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MALNUTRITION AND IMMUNE SYSTEM DYSFUNCTION, AN IMMUNOLOGICAL PERSPECTIVE: STRATEGIES FOR IMPROVEMENT OF IMMUNE SYSTEM

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Abstract
This study explores the critical relationship between child malnutrition, immune system function, and susceptibility to infections. The immune system, consisting of various cells, tissues, and organs, works through innate and adaptive mechanisms to protect the body. Proper nutrition, including essential vitamins, minerals, and bioactive compounds, is crucial for maintaining immune health. Malnutrition, both undernourishment and obesity, weakens immune responses, increasing vulnerability to infections and diseases. Undernourishment, driven by factors like poverty, poor food access, and inadequate healthcare, significantly affects children's physical and cognitive development, contributing to high mortality rates. Conversely, obesity, another form of malnutrition, leads to chronic inflammation and impaired immune responses. Effective strategies to combat malnutrition include improved nutrition education, healthcare access, and community support. Addressing malnutrition's root causes, such as socio-economic disparities and food insecurity, is essential for improving global health outcomes. The WHO's guidelines on undernutrition and interventions targeting childhood malnutrition are vital steps toward alleviating the burden of malnutrition and promoting long-term health in children. This paper explores the link between Protein-Energy Malnutrition (PEM) and nutrient deficiencies, particularly in underdeveloped regions. PEM weakens immune responses, making individuals more susceptible to infections and diseases. It also highlights the need for nutritional intervention in children and HIV-infected populations. The paper also discusses the impact of micronutrient deficiencies on the immune system, particularly in HIV-infected populations and undernourished children in Sub-Saharan Africa. Micronutrients like selenium, zinc, magnesium, and vitamins are crucial for immune function and metabolism. The paper suggests the potential benefits of micronutrient supplementation in enhancing immune function and combating malnutrition. Further research is needed to understand the therapeutic role of supplementation in improving health outcomes in malnourished populations.

INTRODUCTION

The immune system

Several components make up the immune system including cells and tissues and internal organs that work mutually to shield the human body from various threats. The system operates via two distinct mechanisms which include innate and adaptive parts (La Barre, 2011). The skin with white blood cells create physical barriers which rapidly react to multiple infections through the innate immune system. Previous exposures to infections become memories that adapt the specialized adaptive immune system to produce targeted rapid responses during future infections. Health and wellness depend on the life-preserving properties of the immune system. The immune system maintains food defense by correctly distinguishing safe dietary nutrients from possible toxic substances (Özdemir et al., 2022). The gut-associated lymphoid tissue functions as a vital element which oversees and reacts to chemicals that enter the digestive system. Because of their developmental stages children possess immune systems which differ notably from those in adults. Children interact with many new viruses while exploring their environment and attending school as well as when connecting with others. Adjustments in the immune system occur during long-term contact with antigens which leads to creation of multiple diverse immune cell types (Mahmoudi & Rezaei, 2019).

The immunological system in children operates quickly against sickness which produces fever along with a higher number of defense cells. The immune systems of children tend to be durable yet exposure to specific infections might threaten them even though they develop with age (Molecular Biology of the Cell, 2002). A functional immune response depends entirely on receiving appropriate nutrition. A strong immunological response depends on eating the proper amounts of vitamins C D and E and minerals zinc and selenium along with bioactive chemicals (Medicine & Research, 1999). Drastic nutritional deficiencies in these vital substances make the immune system weaker and raises infection risks. Scientific studies indicate that eating plant-based meals containing antioxidants together with anti-inflammatory substances increases immunological function. People with healthy gut flora can obtain it from yogurt and other fermented foods while improving their body's immune system (Premkumar, 2014). A well-balanced immune system functions through delicate component interaction while being strongly influenced by what people eat. A dietary plan that includes balanced nutrients helps both immunological and overall system wellness. This study evaluates the relationship that exists between child malnutrition and their immune system together with their susceptibility to infections. The techniques provide nutritional benefits that strengthen a person's overall health (Salvi & Hajek, 2019).

MALNUTRITION

Undernourishment

Body functions together with growth decrease when people lack essential nutrients. Each of these factors including inadequate food availability and poor nutrient absorption and economic reasons and illnesses play a role in undernourishment. Undernourishment cripples the immune system by blocking numerous defense methods which prevent infections from attacking the body (Biswas & Pinstrup-Andersen, 1985). Undernourishment represents a risk factor with poverty and inadequate food access as well as unhealthy eating habits along with health issues and lack of knowledge. Childhood malnutrition functions as a major health risk that increases global disease load as well as illness severity and death rates in underage children. Over 65 percent of worldwide deaths happen among infants within their first year of living (Romieu et al., 2018).

