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Role of Immunity booster Nutrients against COVID-19

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Abstract

A viral disease due to a coronavirus was reported in a famous city of China, Wuhan, and spread in to all over the world which rapidly changing into an exploding pandemic and posing a severe threat to human health all over the world. There are not sufficient treatment options for the management of this global disease, and a shortage of vaccines. Important aspects that help to defeat coronavirus infection seem to be having a healthy, strong, and resilient immune system. Nutrition and metabolic disorders, such as obesity, cardiovascular disease and diabetes, play an important role in the community health condition in general and especially during this new pandemic. There seems to be a vast impact of lifestyle, metabolic disorders, and immune status on coronavirus disease 2019 (COVID-19). For this reason, it is important to consider the impact of lifestyle and the consumption of well-defined healthy diets during the pandemic.

In this review, we summarise recent findings on the effect of nutrition on COVID-19 susceptibility and disease severity and treatment. Understanding how specific dietary features might help improve public health strategies to reduce the rate and severity of COVID-19.

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1. INTRODUCTION

The appearance of SARS-CoV-2 in late 2019 sparked an infectious disease outbreak known as COVID-19 that rapidly escalated into a global health emergency [1, 2]. By mid-2021, the pathogen and its evolving variants had reached more than 165 million people worldwide, claiming roughly 3.42 million lives [3]. Beyond infection tallies and fatalities, the containment strategies deployed, ranging from home confinement and mobility bans to complete societal shutdowns, generated cascading economic, psychological, and social harms, eroding population well-being and disrupting routine care delivery [4].

Individual clinical experiences with SARS-CoV-2 span an exceptionally wide spectrum. Some infected persons show no symptoms or only transient upper-airway complaints, whereas others progress to fulminant viral lung disease featuring high fever, persistent cough, laboured breathing, diffuse radiographic opacities, and life-threatening hypoxemia necessitating invasive respiratory support [5-8]. Roughly one in five cases advances to critical respiratory complications, with aggregate mortality approaching 2.3% during that phase of the pandemic [3]. Crucially, tissue tropism is not confined to pulmonary structures; the virus invades renal, enteric, ocular, cardiac, and neural compartments, amplifying both immediate clinical complexity and post-acute sequelae [5-8].

Mental and physical conditioning are foundational to immune stability and adaptability, which together determine whether an individual can generate a coordinated antiviral defence [9, 10]. Among host characteristics amenable to intervention, excessive body fat and impaired glucose regulation stand out as powerful predictors of adverse COVID-19 trajectories [11]. Adipose tissue dysfunction fosters metabolic turbulence, hormonal perturbations, chronic subacute inflammation, and compromised leukocyte performance [12]. Physical inactivity compounds these effects, driving progression toward insulin resistance and metabolic syndrome conditions that mechanistically converge on elevated ACE2 receptor availability, the key molecular gateway exploited for viral cell entry [13].

Food intake patterns exert substantial leverage over these metabolic derangements. Habitual consumption of energy-dense, nutrient-poor foods dominated by saturated lipids and processed grains, coupled with insufficient fibre and phytochemical intake, promotes oxidative stress and inflammatory signalling. Conversely, nutrient-adequate eating supports immune coordination and reinforces barriers against microbial invasion [14]. Undernutrition disturbs epigenetic programming, impairs intracellular communication cascades, and destabilises immunoregulatory networks, collectively raising infection risk and worsening clinical outcomes. Poor-quality diets, therefore, undermine antimicrobial preparedness and amplify vulnerability to serious SARS-CoV-2 illness.

Food security and dietary adequacy are unevenly distributed and reflect broader sociocultural and economic gradients that correlate with COVID-19 burden [15]. Within the United States, Indigenous and Hispanic communities have experienced disproportionately high admission rates compared to non-Hispanic White populations, disparities partially rooted in longstanding nutritional inequities and elevated obesity prevalence [15, 16]. Religious and cultural observances also intersect with metabolic health. In resource-limited Islamic-majority settings, the annual Ramadan fast can constrain meal timing and curtail physical exertion [17]. While diminished activity may transiently compromise immune vigilance, controlled energy restriction and meal consolidation have demonstrated favourable effects on glycemic control, antioxidant capacity, and inflammatory tone [17].

