Chapter

Dietary Patterns for Immunity Support and Systemic Inflammation against Infections: A Narrative Review

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Abstract

Nutrition has been recognized to play a regulatory role in human immune response and inflammation which may affect the pathogenesis of diseases. Current evidence suggests that the habitual dietary pattern therapeutical approach provides more synergistic beneficial action than the intervention of a single nutrient constituent. Several healthy dietary patterns are essential for the human immunity support against infectious diseases through alleviation of systemic inflammation. Long-term dietary patterns may affect the diversity of intestinal microbiota composition and lead to the decrease of pro-inflammatory cytokines from immune-related cells. Protease that may cause gut barrier breakdown (leaky gut) can be reduced either thus lessen translocation of endogenous bacterial endotoxin such as lipopolysaccharides (LPS) from the gut lumen to the bloodstream. In this review, we discuss the relationship between common healthy food-based dietary patterns with the protection of infectious diseases as a result of improvement in immune function and low-grade inflammatory indices. In contrary to the deleterious impact of the western diet, healthy eating habits (Mediterranean diet, dietary approaches to stop hypertension, plant-based diet, ketogenic diet) are associated with reduced susceptibility to infectious disease by the improvement of certain underlying metabolic comorbidities. Further studies are needed to determine suitable strategic implications of healthy dietary patterns on infectious disease mitigation in a particular context.

Keywords: nutrition, bioactive, dietary pattern, immunity, inflammation, oxidative stress, antioxidant, infectious disease

1. Introduction

The benefit of dietary patterns has appeared as a complementary and alternative approach to the study of the relation of diet and the risk of diseases. In contrast to a single substance or nutrient approach, an evaluation of whole dietary patterns may provide a more complete picture of a combination of foods and nutrients, such as synergistic and antagonist properties of the foods [1]. People do not eat isolated nutrients and rather consume foods that contain a variety of foods with complex interactive combinations of nutrients. Thus, a single active substance approach might be insufficient for considering complex interactions between food bioactive components in the human study such as vitamin C improves Fe absorption [2]. Often, the high degree of intercorrelation between nutrients (e.g. magnesium and potassium) can be difficult for the evaluation of their separate effects in particular conditions [3]. Additionally, the cumulative effects of several nutrients are more likely detectable compared to the influence of a single substance. In the clinical trial setting, the dietary patterns approach has shown a positive health outcome in degenerative diseases [4]. Nutritional approach as dietary pattern intervention (e.g. Dietary Approaches to Stop Hypertension and Mediterranean Diet) as an integral part of disease management have been studied extensively on metabolic chronic diseases (cardiovascular diseases and diabetes) with beneficial clinical results [5, 6].

To what extend dietary patterns beneficial as an integral part of management and prevention strategy for communicable disease? The dietary pattern approach is more likely not only effective for non-communicable diseases but also infectious diseases [7]. Perhaps, this is a possible explanation that partial nutritional intervention exhibits lower than expected results in infectious diseases study settings. Partial nutritional interventions (macronutrients or micronutrients supplementation) as adjunctive treatment of standard antituberculosis agents among active tuberculosis patients is one of the examples. These nutritional interventions have shown no beneficial effects for main treatment outcomes. Even though the supplementation improves weight gain of the TB patients in some settings [8]. World Health Organization (WHO) has declared officially coronavirus diseases (COVID 19) as a global pandemic on 11 March 2020. Currently, there have been several attempts to recommend nutritional approaches for mitigation strategy the disease [9–14]. The dietary pattern plays important role in this communicable disease due to its severity is affected by a previous underlying disease. Comorbidities such as respiratory system diseases, chronic obstructive pulmonary diseases (COPD), diabetes, hypertension, cardiovascular/cerebrovascular disease have shown significant evidence of associations with the severity and prognosis of COVID-19 [15].

