The Role of Macro and Micro-Nutrients in the Chronic Disease Prevention: A Review

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Abstract

Chronic diseases are a major issue around the globe and cause many notable deaths. Macro and micronutrients play important roles in diets to prevent chronic illness. Macro nutrients like carbohydrate balance can help prevent diseases like diabetes, obesity, and colon cancer. High-fiber diets improve the diversity of the microbes inside the intestine thus increasing immunity. Carbohydrates reduces liver fat more than a diet that was restricted in calories. The immune system depends on proteins for its function. Proteins are involved in apoptosis which prevents cancer. High chromium exposure in the body can cause liver damage and cancer. Magnesium and iron are important for the body in low amounts because they help prevent type 2 diabetes and non-alcoholic fatty liver disease. The maintenance of dental health is the responsibility of vitamins A, C, and E. Vitamins A and C play a role in nonalcoholic fatty liver disease. Zinc, another micronutrient, is involved in lung and brain diseases. Vanadium can cause cancer and is responsible for lung diseases.

Keywords: Chronic diseases, Cancer, Periodontitis, Diabetes, NAFLD.

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Introduction

Chronic diseases led to a notable number of deaths and sicknesses which cost a lot. Chronic diseases include diabetes, chronic liver infection, periodontitis, chronic heart failure, and many more which are important issues around the globe. There is a lot of evidence that supports the fact that macro and micronutrients play a pivotal role in maintaining the health of the body (Robinson, 2015).

Macronutrients such as carbohydrates, proteins, and fats are required for normal body functions and body structure. Micro-nutrients or trace elements such as iron, sulfur, chromium, and vitamins are the cofactors of many enzymes and can be required in fewer amounts for proper function of the body. Sometimes there is an excess that can disturb normal body function and sometimes their deficiency causes disorders especially those that can meddle in intake, absorption, and digestion of nutrients (Berger et al., 2019; Berger et al., 2022; Lepp et al., 2024). However, nutrient imbalance can cause chronic diseases. Medical nutrient therapy plays an important role in treating chronic illness (Ozkol et al., 2013).

Diabetes mellitus is a chronic disease caused when there is no proper metabolism of glucose due to improper function of insulin or may be due to insulin deficiency (Holt, 2004). There are two types of diabetes mellitus, type 1 is insulin-dependent and can be caused due to genetic inclination, environmental factors like nutrition, and viruses (Bastaki, 2005; Patel et al., 2012). It is immune-driven and causes the destruction of beta cells of islets of Langerhans which produce insulin; thus, deficiency of insulin occurs (Kibiti and Afolayan, 2015). Insulin relying diabetes can be due to heredity, physical activity of that patient, and patient obesity (Bastaki, 2005; Patel et al., 2012). It is characterized by defects in insulin action, and insulin insensitivity to cells (Kibiti and Afolayan, 2015). Chromium has a role in diabetes, it amplifies the signal of insulin (Martinon et al., 2021)

Periodontitis (PDs) is a microbial disease where carbohydrates play a significant role in prevention (Najeeb et al., 2016). Nutrients have a notable impact on periodontitis of all ages (Younossi, 2019). Non-alcoholic fatty liver disease is a major cause of cirrhosis and hepatocellular carcinoma and has a global prevalence of 25% (Lepp et al., 2024), which can be caused by the imbalanced diet.

Non-alcoholic fatty liver disease (NAFLD) is a condition where the liver gradually malfunctions due to a pathological buildup of fat, inflammation, and hepatic cell destruction. Vitamins play important role in NAFLD (Tyczyńska et al., 2024).

Nutrients also play a role in many more diseases like cancer, asthma, etc. This book chapter will discuss some of the important ones.

Risk Factors

The risk factors for mineral deficiency-related chronic disease are rather common because they can be due to deficiency or due to mineral excess. Minerals deficiency can vary according to patient type like their age, sex, appetite, lifestyle, or according to disease type whether they are metabolic, malabsorptive, etc. Geographical location also affects disease whether there are sufficient minerals in the soil where the patient lives and, food standards in that area are good or bad (Cefalu and Hu, 2004).