In sum, dietary quality and body composition critically shape population resilience during the COVID-19 era. This review consolidates emerging data on the bidirectional relationship between nutritional status and disease expression, highlighting how eating behaviours and metabolic phenotypes modulate host immunity against SARS-CoV-2. Clarifying which nutritional practices intensify or attenuate illness progression will guide strategic public-health initiatives designed to curb transmission and accelerate convalescence.

Pathogenesis of COVID-19 disease

SARS-CoV-2 principally attacks respiratory epithelia, though extrapulmonary organs are frequently involved. The landmark Wuhan case cohorts documented classic lower-airway infection signs: elevated body temperature, nonproductive cough, and shortness of breath [6]. Concurrent systemic features—including cephalgia, vertigo, profound fatigue, nausea, and loose stools—were also prevalent [18]. Despite its respiratory signature, COVID-19 can persist within intestinal tissue, establishing gastrointestinal reservoirs [19], and neurologic abnormalities have emerged in a sizable fraction of inpatient populations [20].

Respiratory pathology is highly heterogeneous, encompassing subclinical carriers through to profound oxygen desaturation and acute respiratory distress syndrome (ARDS) [8, 21]. Early Chinese data revealed that symptom-to-ARDS intervals could contract to nine days, underscoring the potential for precipitous decline [6]. ACE2 serves as the principal host entry portal for SARS-CoV-2 (22), with molecular investigations confirming tight affinity between the viral spike glycoprotein and this membrane-bound receptor [23-25]. Tissue-level ACE2 abundance is prominent in pulmonary, cardiac, intestinal, renal, and urinary structures [26], and is especially concentrated at the luminal interface of alveolar lining cells [27-28]. This anatomic distribution aligns with the observation that early parenchymal injury clusters in peripheral lung zones [29].

Host genetic architecture influences susceptibility to infectious agents, and primary immunodeficiencies often dictate clinical trajectories [30]. Outcome heterogeneity in COVID-19 likely reflects underlying genetic predispositions as well. Chronological age, biological sex, and pre-existing morbidities such as elevated blood pressure, dysglycemia, airway disease, and cardiac pathology consistently correlate with escalated severity and lethality, marking them as pivotal risk determinants [31].

Morbidity and death from COVID-19 climb steeply in older adults and individuals burdened by chronic illness, including malignancy and atherosclerotic disorders. Nonetheless, sporadic life-threatening presentations occur even among juveniles and previously robust patients [32]. The interplay of vulnerability factors and outcome modulators in SARS-CoV-2 infection remains incompletely mapped. Heightened disease severity has been tied to dysregulated immune activation and ACE2-mediated viral tropism, though additional host genetic elements governing receptor expression and entry cofactor function continue to surface [33].

Competent immune surveillance is indispensable for repelling pathogenic microbes. Yet COVID-19 often disrupts immunological equilibrium, curtailing the capacity to execute coordinated antimicrobial responses [34]. Uncontrolled release of pro-inflammatory cytokines and chemokines, the so-called "cytokine storm", precipitates widespread tissue injury characterised by fluid extravasation, endothelial barrier breakdown, and microthrombi formation. This exaggerated inflammatory cascade underlies the acute lung injury (ALI) and ARDS phenotypes observed in critically ill patients, frequently culminating in death.

