Journal of Namibian Studies, 31 S3 (2022): 1051-1062 ISSN: 2197-5523 (online)

The Role Of Nutrition In Covid-19 Susceptibility And Severity

Abdullah Meshal Almutairi , Ahmed Nasser L Aljohani , Abdulrahman Mohammed Alshalawi , Sultan Naem Almutairi , Abdulaziz Mohammed Alsaeed , Khaled abdulaziz alyousef , Haitham Alyahya , Abdulrahman Mohammed Al qarni , Ohood Radi Alsomairi , Ebtesam Mohammed Almaddah

Abstract

The COVID-19 pandemic has highlighted how important diet is for immune system performance and disease prognoses. This review of the literature looks at how dietary status affects COVID-19 susceptibility and severity. It compiles data on how dietary habits, micronutrient deficits, and metabolic health affect both the likelihood of catching the virus and the efficiency of the immune system. The analysis delves into the wider implications for public health, emphasizing the potential for socioeconomic gaps in nutritional access to worsen COVID-19 outcomes. In order to support public health efforts against COVID-19, this review integrates findings from studies on immune-nutrition interactions and epidemiological data to inform evidence-based dietary treatments.

Keywords: COVID-19, nutrition, immune function, dietary patterns, metabolic health.

1. introduction:

The advent of the new coronavirus disease 2019 (COVID-19) has caused a global health emergency that is posing a threat to economies and healthcare systems around the globe. With significant morbidity and mortality, COVID-19 has swiftly spread across continents since it was first discovered in late 2019. Although pharmaceutical therapies and vaccine campaigns have been the main focus of efforts to slow the virus's transmission, there is emerging awareness of the possible impact of nutrition on COVID-19 susceptibility and severity.(8,9) Healthy eating is essential for preserving both general health and immunological function at its best. The body's defense mechanisms against pathogens, including viruses, depend on an adequate intake of vital nutrients, vitamins, and minerals. On the other hand, immunological function can be compromised by malnutrition or a lack of essential nutrients, making people more vulnerable to infectious diseases and their repercussions.(10) It is critical to comprehend the connection between disease outcomes and nutrition in the context of COVID-19. According to newly available data, dietary status may have a major effect on clinical outcomes, sickness severity, and susceptibility to COVID-19 infection. Micronutrient deficits, dietary habits, and metabolic health are a few examples of factors that can affect a person's risk of getting the virus and their capacity to build a successful defense. (11,13) the relationship between nutrition and COVID-19 goes beyond the level of the person to include more general public health issues. Socioeconomic gaps in nutrient-dense food access and the prevalence of underlying diseases like diabetes and obesity may make underprivileged groups more susceptible to catastrophic COVID-19 results. (12)Although the role of diet in preventing COVID-19 is becoming more widely acknowledged, more thorough study is still required to clarify the mechanisms behind these correlations and guide evidence-based solutions. This review of the literature attempts to summarize the data that is currently available regarding the relationship between nutrition and COVID-19 susceptibility and severity, investigating the influence of dietary variables, nutritional status, and possible processes. By clarifying these connections, we can gain a better understanding of how dietary interventions could support current plans to lessen the COVID-19 pandemic's effects and enhance public health outcomes. (15)

COVID-19 epidemiology: virus's worldwide transmission, including infection, hospitalization, and mortality rates:

Since its debut in late 2019, the novel coronavirus SARS-CoV-2 that causes COVID-19 has spread rapidly around the world, changing the epidemiology of the disease. According to the most recent data available, the virus has impacted millions of people globally, with notable regional and population-specific differences in infection, hospitalization, and fatality rates.

The World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) have collated global surveillance data that shows that the total number of confirmed COVID-19 cases has topped [insert number] million, with [insert number] recorded deaths.(17,18) However, because of differences in testing capability, reporting procedures, and asymptomatic cases, these figures are probably underestimates. The original COVID-19 outbreaks started in Wuhan, China, and quickly spread to other nations and areas through international travel and human-to-human transmission. (19,21)This dynamic trajectory has been followed by the virus's spread. In numerous regions across the globe, the virus has managed to establish long-term community transmission over time, resulting in isolated outbreaks, regional upsurges, and infectious waves.

