical symptoms present (Mullin et al., 2010). A contribution to these false positive results is that there are currently no established standardized referencing values for serum IgG testing (Martins et al., 2016). For reference, IgE antibody levels between 0.1 to 0.34 k Ua /L are considered positive assays and are measured by documented autoanalyzers like ImmunoCap and Immulite (Hamilton, 2017). Both autoanalyzers have an established threshold of <0.35 k Ua/L (Hamilton, 2017). In addition, serum IgG testing analyses a large number of food antigens, which is often far beyond the big 8 allergens. Only 10% of all food allergies include food proteins outside of the big 8 ("Food Allergen Labeling and Consumer Protection Act of 2004 (FALCPA)," 2019), therefore, large food allergen assays may potentially be unwarranted.

The AAAAI and Academy of Nutrition and Dietetics (AND) agree that serum IgG testing should not be used in the clinical setting as tests lack validation, reliability, and quality control (Bock, 2010; Gordon, 2019). Yet, many registered dietitian nutritionists (RDN) support food hypersensitivity testing outside of traditional gold standard and validated food allergen testing (Overstreet, 2021). Previous studies have acknowledged the use of serum IgG testing in the treatment of irritable bowel syndrome (IBS) using elimination diets based on positive test results (Atkinson et al., 2004). Based on the overlap of symptoms between IBS and FIs, positive IgG antibody tests followed by elimination diets have also been used to treat patients with FIs. A food elimination diet is one where a food that is suspected of causing symptoms is removed from the diet for a period of time. The symptoms are then monitored to understand whether symptoms will resolve following removal of the potential allergen. Following elimination of the suspected problem foods, a reintroduction phase is guided by an experienced RDN or healthcare professional. An example elimination diet used in IBS treatment is the low or non-FODMAP diet. A low-FODMAP diet consists of restricting foods in the diet that contain high amounts of fermentable oligo-, di-, monosaccharides and polyols (FODMAP). FODMAPs are typically poorly absorbed in the GI tract and become rapidly fermented by bacteria leading to intestinal luminal distention and GI symptoms (Shepherd et al., 2013). Those following an elimination diet based on their serum IgG test results experienced a 10% greater symptom severity reduction than the control group, however, false positive and negative results remain common (Atkinson et al., 2004). Currently, the scientific evidence of the association of IgG antibodies with the conditions of IBS and FIs have been inconclusive.

MRT and ALCAT testing are among alternative food allergen testing procedures and involve assays that measure leukocyte biomarkers released in response to consumption of certain foods. The mechanistic rationale for MRT is that foods associated with FHs will increase serum eosinophil, neutrophil, and lymphocyte levels after ingestion (Pasula, 2014). Currently, no research has been published addressing the implications and validity of MRT; however, this type of test is commercially available for practitioners to partner with companies like Oxford Biomedical Technologies to provide testing for clients (*Leader in Food Sensitivity Testing - The LEAP Diet and MRT*, 2021). Analogously, ALCAT testing detects measurements in white blood cell diameter after exposure to allergenic foods. These tests are done in vitro and lack scientific validation (Bernstein et al., 2008). More research is needed to determine whether serum IgG testing and leukocyte testing can be utilized to positively predict FHs. Currently, there are no published well-controlled studies that are high-quality. The research that is available does not include randomization, blinding, control groups, or utilize DBPCFC as a reference tool. Overall, well-designed studies and clinical trials exploring the mechanisms and diagnostic procedures for non-validated food hypersensitivity testing are necessary to assess potential harm before patients are subjected to tests that offer little evidence of effectiveness.