Male patients face an elevated risk of severe manifestations and unfavourable outcomes relative to females. Mechanistic clarity remains elusive, though candidate explanations include chromosomal effects, differential modulation by androgenic and estrogenic hormones, and sex-linked variation in innate immune cell repertoires, including mast cell behaviour [35]. Intriguingly, men with prostate cancer receiving androgen-deprivation therapy, a regimen that curtails testosterone signalling fueling neoplastic growth, demonstrated markedly lower SARS-CoV-2 infection rates [36]. This finding implies that testosterone

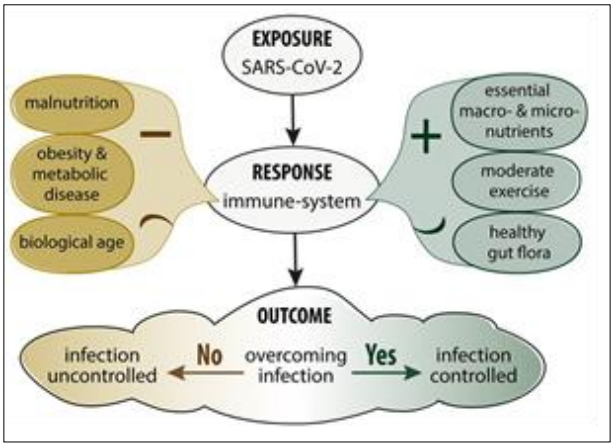
suppression may confer a protective effect. Emerging data also suggest sex-specific variation in pattern-recognition receptor expression and viral entry machinery. While definitive evidence for dimorphic ACE2 and associated protease expression remains pending, these remain plausible mechanistic contributors to observed sex-based outcome disparities in COVID-19.

Physical inactivity, malnutrition, and COVID-19

Adequate nutrient provision constitutes a cornerstone of host defence mechanisms operative against diverse microbial threats [14]. Conversely, nutritional deficits and poor-quality eating patterns markedly erode immunological readiness, thereby amplifying infectious disease vulnerability [37]. Confinement protocols enacted during the pandemic triggered concurrent declines in locomotor activity and elevations in energy consumption, a dual phenomenon of particular concern given that each factor independently escalates COVID-19 severity trajectories [38]. These alterations prove especially detrimental among individuals in the fifth decade of life and beyond, where insufficient physical engagement compromises cardiac functional reserve, alters somatic composition, destabilises metabolic equilibria, reduces skeletal muscle capacity, disrupts hemostatic balance, and weakens immune surveillance networks [39]. Notably, exercise of moderate intensity augments immune coordination mechanisms and associates with diminished upper airway infection frequency, whereas training loads exceeding physiological thresholds may paradoxically attenuate protective responses [39]. Figure 1 depicts the bidirectional relationships linking movement behaviours and nutritional choices to immune system performance. Insufficient nutrient availability can dramatically modulate multiple phases of SARS-CoV-2 pathogenesis from initial host susceptibility through acute disease progression, convalescent recovery kinetics, and potential reinfection susceptibility across diverse patient populations [40]. Dietary regimens characterised by elevated saturated lipid content, simple carbohydrate dominance, and deficits in complex polysaccharides and antioxidant phytonutrients perturb the functional equilibrium between innate recognition systems and adaptive memory responses, thereby compromising antiviral defence architecture [41]. Furthermore, these nutritional profiles demonstrate robust correlations with increased prevalence of established COVID-19 risk determinants and extended post-infectious recuperation intervals [42]. Chronic consumption of saturated fatty acid-enriched foods persistently activates innate immune signalling cascades while concurrently suppressing adaptive immune arm functionality [41, 43]. Mechanistically, saturated fatty acid abundance generates lipotoxic intracellular microenvironments that engage toll-like receptor 4 (TLR4) on macrophage and neutrophil plasma membranes, perpetuating pro-inflammatory signalling networks and cytokine biosynthesis [41, 43]. Nutritional composition additionally regulates TLR9 receptor expression densities and the bioavailability of endogenous TLR9-activating molecular patterns, a pathway hypothesised to contribute to accelerated clinical deterioration trajectories in vulnerable COVID-19 patient subsets [44]. Lipid-enriched dietary patterns elevate TLR9 abundance within visceral adipose tissue compartments across both rodent experimental systems and human study populations [45]. Such nutritional exposures stimulate excessive nucleic acid and associated protein antigen generation, thereby intensifying metabolic inflammatory responses through enhanced macrophage activation states and plasmacytoid dendritic cell (pDC) proliferation within hepatic parenchyma [46]. Preclinical animal investigations additionally demonstrate that sustained high-fat nutritional regimens promote macrophage tissue infiltration into pulmonary interstitium and alveolar airspaces, a phenomenon that mirrors the inflammatory alveolar epithelial pathology and tissue injury patterns documented in obese or metabolically compromised COVID-19 patient cohorts [47]. Furthermore, excessive carbohydrate and lipid intake potentiates oxidative cellular stress responses, restricting lymphocyte proliferative capacity and differentiation processes while simultaneously triggering programmed death signalling pathways, collectively attenuating adaptive antiviral immune competence [48]. In influenza-challenged animal experimental platforms, subjects maintained on lipid-dense nutritional protocols exhibited exacerbated pulmonary tissue destruction patterns and protracted adaptive immune response initiation, accompanied by memory T-lymphocyte functional impairment and diminished antigen recognition efficiency alongside compromised viral clearance capacity [48]. The precise molecular mechanisms driving enhanced pulmonary damage remain under investigation but likely encompass multiple apoptotic and regulated necrotic cellular death programs [49-52]. Given these mechanistic insights, elderly populations, individuals harbouring chronic comorbid medical conditions, and persons demonstrating established COVID-19 vulnerability factors should exercise judicious caution regarding the adoption of nutrient-deficient dietary patterns that potentially amplify disease severity outcomes. In contrast, nutritionally balanced intake protocols delivering sufficient macronutrient quantities, micronutrient adequacy, vitamin sufficiency, essential mineral availability, and potentially beneficial commensal microorganisms, including probiotic species, can support sustained immune functional capacity and facilitate restoration of compromised immune networks [53]. Protein nutritional adequacy, vitamin sufficiency status, and mineral homeostatic balance have historically been acknowledged as pivotal modulators of health resilience and infection resistance phenotypes through their regulatory influences on immune system equilibrium [54]. The immune-enhancing characteristics attributed to traditional botanical therapeutic preparations, exemplified by Shuang-Huang-Lian oral liquid formulations employed for upper respiratory tract