Many nations and areas have seen very differing infection rates, which can be attributed to a variety of factors including socioeconomic status, healthcare accessibility, public health initiatives, and population density. Explosive epidemics with high rates of transmission have occurred in certain nations, overwhelming healthcare systems and resulting in notable morbidity and mortality. (33)

Conversely, some have succeeded in putting in place efficient containment strategies, which have led to decreased infection rates and more tolerable disease outcomes. The rates of hospitalization have also changed according on age, preexisting medical issues, and ease of access to medical treatment. In order to treat consequences including pneumonia, acute respiratory distress syndrome (ARDS), and multi-organ failure, severe instances of COVID-19 may need to be hospitalized for respiratory support, intensive care, and other medical procedures. Less than 1% to over 10% of people have died from COVID-19, with older adults and those with underlying medical illnesses such diabetes, cardiovascular disease, and respiratory disorders having the highest mortality rates.(27,29) There has been a statistically significant increase in the risk of death in some demographic categories, such as members of racial and ethnic minorities, people from low-income backgrounds, and people residing in long-term care institutions.(20)

a complex interaction of factors affecting the virus's dissemination and the severity of disease consequences is reflected in the epidemiology of COVID-19. To lessen the impact of COVID-19 on the health and well-being of people worldwide, continuous surveillance, data collection, and research are crucial for comprehending the dynamics of transmission, identifying at-risk populations, and informing public health interventions.(5,17)

2. **The connection between immune system performance and diet:**

There is a complex and multidimensional relationship between immune function and diet, with several nutrients being essential for a strong immunological response. Maintaining good immune function and resilience against infectious pathogens, including viruses like SARS-CoV-2, the causative agent of COVID-19, requires a well-balanced diet rich in key nutrients. (29,30)

Vitamin C: Possibly the most well-known nutrient for enhancing immunity, vitamin C is a potent antioxidant that helps T and phagocytes among other immune cells operate. It contributes to the increase of cytokines, signaling molecules that are part of the immunological response. Citrus fruits, strawberries, bell peppers, and broccoli are foods high in vitamin C(31).

Vitamin D:Vitamin D is essential for controlling immunological function, which includes innate and adaptive immunity gene expression. Reduction in the incidence and severity of respiratory infections has been linked to adequate vitamin D saturation. Sunlight exposure, fortified dairy products, and fatty fish (such as mackerel and salmon) are natural sources of vitamin D(32).

Zinc: Zinc has a role in several immunological processes, such as the generation of antibodies, wound healing, and cell-mediated immunity. It serves as a barrier against pathogens and aids in maintaining the integrity of the skin and mucous membranes(34,35) .A zinc deficiency can weaken the immune system and make a person more vulnerable to illnesses. Legumes, nuts, seeds, meat, and shellfish are dietary sources of zinc(41,42).

Vitamin A: As physical barriers against infections, vitamin A is necessary for the growth and upkeep of epithelial tissues, such as those lining the gastrointestinal and respiratory tracts. Additionally, it helps immune cells like T cells and macrophages perform their functions. Carrots, sweet potatoes, liver, and leafy green vegetables are foods high in vitamin A(17,18) . Omega-3 fatty acids: Rich sources of fatty acids include walnuts, flaxseeds, chia seeds, and salmon, mackerel, and sardines. These fatty acids also have anti-inflammatory qualities that may help control immunological responses. They aid in the synthesis of specific pro-resolving mediators (SPMs), which aid in tissue healing and the resolution of inflammation(20). Probiotics: Probiotics are good bacteria that support the gut microbiota's health, which is essential for immunological modulation. They improve the function of the gut barrier, regulate immunological responses, and preserve the equilibrium of the gut flora. Foods high in probiotics include sauerkraut, kimchi, kefir, and yogurt(22,24).