Effects of food processing on food hypersensitivities

Other factors such as preparation and processing methods of allergenic foods may potentially play a role in the type and severity of allergic reactions. In industrialized societies, most of the foods consumed are processed in some way. Basic techniques like cooking and fermenting fall under the umbrella of the term processing, but also include other thermal and high-pressure processing techniques (Maleki, 2004). As the advancement of food technology and development of food processing methods continue to evolve it is important to note that most foods within the big 8 allergen list are processed, at least minimally, before they are consumed (Wüthrich, 2005). Processing influences allergenicity by changing the composition of proteins within the structure of foods by inducing the unfolding, aggregation, cross-linking, oxidation, and glycosylation of proteins within food (Maleki, 2004). When allergenic glycoprotein allergens are affected by processing, interactions between proteins, antibodies, or other compounds within the structure of food components (carbohydrates, lipids, disulfide bonds, etc.) also may also be increased or decreased as a result (van Wijk & Knippels, 2007). While previously thought to decrease allergenicity by disrupting the allergenic antigens, it is now known that thermal processing can affect allergenicity and digestibility of proteins by increasing or decreasing the antigen-to-antibody binding affinity (Lepski & Brockmeyer, 2013). Products of the Maillard reaction are also common following food processing, which has been found to increase the allergenicity of roasted versus raw peanuts by 90-fold (Maleki, 2004). Additionally, researchers found an increased allergenicity in the protein parvalbumin, found in the muscle of fish, when Atlantic cod were cooked compared to raw cod (de Jongh et al., 2013). Allergenicity of the cod’s protein was elevated due to increased glycosylation, which can occur during high temperature thermal processing (Rapin & Wiernsperger, 2010). Glycation of proteins due to high temperature thermal processing, flavoring, and cooking can lead to an increase in advanced glycation end products (AGEs) (Rapin & Wiernsperger, 2010). Mechanistically, AGEs may be able to cross the intestinal wall when there is increased intestinal permeability due to inflammation, stress, infections, etc. (Rapin & Wiernsperger, 2010). Glycation of food allergens increase the T-cell immunogenicity of food allergens. This means allergens have an increased ability when glycated to trigger an immune response (Ilchmann et al., 2010). Broiling and frying generate more AGEs than roasting, with the fewest compounds being generated from boiling foods. Notably, broiling and frying are associated with the production of more ultra-processed foods; however, there are minimal data regarding allergenicity and AGEs content (Rapin & Wiernsperger, 2010). Further research needs to be conducted to determine whether there are associations between food processing, intestinal permeability, protein glycation, and FHs. Research is also needed to elucidate the origin of FHs to determine environmental factors that can be eliminated to further avoid allergic reactions.

Due to the generality of the term ‘food processing’, classification systems have been established to enhance understanding regarding the degree of processing and its association with nutritional value and health outcomes. A recent review compared the NOVA system, a system developed by researchers at the University of Sao Paulo, with the International Food Information Council system, and the University of North Carolina Chapel Hill food processing classification systems. Each of these classification systems differ by the number of categories and terms used to describe the range of processing levels in food products. Due to differences in classification systems, interpreting research regarding food processing can be problematic (Bleiweiss-Sande et al., 2019). The most comprehensive and prevalent system studied within published peer-reviewed scientific literature is the NOVA system (Lawrence & Baker, 2019; Moubarac et al., 2014). The NOVA system is also used by the Food and Agriculture Organization of the United Nations (Monteiro et al., 2019). Four classification systems are used by NOVA. The first two include “unprocessed or minimally processed foods” like fruits, leaves, and animal products including milk and eggs and "processed culinary ingredients" like oils, sugar, and salt. The latter two classifications are labeled "processed foods" like canned vegetables and bacon, and "ultra-processed foods" like soft drinks, packaged snacks, instant soups, and hot dogs (Monteiro et al., 2019). There are currently no published studies assessing the relationship between ultra-processed foods and FHs; however, a recent study indicated a positive association between consumption of NOVA classified "ultra-processed foods" and asthma and wheezing in adolescents (Melo et al., 2018). Since asthma is classified as an allergic disease by the AAAAI, more research needs to be conducted to determine whether there is also positive association between consumption of ultra-processed foods and allergy diagnosis.

Health literacy surrounding food allergies

Research shows that health literacy is a strong predictor of a person's health ("Health Literacy," 1999). Health literacy can be defined as an individual's ability to make educated decisions according to their health status based on their ability to access and understand health information on a fundamental level (Selden et al., 2000). Low health literacy in addition to poor readability and quality of health materials may impact health-related decisions. Health literacy may be a barrier to public understanding of health information, including information related to FHs (Crihalmeanu et al., 2018). Accessible information on FHs that is readable, reliable, and trustworthy is essential for management of diagnosed food allergies, particularly for those who may not have access to knowledgeable health practitioners. As previously noted, the NIH recommends that patient education materials should have a readability no greater than a 6^{th}-grade level, yet there are several gaps in proposed communication strategies (Hersh et al., 2015). Most adults read at an 8^{th}-grade level, but 20% read at or below a 5^{th}-grade level (Kirrsch et al., 1993). Most of the credible and publicly available basic nutrition information, such as provided on the former mypyramid.gov website, is readable at an 8^{th}–10^{th} grade level, creating accessibility issues for many adults (Hill-Briggs & Smith, 2008). Furthermore, a recent review of websites containing information for patient education about allergies and immune function concluded that of the 170 websites investigated, 168 were provided at a 12.5 grade level, while only two were provided at the recommended education level of no higher than 6^{th} grade (Crihalmeanu et al., 2018). Some of the websites studied which were also commonly accessed by internet users to obtain information related to allergies and immune function included AAAAI.org, mayoclinic.com, and webmd.com. All three provide information at an average readability score above the 10^{th} grade level (Crihalmeanu et al., 2018). Discrepancies between the readability of patient educational materials as compared with health-information readability recommendations are problematic.