infection management, may partially derive from specific bioactive peptide constituents and additional phytochemical components [2, 55]. A contemporary comprehensive meta-analytic evaluation examining nutritional status influences on immune response capacities directed against respiratory viral challenges concluded that vitamin and mineral nutritional adequacy critically determines host capacity for mobilising efficacious antiviral defence mechanisms and demonstrates direct correlative associations with infection severity outcome patterns [56].

Current global evidence highlights a consistent relationship between micronutrient adequacy and COVID-19 clinical outcomes, including survival rates. Low serum prealbumin concentrations, for instance, have been linked to more severe cases of acute respiratory distress syndrome in SARS-CoV-2–infected patients [57]. Essential micronutrients such as vitamin A, B-complex vitamins, vitamin C, vitamin D, vitamin E, and key trace minerals play crucial roles in coordinating immune signalling, antioxidant defence, and inflammatory regulation [58, 59]. Insufficient levels of these nutrients can compromise immune competence and elevate susceptibility to viral infections, including SARS-CoV-2 [60]. Some studies also report immunomodulatory and protective benefits from natural bioactive compounds of plant origin.



In summary, an individual's nutritional status influences not only the risk of contracting COVID-19 but also the potential severity and recovery trajectory of the disease. The subsequent section further explores the specific roles of proteins, vitamins, and minerals in respiratory viral infections, offering potential insights for preventive and therapeutic strategies against SARS-CoV-2 (Table 1).