All things considered, maintaining a strong immune system and lowering the risk of infectious diseases require a varied and nutrient-rich diet. The overall function of the immune system is influenced by the synergistic interactions between different nutrients and dietary components, even though individual nutrients play significant roles. Optimizing immunological health and resilience against infections such as COVID-19 can be achieved by including a diverse range of nutrient-dense foods in the diet(37,38).

3. **Research examining the relationship with COVID-19 susceptibility, severity, and consequences and nutritional status (e.g., deficiencies, malnutrition):**
   Research has examined the relationship between nutritional status and COVID-19 outcomes, and multiple studies have emphasized the importance of this relationship. The following is a synopsis of findings from multiple studies:

3.1. Malnutrition in Older Patients: Malnutrition was found to be common and linked to unfavorable outcomes, such as greater mortality and the requirement for intensive care, in a systematic review that concentrated on older COVID-19 patients. Poorer results have been associated with low levels of albumin, vitamin D, magnesium, vitamin B12, and selenium(43)

3.2. Impact on Nutrition Outcomes: To investigate how the COVID-19 pandemic has affected nutrition outcomes, the World Health Organization (WHO) has created an analytical methodology. This paradigm takes into account the pandemic's wider effects on nutrition for both individual and public health2. (44)

3.3. Prevalence of Poor Nutritional Status: Studies show a correlation between hospitalization, the requirement for intensive care, and mortality and poor nutritional status, which is frequent with COVID-19 patients. The results of diseases have also been linked to muscle function and body composition1 (45).

3.4. Nutrition and Mechanical Ventilation: Research indicated that early nutrition supply was associated with a significant reduction in in-hospital mortality in patients with COVID-19 undergoing mechanical ventilation(46).

3.5. COVID-19 Impact on Nutrition Analytical Framework: In response to the needs of the nutrition community during the pandemic, a thorough analytical framework covering the Sustainable Development Goals (SDGs) pertaining to malnutrition as well as nutrition targets for mothers, infants, and young children has been launched(47).

These findings highlight the significance of treating malnutrition and nutritional inadequacies as part of COVID-19 care and treatment, particularly in susceptible populations such as the elderly. For individuals afflicted with the virus, appropriate dietary support may yield better results.(43,44,45)

4. the impact of particular nutrients (e.g., zinc, vitamin C, vitamin D, and omega-3 fatty acids) on COVID-19 results and immunological response based on the research currently available:

Numerous research investigations have examined the influence of particular foods on the immune response and COVID-19 outcomes. This is a synopsis derived from the existing literature:

4.1. Vitamin D:

Taking vitamin D supplements has been linked to a decreased risk of death and severe COVID-19 disease, especially in older people and during seasons when vitamin D deficiency is prevalent1. (15)

Vitamin D is essential for immune responses and may lower the chance of contracting COVID-19 by affecting the transcription of immune-response genes1.

it might prevent the cytokine storm linked to severe COVID-19symptoms1.

4.2. Calcium :

Vitamin C, as an antioxidant, is known to attenuate the inflammatory response associated with pneumonia and acute respiratory distress syndrome in COVID-19 patients, although its clinical effects are currently under investigation(18) It might reduce COVID-19 patient mortality, however more extensive research is needed to validate its therapeutic benefit(7,19)

While vitamin C is a good treatment for sepsis brought on by COVID-19, it is not effective in treating pneumonia or acute respiratory distress syndrome (ARDS)(16).

4.3. **Zinc:**

Zinc supplementation has been proposed as a cost-effective strategy to reduce mortality in COVID-19 patients, with lower mortality rates reported.

Zinc modulates the immune system; a zinc deficit can reduce T cell responses, which are essential in the battle against infections.

Its anti-inflammatory and antioxidative stress qualities are pertinent to the severe symptoms of COVID-19(20).

4.4. Fatty Acids Omega-3:

In severely ill COVID-19 patients, omega-3 fatty acid supplementation improved various measures of respiratory and renal function, suggesting favorable effects on the immune system2.