Micronutrients

Following are the roles of micronutrients in chronic illness prevention.

Chromium

Chromium (Cr) naturally occurs in Earth's crust. It is a metal and is present in trivalent (+3) and hexavalent (+6) forms. The trivalent form of chromium is very toxic, but it is essential in food and nutrition with low toxicity (Kibiti and Afolayan, 2015). It is important in the metabolism of carbohydrates and lipids, although its metabolism is still not clear, and it is present in concentrated form in the kidney and liver (Hepburn and Vincent, 2003). According to earlier research, it was believed that Cr enhances the effects of insulin and that Glucose Tolerance Factor, a unique chemical form, is an effective oral treatment for diabetes (Weksler-Zangen et al., 2012). Most recent studies say that Cr supplementation does not affect body index, glycosylated hemoglobin, and lipid content in type 2 diabetic patients (Abdollahi et al., 2013). A Chinese cohort study's risk analysis revealed that male employees who were exposed to occupational Cr toxicity had a higher chance of developing liver or lung cancer (Yang et al., 2013).

Magnesium

The second most prevalent cation inside cells and the fourth most prevalent cation overall is magnesium (Mg). About 23g of magnesium is normally present in the body, with 50–60% of that amount found in bone. Magnesium transport varies from cell to cell and it is elevated in the heart, kidney, liver and relatively lower in skeletal striated muscles, RBCs, and brain cells (Spiegel, 2007; Faryadi, 2012). This function is made possible by two significant characteristics of magnesium: its capacity to compete with calcium for binding sites on proteins and membranes and to form chelates with significant intracellular anionic ligands, particularly ATP. In the cardiovascular and neuromuscular system Mg is an important nutrient in the synthesis of proteins and nucleic acid for their specific functions (Geiger and Wanner, 2012). Magnesium plays a peak role in maintaining the traffic of ions such as sodium, potassium, and calcium present in the body fluids across the sarcolemma membrane affecting the cardiovascular system. Help to avoid chronic heart disease (Swaminathan, 2003).

Mg also has an important role in chronic diabetes and is well-known among researchers. When insulin is released by the pancreas Mg makes sure receptor sites of the insulin are clear and there is no difficulty for the insulin to pass through the cell membrane along with glucose (Faryadi, 2012).

Nonalcoholic fatty liver disease (NAFLD) can also be caused due to low magnesium levels in serum which, on the other hand, low serum magnesium can be due to intestinal swelling or may be due to low albumin levels (Liu et al., 2019). Low Mg levels in the body affect normal mitochondrial activity, inflammation, and problems with translocation of protein kinase C. Mg shortage further exacerbates the inflammation or oxidative stress (OS) in NAFLD. A reduced extracellular magnesium diet activates macrophages, increases calcium uptake into cells, and sparks pro-inflammatory cytokine release (Nielsen, 2010). Mice were taken in an animal experiment. They are given a magnesium-limited diet which causes hepatocyte hypertrophy and hepatocytes to expand due to lipid deposition. In humans, it indicates early ballooning cell destruction (Fengler et al., 2021).

Vitamin A

All-trans retinol is biologically associated with a class of fat-soluble molecules known as vitamin A. While provitamin A carotenoids are found in carrots, green leaves, broccoli, ripe mangos, sweet potatoes, orange-yellow vegetables, fruits, and red palm oil, preformed vitamin A is found in animal-derived foods such milk, cheese, liver, and eggs (Najeeb et al., 2016; Dommisch et al., 2018). The UK National Health Service states that men between the ages of 19 and 64 require 0.7 mg of vitamin A daily, while women in the same age range require 0.6 mg (Dommisch et al., 2018).