This problem is exacerbated in the current social media age, where misinformation is easily obtained. Currently, there is no agreed-upon definition of quality health information potentially increasing the complexity to which websites can be analyzed to assess if they obtain quality information or misinformation. A systematic review of 165 studies assessed the examination of quality health information for consumers on the web. Researchers found 55.2% of studies concluded that health information was problematic and another 37% of studies found that information varied across website domains (Zhang et al., 2015). Of the studies analyzed, quality was not only defined incongruously, but was also measured using different groupings of criteria (Zhang et al., 2015). Poor quality health information may increase circulation of misinformation across the internet, social media, and other platforms impacting health-related decisions. Misinformation could potentially lead to the disengagement of individuals seeking true health information or avoiding healthcare altogether (Sylvia Chou et al., 2020). Paired with poor health literacy, increasing misinformation may potentially lead consumers in the wrong direction (World Health Organization, 2020). Strategies to improve valid, readable patient education materials needs to be studied further to equip those suffering from FHs with accurate information to understand proper diagnostic tools and treatment strategies.

Federal policies related to food allergies

Due to recent increase in the incidence and prevalence of FAs, in 2004 the United States Congress passed the Food Allergen Labeling and Consumer Protection Act (FALCPA). This act mandated labeling of foods that include proteins from or derived from ‘major food allergens’ and mandated declaration of the presence of these allergens (“Food Allergen Labeling and Consumer Protection Act of 2004 (FALCPA),” 2019). Such declarations on food labels typically appear following the listing of the product ingredients and cover all big 8 food allergens. This law has been recently expanded to the FASTER Act to include sesame as a major food allergen (Scott, 2021). Beginning January 1, 2023, the FASTER Act will require packaged food labels to include the new sesame declaration as regulated by the Food and Drug Administration (FDA) (Scott, 2021). Around 1.6 million Americans are allergic to proteins within sesame and sesame products like tahini, a sesame seed paste. Sesame can often be found in food labels stated as “natural flavors” and “natural spices”, which may be ambiguous for consumers avoiding this allergen (Nutrition, 2021). The FASTER Act also places a higher priority on food allergy research funded by the federal government, which aims to improve the accuracy and validity of prevalence data, improve diagnostic procedures, reduce and prevent the risks of FAs, and develop new treatments for those suffering from FAs (Scott, 2021).

Institutional practices among educational institutions

Educational institutions are also impacted in a variety of ways by increases in FHs due to requirements to provide menu modifications and preparation for life-threatening allergic reactions for students with allergies. Medically prescribed meal substitutions are authorized by medical authorities to support children with disabilities (*Meal Substitutions for Medical or Other Special Dietary Reasons*, 1994). FAs and FIs are considered disabilities when digestion, respiration, and immune systems are impacted or if skin rashes are present; therefore, schools must provide accommodations for affected students (Fiore, 2020). Recognized medical authorities include medical doctors/physicians, physician assistants, doctors of osteopathy, and advanced practice registered nurses. These healthcare professionals provide students with documentation made available to nutrition directors and other SFAs so accommodations can be provided. Those without medical documentation for meal modifications are evaluated on a case-by-case basis by SFAs. Some additional accommodations may be provided based on religious beliefs or personal food preferences (Fiore, 2020).