Intestinal dysbiosis (gut microbiota imbalance) recently has been proposed as a significant factor that is associated with several immune-related human diseases including infectious, inflammatory, neoplastic, metabolic, autoimmune diseases [7, 16, 17]. Within the gut lumen itself, the human gut microbiome will provide antigens and signals with the potential to interact with resident and systemic immune cells. The composition of the gut microbiome changes over the life course, in response to dietary components, infection, antibiotic exposure [18]. All of these may result in dysbiosis. During this condition, nutritional changes have been suggested as a suitable approach to restoring a healthy gut microbiota and host homeostasis [19]. Also, it has been proposed dietary patterns such as Mediterranean diet and low-fat diet possess the ability to restore partially microbiota dysbiosis [20]. Despite commonly studied single nutrient supplementation, this narrative review aimed to provide current perspectives on the association between the major dietary patterns and infectious disease susceptibility through immune response and systemic inflammation. Relevant articles (original articles, literature reviews, systematic reviews and meta-analyses articles) that identified major dietary patterns and related keywords (e.g., "infection", "disease", "immune system", "inflammation", and "gut microbiota") were searched in Google Scholar, PubMed, MEDLINE, and Cochrane databases from the year 2010 to the year 2020 with exception for one article.

2. The role of bacteria homeostasis in gastrointestinal

Dietary patterns and quantity of food intake have been described to influence the microbiome in the gut [21]. *Bacteriodetes, Firmicutes, Actinobacteria,* *Fusobacteria, Proteobacteria and Verrucomicrobium* are predominant phyla of microbiota in the human gastrointestinal tract [22]. Among these phyla, more than 90% of the microbiome colonies in the colon are *Bacteriodetes* (*Bacteroides, Prevotella*) and *Firmicutes* (*Eubacterium, Lactobacillus*) [23]. In Western countries, it has been shown that *Firmicutes* phylum becomes blooming and *Bacteroidetes* phylum population decrease due to prominent animal product consumption [24]. On the other hand, it has been demonstrated that high content fiber in the diet resulted in more *Bacteroidetes* phylum bacteria dominance and an increased amount of concentration of short-chain fatty acids (SCFAs) among children from Africa compared to children of European origin [25]. Short-chain fatty acids are fatty acids with fewer than six carbon atoms (acetate, propionate, and butyrate) derived from intestinal microbial fermentation of dietary fibers and resistant starch [26]. The concentration of short-chain fatty acids in the colon and systemic blood is crucial for immune response regulation. The fermentation of dietary fiber by gut microbes, resulting in the establishment of SCFAs, has been proposed to regulate anti-inflammatory pathways through numerous receptors such as G-protein coupled receptors [27]. Additionally, fermented foods and beverages are found to produce beneficial improvements in intestinal barrier function and permeability [28].

It has been suggested that vegan or vegetarian diets may stimulate intestinal microbiota that promotes anti-inflammatory response and lead to be more varied and steadier microbiota systems [29]. Contrary to this, particular food items such as red meat, gluten in wheat, and alcohol can induce dysbiosis which might cause a heightened pro-inflammatory response triggered by viral infections such as COVID-19 from underlying diet-derived chronic inflammation [21]. This intestinal mucosal chronic inflammation is characterized by the presence of cytokines (TNF-α and IFN-γ) which are produced by macrophages, T-cells and natural killer. Besides cytokines, various proteases are also released into the mucosa that has been reported to cause leaky gut due to degradation of tight junctions [30]. Thus, leaky gut allows translocation of microbial products such as lipopolysaccharides (LPS) from the gut into the blood circulation. This condition may transform the existing state of gut inflammation into chronic systemic inflammation during infections such as HIV [31]. This chronic inflammation may remain undetected as a predisposing risk factor and can develop any time into serious morbidity including infectious diseases [23].

Several studies have shown the association between the change of intestinal microbiomes with infectious diseases. It has been reported that intestinal bacterial diversity significantly decreases inversely associated with the severity in patients of chronic viral hepatitis C compared to healthy individuals. The gut microbiome could be a biological indicator and a novel potentially therapeutical approach to reduce the complications of chronic liver disease [32]. Another study has identified *Lachnospiraceae*, *Ruminococcaceae*, and butyrate-producing anaerobic bacteria can be significantly decreased in diarrhea caused by *Clostridium difficile* infection [33]. A short-term nutritional intervention study has reported the positive effect of the supplement on HIV-associated dysbiosis, which was most apparent among untreated individuals but less so in subjects with anti-retroviral therapy, whose gut microbiota was found more resilient [34].