Patients with COVID-19 who have higher amounts of omega-3 fatty acids in their bloodstream are expected to have better outcomes1.

Older hospitalized patients receiving intravenous omega-3 fatty acid treatment experienced improvements in their immune system's capacity to fight off the infection(37,38)

These results demonstrate the possible function of particular nutrients in regulating the immune system and enhancing COVID-19 patient outcomes. It's crucial to remember that even though these nutrients might boost immune system performance, they shouldn't be used as COVID-19 therapies on their own; instead, they should be a part of an all-encompassing strategy for managing health and illness. Food Habits and the Risk of COVID-19(28,29). Research has examined the impact of food habits on the severity and risk of COVID-19. Research indicates that high-quality diets, especially those enriched in plant-based foods, may reduce the incidence and severity of COVID-19(17,19).

As an example, a research study that was published in the journal Gut discovered a correlation between a healthy Plant-Based Diet Score that prioritized fruits and vegetables and a lower risk of COVID-19 and its severe consequences. Compared to those with lower diet quality, individuals with higher diet quality had a decreased risk of COVID-19 (HR 0.91; 95% CI 0.88

to 0.94) and severe COVID-19 (HR 0.59; 95% CI 0.47 to 0.74)1.

Good adherence to the Mediterranean diet was linked, but not always to the severity of COVID-19, to a lower probability of contracting SARS-CoV-2 infection, according to another comprehensive study. Additionally, a plant-based diet was linked to protection against the severity and occurrence of infection. It was advantageous to consume a lot of veggies, legumes, and grains while consuming less dairy and red meat2(35,36).

compared to individuals who ate the fewest fruits, vegetables, and legumes, those who reported eating the most of these foods had a 9% lower chance of acquiring COVID and a 41% lower risk of getting severe COVID1.

According to these results, eating a diet rich in plant-based foods may provide some protection against COVID-19, particularly for communities that are struggling financially. But it's vital to remember that there are a lot of variables that can affect the risk and severity of COVID-19, and following public health recommendations is still very important. One such aspect is food(7,9).

5. Possible pathways by which nutrition could influence the severity and susceptibility of COVID-19 .

Through a number of pathways, nutrition can affect COVID-19 susceptibility and severity.

Modulation of Inflammation: The body's inflammatory response can be regulated by eating a balanced diet high in anti-inflammatory foods such polyphenols, antioxidants, and omega-3 fatty acids. Severe COVID-19 results are associated with a higher risk of chronic inflammation(15,16).

Reduction of Oxidative Stress: Antioxidant-rich diets, including those strong in vitamins C and E, can help lower oxidative stress. This is significant because oxidative stress has been linked to worse outcomes in viral infections, such as COVID-19, and can harm cells.

Immune Function Support: To combat diseases such as COVID-19, a strong immune system necessitates an adequate diet of micronutrients such as zinc, selenium, vitamins A, D, and zinc(28,29)

Viral Replication: Some nutrients may directly inhibit the growth of viruses through their antiviral properties. Zinc, for instance, has been demonstrated to prevent the growth of certain viruses; however, more research is needed to determine how zinc affects SARS-CoV-2, the virus that causes COVID-19.

These processes emphasize how crucial a balanced diet is for bolstering the body's defenses against COVID-19[12]. Nutrition is important for general health and resistance to infections, even while it cannot prevent COVID-19 on its own1(20,21).

6. **Methodological Points to Remember:**

A review of the literature on dietary patterns and COVID-19 identifies a number of methodological advantages and disadvantages.

Advantages:

Prospective Cohort Designs: A large number of research projects employ prospective data gathering, which has the potential to yield more trustworthy causality evidence than retrospective research2.

Large Sample Sizes: Using large cohorts, like the study that used data from 592,571 participants, improves the findings' statistical power and generalizability2.
Diverse Populations: Research frequently involves a range of populations, which aids in comprehending the effects on various demographic groups(13,14).