Proteins

Proteins are critical factors in immune-nutrition and essential for the production of, for example, immunoglobulins and cytokines. Dietary proteins are digested to their constituent amino acids, and dietary protein deficiency reduces plasma concentrations of most amino acids. Amino acids, such as arginine, are the precursors of polyamines that play a significant role in the regulation of DNA replication and cell division. In addition, optimal antibody production requires a sufficient plasma arginine level. Supplementation with arginine significantly increases T cell function as well as enhances their numbers compared with control subjects [61]. Furthermore, arginine is essential for the generation of nitric oxide by macrophages, an essential component of the innate immune response. In contrast, methionine has an important role in the growth, development and histological structure of immune organs and enhances macrophage phagocytic activity [62]. Methionine deficiency also decreases lymphocyte activities and inhibits the proliferation and differentiation of B and T cells [63]. Methionine also plays a role in both humoral and cellular immunity since methionine deficiency significantly affects antibody titre and decreases serum levels of IgG, IgA, and IgM. Furthermore, methionine deficiency

Decreases the relative percentage of $CD3^+$, $CD3^+/CD8^+$, and $CD3^+/CD4^+$T lymphocytes (64). Given the importance of T cell immunity in the defence against COVID-19, this aspect of methionine deficiency is essential in the prevention of and reduction in the severity of infection.

Reduction of sulphur-containing amino acids in the serum significantly reduces the hydroxyl radical scavenging activity of superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), which helps to protect the host against viral infection [3, 4]. Thus, methionine deficiency can result in oxidative damage and lipid peroxidation, which will lead to a failure in cellular immunity.

Amino acids are also important components for cytokine production. The production of interleukin (IL)-1, IL-6 and tumour necrosis factor (TNF) α is strongly dependent on the metabolism of sulphur-containing amino acids, including methionine and cysteine [65].

The effect of dietary proteins in improving immune function has been reported in cancer patients. In a clinical trial, whey protein isolate (WPI) enriched with Zn and Se improved cell-mediated immunity and antioxidant capacity in cancer patients undergoing chemotherapy. WPI is an alternative oral nutrition supplement (ONS) that contains high-quality protein and amino acid profiles. WPI increases GSH function because of its cysteine-enriched supplementation, reduces oxidative free radical formation and prevents infection (5). This suggests that WPI supplementation may improve GSH levels and thereby enhance immunity in subjects at risk of COVID-19, as well as reduce the severity of the disease in patients already infected with SARS-CoV-2.

Vitamins

Role of Vitamins in Immune Regulation and COVID-19

Robust immune responsiveness underpins both prophylactic protection and therapeutic management of COVID-19 (62). Micronutrient vitamins constitute essential modulators of immunological equilibrium, with

intake levels directly governing the body's capacity to orchestrate immune homeostasis [66] (Table 1). Illustratively, retinoids (vitamin A) and cholecalciferol (vitamin D) augment antibody generation following pediatric influenza immunisation [63, 67]. Individuals practising intermittent fasting or caloric restriction should prioritise strategic consumption of nutrient-concentrated foods and vitamin sources to preserve physical performance capacity and immune operational efficiency [17].

Vitamin A

Retinol and its metabolites serve fundamental functions across both cell-mediated and antibody-driven immunity, amplifying humoral responses post-antiviral vaccination [56]. Operating via retinoic acid nuclear receptors, vitamin A orchestrates immune-cell proliferation and lineage commitment while tempering pro-inflammatory mediators, including tumour necrosis factor-α and interleukin-6 [68-71]. Sufficient retinoid availability correlates with reduced susceptibility to respiratory tract infections, human immunodeficiency virus, and malarial parasitemia [72, 73]. Coronavirus-infected animal models exhibit marked reductions in circulating retinol and retinol-binding protein concentrations, whereas adequate dietary vitamin A provision enhances survival trajectories following respiratory challenge [74, 75]. These mechanistic observations suggest that optimising vitamin A status—or intervening therapeutically when deficient may attenuate COVID-19 infection risk and mitigate disease progression severity.

