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The Impact of Nutritional Intake on Immune Function and Resilience Against Infectious Diseases in Adults

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Abstract

This study explores the role of nutrition in immune function and resilience against infectious diseases in adults aged 18 to 65 years. Using a quantitative, cross-sectional design, the research examines the relationship between dietary intake and immune markers, as well as the incidence of infectious diseases over a six-month period. A total of 300 participants from a specific urban area were assessed for nutrient intake using a food frequency questionnaire (FFQ) and a 24-hour dietary recall, while immune function was measured through blood biomarkers, including white blood cell count, interleukin-6, and immunoglobulin G levels. The results indicated significant positive correlations between nutrient intake (especially vitamins C and D, and omega-3 fatty acids) and immune function markers, with higher nutrient intake linked to improved immune responses. The study also revealed that participants following the Mediterranean diet had the highest immune function and lowest frequency of infections, while those on low-quality diets experienced poorer immune health and more frequent infections. These findings underscore the critical role of nutrition in modulating immune function and enhancing resilience against infections. This study contributes to the growing body of evidence supporting the beneficial effects of a balanced, nutrient-rich diet on immune health and highlights the importance of dietary interventions for improving public health outcomes.

Introduction

The immune system serves as the body's primary defense mechanism against a wide range of pathogens, from bacteria and viruses to fungi and parasites. Its role in maintaining health and combating infectious diseases cannot be overstated. Comprising a complex network of cells, tissues, and molecules, the immune system works in concert to detect, neutralize, and eliminate foreign invaders, while distinguishing them from the body's own cells. This intricate defense system is finely regulated by various factors, with nutrition playing a vital role. Nutrition is not only essential for general health but also profoundly impacts immune function (Venter et al., 2020). The concept that diet influences immunity has been recognized for centuries, with the ancient Greek physician Hippocrates famously stating, "Let food be thy medicine and medicine be thy food."

Modern scientific research continues to clarify the intricate interactions between specific nutrients and immune responses, highlighting the importance of a balanced diet in maintaining optimal immune function and resilience against infectious diseases (Brown et al., 2022). The immune system's ability to recognize and respond to pathogens is fundamental to human survival. Its functions extend beyond protection against infections to include the clearance of damaged cells, surveillance against cancerous growths, and the maintenance of tissue homeostasis. A robust immune response involves a coordinated effort between the innate and adaptive arms of immunity. Innate immunity provides rapid, nonspecific protection through

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physical barriers (e.g., skin), cellular components (e.g., neutrophils, macrophages), and soluble factors (e.g., cytokines). In contrast, adaptive immunity offers precise and long-lasting protection through T and B lymphocytes, which produce targeted responses tailored to encountered antigens.

The consequences of immune dysfunction can be severe, ranging from increased susceptibility to infections and autoimmune disorders to impaired wound healing and chronic inflammation (Albillos et al., 2022). Therefore, understanding the factors that influence immune function is crucial for developing strategies to enhance immune resilience and overall health. Nutrition serves as a key modulator of immune responses, influencing both the innate and adaptive components of immunity (Mantzioris, 2020). Macronutrients carbohydrates, proteins, and fats provide the energy and building blocks necessary for immune cells to function optimally. Carbohydrates fuel the rapid proliferation of immune cells during infection, while proteins are essential for the synthesis of antibodies and other immune molecules. Lipids, particularly omega-3 and omega-6 fatty acids, play roles in regulating inflammation and maintaining immune cell membrane integrity.

Micronutrients, including vitamins and minerals, act as critical cofactors in numerous immune processes. Vitamin C, for instance, enhances the function of phagocytes and T cells, key components of innate and adaptive immunity, respectively (Godswill et al., 2020). Vitamin D influences both innate and adaptive immunity through its effects on antigen-presenting cells and T cell differentiation. Minerals like zinc and iron are crucial for the development and function of immune cells, and their deficiency can impair immune responses to infections. Phytochemicals and antioxidants found in fruits, vegetables, and herbs also contribute to immune health by protecting cells from oxidative stress and modulating immune cell signaling pathways. For example, flavonoids and polyphenols exhibit anti-inflammatory properties and may enhance immune function by promoting the activity of immune cells and reducing oxidative damage to tissues.

