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Nutrition as a Bridge between Communicable and Non-communicable Diseases: A Review

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Abstract As humans, immune competence is an important factor in ensuring that the risk and severity of infection differ and has to do with how the immune system develops, matures, and declines. Nutrition has a bidirectional relationship with communicable and non-communicable diseases, and several factors influence the immune system and its competence. Poor nutrition can compromise immune function and increase the risk of diseases. Micronutrient deficiencies have become a global public health issue, and malnutrition predisposes individuals to certain infections. Although immune function can be enhanced by restoring micronutrients deficiency to recommended levels, this may promote higher resistance to disease and facilitate faster recovery during illness. However, a few pieces of literature exists on the relationship between nutrition and diseases. This review contributes to knowledge by looking at the role of nutrition in the susceptibility of individuals to communicable and non-communicable diseases, considering factors such as malnutrition, gut microbiota, genetic composition, and diet.

Keywords: *nutrition, communicable diseases, non-communicable diseases, immunity*

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1. Introduction

The embryonic stage is a state at which the human immune system begins. When a pregnant woman consumes protein, vitamins, and minerals in adequate quantity, especially during the first trimester of pregnancy, this will help the embryo tissue develop properly. The primary cause of immunodeficiency globally is malnutrition, and the most affected people are infants, children, adolescents, and elders there is a strong association between malnutrition, infections, and infant mortality rate. Nutrition is a necessity in ensuring that humans have a high defense (immunity) system against pathogens in the environment. Development is important for the weight and size of the fetus because the normal weight of the fetus determines his/her health. If the fetus is malnourished the immune system will not properly develop due to lack of required nutrients, and as a result, cannot defend against pathogens as the child grows. For infants, exclusive breastfeeding is one of the most important means of proper immune development which provides adequate minerals and vitamins that a baby needs for growth and health given that poor nutrition leaves children underweight and weakened [1]. When a child is malnourished, he/she will be vulnerable to infectious diseases primarily because of epithelial integrity and inflammation [2].

Nutrition contributes to growth and development throughout infancy, childhood, and adolescence; and it is during the period of adolescence that nutrient needs are the greatest [3]. Adolescents' malnutrition may represent a heavy health burden, and could give rise to nutrition-related disorders such as obesity, are ignored in these figures [4]. Although, various relationships exist between nutrition and diseases, ranging from gastrointestinal infections, food poisoning, the association between malnutrition and infectious diseases, the relationship between over-nutrition and infections to nutrition in immune-deficient patients. In our understanding of this interaction between infection and malnutrition, it is important to remember that a decreased immune function is not always a defective one because an immunodeficiency disorder can be mild so that the person may not be aware. The effectiveness of nutrients can be determined by the status of the host (immune - compromised), genetic composition, and age, and health [5].

This paper focuses on the effect of nutrition on the susceptibility of individuals to diseases, taking into consideration factors such as malnutrition, gut microbiota, genetical composition, and diet. Information related to pathophysiological and immunological backgrounds, as well those focusing on specific metabolic imbalances and host nutritional status with the emergence of diseases are also provided.

2. Nutrition as a Strong Immune-Determining Factors.

Nutrition: it involves eating enough nutrients as part of a varied diet required for the health and function of all body cells, including immune cells. Certain dietary patterns (whole grain, vegetable, fruits and healthy proteins) may help in preparing the body for microbial attacks and excessive inflammation, The strength of the body's immune response depends on the presence of many micronutrients (including vitamin C, vitamin D, zinc, selenium, iron, and protein) [6]).

Guillin *et al* discovered that poor nutrition or malnutrition can reduce the performance of immune cells and antibodies[7]. Malnutrition refers to when a person's intake of energy or nutrient is deficient, surplus, or imbalance. Malnutrition can be categorized into under nutrition (characterized by stunted growth), wasting (characterized by low weight for the height), underweight (characterized by low weight for age), micronutrient deficiencies (characterized by a lack of required vitamins and minerals), and overweight (characterized by obesity and diet-induced non-communicable diseases which could lead to heart disease, stroke, diabetes, and cancer). The lack of nutrients such as protein and Vitamin A has caused an increased rate of infectious diseases in the world's poorest areas [8]. In a synergistic reaction, an infection can enhance malnutrition and malnutrition can increase the prevalence of infection [9]. Conditions such as iron deficiency, anorexia, reduced intestinal absorption, and reduction of vitamin concentrations can weaken the body's efficiency in fighting infection, leading to malnutrition. For example, anorexia can weaken the immune system against infections by causing malnutrition. Reduced intestinal absorption won't be able to properly absorb fat, protein, and carbohydrates, hence such a person's diet may be restricted [10].