In contrast to short-term supplement intake, long-term dietary patterns and habitual diet are key factors that influence the composition of the gut microbiota. It reflects the potential for therapeutic dietary approaches to modulate microbiome variety, formation, and stability. Besides diet, the intestinal bacteria are formed by a composition of extrinsic (e.g., lifestyle and medication) and intrinsic (e.g., host genetics, immune and metabolic regulations) factors [35]. Changes in dietary patterns following the western diet, along with modifications in dietary components, result in significant changes in the intestinal microbial configuration and function. As an example, changing from a low-fat, high-fiber diet to a high-fat, high-protein, low-fiber diet leads to reduced α-diversity (intra-individual gut microbiota richness), increased β-diversity (inter-individual gut microbiota diversity) and deteriorated richness or even the extermination of *Prevotella* and *Treponema* species, with lower butyrate levels [36].

3. Western-style diet effect

From a current perspective, the western diet is defined as a modern diet that is primarily characterized by high consumption of red and processed meat, sugar-sweetened beverages, with a lower intake of cheese, wine, beer, cream, tea, vegetables and high-fiber foods [37]. This dietary pattern combined with a sedentary lifestyle can induce chronic systemic metabolic inflammation, termed as metainflammation. Systemic inflammation generates common prevalent modern non-communicable disease [38]. Western diet-induced obesity can result in gut dysbiosis then change lean adipocytes to obese adipocytes. **Figure 1** describes deleterious impact of the alteration to macrophages and adipocytes that lead to metabolic syndrome and diabetes. The western diet is closely associated to several degenerative or metabolic conditions such as obesity [40], metabolic syndrome [41], diabetes [42], cancer [43], hypertension [44], cardiovascular diseases [45], chronic kidney disease [46], and Alzheimer's disease [47].

Western diet pattern may also increase the risk of communicable diseases. It has been shown that women with the western diet might have a higher risk of Human Papilloma Virus infection compared to the Mediterranean-like diet [48]. People with obesity due to the western diet pattern may have a higher level of inflammatory cytokines, immunologic tolerance to inflammatory cytokines, reduced leukocyte number and function, and less control of infection [49]. Subsequently, obesity becomes a risk factor for increased morbidity and mortality of COVID-19 [50–53].