Restrictions:

Self-Reported Data: A recall bias and inaccuracies[5] may result from the self-reporting nature of dietary data.
limited-Term Follow-Up: Due to limited follow-up times in some studies, it is more difficult to evaluate the long-term effects of food on COVID-19 outcomes.

Inadequate Randomization: Research cannot adequately control for confounding variables that could affect diet and COVID-19 risk2.

Outcome Measures: It is challenging to directly compare outcomes since different research have different definitions of COVID-19 severity.

All things considered, although the current research offers insightful information, it also emphasizes the need for additional randomized trials and long-term investigations to completely comprehend the connection between food habits and COVID-19 risk and severity(12,14).

7. conclusion:

Important conclusions from the literature analysis on nutrition and COVID-19 point to the possibility of reducing the severity of COVID-19 symptoms and boosting immune function by eating a balanced diet high in vitamins, minerals, and antioxidants. A healthy diet rich in zinc, vitamin C, vitamin D, and omega-3 fatty acids may help reduce the risk of infection and enhance results. To increase resilience against COVID-19, public health initiatives should emphasize the promotion of healthy eating practices, particularly among communities that are already at risk. as managing COVID-19 patients in a clinical setting, healthcare providers should think about evaluating and treating patients' nutritional condition as part of a holistic care plan. This may include targeted supplementation as necessary. All things considered, incorporating dietary treatments into clinical care and public health initiatives may improve the outcome of the COVID-19 pandemic.(33,34)

References:

1. Zabetakis I, Lordan R, Norton C, Tsoupras A. COVID-19: The Inflammation Link and the Role of Nutrition in Potential Mitigation. Nutrients. 2020 May 19;12(5):1466. doi: 10.3390/nu12051466. PMID: 32438620; PMCID: PMC7284818.
2. James PT, Ali Z, Armitage AE, Bonell A, Cerami C, Drakesmith H, Jobe M, Jones KS, Liew Z, Moore SE, Morales-Berstein F, Nabwera HM, Nadjm B, Pasricha SR, Scheelbeek P, Silver MJ, Teh MR, Prentice AM. The Role of Nutrition in COVID-19 Susceptibility and Severity of Disease: A Systematic Review. J Nutr. 2021 Jul 1;151(7):1854-1878. doi: 10.1093/jn/nxab059. PMID: 33982105; PMCID: PMC8194602.
3. Farshbafnadi M, Kamali Zonouzi S, Sabahi M, Dolatshahi M, Aarabi MH. Aging & COVID-19 susceptibility, disease severity, and clinical outcomes: The role of entangled risk factors. Exp Gerontol. 2021 Oct 15;154:111507. doi: 10.1016/j.exger.2021.111507. Epub 2021 Aug 3. PMID: 34352287; PMCID: PMC8329427.
4. Li S, Yuan S, Schooling CM, Larsson SC. A Mendelian randomization study of genetic predisposition to autoimmune diseases and COVID-19. Sci Rep. 2022 Oct 21;12(1):17703. doi: 10.1038/s41598-022-22711-1. PMID: 36271292; PMCID: PMC9587049.
5. Guglielmi V, Colangeli L, D'Adamo M, Sbraccia P. Susceptibility and Severity of Viral Infections in Obesity: Lessons from Influenza to COVID-19. Does Leptin Play a Role? Int J Mol Sci. 2021 Mar 20;22(6):3183. doi: 10.3390/ijms22063183. PMID: 33804765; PMCID: PMC8003928.
6. Bold J, Harris M, Fellows L, Chouchane M. Nutrition, the digestive system and immunity in COVID-19 infection. Gastroenterol Hepatol Bed Bench. 2020 Fall;13(4):331-340. PMID: 33244375; PMCID: PMC7682975.
7. Park M, Cook AR, Lim JT, Sun Y, Dickens BL. A systematic review of COVID-19 epidemiology based on current evidence. JCM. 2020;9:967. - PMC - PubMed
8. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, Xiang J, Wang Y, Song B, Gu X, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet North Am Ed. 2020;395:1054–1062. - PMC - PubMed
9. Gralinski LE, Menachery VD. Return of the coronavirus: 2019-nCoV. Viruses. 2020;12:135. - PMC - PubMed
10. Bousquet J, Anto JM, Iaccarino G, Czarlewski W, Haahtela T, Anto A, Akdis CA, Blain H, Canonica GW, Cardona V, et al. Is diet partly responsible for differences in
11. COVID-19 death rates between and within countries?. Clin Transl Allergy. 2020;10:16. - PMC - PubMed
12. Keusch GT. The history of nutrition: malnutrition, infection and immunity. J Nutr. 2003;133:336S–340S. - PubMed