Diet: in this situation refers to the food and drink a person consumes daily in conjunction with the mental and physical circumstances surrounding the consumption. Nutrition involves more than simply eating a "good" diet but about nourishment on every level. Diet is partly responsible for 30 to 40 percent of all types of cancers [11]. Eating inadequate or excess amounts of protein, carbohydrates, fats, vitamins, minerals, water, or eating the wrong classes of food can lead to muscle wasting, a poor immune system, obesity, and cardiovascular disease. Health maintenance can be obtained by diet control and this includes non-communicable disease prevention and treatment as well as proper weight management. To maintain a healthy body system, a balanced diet with an adequate amount of essential nutritional elements is required, but excessive or inadequacy of these nutritional elements may result in or can be associated with disease establishment. Nutritional excesses in some food classes such as carbohydrates and saturated fats may also pose a health threat. For example, energy imbalance due to overeating and lack of physical activities can result in chronic inflammatory conditions such as obesity, diabetes mellitus, and cardiovascular disease. Other determining factors of a strong immune system are as follows:

Gut microbiota: microbiota development begins from birth, [12], After the child is born, the Gastro-Intestinal (GI) tract is rapidly introduced to life events such as diseases, antibiotic treatment, and diet changes thereby causing major alterations in the microbiota [13]. Apart from the above-mentioned factors that may alter the microbiota, the mode of delivery also seems to affect the microbiota composition, according to research, the microbiota of vaginally birthed infants' contains a high level of lactobacilli while the microbiota of infants birthed by Caesarean section is colonized by facultative anaerobic Clostridium species [14]. Some of the most important health roles performed by microbiota are to help in maintaining the provision and supply of nutrients such as vitamins as well as offering protection against pathogens, and finally, the microbiota is crucial for effective immune function.

Genetical composition: Inherent or genetic immunity provides the unborn with protection and appropriate living structure by the power of inherited traits of immunity. Genetic immunity is the ability of a living structure under the influence of genetic determination to resist the relevant impact of infectious diseases or physiological agents [15].

All these factors listed above are strong determining factors of developing a strong immune system, which in turn can prevent infants, children, and adults from communicable and non-communicable diseases. In severe immune deficiency, there can be a prevalence of susceptibility to infection which is likely not to occur with a healthy individual. A healthy person may consume some contaminated food and not get the infection but in case of severe immune deficiency, such a person may break down from disease.

3. Brief History of the Discovery of the Relationship between Immunity, Nutrition, and Infection

In the history of nutrition and immunity, there has been visible progress made in the past 50years. During the decade of the 1950s, the knowledge of the immune system was primitive, there was really no contact or midpoint of immunologists and researchers in the field of infectious diseases. Thus the knowledge of immunology was not being applied to nutritional diseases. Between 1959-1968 was a period referred to as renaissance, Taylor, and Gordon documented the interactions between malnutrition and infection [16]. These scientists revealed that malnutrition increased susceptibility to infection, and there is a cyclic system (rotation) of malnutrition and infection. More nutritional deterioration results in a higher prevalence of infection, hence, improving nutritional intake can help reduce the infection rate except in the cases of repeated exposure (nutritional intake may not reduce infection). The period between 1970-1980 (known as the reformation period) gave insights into the relationship between nutrition and infection.

Observation of the immune system of patients with hereditary defects of particular limb showed that these defects caused specific susceptibility for some classes of

infectious agents; such studies have shed more light on the nature of the host defect. From 1980-1990, the reconstruction period, the discoveries made started to capture the best interest of immunologists to study the impact of nutrition on immune function. This has led to the establishment of possible collaborations between immunologists and nutritionists and by this time, the intimacy of immune and metabolic responses to infection became clear. From 1990-2000, referred to as the modern era, the role of micronutrient deficiency serving as an enhancing factor in the host response to infection became clear and recognized.