B-Complex Vitamins

The B-vitamin family, notably folate, cobalamin (B_{12}), and pyridoxine (B_6), executes pivotal functions in metabolic pathways governing immune regulatory networks. Pyridoxal-5'-phosphate, the bioactive coenzyme form of vitamin B_6, catalyses amino-acid transformations and biosynthesis of critical immune signalling molecules [76, 77]. Adequate B-vitamin status sustains natural-killer lymphocyte activity and $CD8^+$ cytotoxic T-cell functionality, both indispensable for antiviral clearance mechanisms [78].

Vitamin D

Cholecalciferol represents a lipophilic secosteroid exhibiting hormone-like regulatory properties across multiple physiological systems, prominently including immune signal transduction [79]. Vitamin D receptors populate respiratory epithelial surfaces and immune cell populations, wherein cytokine networks and pattern-recognition receptors activate vitamin D-responsive genetic programs [79, 80]. Epidemiologic investigations demonstrate that hypovitaminosis D amplifies infection susceptibility to influenza viruses, parainfluenza strains, and respiratory syncytial virus [81, 82]. Circulating 25-hydroxyvitamin D concentrations exceeding 95 nmol/L associate with approximately 50% reductions in acute respiratory infection incidence [60]. Insufficient vitamin D availability correlates with elevated pro-inflammatory cytokine elaboration and increased prevalence of thrombotic events, adiposity, and glucose dysregulation—comorbidities consistently linked to adverse COVID-19 clinical trajectories [84]. Laboratory investigations further reveal that cholecalciferol metabolites suppress SARS-CoV-2 replicative capacity within nasopharyngeal epithelial cell cultures (85). Epidemiologic analyses connect vitamin D insufficiency with heightened mortality risk, particularly within populations exhibiting endemic low serum levels, exemplified by African-American communities in metropolitan Chicago [66, 86-88]. Though scholarly debate persists, preponderant evidence supports that maintaining vitamin D sufficiency diminishes both COVID-19 acquisition risk and severity; supplementation strategies may therefore merit consideration for vulnerable population subsets [89].

Vitamin E

Tocopherols and tocotrienols function as lipid-phase antioxidants modulating immune and inflammatory signalling cascades through transcriptional regulation and membrane stabilisation [90-93]. Deficiency states compromise both humoral antibody production and cellular immune competence [94]. While supraphysiologic supplementation elevated pneumonia incidence among tobacco users [95], clinical evidence alternatively documents therapeutic benefits, including improved hepatitis B viral clearance and enhanced pediatric seroconversion rates [96, 97]. Computational docking analyses additionally propose that vitamin E may disrupt SARS-CoV-2 spike protein engagement with angiotensin-converting enzyme 2 and transmembrane serine protease 2 receptors, suggesting potential antiviral mechanisms warranting empirical investigation [98].

Vitamin C

Ascorbic acid supports diverse immune operations encompassing leukocyte chemotaxis, immunoglobulin biosynthesis, and reactive oxygen species neutralisation [58, 97]. It additionally facilitates neuroendocrine hormone synthesis, connective tissue repair, and maintenance of immune homeostatic balance. Experimental systems demonstrate that vitamin C potentiates type I interferon production during influenza A challenge, constraining viral replication dynamics [100]. Elevated plasma ascorbate concentrations associate with diminished pneumonia frequency and abbreviated upper-respiratory infection duration [101, 102]. Furthermore, high-dose intravenous ascorbic acid administration attenuates acute respiratory distress syndrome (ARDS) severity precipitated by viral pneumonias, a pathologic hallmark of severe COVID-19 presentations [103, 104]. Except for individuals harboring renal insufficiency or glucose-6-phosphate dehydrogenase enzymatic deficiency, high-dose oral or parenteral vitamin C administration has not elicited clinically significant adverse sequelae [105, 106].