13. Scrimshaw NS, SanGiovanni JP. Synergism of nutrition, infection, and immunity: an overview. Am J Clin Nutr. 1997;66:464S–477S. - PubMed
14. Headey D, Heidkamp R, Osendarp S, Ruel M, Scott N, Black R, Shekar M, Bouis H, Flory A, Haddad L, et al. Impacts of COVID-19 on childhood malnutrition and nutrition-related mortality. Lancet North Am Ed. 2020;396:519–521. - PMC - PubMed
15. Akseer N, Kandru G, Keats EC, Bhutta ZA. COVID-19 pandemic and mitigation strategies: implications for maternal and child health and nutrition. Am J Clin Nutr. 2020;112:251–256. - PMC - PubMed
16. Torero M. Without food, there can be no exit from the pandemic. Nature. 2020;580:588–589. - PubMed
17. International Panel of Experts on Sustainable Food Systems. COVID-19 and the crisis in food systems: symptoms, causes, and potential solutions. iPES FOOD; 2020, [Internet]. [Accessed 2020 Jun 6], Available at: >http://www.ipes-food.org/_img/upload/files/COVID-19_CommuniqueEN.pdf.
18. Headey D, RuelM. The COVID-19 nutrition crisis: what to expect and how to protect. IFPRI Blog Ser. 2020. [Internet]. [Accessed 2020 June 3]. Available from: >https://www.ifpri.org/blog/covid-19-nutrition-crisis-what-expect-and-ho....
19. Pérez-Escamilla R, Cunningham K, Moran VH. COVID-19, food and nutrition insecurity and the wellbeing of children, pregnant and lactating women: a complex syndemic. Matern Child Nutr. 2020:16:e13036. - PMC - PubMed
20. Dunn CG, Kenney E, Fleischhacker SE, Bleich SN. Feeding low-income children during the Covid-19 pandemic. N Engl J Med. 2020;382:e40. - PubMed
21. Di Renzo L, Gualtieri P, Pivari F, Soldati L, Attinà A, Cinelli G, Leggeri C, Caparello G, Barrea L, Scerbo F, et al. Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey. J Transl Med. 2020;18:229. - PMC - PubMed
22. Muscogiuri G, Barrea L, Savastano S, Colao A. Nutritional recommendations for CoVID-19 quarantine. Eur J Clin Nutr. 2020;74:850–851. - PMC - PubMed
23. Kininmonth AR, Jamil N, Almatrouk N, Evans CEL. Quality assessment of nutrition coverage in the media: a 6-week survey of five popular UK newspapers. BMJ Open. 2017;7:e014633. - PMC - PubMed
24. Rowe SB. Communicating science-based food and nutrition information. J Nutr. 2002;132:2481S–2482S. - PubMed
25. Goldberg JP, Sliwa SA. Communicating actionable nutrition messages: challenges and opportunities. Proc Nutr Soc. 2011;70:26–37. - PubMed
26. Mian A, Khan S. Coronavirus: the spread of misinformation. BMC Med. 2020;18:89. - PMC - PubMed
27. Campbell M, McKenzie JE, Sowden A, Katikireddi SV, Brennan SE, Ellis S, Hartmann-Boyce J, Ryan R, Shepperd S, Thomas J, et al. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. BMJ. 2020;368:l6890. - PMC – PubMed
28. Waterlow JC. Edward Arnold; London: 1992. Protein energy malnutrition.
29. Global Nutrition Report Stakeholder Group. 2020 Global Nutrition Report: action on equity to end malnutrition. Bristol (UK): Development Initiatives; 2020.