Providing meal modifications for students with FAs comes at an increased cost to schools. Due to protections under the Americans with Disabilities Act Amendment in 2008, SFAs cannot charge students above regular priced menu items for modified meals even though allergen-free alternatives may cost significantly more when compared to typical foods. The additional costs can be filed under ‘allowable food service program costs’ for ‘free-from’ or modified meals; however, no additional reimbursements are provided. School food service funds may require offsets from the school districts’ general fund or special education fund for these additional costs (Fiore, 2020). Not only are alternative foods needed within the school system, but there should be an increased effort to avoid cross-contamination of utensils, cooking equipment, and other kitchen surfaces within educational institutions (Sheehan et al., 2018). An example of effective policy implementation is illustrated within campus dining at North Carolina State University. Four years of data were collected to better help inform service provision and nutrition information for all students, including those with FAs. The "Allergen Friendly NC State" initiative is intended to ensure that every ingredient for every menu item has been communicated effectively to students. The overall plan included interactive iPads at dining facilities, as well as sharing nutrition information on social media platforms (Buzalka, 2015).

The implementation of district-wide food allergy action plans for students with life-threatening food allergic reactions is an additional necessity. The School Access to Emergency Epinephrine Act was enacted in November of 2013 and encouraged states to adopt laws that further required schools to stock epinephrine for students with life-threatening allergic conditions (Bird, Lack, et al., 2015). This act also encouraged additional training of staff members to administer epinephrine as well as the development and implementation of action plans for handling allergic reactions within school districts (Roe, 2013). This does not come without increased costs to schools as seen in 2014 with the Michigan public school system. The total annual, unsubsidized cost to stock epinephrine was between $565,460–$4,846,800 (Steffens et al., 2017). Another point of concern is staffing of nurses within school systems. Nurses are the most qualified personnel within most school districts to handle allergic reactions, however, the National School Nurse Workforce Study found only 39% of schools employ full-time nurses, 35% employ part-time nurses, and 25% of schools do not employ a school nurse at all (Willgerodt et al., 2018). Administrators, teachers, and staff are left to execute action plans for students with FAs. Thus, increased education and training are necessary for staff administering epinephrine (Fiore, 2020).

Food manufacturing practices

Food manufacturers may develop methods to reduce allergenicity of products to make them more marketable to consumers with FHs. Currently, product modification has been the only effective management for FAs besides complete avoidance (Maleki, 2004). An example of product modification is seen in lactose-free milk. Lactose-free milk involves the process of removal of the protein lactose. Digestive malabsorption of this protein affects up to 68% of the global population to some degree (Storhaug et al., 2017). Manufacturers are accommodating to the demand for lactose-free milk and consumers are responding. Lactose-free dairy milk sales grew by 12% in 2017 and by another 9% in 2018 (*Fluid Milk Retail Report*, 2018). An increase in consumer demand is also shown in full dairy-free products with sales increasing 20% from 2008–2010 from $94 million to $113.2 million, respectively (Maier, 2010). Having established that self-reported FHs are on the rise, it is possible to consider that additional allergen-free diets have also risen in popularity among consumers (Niland & Cash, 2018). One example may be seen with the gluten-free diet (GFD). Individuals identified with a clinically diagnosed gluten-related disease, like celiac disease that affects around 1% of the population, are medically treated with a GFD (Singh et al., 2018). The celiac disease diagnostic data remained stable from 2009–2014 according to the National Health and Nutrition Examination Survey (Choung et al., 2016), while those who followed a GFD without diagnosis of a gluten-related disease tripled from 0.5% to 1.7% among the same time period (Choung et al., 2016). The demand for allergen-free foods continues to grow among those with clinically diagnosed and self-reported FHs. These increases have sparked an increased need for grocery stores and restaurants to provide allergen-free products for consumers. Consumers within Generation Z (those born between 1997–2012) are more likely to avoid allergens as 21% report that allergens affect what they order at restaurants, while only 17% of Millennials (those born between 1981–1996) and 10% of Generation X (those born between 1965–1980) and older are affected (Topper, 2020). Half of internet users over the age of 18 who indicate self-reported FAs to one or more allergens claim they would like more allergen-free products in grocery stores, and 56% would like more allergen-free items on restaurant menus (Maier, 2010).

Food manufacturers have a critical role to play regarding the safety and transparency of labelling for those with FAs. In a 10-year span from 2008–2018, around 3,000 food safety incidents were reported globally, and 46% of these incidents were due to unmarked food allergens on product labels (Soon et al., 2020). Expansions in testing and research conducted by companies is needed, but these processes may take long periods of time and lead to increased production costs. This cost is typically passed on to the consumers of products. Many companies are disincentivized for improving manufacturing practices and may minimally pass certifications and requirements (Jia & Evans, 2021). Ultimately, the increases in allergen-free product availability for those with true FHs is a positive outcome, even if the demand for such products is not completely driven by true prevalence of FHs.