During this decade, further studies conducted on AIDS have revealed that the wasting syndrome of this disease involves an imbalance in the levels of pro- and anti-inflammatory cytokines (IL-1, IL-6, and TNF-α) which is synthesized by mononuclear cells [17]. The year 2000 and beyond known as the millennium period [18] has demonstrated the general interest of individuals and groups in this field, with a major increase in the numbers of serious immunologists as research partners. Also, the Human Genome Project and the development of rapid sequencing methods is a biological revolution created and has granted the possibility of detecting a minor sequence variation in specific genes that gives genetic expression in which proteins are encoded [19]. After the journey of evolution of the field of nutrition, it is now known that this field is largely applied globally and has helped in the discoveries links between nutrition and infections, benefits of nutrition therapy, and preventive nutrition.

4. The Connecting role of Nutrition to Non-communicable and Communicable Diseases

Nutrition has proven to serve as a “walkway” to other diseases if insufficient or inappropriately consumed, thereby playing a huge impact in the development of non-communicable and communicable diseases. Nutrition contributing to non-communicable diseasesinvolve behavioral factors such as unhealthy lifestyle, smoking, excessive alcohol intake, and fewer physical activities; these are major risk factors for non-communicable diseases to thrive apart from the impact of genetic factors. However, recognizing any of these risk factors can prevent the occurrence of these diseases and initiate a positive change in lifestyles [20]. The major non-communicable diseases associated with diets are cardiovascular diseases (CVDs), diabetes mellitus (DM), overweight to obesity, dental cavities, and cancers amongst others. Diet-related diseases such as obesity, increased blood lipids hyperglycemia, hypertension can serve as major enhancers for the development of cardiovascular diseases, and diabetes mellitus. The result of non-communicable diseases (NCDs) by the Global Burden of Disease Study (GBD) estimated above 91% of deaths and almost 87% of disability-adjusted life-years (DALYs) in the European Union, of which approximately 61% and 46% respectively can be linked to the risk factors evaluated in the study. According to the GBD, above 950,000 deaths and more than 16 million disability-adjusted life-years (DALYs) are as a result of unhealthy diets [21]. Risk factors of cardiovascular diseases have not decreased over the past two decades instead it has been increasing [22]. It is gathered that between 1990 and 2010 hypertension has increased by 60%; dietary risk factors have increased by 45%, and elevated plasma glucose has increased by almost 30% in sub-Saharan Africa [23]. Another study from the in-depth analysis of the disability burden of NCDs in sub-Saharan Africa from 1990 to 2017 revealed that there is an increase in disability-adjusted life-years (DALYs) due to NCDs from 90.6 million (DALYs) in 1990 to 151.3 million (DALYs) in 2017 [23].

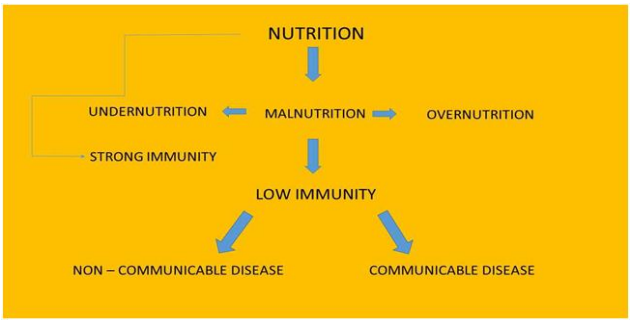

Figure 1. Nutrition as a bridge between non-communicable and communicable diseases

Table 1. Total disease burden of non-communicable and communicable diseases, maternal, neonatal and nutritional diseases globally and by continents of the world, from 1990 to 2017