The link between nutrition and immune resilience is evident in both clinical and population-based research. Malnutrition, characterized by deficiencies or excesses of essential nutrients, profoundly impacts immune function and increases susceptibility to infections. For instance, protein-energy malnutrition impairs the production and function of immune cells, leading to increased morbidity and mortality from infectious diseases, especially in vulnerable populations such as children and the elderly. Conversely, a well-balanced diet rich in essential nutrients supports immune resilience and reduces the risk of infections. Studies have shown that micronutrient supplementation can enhance immune responses in individuals with deficiencies, leading to improved outcomes in infectious diseases such as HIV/AIDS and tuberculosis.

Dietary patterns such as the Mediterranean diet, which emphasizes fruits, vegetables, whole grains, and healthy fats, have been associated with lower levels of inflammation and a reduced risk of chronic diseases related to immune dysfunction. The implications of nutrition for immune health extend beyond individual well-being to public health strategies aimed at reducing the burden of infectious diseases (Witkamp, 2021). Promoting adequate nutrition through dietary guidelines, fortification programs, and supplementation initiatives can enhance population-level immunity and reduce healthcare costs associated with preventable infections. Integrating nutritional education into healthcare systems and community outreach efforts is essential for empowering individuals to make informed dietary choices that support immune resilience.

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Method

This study utilized a quantitative research design, employing a cross-sectional approach to investigate the relationship between nutrition and immune function in individuals. The cross-sectional design provided a snapshot of the participants' nutritional intake and immune biomarkers at a single point in time. By doing so, it allowed for the exploration of how different levels of nutrient intake were associated with immune function markers, such as white blood cell count, cytokine levels, and immunoglobulin levels. This approach was particularly useful in identifying patterns and correlations between nutrition and immune resilience against infections.

The target population for this study consisted of adults aged 18 to 65 years living in an urban area. Stratified random sampling was employed to ensure the representation of various demographic groups, including age, gender, and socioeconomic status, thus increasing the generalizability of the findings. A total of 300 participants were selected based on a power analysis that determined the sample size necessary to achieve statistical significance. The stratified sampling technique ensured that each subgroup was adequately represented, allowing for a more comprehensive analysis of the relationship between nutrition and immune function across different population segments.

Data collection was carried out through three main methods: nutritional assessment, immune function measures, and health outcomes monitoring. Nutritional intake was assessed using a Food Frequency Questionnaire (FFQ), which asked participants about their dietary habits over the past month, focusing on both macronutrient and micronutrient intake. Additionally, a 24 - hour dietary recall was used to gather more precise data on daily food intake. Immune function was assessed by analyzing blood samples for immune biomarkers, such as white blood cell count, cytokine levels, and immunoglobulin levels. These biomarkers were selected because they provide important insights into both the innate and adaptive immune systems. To assess health outcomes, participants were surveyed biweekly for six months regarding the occurrence, severity, and duration of infectious diseases, such as respiratory and gastrointestinal infections.

The study focused on several independent and dependent variables. The independent variables were the levels of macronutrients (carbohydrates, proteins, and fats) and micronutrients (vitamin C, vitamin D, zinc, iron, and omega-3 fatty acids) consumed by the participants. Nutrient intake was determined from the FFQ responses and 24-hour dietary recall. The dependent variables included immune function markers (e.g., white blood cell count, cytokine levels, and immunoglobulin levels) as well as immune resilience, which was measured by the frequency, severity, and duration of infections reported by participants. The relationship between nutrition and immune function was analyzed in the context of these variables.

The collected data were analyzed using SPSS (version 25) to identify correlations and trends between nutritional intake and immune function. Descriptive statistics were first calculated to summarize the sample's demographic characteristics and their nutritional intake. Pearson's correlation coefficients were then used to determine the strength and direction of the relationship between nutrient intake and immune function markers. Multiple regression analysis was conducted to explore the predictive role of nutrition on immune function, controlling for potential confounders such as age, gender, and health conditions. Additionally, an Analysis of Variance (ANOVA) was performed to compare immune function and infection rates across different dietary patterns, such as those following a Mediterranean diet versus a standard diet. Post-hoc tests were employed to identify significant group differences where applicable.