Child malnourishment affects the world because it stems from inadequate nutrition combined with socio-economic difficulties and social inequality. Physical development and cognitive growth of children suffer reduction because of malnutrition which then affects their overall health status. The combined factors of food insecurity together with limited access to healthy food and insufficient healthcare services lead to child malnutrition (D'Odorico et al., 2018). The risk of diseases increases in combination with reduced intellectual capacity leading to higher death rates among malnourished children. Malnutrition impacts whole communities as well as societies while restricting economic development and making it more difficult for people to escape the continuous cycle of poverty

(Fund, 2007). Infant malnutrition requires multiple solutions which combine strategic measures for nutrition education with healthcare systems and clean water access alongside education access. Raising community awareness about disadvantaged families through support efforts must occur at the same time as global initiatives to fight hunger while advancing sustainable agriculture systems. The process of prioritizing children's nutrition needs coupled with solving the basic sources of malnutrition leads to a world with empowered generations who achieve their full potential. The WHO is creating a new guideline for undernutrition control and prevention. A holistic worldwide plan dedicated to fighting acute childhood malnutrition in children under five years applies nutrition services while developing healthcare systems (Bulletin of the Atomic Scientists, 1985). The care of children stands as the main principle which nursing and home menu development require for success. An intervention program focuses on child under-five-year-old malnutrition and nutritional edemas through milk supplementation combined with rehydration and hydrolyzed formulas or ready-to-use therapeutic food. The WHO is creating a new guideline for undernutrition control and prevention (Ministers, 2014). A holistic worldwide plan dedicated to fighting acute childhood malnutrition in children under five years applies nutrition services while developing healthcare systems. The care of children stands as the main principle which nursing and home menu development require for success. An intervention program focuses on child under-five-year-old malnutrition and nutritional edemas through milk supplementation combined with rehydration and hydrolyzed formulas or ready-to-use therapeutic food (Black et al., 2016).

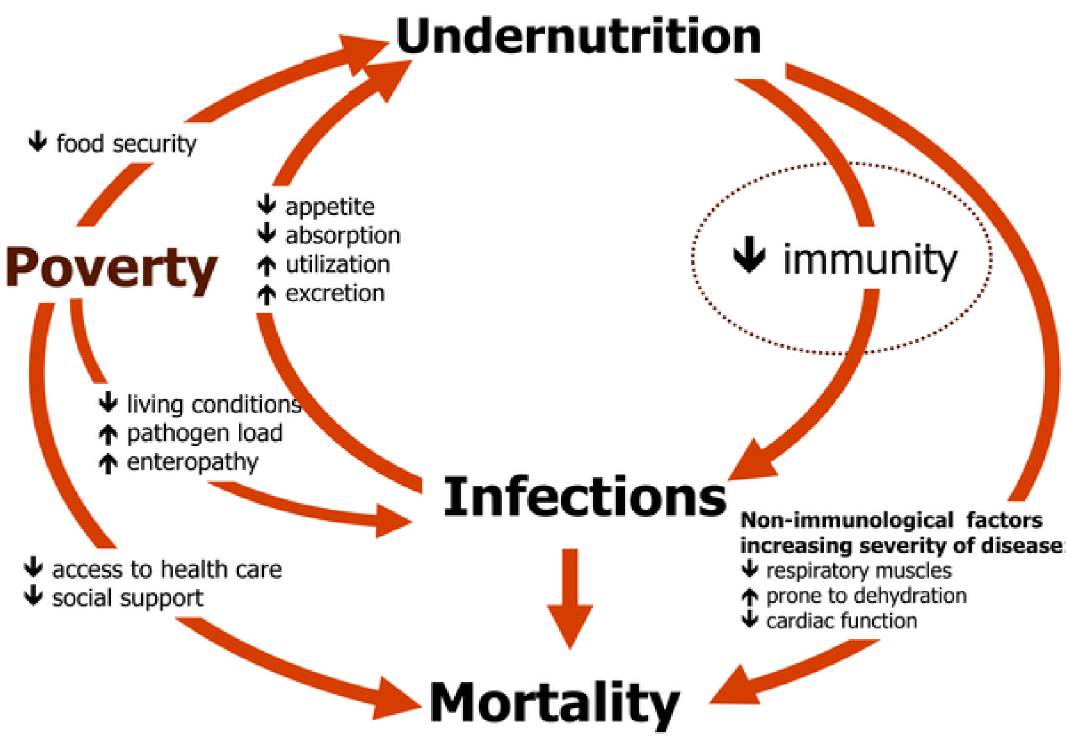

Figure 1. Conceptual framework on the relationship between malnutrition, infections and poverty.

Overweight and obesity

The condition of being overweight or obese represents malnutrition even though children receive excessive food. Overweight along with obesity develops when someone eats improperly and lacks physical activity or when it involves genetics or medical explanations. Persistent inflammation acts as a result of these disorders thus affecting immunological function (Organization, 2015). People with high body mass indexes along with belly obesity become more likely to get sick because these conditions alter their immune system response which reduces how effective vaccines become. Sedentary lifestyle together with poor diets represent major risk elements according to research (Hu, 2008).

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Primary healthcare facilities throughout low- and medium-resource sectors obtained new assessment and management guidelines from WHO in 2017. Primary healthcare facilities should implement two recommendations which instruct healthcare professionals to both deny additional foods to mildly malnourished children and stunted infants along with providing nutritional education to parents of overweight kids under age 5. Children who come from undernourished backgrounds which include low birth weight or stunted growth or improper weight gain in preschool and school subsequently become obese in their later years (Nations et al., 2020).

IMPACT OF MALNUTRITION ON IMMUNITY AND INFECTION

PEM represents one form of malnutrition while nutrient deficiency constitutes another cause. Underdeveloped nations experience malnutrition as their prime medical cause responsible for the highest incidence of health issues and fatalities among pregnant mothers and children under five years of age (1). Failing immune strength caused by malnutrition creates pathogenic susceptibility which leads to death (Ezzati, 2004).