Continents	From 1990	Non-communicable diseases (NCDs) DALYs		%Relative Change	Communicable, maternal, neonatal and nutritional diseases. DALYs lost			%Relative Change
		To 2017	Absolute Change		From 1990	To 2017	%Absolute Change	
Africa	216.4 million	349.32 million	+132.92 million	+63.4%	149.66 million	241.38 million	+91.72 million	+61.28%
Asia	593.51 million	871.14 million	+277.63 million	+46.8%	690.15 million	337.6 million	-352.55 million	-50.1%
Oceania	1.72 million	3.46 million	+1.74 million	+102%	1.4 million	1.89 million	+463,323.84 million	+32%
Australia	3.68 million	4.88 million	+1.20 million	+32%	241,177.06	240,764.01	-413.06	>-1%
Europe	104 million	104.66 million	+0.66 million	+0.64%	13.75 million	11.62 million	-2.13 million	-15.5%
North America	68.27 million	93.26 million	+24.99 million	+37%	6.62 million	5.69 million	-921,837.09 million	-13.9%
Southern America	10.68 million	13.40 million	+2.73 million	+26%	2.44 million	1.9 million	-541647.13	-22.2%

In 2017, the global level of the burden of diseases as a result of non-communicable diseases (NCDs) was more than more than 60 percent of the total burden of disease, with Asia toping the chat and Europe having the lowest rate of non-communicable disease burden, on the other hand, communicable, maternal, neonatal and nutritional diseases accounts for lower percentage of the global burden of disease. As standard of living improves due to income rises [24] there seem to be a shift in the burden towards non-communicable diseases (NCDs) which account for more than 80% in high-income countries and a significant reduction in communicable and preventable disease, although in some developing nations communicable disease still accounts for more than 60% across these countries [25]. The relative rates across the continents shows high increment in the burden of non-communicable diseases (NCDs) particularly in Asia and Africa. The best health is Europe (-15.5%) which is below 20,000 DALYs per 100,000 individuals by 2017. Nutrition and communicable disease can influence one another, the food we consume and our nutritional status can serve our body benefits such as energy, health, and immunity as a source. However, from this same food can occur microbial contamination, which can cause conditions such as food poisoning and gastrointestinal diseases, based on the seasons. Interestingly, Food poisoning is caused by the ingestion of contaminated foods, which is why eating expired /spoiled canned foods is not advisable as this can cause food poisoning [26]. Salmonella species are known for causing gastrointestinal diseases such as typhoid fever because it is food and waterborne and also one of the most dangerous diseases transmitted through contaminated water and food [27].

Cholera is an acute diarrheal disease caused by the ingestion of the bacterium *Vibrio cholerae* through contaminated food or water. Cholera which is a hot weather infection has remained a global threat to public health and has been estimated by researchers to have yearly cases of 1.3 to 4.0 million, and 21 000 to 143 000 deaths worldwide [28]. Brucellosis is an infectious (bacterial) disease that spreads from animals to people and it's caused by the consumption of contaminated unpasteurized dairy products (food) and water. This bacterium can also cause illness in farm animals for example goats, pigs, sheep, cows, and pigs. Another way humans become infected with *Brucella* is by being in close contact with secretions from infected animals [29] another parasitic infection transmitted through contaminated food is Pinworm disease which is more prevalent in children [30]. Coronaviruses are a large family of viruses that cause illnesses in animals or humans. The most recently discovered coronavirus causes respiratory infections ranging from the common cold to more severe diseases including Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS) in humans [31]. A healthy nutrition lifestyle can help optimize the function of the immune system, promote immunometabolism, and are a modifiable supporter of the development of complications that are associated with COVID-19 deaths. Nutrition may have a good impact on COVID-19 as it provides support to people at higher risk of the disease such as elderly people and people with underlying conditions (diabetes, cancer, asthma, obesity, heart conditions e.t.c) [32]. According to clinical microbiology research, microbes can sense their environmental nutrient content, which could then trigger their virulence (insufficient micronutrient) or result into dormant behavior of the pathogen (sufficient micronutrient with a strong immunity). Also, less or more concentrations of environmental and cell metabolites give rise to disease development or tolerance [33]. Imbalances of nutrient concentrations or incomplete metabolic circuit are mostly found in patients with infectious diseases or malnourished individuals which may serve as predisposing factors for other infections.