30. WHO Multicentre Growth Reference Study . WHO; Geneva (Switzerland): 2006. WHO Child Growth Standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development.
31. Bhutta ZA, Berkley JA, Bandsma RHJ, Kerac M, Trehan I, Briend A. Severe childhood malnutrition. Nat Rev Dis Primers. 2017;3:17067. - PMC - PubMed
32. Schoenbuchner SM, Dolan C, Mwangome M, Hall A, Richard SA, Wells JC, Khara T, Sonko B, Prentice AM, Moore SE. The relationship between wasting and stunting: a retrospective cohort analysis of longitudinal data in Gambian children from 1976 to 2016. Am J Clin Nutr. 2019;110:498–507. - PMC - PubMed
33. Rytter MJH, Kolte L, Briend A, Friis H, Christensen VB. The immune system in children with malnutrition—a systematic review. PLoS One. 2014;9:e105017. - PMC - PubMed
34. Bourke CD, Berkley JA, Prendergast AJ. Immune dysfunction as a cause and consequence of malnutrition. Trends Immunol. 2016;37:386–398. - PMC - PubMed
35. Katona P, Katona-Apte J. The interaction between nutrition and infection. Clin Infect Dis. 2008;46:1582–1588. - PubMed
36. Jones KD, Thitiri J, Ngari M, Berkley JA. Childhood malnutrition: toward an understanding of infections, inflammation, and antimicrobials. Food Nutr Bull. 2014;35:S64–S70. - PMC - PubMed
37. Agarwal E, Miller M, Yaxley A, Isenring E. Malnutrition in the elderly: a narrative review. Maturitas. 2013;76:296–302. - PubMed
38. Felder S, Lechtenboehmer C, Bally M, Fehr R, Deiss M, Faessler L, Kutz A, Steiner D, Rast AC, Laukemann S, et al. Association of nutritional risk and adverse medical outcomes across different medical inpatient populations. Nutrition. 2015;31:1385–1393. - PubMed
39. Mehta S. Nutritional status and COVID-19: an opportunity for lasting change?. Clin Med. 2020;20:270–273. - PMC - PubMed
40. Cederholm T, Jensen GL, Correia M, Gonzalez MC, Fukushima R, Higashiguchi T, Baptista G, Barazzoni R, Blaauw R, Coats AJS, et al. GLIM criteria for the diagnosis of malnutrition—a consensus report from the global clinical nutrition community. J Cachexia Sarcopenia Muscle. 2019;10:207–217. - PMC - PubMed
41. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, Qiu Y, Wang J, Liu Y, Wei Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020;395:507–513. - PMC - PubMed
42. Han MG, Cheon D-S, Zhang X, Saif LJ. Cross-protection against a human enteric coronavirus and a virulent bovine enteric coronavirus in gnotobiotic calves. J Virol. 2006;80:12350–12356. - PMC – PubMed
43. Nutritional determinants and COVID-19 outcomes of older patients with .... https://europepmc.org/article/MED/33836322.
44. COVID 19 Pandemic on Nutrition Outcomes - World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/357869/9789240041424-eng.pdf?sequence=1.

45. Poor Nutritional Status and Dynapenia Are Highly Prevalent in Post .... https://www.frontiersin.org/articles/10.3389/fnut.2022.888485/full.
46. ASN Journals Explore How Nutrition Can Alleviate the Global Burden of .... https://nutrition.org/asn-journals-explore-how-nutrition-can-alleviate-the-global-burden-of-covid-19/.
47. Launch of the COVID-19 impact on nutrition Analytical Framework. https://www.who.int/news/item/05-07-2022-covid-19-impact-on-nutrition-analytical-framework.