Unknown researchers predicted that 852 million people became undernourished from 2000 to 2002 yet most of them (815 million) resided in developing regions especially southern Asia and Sub-Saharan Africa (Mathers & Organization, 2008). Death is one possible outcome of malnutrition yet the condition simultaneously heightens infection risk while ranking as a major factor when diseases coincide for sickness and mortality rates. It directly leads to the death of 300,000 people each year while contributing to half of the deaths reported in young children. The studies demonstrate that severe malnutrition makes individuals more susceptible to mortality (Holmes et al., 2017). UTF remains concentrated throughout populations that exist in poverty thereby contributing to their high prevalence rates of PEM. A number of factors create malnutrition such as socioeconomic and political instability together with impaired education and unsanitary conditions and poor food practices and breastfeeding habits and ineffective nutrition programs (Experts, 2019).

Immunological suppression coexists with malnutrition so that infections produce major consequences for nutritional care. The presence of gastrointestinal parasites in human bodies leads to diarrhea development as well as the reduction of red blood cells and decreased dietary element uptake. Cachexia together with anemia accompanies common chronic illnesses which include Aids and tuberculosis (Koletzko et al., 2015).

The condition of PEM in children exists when their measured metrics fall below two standard deviations from the typical size metrics for their age group for weight relative to age (underweight), height according to age (stunting), and weight relative to height (wasting). The prevalence rate for underweight children under 5 amounts to 31% in underdeveloped countries while stunting affects 38% and 9% experience wasting (Black et al., 2016b). Children suffer most from severe malnutrition due to which these conditions develop: severe wasting and marasmic kwashiorkor with edema and kwashiorkor. The body's normal response to energy allocation causes the loss of subcutaneous fat together with muscle tissues during marasmus development (Development, 2000). The clinical presentation of this condition includes a triangular facial appearance together with delayed menstruation and both enlarged abdomen and anal and rectal prolapse.

The combination of Kwashiorkor leads to edema together with hair and skin color alterations and anemia and hepatomegaly and lethargy as well as fatal immunodeficiency and early death. Multiple organs experience fat degradation as one of the primary features of severe PEM (Laskaris, 1994). The situation requires immediate medical intervention because it develops into cardiac insufficiency. Body temperature regulation together with water storage ability becomes compromised when subcutaneous fat loss occurs since this results in dehydration and hypothermia and hypoglycemia. Small intestinal atrophy because of PEM results in worse absorption and digestibility (Mba & Hobbins, 2008).

PROTEIN-ENERGY MALNUTRITION:

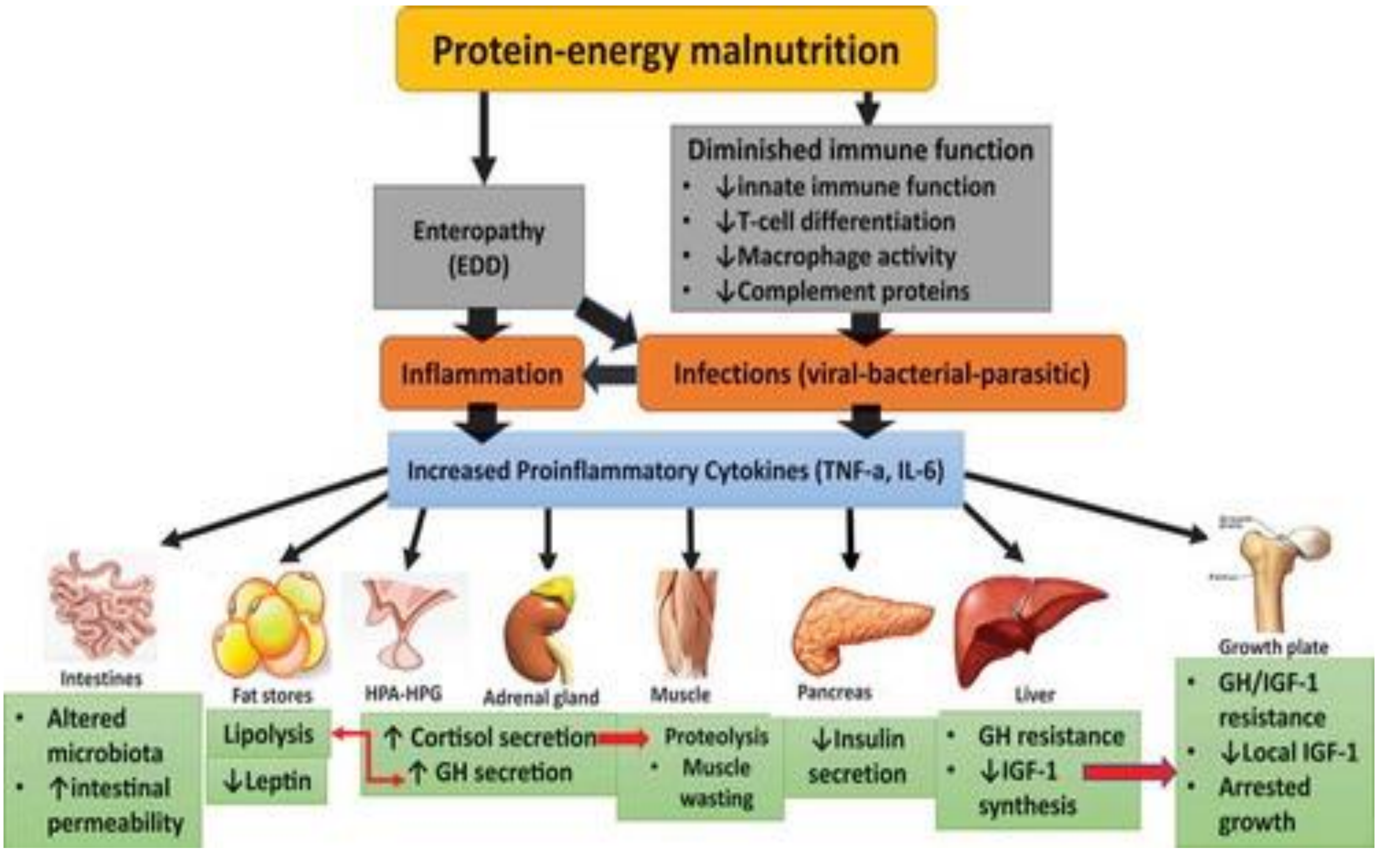

Figure 2. Malnutrition, infection, and inflammation interactions

Medical professionals frequently equate malfunction and Protein-Energy Malnutrition (PEM) as one condition. PEM represents an incorrect terminology because it occurs frequently without micronutrient deficiencies including vitamins and minerals which creates intricate conditions for medical diagnosis (Morley et al., 1995). Laboratory research that reduces dietary protein intake while preserving standard dietary quality leads to multiple physical manifestations common in undernourished humans. When subjected to a 1-2% protein diet the condition becomes severe which simultaneously delays growth of the body weight. When individuals consume low protein amounts together with suitable calorie intake they do not lose body weight substantially due to muscle preservation. The occurrence of wasting leads to elevated fat production while simultaneously causing edema to develop (Nations et al., 2019). Thus, biochemical measures in blood (e.g., The measure of serum albumin acts as a key element for determining whether PEM continues present in a patient. Human starvation exists worldwide throughout developing nations along with modern countries. Two main negative outcomes result from malnutrition which involve respiratory tract infections and diarrhea that cause high death rates together with severe illness (Olson, 2012). The current research on PEM-related immune response studies linkages between T and B lymphocytes focused on both intestinal and salivary immune mechanisms. Scientists concentrate on developing immunoglobulin A (IgA) as a molecule that stops germs and allergens from entering the body. Prevention of malnutrition remains possible despite the multiple factors that lead to its development. PEM shows partial reversal capacity which the immune system can activate (Tomkins & Watson, 1989).

IMPACT OF HIV INFECTION ON NUTRITIONAL STATUS.

Metabolic changes produced by HIV infection result in elevated protein metabolism along with elevated hepatic protein production and skeletal muscle wasting and triglyceride increases with hepatic fatty acid production and impaired lipoprotein enzyme activities and blood glucose elevation with insulin resistance and elevated sugar synthesis. The average adult patient with HIV does not show signs of lean body mass reduction. (Saltiel & Pessin, 2007). Development failure is common in HIV-positive infants and early children who do not have other infections because they cannot synthesize lean tissue effectively and control protein breakdown. Reduced food consumption is a result of HIV infection because appetite loss combines with drug side effects and oral lesions along with feeling depressed and the extreme poverty common in Nigerian communities (Dumais, 2020). The use of nutrients by HIV-infected patients is enhanced through metabolic changes alongside nutrient malabsorption of fats, fat-soluble vitamins and carbohydrates. Weight loss in individuals with HIV occurs mainly due to reduced appetite along with cytokine-caused metabolic dysfunctions that secondary infections may intensify (Organization & Fao, 2004). The proper balance of inflammatory factors including IL-1 and IL-6 is essential. The expression levels of HIV increase with TNF and IL-18 yet anti-inflammatory and regulatory cytokines potentially have protective effects (Hoenigl et al., 2020).