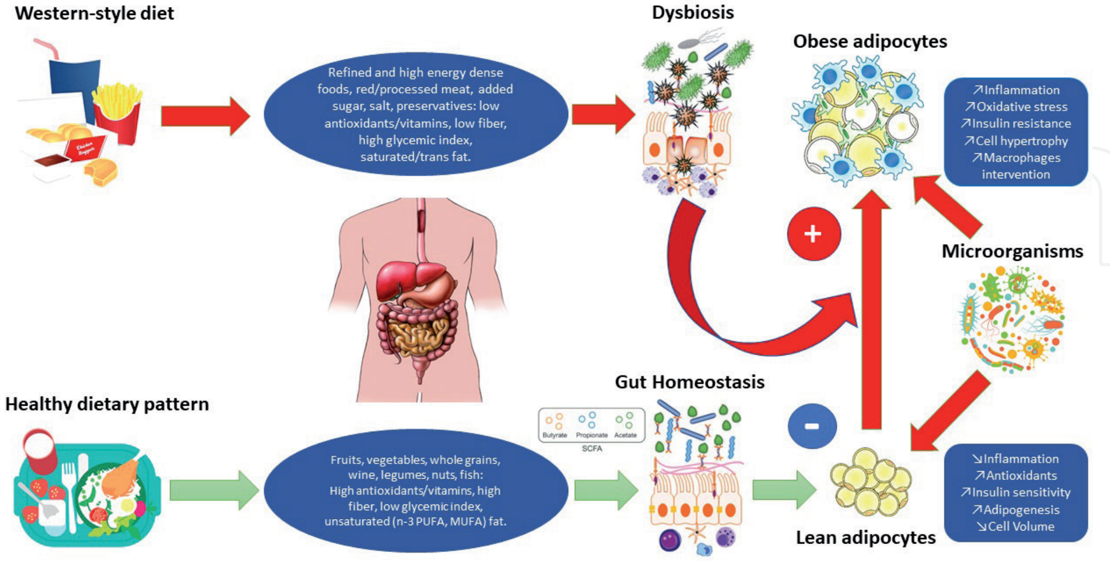

Figure 1.
Unhealthy dietary pattern (western-style diet) along with sedentary life style and genetic predisposition may lead to dysbiosis and contribute toward obesity. Obesity may induce changes to adipocytes and macrophages lead to abnormal inflammation response, decrease insulin sensitivity, and low antioxidant capacity that may finally induce systemic inflammation, oxidative stress, and insulin resistance [39]. On the other hand, healthy dietary pattern provides fiber derived short chain fatty acids (SCFAs) that regulate intestinal barrier and immune system through protein G-coupled receptors signaling. Preservation of gut homeostasis may prevent leaky gut thus reduce inflammation during infection by microorganisms through several mechanisms.

Body mass index (BMI) has been proposed as a prognostic score since higher BMI (BMI ≥30 kg/m^2) more likely results in poor outcome in COVID-19 patients [50, 53]. Body mass index ≥30 kg/m^2 is more likely associated with lower oxygen saturation of blood by weakened ventilation at the base of the lungs. Furthermore, systemic low-grade inflammation due to obesity may occur, such as higher levels of pro-inflammatory cytokines may result in compromised immunity [54]. Therefore, obese COVID-19 patients should receive special attention for their treatment.

Similarly, other non-communicable diseases strongly associated with western diet patterns are also comorbidities for COVID-19. Some comorbidities have been extensively investigated such as diabetes, hypertension, cardiovascular diseases, cerebrovascular diseases, chronic respiratory system diseases, chronic kidney disease [54–57]. Since SARS CoV-2 invades the host cell via ACE-2 receptor on the surface of the cell, certain comorbidities have a strong association with ACE-2 receptor upregulation and impaired immune response that may give rise to susceptibility for viral invasion into the host cells [54]. The infection of SARS-CoV-2 among individuals with these comorbidities can be harmful and might end up with acute respiratory distress syndrome, multiple organ failure, shock, arrhythmias, heart failure, renal failure, and, eventually, mortality [58].

4. Healthy dietary patterns

4.1 Mediterranean diet

Mediterranean diet is a dietary pattern traditionally applied by people who live near Mediterranean Sea, particularly in the region where olive trees are cultivated. It describes the frequent consumption of vegetables, fruits, legumes, nuts, and olive oil as a primary fat source. Additionally, this eating habit is characterized by moderate consumption of fish, poultry, dairy products, wine, and limited intake of red meat [59]. The dietary pattern is one of the most frequently studied for the protective effect of non-communicable diseases such as cardiovascular disease and coronary heart disease [60–62], diabetes [63–65], cognitive disorders [66–68], and malignancies [69–71]. It might be due to the effect of reduced inflammation through changes of C-reactive protein level [72], myeloperoxidase and 8-hydroxy-2-deoxyguanosine [73], white blood cell count and fibrinogen [74], methylation in inflammation-related genes [75]. Additionally, the diet habit also demonstrates modulation of the gut microbiome that results in a reduction of metabolic endotoxemia and subsequently lower systemic inflammation [73, 76, 77].