In contrast, a decrease in the number of locations with a probing depth > 3 mm following scaling and root planing is associated with an increase in beta-carotene consumption (\geq 7.07 mg/day) (Dondington et al., 2015). It is believed that vitamin A contributes to the preservation of epithelial cells' integrity (Gondivkar et al., 2019).

Serum retinoic acid (RA) concentrations are lower in patients with NAFLD and NASH. Reduced RA concentration is linked to intrahepatic lipid levels, the degree of hepatic steatosis, and liver damage in patients with NAFLD (Liu et al., 2015). Furthermore, there is a negative correlation between blood RA levels and markers of obesity and liver impairment, such as intrahepatic triglyceride and transaminase levels. The idea that vitamin A may affect the liver's metabolism of fats and carbohydrates is further supported by this negative association (Podszun et al., 2021, Pickett et al., 2018). The ability of retinoic acid to increase the expression of genes involved in the liver's stimulation of lipid oxidation is responsible for the observed behavior. These genes include Carnitine Palmitoyltransferase I (CPT1), fibroblast growth factor 21 (FGF21), uncoupling protein 2 (UCP2), and proliferator-activated receptor alpha (PPARa) (Raza et al., 2021).

Vitamin E

Eight naturally occurring, lipid-soluble antioxidant micronutrients—four of which are tocopherols and four of which are tocotrienols make up the vitamin E complex family. They stop lipid peroxidation and are the most significant lipid-soluble antioxidant (Dommisch et al., 2018). Vegetable oils, fortified cereals, nuts, seeds, meats, fruits, and vegetables are the main food sources (EFSA Panel, 2015). In the USA, the recommended daily dosage is 15 mg, although the UK National Health Service suggests 4 mg for men and 3 mg for women (Dommisch et al., 2018, EFSA Panel, 2015).

Serum vitamin E levels and PDs did not significantly correlate, according to Pfeiffer et al. (2013). Nonetheless, a more recent cross-sectional investigation with 4708 participants found a negative correlation between the severity of Periodontitis and blood alpha-tocopherol levels. This discrepancy may be explained by Zong et al. (2015) taking blood lipids and other confounding variables into account.

Vitamin C

Ascorbic acid, or vitamin C, is present in a wide variety of fruits and vegetables. A dosage of 40 mg per day is advised for adults by the UK National Health (Dommisch et al., 2018). In a multicenter, parallel-group, controlled clinical research with 300 gingivitis patients, Shimabukuro et al. found that using toothpaste containing magnesium salt and vitamin C can lessen gingival inflammation. This toothpaste showed noticeably greater activity against reactive oxygen species than regular toothpaste, which may be linked to the development and progression of gingival inflammation (Shimabukuro et al., 2015).

Dyslipidemia is the result of oxidative stress inflammation of the liver cells. Due to its potent antioxidant properties, vitamin C (ascorbic acid) may help prevent NAFLD (Caritá et al., 2020). Additionally, ascorbic acid is linked to the control of adiponectin, which slows down hepatic cell inflammation and lipid buildup in the liver, potentially reducing the risk of nonalcoholic fatty liver disease (Rose et al., 2010). A moderately inverse relationship between dietary vitamin C intake and non-alcoholic fatty liver disease (NAFLD) was found in middle-aged and older persons, particularly in the male and non-obese populations, according to a cross-sectional study on the subject (Wei et al., 2016).

Iron

The most prevalent metal on Earth is iron (Fe). It is a micronutrient that is sufficient for normal health when taken daily at milligram levels. Malnutrition-induced iron deficiency is a worldwide health concern, even with such a low dietary need. The average adult human body contains about 4 g of iron, of which roughly half is found in hemoglobin, 25% is kept in the liver, and the remaining portion is made up of myoglobin and other proteins that contain iron (Nadadur et al., 2008). Iron plays a crucial role in the bloodstream's ability to carry oxygen from the lungs to the tissues. Myoglobin, a related protein found in muscle, stores oxygen for usage during muscular contraction and also includes iron. Iron is concentrated in the area of the cell that produces energy and serves as a cofactor for several enzymes, including cytochromes, catalase, and succinic dehydrogenase. Fe influences glucose metabolic processes, while glucose metabolism influences several iron metabolic processes. The interaction is reciprocal. Insulin is an anabolic hormone and increases the uptake of a variety of nutrients by cells, such as hexoses, amino acids, cations, and anions (Fernández-Real et al., 2002). Iron negatively affects endothelium and speeds up the development of atherosclerosis, increased iron availability is a contributing factor to macrovascular disease. As atherosclerotic plaque develops, ferritin gene expression rises (Habib and Finn, 2014). Depletion of iron is beneficial for coronary arteries (Fernández-Real et al., 2002).