Minerals

In addition to vitamins, several essential minerals contribute to antiviral defence mechanisms and may help control COVID-19 (Table 1). Zinc is particularly important for regulating immune responses and supporting both antiviral and antibacterial activity [107]. Insufficient zinc levels are linked with higher vulnerability to infections, while adequate levels promote balanced immune regulation and cytokine signalling [108]. Evidence from patients infected with torque tenovirus (TTV) shows that zinc administration can enhance immune responses [107]. Similarly, moderate supplementation of zinc in combination with selenium has been found to strengthen humoral immunity to the influenza vaccine and elevate antibody titres [109].

Laboratory data indicate that zinc can inhibit the replication of SARS-CoV-2 by blocking viral RNA polymerase activity [110]. Compounds such as chloroquine may act as zinc ionophores, facilitating intracellular zinc uptake and further enhancing antiviral effects [111]. Moreover, zinc may influence ACE2 enzyme activity and modulate interferon-α (IFNα) production, thereby improving antiviral signalling [108]. Through its anti-inflammatory actions—such as suppression of NF-κB signalling and regulation of T-cell function zinc can also contribute to controlling the excessive cytokine response observed in severe COVID-19 cases [112].

TABLE 1 | Overall role and impact of nutrition on immune function.

Table 1: Role and Impact of Nutrients and Bioactive Compounds on Immune Responses

Category	Specific Nutrient	Role and Impact on Immune Responses
Protein	—	• Promotes cytokine and antibody synthesis. • Regulates both humoral and cellular immunity, especially T-cell activity. • Supports DNA synthesis, repair, and cell division. • Facilitates the generation of nitric oxide, superoxide dismutase (SOD), and glutathione peroxidase (GSH-Px), contributing to antioxidant defence.
Vitamins	A group of vitamins	• Strengthen antiviral immune defence. • Control immune-cell proliferation and differentiation through nuclear retinoic acid receptor activation.
	B group vitamins	• Act as cofactors in immune metabolic pathways. • Support viral clearance by regulating natural killer (NK) and $CD8^+$ cytotoxic T-cell functions.
	C group vitamins	• Function as enzymatic cofactors and antioxidants that enhance phagocytosis, signalling, antibody production, hormone balance, and leukocyte migration.
	D group vitamins	• Reduce lung inflammation. Stimulate proliferation and activation of virus-specific immune cells via vitamin D receptors. Promote cytokine production and immune-cell recruitment to infection sites.
	E group vitamins	• Exhibit antioxidant properties. • Regulate genes linked to T-cell proliferation, phagocytosis, and cytotoxicity. • Control the generation of reactive oxygen (ROS) and nitrogen species (RNS) and modulate intracellular signalling pathways.
Minerals	Zinc	• Enhances antiviral and antibacterial immunity by inhibiting viral RNA polymerase and ACE2 activity. • Modulates inflammatory cytokine production. • Promotes Th1 cytokine responses and supports immune metabolic activity.
	Selenium	• Provides antioxidant and anti-inflammatory benefits. • Increases T-cell proliferation. • Upregulates IL-10 for immune regulation.
	Copper	• Restrains viral replication and release. • Prevents virus-induced apoptosis. • Maintains antioxidant enzyme systems via ceruloplasmin, benzylamine oxidase, and superoxide dismutase activity.
	Magnesium	• Acts as a cofactor in numerous enzymatic reactions. • Regulates NF-κB, IL-6, C-reactive protein, and associated immune signalling pathways.
Probiotics	—	• Influence immune balance by up- or down-regulating immune responses depending on host needs.

Zinc

Deficient zinc status has been linked to higher vulnerability to viral infections, including those caused by HIV and HCV [113]. Evidence from randomised controlled trials (RCTs) suggests that zinc supplementation enhances Th1-type immune activity by stimulating IL-2 and IFN-γ release following influenza vaccination [107]. Additional RCT data indicate that administering high-dose zinc after stem-cell transplantation may restore thymic function and expand $CD4^+$ naïve T-cell populations, which corresponded with reduced TTV reactivation risk [107]. Conversely, studies in older adults report that elevated plasma zinc concentrations do not significantly affect antibody generation or lymphocyte proliferation after influenza vaccination [114].