More likely these positive effects of Mediterranean may produce also protection for infectious diseases. Among communicable diseases, this dietary approach has been proposed for COVID-19 to reduce the mortality rate through the suppression of cytokines [78]. The Mediterranean diet might describe a possible dietary approach to mitigate both short - and long - term complications related to COVID-19 infection. It may decrease the severity and improve mortality and improve the overall well-being of affected populations [79]. **Table 1** shows several studies related to beneficial effects of Mediterranean diet among individuals with diseases caused by virus. A viral infection disease such as chronic hepatitis C and B viruses has shown an inverse correlation to the Mediterranean diet adherence [81]. Cervical cancer that caused by human papillomavirus also has described the same tendency in relation to this dietary pattern and opposite results can be caused by unhealthy diet habit [83]. Mediterranean diet has been found to be beneficial on metabolic indices in human immunodeficiency virus (HIV) patients with the highly active antiretroviral therapy [80]. Perhaps, parasitic infections could be also mitigated by the Mediterranean diet

Author and year	Dietary pattern	Study design (n) and assessment	Population	Outcomes
Tsiodras, S., et al. 2009 [80]	Mediterranean dietary pattern	Cross-sectional study (n = 227). Food frequency questionnaire (FFQ), and Mediterranean Diet Score (MedDietScore).	Human immunodeficiency virus (HIV) positive adult patients with the highly active antiretroviral therapy (HAART) in Israel.	Adherence to a Mediterranean dietary pattern was favorably related to cardiovascular risk factors such as insulin resistance, high density lipoprotein level, and circulating triglyceride level.
Turati, F., et al. 2014, [81]	Traditional Mediterranean diet.	Case–control study (n = 518 *vs.* n = 772). MedDietScore.	Adult hepatocellular carcinoma (HCC) patients, chronic infection with hepatitis B and/or C viruses in Italy and Greece	Adherence to the Mediterranean diet demonstrates protective effect against HCC. Potential benefits from adhering to the dietary pattern for individuals with chronic infection of hepatitis viruses.
Policarpo, S., et al. 2017 [82]	Mediterranean diet	Cross-sectional (n = 571). MedDietScore	Adult HIV positive adults in Portugal	A higher adherence was associated to individuals with a BMI $\geq$ 25 kg/m^2, to subjects with metabolic syndrome and to patients with moderate to high cardiovascular risk.
Barchitta, M., et al., 2018 [83]	Mediterranean diet, prudent dietary pattern, western style diet	Cross-sectional study (n = 539). FFQ and MedDietScore.	Adult women with high-risk human papillomavirus (hrHPV) infection and the risk of high-grade cervical intraepithelial neoplasia (CIN2+) in Italy	Inverse association of Mediterranean-like dietary patterns with hrHPV infection and cervical cancer. The outcomes discourage unhealthy eating habits.

Table 1.
General characteristics of studies examining the role of Mediterranean diet on mitigation of communicable diseases caused by virus.

via the positive effects of omega-3 and omega-9 from olive oil and fish intake. These fatty acids modulate intracellular pathways and transcription factor activation, as well as metabolic and immune regulatory effects [84].

Polyphenols, monounsaturated and polyunsaturated fatty acids, or fiber are more likely bioactive ingredients of the Mediterranean diet [85]. Olive oil is one of the main components of the Mediterranean Diet which has a high profile of fatty acids and phenolics. Oleic acid, a predominant monosaturated fatty acid component in olive oil that can prevent inflammation and insulin resistance induced by palmitic acid in skeletal muscle, adipose tissue, pancreas, and liver. This preventing effect might be due to a reduction in palmitic acid-mediated adenosine monophosphate-activated protein kinase activity which is similar to Metformin [86].

Several minor constituents of Olive oil demonstrate possible synergic effects to counter inflammation. Oleocanthal is known as a minor ingredient of olive oil with significant anti-inflammatory properties that may have therapeutic potential [87]. It has been shown that Oleocanthal has a natural anti-inflammatory property by inhibition of cyclooxygenase enzymes [88]. Hydroxytyrosol is another salient minor phenolic compound of Olive oil that exhibits potential nutraceutical through immunomodulatory and nutrigenomic mechanisms [89].