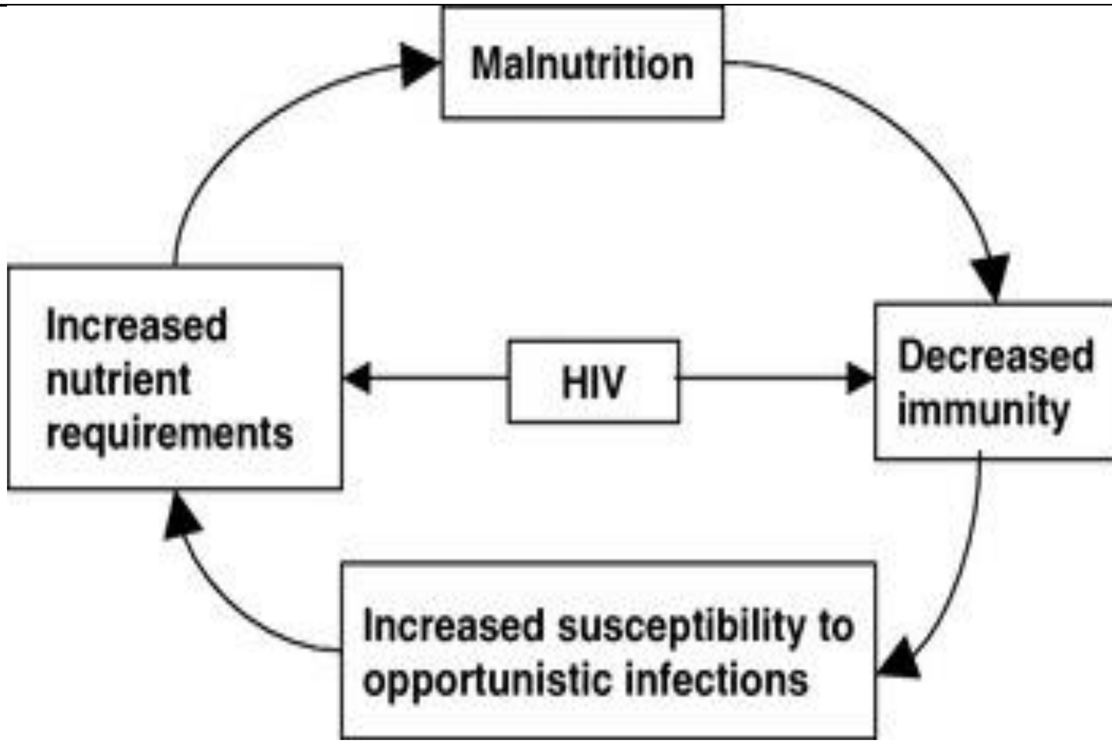

Fig. 3. Vicious cycle of HIV and malnutrition.

DEFICIENCY OF MICRONUTRIENTS AND OXIDATIVE STRESS

Micronutrient deficiency manifests as a usual symptom of HIV infection and its related pandemic mainly among rural Nigerian populations who cannot obtain sufficient nutrition. Among the depleted micronutrients are selenium combined with zinc along with magnesium and vitamin E and cyanocobalamin and retinol and vitamin C and folic acid and niacin and 1,25-dihydroxycholecalciferol (Hurrell & Organization, 2006).

A study revealed that deprived Nigerian children who do not have HIV suffer from micronutrient deficiencies as documented by research groups. The same level of glutathione (-glutamyl-cysteinyl-glycine) depletion occurs in undernourished African children both with and without HIV (Food et al., 2006). Each of these microelements performs several vital functions related to immunology, tissue structure maintenance, DNA formation along with blood cell development plus various biological and metabolic events (Vernet, 1992). The antioxidant defense system depends heavily on micronutrients and shows extensive deterioration in HIV-positive patients because of oxidative stress. HIV infection lowers the concentrations of essential selenoproteins in T cells among the known 35 proteins. Selenoproteins play major roles in redox functions (Malavolta & Mocchegiani, 2018). Harmful lipid and phospholipid hydroperoxides become inactive compounds through the work of selenium-dependent glutathione peroxidases. This same effect has been shown in laboratory tests where selenium stops HIV-1 from proliferating. HIV-positive females have an increased probability of sexually transmitting the virus to their partners when they maintain lower selenium levels as compared to females keeping higher selenium levels. The quick spread of HIV-1 in Sub-Saharan Africa might result from dietary selenium deficiency (Risher, 2011). Patients dealing with HIV display survival deficiencies because of abnormal plasma selenium levels and glutathione (GSH) amounts as well as reduced plasma peroxidase function. During inflammatory conditions as well as with HIV infection or through malnutrition the depletion of glutathione leads to increased selenium consumption because of oxidative stress (Dumais, 2020b). The studied biological actions of this small thiol molecule extend from antioxidant protection to immunological control and harmful substance breaking down of electrophilic toxins. GSH functions to stop inflammatory mediators together with other factors from triggering NF-9B thus leading to viral replication. 4 Studies show N-acetylcysteine supplementation helps boost glutathione production in extremely malnourished children's red blood cells (Morales-Gonzalez, 2013).

Free radical scavenging duties are performed by various micronutrients including as tocopherol, ascorbate and $-carotene according to multiple publications. Previous research demonstrated that vitamin C uses glucose transporter 1 (Glut 1) to enter the mitochondria before protecting them from oxidative damage (Carr & Lykkesfeldt, 2018). The production of reactive oxygen species occurs substantially in cells through mitochondria. Evidence collected through observational research in Sub-Saharan African countries demonstrates that maternal vitamin A health status determines how frequently HIV transmission occurs from mother to child during pregnancy (Mba & Hobbins, 2008b). The measurement of serum retinol below 1.4: mol/L may cause increased vaginal DNA viral loss. Studies indicate that anti-retroviral therapy combined with exclusive breastfeeding present the most efficient methods to stop the transmission of virus from mothers to their children (De Quadros & Organization, 2004).

STRATEGIES FOR IMPROVING IMMUNE FUNCTIONS:

PROTEIN SUPPLEMENTATION

Undernourishment

Protein supplementation helps protein-energy malnutrition patients recover their weakened humoral and cell-mediated immune function or immunity. Maternal deprivation creates epigenetic changes that scientists connect to nutritional influences on developing immunity in the offspring even before conception. Medical interventions along with optimal nutritional care must happen during the first 1000 days which start at conception to age two for reaching full immune capacity (Development, 2000b). Ready-to-use therapeutic foods are solid dietary products developed through modifications of F-100 liquid diet formula making up the WHO standard treatment for severe acute malnutrition catch-up remedy for children. Weight growth obtained positive results in both severely and moderately malnourished adults and children from the completed products (Koletzko et al., 2015b).