Selenium

Selenium is an essential trace element recognised for its antioxidant and anti-inflammatory roles [115]. Supplementation has been associated with accelerated poliovirus clearance following influenza vaccination and has demonstrated dose-dependent stimulation of T-cell proliferation, along with increased IL-8 and IL-10

production. These immunologic changes, however, did not yield marked improvements in influenza-specific mucosal antibody titers [116].

Copper

Copper contributes to the differentiation and function of immune cells and plays a vital role in antiviral defence [117]. Experimental studies have shown that complexes containing copper and thujaplicin can mitigate influenza-induced apoptosis, inhibit viral replication, and reduce viral release from infected cells [118]. Within host cells, copper appears to interfere with multiple stages of viral replication [119]. Sufficient copper intake supports antioxidant defences by increasing the activity and serum concentrations of ceruloplasmin, benzylamine oxidase, and superoxide dismutase [118, 120].

Magnesium

Magnesium is critical for maintaining immune balance and serves as a cofactor in numerous enzymatic reactions involved in innate and adaptive immunity [121, 122]. Adequate intake helps regulate inflammatory signalling through modulation of NF-κB, IL-6, and C-reactive protein pathways [123]. Experimental models consistently indicate that magnesium contributes to antiviral defence mechanisms [121, 124]. Clinically, combined supplementation with magnesium, vitamin D, and vitamin B12 has been associated with milder COVID-19 progression and fewer cases requiring intensive care [125].

Probiotics

SARS-CoV-2 infection alters gastrointestinal function via ACE2- and TMPRSS2-mediated entry into intestinal epithelial cells, triggering release of pro-inflammatory cytokines and chemokines [126, 127]. Elevated faecal calprotectin and serum IL-6 concentrations serve as markers of virus-induced intestinal inflammation [127]. Although evidence on probiotics and prebiotics in COVID-19 remains limited, two RCTs involving mechanically ventilated patients reported that supplementation with Lactobacillus rhamnosus GG, Bacillus subtilis, and Enterococcus faecalis reduced the incidence of ventilator-associated pneumonia compared with placebo [128, 129]. Given the immunopathological overlap between severe COVID-19 and ARDS, probiotic-based interventions merit continued investigation.

Patients with COVID-19 frequently exhibit gut microbiota dysbiosis, with depletion of beneficial genera such as Eubacterium ventriosum, Faecalibacterium prausnitzii, and Roseburia, alongside expansion of opportunistic pathogens like Clostridium hathewayi and Actinomyces viscosus [130]. While causality remains unclear, restoring microbiota balance may enhance immune modulation and reduce inflammation [131]. Because dysbiosis is prevalent among elderly individuals and those with metabolic or cardiovascular disorders [132], microbiome-targeted nutritional strategies could improve recovery outcomes, though large-scale RCT confirmation is required [133].

CONCLUSION

COVID-19 continues to exert a major global health burden. Until long-term vaccine and therapeutic coverage becomes universal, maintaining optimal nutritional status is central to immune resilience. Sufficient intake of essential micronutrients influences infection susceptibility, therapeutic response, and recovery potential. Diets abundant in vitamins and minerals support recovery in individuals with cardiovascular, pulmonary, or metabolic conditions, as well as in patients affected by malnutrition or muscle wasting [134]. Implementing early, individualised nutrition interventions throughout rehabilitation may improve recovery trajectories and decrease the likelihood of long-COVID [134].

From a public health standpoint, equitable access to nutritious food must be prioritised. Coordinated governmental and community programs that strengthen food security and nutrition literacy are essential to reduce health disparities and enhance preparedness for future infectious disease threats.

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