The immune system is closely correlated with inflammatory processes and oxidative stress [90]. The precise mechanism of oxidative stress during infection is not fully understood, but free radicals have played an important role to defend against microorganism's invasion [34]. Persistent oxidative stress may happen during chronic viral infections and has been associated with a weakened immune system due to long-lasting inflammation activation [90]. The anti-inflammatory effect of the Mediterranean diet may stop a vicious circle in which chronic oxidative stress and inflammation feed each other. Therefore, the Mediterranean diet might prevent further consequences such as impaired immune response. Additionally, The Mediterranean diet which rich in unsaturated fats and fiber may reduce the circulating level of endotoxin from gastrointestinal bacteria that has been proposed as a cause of inflammation [76]. In other words, The Mediterranean dietary patterns possess the ability to restore the gut to normal microbiota homeostasis through its anti-inflammatory effect [91]. Since gut microbial communities are involved in the modulation of the host innate and adaptive immune response so that this approach will play an important role in future therapeutic development for major global infectious diseases [92].

4.2 Dietary approaches to stop hypertension (DASH)

The Dietary Approach to Stop Hypertension (DASH) was designed as a non-pharmacological treatment for lowering blood pressure among adults. The dietary pattern consists of a higher intake of fruits, vegetables, whole grains, fish, poultry but less consumption of saturated fats, meat, and sugar. As result, DASH diet is high in calcium, potassium, magnesium, fiber, and protein. It is not a restricted sodium diet but its effect can be improved by less sodium consumption [93]. Adoption of this dietary pattern is effective not only in reducing blood pressure but also results in lower body weight so that it might be suitable for bodyweight management in overweight or obese individuals [94, 95]. Besides, the diet has shown an association with a lower incidence of cardiovascular diseases, coronary heart disease, stroke, and diabetes. The evidence of cardiometabolic beneficial effects is not only among diabetes patients but also people without diabetes [96]. It has been demonstrated that DASH can control glucose level, infant birth weight and decrease gestational preeclampsia risk among pregnant women [97, 98]. DASH approach is also associated with lower mortality from different cancer types [99, 100]. It means this dietary pattern is suggested as an effective treatment approach for various non-communicable diseases with long-lasting effect [101].

Since hypertension, diabetes and cardiovascular diseases are well-known comorbidities for viral infection COVID-19 [15, 102, 103], so that DASH might be helpful to mitigate the severity and fatality of the disease. The foods in the dietary pattern are rich in bioactive compounds that exhibit potent modulation of pro-inflammatory pathways and may support the immune response to reduce the morbidity and mortality of an infectious disease [104]. Furthermore, the improvement of the antioxidant defense of the body and decrease oxidative stress can be achieved by adherence to DASH diet. These effects might be due to lower malondialdehyde and glutathione levels mechanism [105]. It is suggested that oxidative stress plays a dual role during infections. Reactive species (e.g., nicotinamide adenine dinucleotide phosphate oxidase, myeloperoxidase, and nitric oxide synthase) can induce cell apoptosis or destroy invading microorganisms as a defense mechanism. However, they can also cause tissue injury and resulting inflammation [106]. It has been proposed that the immune system plays important role in the etiology of hypertension. The DASH may promote the expansion of protective microbes that release gut metabolites such as short-chain fatty acids which are protective for the immune system and blood pressure [107]. Eventually, a healthy eating habit supports the immune system that protects against the invasion of microorganisms or viruses and produces antibodies to eradicate pathogens.

4.3 Plant-based diet

The plant-based diet generally consists of two dietary patterns: vegetarian diets and vegan diets. Vegetarian diets are characterized by reduced or eliminated animal products intake but may include dairy products and/or eggs, while vegan diets contain only plant foods. Both vegetarian and vegan are dietary patterns that emphasize the consumption of vegetables, fruits, grains, legumes, and nuts [108]. Several potential beneficial effects of a plant-based diet are ameliorating insulin resistance, including preservation of healthy body weight, higher intake in fiber and phytonutrients, promoting food-microbiome interactions. The adoption of a plant diet decreases levels of advanced glycation end products, saturated fat, heme iron, and nitrosamines [109]. Several studies have shown plant-based diet efficacy for the prevention and treatment of diabetes [109–112]. The plant-based diet has also demonstrated a significant positive impact on cardiovascular diseases, coronary heart diseases, hypertension, and hypercholesterolemia [113–118].