Analysis of dietary substances on the immune system by various authors revealed both the potential to create specific immune responses as well as effects on children's immunometabolic health status. The immune system of kids who lacked protein energy improved following treatment with curd and leaf proteins according to research found in (Egbuna & Hassan, 2021). The researchers evaluated vitamin and mineral supplementation effects on malnourished children (n=80) with protein-energy abnormalities (mean age: 24.91±11.13 months) through measurements of their nutritional condition and immune status using anthropometric and hemoglobin and ferritin tests and T-cell subpopulations and C-reactive protein testing. The intervention treatment both improved weight together with hemoglobin levels and CD4:CD8 T-cell counts simultaneously reducing serum ferritin levels (Mehta & Finkelstein, 2018).

The experts propose that the immune systems of malnourished children receive advantages from these substances that could reduce recovery time. Scientists require more studies to validate these research results in broader patient groups. A research examined the immune system responses of infants who received treatment according to the WHO guideline (Medicine et al., 2010). The researchers examined how extreme malnutrition influenced the natural defenses of children when compared to regular children. The research analyzed twenty children who included ten extremely malnourished and ten healthy, under two-year-old individuals. The WHO nutritional rehabilitation program started for this malnourished group (Bhatia et al., 2013). The phagocytic function improved and oxygen radical emission increased as well as the lymphocyte count reduced during a 30-day intervention period for the malnourished participants. The lymphocyte and free radical production rates in undernourished children were lower than those of healthy children. Future studies must establish whether continuing nutritional treatments can effectively manage the immunodeficiency in patients and normalize their immune system profiles to match average young children (Administration, 1970).

Overweight and Obesity

Roth et al. examined the influence of reducing fat and sugar intake on cardiovascular risk factors, insulin resistance, and inflammatory markers in obese children, as well as their relationship. The study compared obese children (n = 115, average age 10.7 years) to normal-weight youngsters as a control group. During the one-year intervention, only 62 participants could be followed up. The authors found clear relationships between BMI, resisting, and monocyte chemo attractant protein-1 (Romieu et al., 2018b). Adiponectin interacts with several inflammatory mediators, such as TNFα, IL-1β, IL-6, and IL-8. Correlations existed between body weight and the four inflammatory cytokines along with IL-1β and IFNγ and IL-6 as well as IL-8 and TNFα. Metabolic risk factors maintained a strong relationship with children's immunometabolic status during initial testing as well as testing performed after weight modifications (Cao, 2013). A combination of hypocaloric diet and moderate physical activity provided beneficial effects for 50 obese children throughout a 6-month period according to Garanty-Bogacka et al… The participants in this study had a mean age of 14.2 years. The authors monitored both weight reduction and serum concentrations of inflammatory markers that included high-sensitive C-reactive protein and IL-6 and fibrinogen as well as white blood count, glucose, insulin, insulin resistance index (HOMA IR), glycosylated hemoglobin (HbA1c), lipids and systolic and diastolic blood pressure(Feng et al., 2024). The treatment intervention yielded an average weight reduction of 5.3 ± 3.4 kg together with reduced levels of serum IL-6 and C-reactive protein and white blood count and fibrinogen. Research demonstrated that the changes in cholesterol and triglyceride levels related statistically to measured alterations in body fat percentage and HOMA-IR scores (Bouchard & Katzmarzyk, 2010). Additional studies must verify how apparent connections between this intervention and improved insulin resistance affect obesity prevention. A research at Mexican hospitals observed lower B cell numbers and major alterations in leukocyte subtype distribution among obese mothers' colostrum. The neutrophils had increased proportions (up to 5 times higher) because of changes in cell size and internal complexity and altered CD45 and CD16 surface expressions. The study seeks to investigate the effects that alterations in colostrum produce on the children who ingest it (Ministers, 2005).

PROBIOTICS

Undernourishment

When consumed as a probiotic bacterium Lactobacillus manages immune functions in the intestinal mucosa. The health benefits from probiotics appear most strongly when treating diarrhea which serves as the main contributor to nutritional deficiencies. Rocha-Ramirez et al. investigated how heat-killed Lactobacillus casei modified macrophage immunological reactions in malnourished children (Shah, 2017). A research team investigated how malnourishing conditions affected in vitro cellular responses of monocyte-derived macrophages MDMs extracted from healthy and malnourished children and well-nourished infected children. Scientific findings reveal that the bacteria enhances TNFα, IL-1β, IL-6 and IL-10 cytokine production along with upgraded phagocytosis capability and bacterial killing effects on immune macrophages(Sergi, 2020). The consumption of Lactobacillus acidophilus through clinical research in Ethiopia led to improved immune cell counts in malnourished children within the age group of 7-8 years according to study results. The subjects required two monthly doses of Lactobacillus consumption to control lactose intolerance and diarrhea symptoms during the 35-40 day feeding period (Muehlhoff et al., 2013).