5. How to Build Immunity

Immunity is the effectiveness of the defense system against disease. This is done by the immune system which consists of several cells, tissues, molecules and can be classified into major groups: innate (involving phagocytes which response very quickly but may not be specific) and adaptive (involving T and B lymphocytes which have both specificities of antigen and recognition properties, but takes much time to develop on first exposure to infection) [34,35]. Building your immune system is necessary and can be done with the appropriate proportions of nutrition. These five classes of Vitamins (A, B6, C, D, and E) can help increase the strength of the immune system, as they all have their contributions in ensuring proper immune function. Exposure to sunlight (10-15 minutes) is one of the major production to the production of Vitamin D in human bodies. Vitamin D is essential to the body to synthesize antibodies, and deficiency in this vitamin has been linked to the major reasons for respiratory problems. Vitamin C which can be obtained from fruits (like oranges, and grapefruits) is known as the highest immune booster, deficiency in Vitamin C can give rise to disease such as Scurvy amongst others [32]. Researchers have revealed the major immune boosters to be vitamins, minerals, antioxidants, probiotics, including functional foods (conventional and modified foods) [36].

The first breast-milk from nursing mammals is called Colostrum which is rich in protective antibodies that an infant obtains from the mother. These antibodies help in the shaping of the babies' defense systems to be able to fight through and have lower risks of infections. Physical exercise on a regular basis has been scientifically certified to boost the immune system, by mobilizing the white blood cell which protects the body against infection. Lastly getting adequate sleep is important, because the reduction in the activity of the body's T cells and the activation of the immune response can be caused by lack of sleep which can weaken the immune system [35,37].

6. Global Examples of the Impact of Malnutrition in Association, with Infection

An evaluated data obtained from northeast Brazil revealed that malnutrition is a product of diarrhea, this condition can lead to impaired weight or even height gains

for age. According to this research, the malnutrition effect leads to the increased occurrence and longer periods of diarrheal illnesses. Diarrhea burden in malnourished children has doubled with a 37% increase frequency (rate of occurrence) and a 73% increase in duration (days of diarrhea) [38]. In global enteric research conducted in sub-Saharan Africa and South Asia, 9439 children with moderate-to-severe diarrhea and 13,129 control children without diarrhea were examined and discovered to be associated with *Rotavirus, Cryptosporidium, Escherichia coli, and Shigella.* Results revealed a direct relationship among diarrhea, impaired growth, and more post-diarrhea death (87•9%) occurred in the first 1 year and 11 months of life [39]. In 2006, research on Amebiasis caused by a parasite called *Entamoeba histolytica* was carried out. The parasite can be spread through fecal contamination of water and food, Amebiasis is characterized by diarrhea, with an incidence rate of diarrhea 2-10% amongst children living in developing countries. It's annual global mortality and infection rate is estimated to be about 100,000 and 50 million, respectively. Their result showed an increased rate of *Entamoeba histolytica* in malnourished children [40].

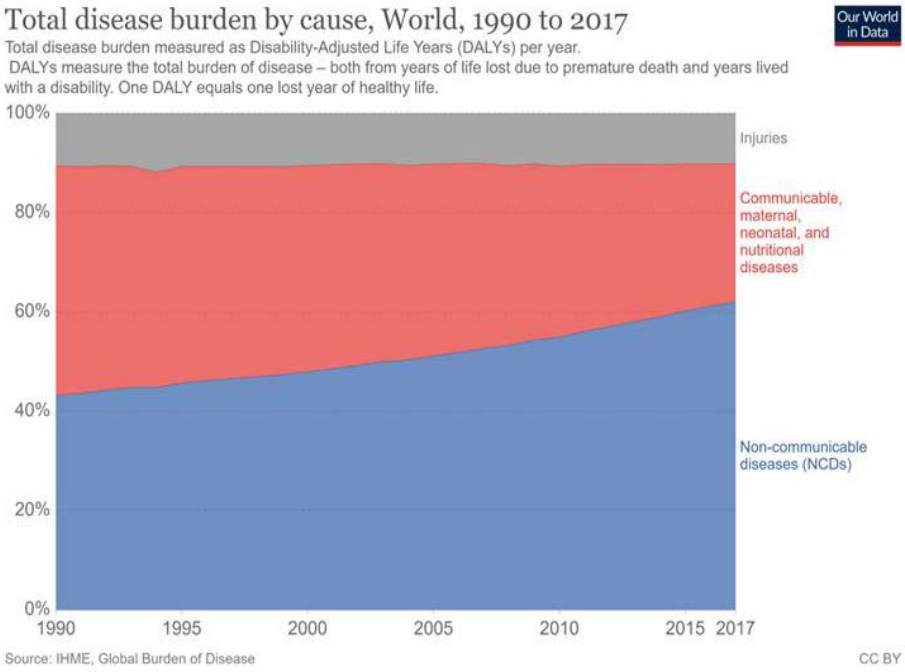

Figure 2. Global causes of death. Source IHME, Global Burden of Disease [41]

Here is a graph of the distribution of global deaths broken down according to three categories namely; communicable diseases, non-communicable diseases, and injuries over time.