In contrast to the western diet which consists of red meat, wheat and alcohol consumption, the plant-based diet has suggested having the ability to maintain symbiosis and prevent dysbiosis of the microbiome and results in lower morbidity and mortality during an infection such as COVID 19 [23]. The implementation of plant-based diets could improve the diversity of nutrients for the host by the gut microbiome. The undigested plant cell walls components are not absorbed by gastro intestinal tract and lead to microbiota-derived nutrients such as peptides and lipids. These subtances can promote the development and function of the host immune system [119]. There might be situations in which immune cells of the gut-associated lymphoid tissue come into direct contact with nutrients or gut microbiome, such as in the circumstance of increased epithelial permeability (leaky gut) ocurred in both acute and chronic gut inflammation [120]. Numerous plant-based biologically active compounds exhibit antibacterial [121], antifungal [122], and antiviral activity [123]. Moreover, China and India predominantly rely on plant-based medications under different domain names like Chinese Traditional Medicines and Ayurveda but the plant-based therapeutical approach remains largely unexplored [123]. Therefore, a more likely plant-based dietary pattern has protective effects against infection due to its anti-inflammatory and immune response modulation properties that come from plant bioactive molecules. Plant-based food has been recommended also as a nutritional approach treatment for COVID-19. The dietary pattern improves the gut beneficial bacteria and rich in plant bioactive compounds, vitamins C, D, E, magnesium, and zinc [124].

4.4 Ketogenic diet

Ketogenic diet (KD) is a dietary pattern that promotes a low carbohydrate intake (usually to <50 g/day), adequate proportions of protein and higher percentages of fat [125]. Since the diet provides lower carbohydrates intake, glucose reserves become insufficient both for Krebs cycle and for the central nervous system (CNS). Thus, after several days of carbohydrate restriction, the CNS is forced to find an alternative source of energy. This alternative source of energy is ketones and there are two types of ketone bodies produced in the liver: acetoacetate and β-hydroxybutyrate [125]. Ketosis is a physiological mechanism and it reflects the breakdown of fats in order to compensate for a low level of glucose. The ketogenic diet originally was introduced for epilepsy treatment and the current evidence suggests that KD could help children with drug-resistant epilepsy [126]. Despite its therapeutic application for a neurological disorder such as Alzheimer, malignant glioma and adult epilepsy have shown potential benefits [127], but this may lead to further lowering of consumed essential nutrients by elderly persons with neurodegenerative diseases [128]. Recent findings suggest that even though not all types of cancers give a positive response but KD as a adjuvant treatment, it may give beneficial effect for body composition and quality of life among cancer patients [129]. However, controversies remain on the implementation of the KD especially for diabetes and obesity since the risks, benefits, and applicability of the diet to avoid unnecessary harm and costs to patients [130]. Additionally, the improvements in some cardiovascular risk factors (obesity, type 2 diabetes and high-density lipoprotein (HDL) cholesterol level) are usually not long-lasting and the development of insulin resistance might occur [131]. The international ketogenic diet study group has suggested that constant nutritional monitoring is needed for ketogenic diet therapy to ensure its effectiveness and to reduce potential adverse effects [132]. Perhaps, the sequential method in a biphasic combination of two dietary patterns such as ketogenic diet and Mediterranean diet may provide an effective strategy against obesity-related inflammation with higher compliance of consumers [133].

On the other hand, the short-term ketogenic diet therapy has been applied for COVID-19 patients in order to perform a rapid reduction of comorbidities. These comorbidities (obesity, type 2 diabetes and hypertension) are well known as modifiable risk factors for COVID-19 patients [134]. The rationale behind this approach is the induction of ketosis may reduce hyperglycemia and eucaloric ketogenic diet could affect macrophage phenotype M1 limiting cytokine storm syndrome. Furthermore, SARS-CoV-2 replication could be inhibited by the antiglycolytic action of eucaloric ketogenic diet [135]. It has been suggested that therapies that increase levels of (R)-beta-hydroxybutyrate, such as the ketogenic diet or consuming exogenous ketones, should restore altered energy metabolism and redox state in patients with COVID-19. This approach is marked at the molecular level by reduced energy metabolism, modulate redox state, decreased oxidative stress, and cell death lead to blunt cytokine storms caused by Human SARS-CoV-2 infection [136].