Zinc

Zinc has a crucial duty in everyday living body processes in different forms (zinc ion, zinc transporters, zinc albumin complex). Zinc is a vital trace element that serves as a catalyst in our bodies. It also works as a regulatory ion. It is included in homeostasis and in immune response. Zinc-binding proteins are performing function under stress, in exposure to oxidative metal (Stefanidou et al., 2006). Role of zinc in signal transduction, importance of zinc for immune cell function, and competition for zinc between host and pathogen known as nutritional immunity (Mayer et al., 2014). Zinc causes chronic diseases in our body like bronchial asthma, rheumatoid arthritis, and Alzheimer's disease (Tudor et al., 2005). Zinc causes bronchial asthma by participating in oxidant by acting as a co-factor for the enzyme superoxide dismutase, with antioxidant properties. Symptoms of asthma show by lack of zinc (Cheng, 2024).

Zinc has been linked to a possible role in the pathogenesis of Alzheimer's disease (AD), but a causal role in AD has not yet been definitively demonstrated. At present, the role of zinc in the development of AD is unclear (Shcherbatykh et al., 2007).

Vanadium

Vanadium is a tracing mineral. The body needs to take a small amount of vanadium for normal bone growth. It causes various diseases in humans like physical abnormalities, swollen joints, skeleton deformation, retard growth, impairment of reproduction, and metabolic disruption.

Inhalation of vanadium particles can cause respiratory irritation, bronchitis, asthma, rhinitis, coughing, and wheezing (Rehder, 2013). Vanadium inhalation affects the respiratory tract, enters the stomach and is absorbed in the intestine causing gastrointestinal diseases like nausea, diarrhea, abdominal pain, and vomiting. It increases the risk of kidney, lung, and liver cancer. Vanadium particles are genotoxic, teratogenic, and suspected carcinogens and its particles cause the formation of tumors (Gorzsás et al., 2006).

The National Health and Nutrition Examination Survey study participant's estimated average mineral requirements by age and sex were used to assess micronutrient deficiencies from 2007 to 2018 has been presented in Table 1.

Macronutrients

Following are the roles of macronutrients in chronic disease prevention.

Carbohydrates

One of the 3 critical macronutrients required to hold human health, carbohydrates are essential for power production and metabolism. While fed on as a part of a balanced weight reduction, they function as a supply of power and may appreciably lessen the threat of ailment (Clemente-Suárez et al., 2022).

Table 1: Minimum Bod	y Micronutrient Re	quirement according	g to age and sex (Ila	ayan et al., 2024)
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Age (Men)	Vitamin A (µg/d)	Vitamin C (mg/d)	Vitamin E(mg/d)	Zinc(mg/d)	Iron (mg/d)	Magnisium (mg/d)
19-30 y	625	75	12	9.4	6	330
31-50 y	625	75	12	9.4	6	350
51-70 y	625	75	12	9.4	6	350
>70 y	625	75	12	9.4	6	350
Women						
19-30 y	500	60	12	6.8	8.1	255
31-50 y	500	60	12	6.8	8.1	265
51-70 y	500	60	12	6.8	5	265
>70 y	500	60	12	6.8	5	265

Prevention of diabetes relies upon the type of carbohydrate absorbed. Nutritional fiber is present in grains, culmination, and vegetables improving insulin sensitivity and glycemic management. Carbohydrates with high glycemic index purpose high blood sugar levels resulting in insulin resistance that leads to type 2 Diabetes (Reynolds et al., 2019).