Yellow: Comprises of Injuries caused by road accidents, homicides, conflict deaths, drowning, fire-related accidents, natural disasters, and suicides.

Blue: Non-communicable diseases often include chronic, and long-term illnesses such as cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases which is reducing as the year increases.

Red: Communicable diseases such as HIV/AIDS, malaria, diarrheal, and tuberculosis together with deaths from malnutrition, maternal deaths, neonatal deaths. According to this graph majority of global deaths are caused by non-communicable diseases (NCDs). NCDs account for more than 73% of global deaths. The share of deaths from infectious diseases is declining according to this source; a larger population is dying from non-communicable diseases (NCDs) [24].

7. Application of Nutrition and Its Health Benefits

In a multi-center trial study in Kenya, it was shown that drug therapy may not be effective in malnourished individuals. The study revealed daily administration of co-trimoxazole prophylaxis didn't significantly reduce severe diarrhea infections after being discharged from the hospital [42].

According to this "Nutritional Medicine" research, nutritional therapy can be helpful by using food to prevent and reverse diseases such as diabetes, obesity, heart disease, arthritis, and depression that are affecting most developed societies. It is revealed here for food to be therapeutic, it has to be rich in nutrients. Food should be evaluated for nutrients and anti-nutrients agents and ensure everything is in appropriate proportion before consumption. Nutritional therapy is safe, effective, and helpful in the treatment of patients with obesity and chronic illness and can also be beneficial in individuals wanting to promote their general health and well being [43].

Brian J. Bennett evaluated dietary disturbance affecting microbial diversity, plasma lipids, and circulating trimethylamine-N-oxide levels and discovered that a strain-diet interaction with a particular strain shows the higher separation between the atherogenic and control diets. The study revealed diet- and gene-regulated taxa is greatly linked to metabolic disease [44]. According to a study by Raqib and Cravioto, molecular and genetic techniques were used to measure the impacts of foods on genomics and metabolism and the result showed nutrients can

influence specific immune functions [45]. Responsible for life preservation and sustenance is the innate immunity (which depends on essential nutrients to produce energy, generate metabolic precursors to project their responses to infectious agents) and nutrient metabolism which works for hand in hand to ensure the smooth operation of the biological system. Immune incompetence as a result of damaged nutritional status leads to high susceptibility to infection due to nutrient deficiency, over-nutrition, and metabolic risk factors [46]. Research has shown that foods are capable of influencing innate or even acquired immunity [47].

8. Future Studies

In the future, more studies have to be done on intestinal or systematic immunomodulation. Emphasis should be laid on fixing nutrition in an appropriate proportion by stakeholders, so as to overcome diet-related challenges in society. Proper guidelines need to be put in place for food manufacturers to produce affordable, nutritious, and organic food products with less trans-fatty acids, sugar and most importantly reduced calories with appropriate combination of essential nutrients. Governments agencies need to ensure that required standards are met in order to protect consumers [20]. The United Nations' Taskforce on NCDs, and the WHO need to provide test kits to enable both developed and developing countries in the development and implementation of effective policies. Strategies can be put in place for these policies to be implemented in developing countries by increasing public and health professional awareness, which will be helpful in the future [48]. Finally, more attention needs to be given to the use of diet in bodyweight reduction and adjustment to help reduce the burden of non-communicable diseases.

9. Conclusion

Nutrition plays an important role in the development and prevention of non-communicable and communicable diseases. Malnutrition, diets, gut microbiota can influence the development of the human immune system; however, the application of the study of nutrition has helped to elucidate the interactions between nutrition, immunity, malnutrition genetic, gut microbiota, and dietary factors, and how these factors influence human health. Further studies in the area of nutrition and its application in disease treatment can help improve the quality of life and better health.

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Conflicts of Interest

No conflicts of interest.

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