Overweight and Obesity

Overweight and obese children and adolescents received testing of a human Lactobacilli and fructo-oligosaccharide supplement to evaluate its anti-inflammatory properties in relation to gut microbiota and immune system functions according to Kelishadi et al. A random triple-masked controlled study including 70 participants aged 6 to 18 months was used for the investigation (Arora et al., 2019). A study duration of eight weeks served to administer the test item. The supplementation procedure resulted in decreased TNFα and IL-6 levels together with elevated adiponectin. The research results depended on the participants achieving weight reduction. The research demonstrated that consuming bifid bacterium pseudocatenulatum CECT 7765 with insulin-resistant obese children led to curative outcomes for their inflammation (Camara et al., 2021). For thirteen weeks researchers provided 48 obese participants between 10 to 15 years old probiotic capsules at 109-10 CFU concentration. The research protocol led to substantial effects on circulating high-sensitive C-reactive protein and monocyte chemoattractant protein-1 levels as well as changes in microbiota composition (Villena & Kitazawa, 2018).

MACRONUTRIENTS

Vitamin A

The anti-infective properties of Vitamin A were established in 1932 for reducing death from measles. Trials performed in Ghana together with Indonesia and various developing nations have proved that vitamin A supplementation effectively reduces the severe effects of infectious diseases particularly measles and diarrhea. Research has conducted two clinical trials to evaluate whether vitamin A supplementation affects the development of malaria. Vitamin A supplementation did not affect malaria morbidity in Ghana according to research but studies in Papua New Guinea showed children who received vitamin A had fewer malaria cases (Semba, 2013). Studies report that vitamin A supplementation has a potential effect in reducing placental infections. Supplementary Vitamin A has been proven to reduce infections found in the placenta. Scientists still need to determine if supplementing with Vitamin A impacts immunity response together with other defenses such as epithelial safety (Vitamin E in Health and Disease, 2021).

Laboratory tests demonstrate that the major oxidation product of Vitamin A known as retinoic acid drives immunological reactions toward Th2 in mice. Research data shows that retinoic acid creates an improved antibody response for antitetanus antibodies. The research data shows unclear results regarding an immune system enhancement response in human subjects (Beattie, 2006).

Scientists performed extensive evaluation on this evidence during the recent period. The research study indicates that vitamin A strengthens epithelial integrity in the intestine (68) while failing to impact antibacterial properties in breast milk or vaginal protection (Watson & Preedy, 2015).The initial studies show that certain infections lead to reduced TNF-α and IL-6 output. Evidence shows modest improvement of CD4 counts while receiving vitamin A supplementation. Counts in HIV-positive children, but not in adults. Lack of reliable scientific evidence confirms that vitamin A does not influence cytokine output. Healthcare providers can achieve better antibody responses to tetanus toxoid after giving vitamin A as a pretreatment (Fulop et al., 2009). There is currently no available information about how vitamin A affects the immune system even though it successfully reduces childhood mortality from measles and diarrhea. The primary role of vitamin A depends on the condition of epithelial barriers and protective tissues (Medicine & Deficiencies, 1998). HIV-infected pregnant women consuming the combined vitamins B, C and E and vitamin A showed reduced benefits when the vitamin A supplement was added which demonstrates the potentially negative effects of vitamin A despite increased cell-mediated immune responses(Medicine & Research, 1999b).

Zinc

Research studies show that zinc helps operate the immune system because it plays an essential role in immune system function. Zinc functions to prevent cases of diarrhea. Research based on nine studies [6] revealed diarrhea incidence decreased by 70% statistically. The clinical trials suggestive of improvement in pneumonia and malaria severity appear in limited numbers (Mills, 2013). The use of zinc decreases mortality rates in diarrhea patients by 42% (95% CI 10-63%) although high doses could potentially cause problems. Research results show that zinc supplements decrease malaria incidence by 36% (95% CI 9-55%) in clinical trial monitoring. The research found no improvement in malaria disease incidence and severity rates (Chen, 2012). Researchers have found that zinc supplementation helps reduce both morbidity rates and mortality from diarrhea and malaria at the childhood stage. What area of the body does this modify between immunity and host defense?

The available evidence shows that deficient zinc levels harm the immune system while supplementing leads to improvements. Although researchers studied human subjects in the 1970s the evidence was insufficient to establish this premise. Acrodermatitis enteropathica patients who have a natural deficiency of zinc absorption show reduced thymus size along with fewer immune cells and weakened lymphocyte reactions to additives and lower skin responsiveness and antibody responses (Hurrell & Organization, 2006b). The evaluation of immunological deficiencies becomes difficult in zinc-deficient patients because kidney dysfunction combined with zinc deficiency reduces immune system performance. Research investigating Indian child diarrhea discovered that supplementing their diet with zinc allowed CD3 and CD4 cells to increase in circulation without impacting CD8 cells or B cells and NK cell (Mba & Hobbins, 2008c). Paneth cells depend on zinc for their antibacterial defense functions in protecting the human small intestine. A thirty-day zinc deficiency in mice reduced cell-based immune responses, DTH reactions, antitumor immunity and antibody responses to an 80% decrease. Low-dose Trypanosoma cruzi and intestinal nematodes exposure in zinc-deficient animals resulted in death for 79 percent of the affected animals. There were fewer lymphocytes throughout the deficient state because lymphopoiesis was reduced yet individual cellular antibody production remained unaffected (Bhunia, 2007).