Regardless of total weight loss, a diet that was only limited in carbohydrates reduced liver fat more than a diet that was restricted in calories (Browning et al., 2011)

Complete grain consumption has acquired special attention. Each greater serving of complete grains daily reduced the danger of coronary heart sickness by using 9 %, in step with a scientific overview (Aune et al., 2016). Improved cholesterol metabolism, blood strain manipulation, and nutritional fiber properties are the elements at the back of this advantage (Soliman, 2019).

Dietary carbohydrates impact intestine microbiota, oxidative pressure, and insulin ranges, all of which result in cancer danger, due to the fact excessive GI meals affect insulin and insulin-like growth aspect pathways, they were related to an extended danger of some malignancies, along with breast and colorectal cancer (Doaei et al., 2019).

Alternatively, diets excessive in resistant starch and dietary fiber are linked to a decreased threat of colon cancer. The preventive effect of dietary fiber on the development of most cancers is steady with the consequences of a meta-analysis of a huge sample published by means of Andrew Reynolds in the Lancet, which confirmed a 13% reduction of most cancer mortality in folks who consumed the maximum dietary fiber in comparison to people who ate the least (Hu et al., 2023).

High-fiber diets improve the diversity of the microbes inside the intestine, which enhances immunity and lowers infection. This may reduce the risk of inflammatory bowel disorders and even systemic situations like type 2 diabetes and obesity. Following the analysis, people who eat numerous nutritional fibers had lower fees for gastrointestinal conditions such as diverticulitis and irritable bowel syndrome (IBS) (Slavin, 2013).

Notwithstanding having the same calorie intakes, a randomized controlled trial confirmed that people following a high-fiber weight reduction lost more weight and improved their metabolic indicators extra than the ones following a low-fiber weight loss (Waddell and Orfila, 2022).

Protein

Proteins are composed of amino acids and serve a wide array of capabilities inside the human frame, which includes enzymatic catalysis, transportation, structural aid, and signaling. Those capabilities are critical to maintaining fitness and preventing diseases starting from infections to chronic disorders which include diabetes and cardiovascular diseases. Their function in ailment prevention can be extensively classified into direct and oblique mechanisms. The immune system depends upon protein for its function, Cytokines, antibodies, and complement proteins are vital in the protection of the body against infectious agents. Proteins like insulin are important in glucose law. Additionally, nutritional proteins can assist in maintaining muscle groups and regulate blood sugar degrees. Research in human beings has shown that whey protein decreases postprandial glycemia and could be used in medical/nutritional therapy to regulate blood sugar (Lesgards, 2023).

Conclusion

Based on the above-mentioned review, it is postulated that micro and macronutrients play significant roles in preventing chronic illnesses like diabetes, cancer, and fatty liver disease. Even a low quantity of Cr is toxic to the body and can result in cancer. Mg clear receptor sites for insulin uptake thus can help to prevent diabetes. Vitamin A deficiency may increase vulnerability to specific types of chemical carcinogenesis. Vitamin E plays an important role in the early phases of cancer. Vitamin E may have antitumor proliferative and anticancer properties through modifying gene expression. Protective action of vitamin C is the inhibition of the production of carcinogenic nitrosamines in the stomach.Fe influences glucose metabolism, while glucose metabolism influences some iron metabolic processes. Zinc is crucial for all processes in the human body absence of zinc releases adverse effect on the immune system. Role of zinc in signal transduction, importance of zinc for immune cell function, and competition for zinc between host and pathogen known as nutritional immunity. Inhalation of vanadium particles can cause respiratory irritation, bronchitis asthma, rhinitis, coughing, and wheezing. Carbohydrates normal intake helps prevent obesity, and diabetes and increase immune function. Proteins are involved in preventing cancer.

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