Social distancing, quarantine, and isolation for prevention of COVID-19 spread may lead to a sedentary lifestyle, one of the factors for overfat that can affect negatively immune function [137]. The pandemic may aggravate depression due to social distancing and isolation, and thus unhealthy eating habits are used to compensate [138]. These Societal interventions against the COVID-19 pandemic might induce a sequence of psychobiological mechanisms that stimulate obesity incidence and raise the risk of comorbidities [139]. Perhaps, an alternative combination of dietary patterns between the ketogenic diet and a low-calorie diet may provide a safe, rapid and long-lasting approach for body weight as well as fat mass reduction. Very-low-calorie ketogenic (VLCK) diets are a dietary pattern that imitates fasting by limiting carbohydrates and fat intake with a relative increase in protein consumption [140]. Very-low-calorie ketogenic diet is able to reduce body weight especially in a relatively short time at the expense of fat mass and visceral mass; muscle mass and strength were preserved [141]. This effect can be long-lasting up to one year among patients that lose more than 10% of their initial weight without any impact on the muscle mass [142]. It has been shown that the VLCK diet also induced more weight reduction compared to the low-calorie diet until 24 months follow-up and decreased the individual burden of disease among obese patients [143]. The modified ketogenic dietary patterns may exhibit a more suitable and safer solution for a longer effect to mitigate obesity-linked comorbidities.

5. The health implication aspects of dietary patterns

Several factors can be differentially contributed to the implication of major dietary patterns such as meal-specific patterns which are identified as one of these factors [144] besides dietary composition [145]. An unhealthy meal pattern may have an association with dietary quality and diversity and it has been shown that lower dietary diversity scores increase the probability of metabolic syndrome [146]. A low dietary diversity score might be predisposed to nutrients deficiency such as iron deficiency anemia among adolescent girls [147]. Nutrients deficiency is considered a significant factor for infection susceptibility due to immune response impairment if left untreated in some settings [148, 149]. Furthermore, age category might affect the dietary pattern preference for example adults, their common dietary pattern is a western diet-like style and it may increase the risk of metabolic syndrome, obesity, hypertension and cardiovascular disease [150, 151]. Older people are more likely to consume fruits and vegetables and less likely to consume red meat, whole milk, and other fatty foods compared to younger people. However, older individuals tend to consume less calorie intake and a reduction in the quantity of food due to a decrease in physical activity as well as muscle mass [152]. Diet alone may not be sufficient to prevent micronutrient deficiency during aging and this situation can compromise immune function and increase infection risk [153]. Food insecurity is also an essential factor that associated with the unhealthy dietary pattern and it may refer to the limited ability to acquire nutritious food in socially acceptable ways [154]. Therefore, food insecurity may affect negatively infectious diseases susceptibility such as viral suppression of HIV/AIDS [155], COVID 19 spread [156, 157] TB treatment failure and mortality [158], and Malaria [159].

6. Conclusions

Healthy dietary patterns might be protective against inflammation triggered by oxidative stress which is an important determinant of chronic diseases. The proposed mechanisms include preservation of gut microbiome homeostasis and integrity of the epithelial lining of the gastrointestinal tract. These conditions could alleviate lipopolysaccharide-induced inflammatory response and endotoxemia due to leaky gut. Additionally, short-chain fatty acids from fermented dietary fiber as common component of the dietary patterns exhibit anti-inflammatory properties. Therefore, healthy dietary patterns may improve metabolic indices, certain medical conditions and pre-existing comorbidities in infectious disease. In a nutshell, the healthy dietary pattern might be suggested as an alternative for prevention or an integral part of infectious disease management that can be adjusted to local settings.

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Conflict of interest

The authors declare no conflict of interest.

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