The researchers proposed a substantial hypothesis that described how zinc deficiency predominantly affects lymphoid cell populations without influence on myeloid cells according to Fraker et al... The proper function of lymphocyte cells needs both zinc and multiple vitamins at sufficient amounts (Molls et al., 2009). Active defenses have higher priority in nutritional stress situations compared to adaptive immune responses. The concept presented by Fraker needs further scientific examination. Confirming this potential discovery would lead to important findings regarding the treatment of infectious diseases in malnourished patients (Friedman et al., 2012).

Zinc deficiency diminishes NK cell activity and macrophage phagocytosis and it might stem from reduced oxidative burst capacity which occurs in trypanosomiasis. Zinc treatment given to infected mice reduced oxidative stress markers according to study results from 81 although the impact remains uncertain (Carr & Lykkesfeldt, 2018b). The application of zinc causes macrophages to release IL-1, IL-6, TNF-α and IFN-γ while maintaining their non-releasing properties toward T cells. High supraphysiological doses decrease T-cell activity. Scientific research indicates that zinc supports the proper functioning of antimicrobial peptide delivery through the small intestine. Laboratory tests on humans who underwent food-restriction-induced zinc deficiency exhibit definitive proof that zinc supports essential functions of the immune system (Saltiel & Pessin, 2007b). Thymulin blood levels dropped while the CD4/CD8 ratio decreased because of deficiency. The low production of IL-2 and IFN-γ Th1 cytokines occurred due to zinc deficiency while the levels of IL-4, IL-6, and IL-10 Th2 cytokines remained unaffected. The immune system function of volunteers remained diminished when they followed a zinc-deficient dietary plan (Oz, 2018).

Iron

Studies have proved that humans suffer from compromised adaptive and innate immunity due to iron deficiency while iron therapy returns their immune abilities. People with adaptive immune deficiencies show decreased T-cell counts along with poor T-cell proliferation and diminished abilities to produce IL-2 and MIF and show weak tuberculin skin reactivity (Organization, 2016). A deficiency of neutrophil killing capability constitutes an innate immune deficiency mainly because myeloperoxidase levels decrease. Lactoferrin in Human breast milk has the ability to control bacterial growth through its process of chelating iron that serves as a fundamental element for bacteria survival (Nriagu & Skaar, 2024). Iron treatment destroys the bacteriostatic effects of human milk which could accelerate newborn intestinal bacterial infections. The use of iron supplements by milk-drinking nomads has shown to increase Entamoeba histolytica infections because saturated milk transferrin has a stronger impact than protective measures (Floch-Fouéré et al., 2024).

Research indicates that providing iron medication to nomads causes a return of malaria together with schistosomiasis infection. Analysis of the studies on iron supplementation effects within malarious environments included 11 trials according to this review. Research on clinical malaria through nine trials established adverse effects in five cases and did not demonstrate any positive outcomes (Organization, 1982). The frequency of infectious diseases rose among study participants through respiratory infections but no changes were detected regarding diarrheal illness. A Kenyan observational research indicated iron-deficient children experienced reduced clinical malaria occurrences because their IRR reached 0.70 with CI between 0.51 and 0.99. Medical studies within nonmalarious nations demonstrate that iron supplementation does not generate negative effects on infectious diseases (Holmes et al., 2017b). Dialysis patients along with multiply transfused patients who have excessive iron levels show evidence of immunological deficiencies according to research. According to a major new study the administration of iron supplements results in a 15% increase of infectious illness deaths alongside an 11% higher rate of hospitalizations for such illnesses (Organization, 2009). Several studies indicate such immunological effects show meaningful significance. Research does not provide sufficient information to conclude whether iron deficiency affects parasitic immunology in malnutrition cases. The immune system's T-cells together with innate immune function experience decreased performance from iron deficiency. The intake of excessive iron-based supplements leads to more susceptibility against malaria and other infectious diseases (Medicine & Research, 1999c).

CONCLUSION:

The immune system acts as a vital protector of the body through nutrition-dependent operations that fight multiple infections. The immune protection originates from the combination of innate response and adaptive response and a nutritionally balanced diet comprising vital vitamins and minerals and bioactive compounds supports the immune system. The immune system suffers from malnutrition in both its undernourished and obese forms because these states weaken defense mechanisms and reduce health quality. Malnutrition in children creates important worldwide health problems which cause physical and mental disabilities while raising ill health competitions and increasing death numbers. Effective actions that handle undernourishment and obesity together through enhanced dietary instruction in combination with medical services availability and community backing prove vital for reducing malnutrition effects. The WHO guidelines demonstrate how complete global guidelines function as essential tools to control both childhood malnutrition and its persistent medical effects. Child nutrition needs priority status because it creates stronger healthier populations while also leading to enduring health results across the globe Protein-Energy Malnutrition (PEM) along with nutrient deficiencies affect millions of people especially in developing nations. The combination of these health problems results in excessive illness-related deaths among children and pregnant mothers as well as immune system deterioration and enhanced risk of infections. The solution requires focusing on poverty elimination and improved healthcare facilities and food distribution mechanisms. Immune capacity and recovery improve when patients receive supplementation that targets selenium zinc vitamin A and iron deficiencies which negatively affect immunity. Clinical data indicates that supplementing protein alongside giving probiotics enhances immune system response. Improving both access to essential nutrients and comprehensive healthcare systems remains essential for reducing the worldwide health risks from malnutrition which mostly affect vulnerable groups. The establishment of proper nutrition care starting from early childhood development serves as the foundation for building healthier communities with better resistance to health challenges.

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