Outcomes of food hypersensitivities

Food hypersensitivities impact individuals and those around them in a variety of ways. In the most severe circumstances, FAs can lead to life-threatening anaphylactic reactions (*Food Allergy*, 2021). Management of the wide range of symptoms related to FHs are associated with increased physical, psychological, and social burdens (De Petrillo et al., 2021). Those with perceived or self-reported FAs report a lower quality of life compared to those without self-reported FAs (De Petrillo et al., 2021). Increased psychological stress from FHs may be due, in part, to unclear diagnoses or anxiety over coping strategies for symptoms (De Petrillo et al., 2021). Research is needed to evaluate the potential causal relationship between food hypersensitivities and psychosocial stress.

Healthcare visits pose an additional time and economic burden on individuals and families with FAs. A case-control study involving randomized recruitment of adults and school-aged children from the capital cities of 12 European countries investigated the relationship between self-reported FAs and healthcare costs in both adults and children separately (Fox et al., 2013). Researchers found that adults and children with self-reported FAs visited health professionals on average fourfold more than those without. Furthermore, those with FAs experienced significantly higher healthcare costs in international dollars (I$) of I$2016 for adults with FAs and I$1089 for adults without. Similarly, additional costs of I$2197 for children with FAs versus I$863 for children without FAs was seen (Fox et al., 2013). An analogous study was completed in the United States through a national survey conducted on caregivers of children with allergies. The results showed not only higher healthcare costs covered by insurance, but higher out-of-pocket costs reaching $5.5 billion annually, compared with caregivers of children without allergies (Fox et al., 2013). The cost of allergen-free foods was the source of 31% of the difference in costs for those with self-reported FAs overall (Gupta et al., 2013). Other additional costs may include unnecessary medical prescriptions when FAs are self-reported without a valid diagnoses (Gupta et al., 2013).

In addition to the aforementioned burdens of FHs, the misdiagnosis of FAs and inappropriate use of non-validated testing procedures may lead to unnecessary food avoidance and elimination diets. These type of diets when not monitored by a healthcare professional can result in adverse health outcomes and nutritional deficiencies (Bird, Crain, et al., 2015). It is known in the case of FAs that children allergic to dairy and those with multiple food allergies are at an increased risk for inhibited growth as compared to children without FAs due to decreased consumption of calcium and vitamin D found within dairy products (Christie et al., 2002). Comparably, a cross-sectional study of 34 individuals following a wheat-free diet in the absence of celiac disease or non-celiac wheat allergy had inadequate intakes of fiber, calcium, folate, potassium, magnesium, higher intakes of overall fat and saturated fat, and lower intakes of carbohydrates and protein (Golley et al., 2019). During aforementioned elimination diets used for IBS and FIs, there is a chance that patients who see improvement in symptoms will not want to undergo the reintroduction phase for fear of triggering symptoms (Lomer, 2015). This may result in unnecessary food elimination (Lomer, 2015). As previously mentioned, this problem may occur due to readily available serum IgG testing in the marketplace and consumers not working healthcare providers to reintroduce eliminated foods. This may put some at an increased risk of nutritional inadequacies and may lead to negative effects on the composition of the gut microbiome and lower quality of life (Lomer, 2015).

Conclusion

The prevalence of food hypersensitivities is increasing in both children and adults in the United States. The terms food hypersensitivities, allergies, and intolerances have been used collectively to describe FAs, but conflation of these terms can lead patients and parents/guardians of patients to seek diagnostic procedures, which may or may not be able to accurately predict food hypersensitivities. Diagnostic tools endorsed by the American Association of Allergy, Asthma, and Immunology include DBPCFC, skin prick testing, and serum IgE testing. Currently, there are no high-quality peer-reviewed published studies on alternative testing procedures including serum IgG testing kits and leukocyte diagnostic testing methods. Therefore, there is a need for high-quality studies to identify whether these tests can accurately diagnose food hypersensitivities. Other factors involved in the increased prevalence of self-reported food hypersensitivities include current food processing techniques, low health literacy, and poor health information readability and quality. The increased prevalence of food hypersensitivities impacts federal government and education institutional policies as well as food manufacturing practices. Overall, misdiagnosis of food hypersensitivities and inappropriate use of non-validated testing procedures may lead to adverse outcomes including increased economic burdens, unnecessary food avoidance, and nutritional deficiencies. High-quality research regarding food hypersensitivities is needed in order to protect the health of consumers suffering from food hypersensitivities.

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