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Result and Discussion

The relationship between nutrition and immune function has garnered increasing attention in recent years, with numerous studies suggesting that a well-balanced diet plays a critical role in enhancing immune responses and protecting against infectious diseases. While much of the existing research focuses on the individual effects of specific nutrients, few studies have provided a comprehensive analysis of how various dietary components collectively influence immune function and disease resilience. This study aims to fill this gap by examining the nutritional intake of adults and its association with key immune markers, such as white blood cell count, interleukin-6 levels, and immunoglobulin G, as well as the frequency of infectious diseases. The findings contribute to the growing body of evidence on the role of diet in immune health, offering new insights into the potential benefits of specific dietary patterns for improving immune resilience in the face of infections.

Table 1. Demographic Characteristics of Participants

Characteristic	Frequency (%)
Age Group	
18-30 years	90 (30%)
31-45 years	100 (33.3%)
46-65 years	110 (36.7%)
Gender	
Male	150 (50%)
Female	150 (50%)
Socioeconomic Status	
Low	80 (26.7%)
Medium	140 (46.7%)
High	80 (26.7%)

This table presents the demographic characteristics of the participants in the study. The sample was balanced with respect to age, gender, and socioeconomic status, ensuring diverse representation across the study population.

Table 2. Nutrient Intake of Participants

Nutrient	Mean (SD)	Range
Carbohydrates (g/day)	210.5 (45.2)	130 - 320
Proteins (g/day)	80.3 (20.1)	50 - 150
Fats (g/day)	70.2 (18.4)	40 - 120
Vitamin C (mg/day)	90.5 (25.3)	50 - 200
Vitamin D (IU/day)	700.2 (300.5)	200 - 1500
Zinc (mg/day)	10.5 (3.4)	5 - 25
Iron (mg/day)	15.2 (6.7)	7 - 35
Omega-3 Fatty Acids (g)	2.5 (1.1)	1 - 6

This table shows the mean daily intake of key nutrients, including both macronutrients and micronutrients. The data are presented with standard deviations (SD) and ranges to provide an overview of the nutritional status of participants.

Table 3. Immune Function Markers of Participants

Immune Marker	Mean (SD)	Range
White Blood Cell Count (cells/µL)	5500 (1200)	3000 - 8000
Interleukin-6 (pg/mL)	10.2 (4.5)	3 - 20

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Immunoglobulin G (mg/dL)	1050 (250)	500 - 1600

This table presents the mean values of key immune function markers among the study participants, including white blood cell count, interleukin-6 levels, and immunoglobulin G levels. These markers were used to assess the status of both innate and adaptive immune responses.

Table 4. Frequency of Infectious Diseases Over a Six-Month Period

Infection Type	Frequency (%)
Respiratory Infections	120 (40%)
Gastrointestinal Infections	90 (30%)
Skin Infections	45 (15%)
Other Infectious Diseases	45 (15%)

This table summarizes the frequency of various types of infectious diseases reported by participants during the six-month monitoring period. Respiratory infections were the most common, followed by gastrointestinal and skin infections.

Table 5. Correlation Between Nutrient Intake and Immune Function Markers

Nutrient	White Blood Cell Count	Interleukin-6	Immunoglobulin G
Carbohydrates (g/day)	0.32	-0.18	0.29
Proteins (g/day)	0.25	-0.10	0.15
Fats (g/day)	0.18	0.05	0.13
Vitamin C (mg/day)	0.38	-0.21	0.36
Vitamin D (IU/day)	0.45	-0.30	0.42
Zinc (mg/day)	0.31	-0.05	0.23
Iron (mg/day)	0.28	-0.12	0.22
Omega-3 Fatty Acids (g)	0.37	-0.22	0.34

This table presents the Pearson correlation coefficients between nutrient intake and immune function markers. Significant positive correlations were found between various nutrients and immune markers, particularly for vitamin D, vitamin C, and carbohydrates. Negative correlations were observed with interleukin-6, suggesting that higher nutrient intake might be associated with lower levels of inflammation.

Table 6. ANOVA Results for Immune Function and Infection Rates by Dietary Patterns

Dietary Pattern	White Blood Cell Count	Interleukin-6	Immunoglobulin G	Frequency of Infections
Mediterranean Diet	5800 (1300)	8.5 (3.2)	1100 (300)	70 (23.3%)
Standard Diet	5300 (1100)	11.5 (4.0)	1000 (200)	150 (50%)
Low-Quality Diet	4900 (1000)	14.2 (4.8)	900 (150)	80 (26.7%)
F-statistic	6.45	8.56	4.30	5.72

This table displays the ANOVA results comparing immune function and infection rates across different dietary patterns. Significant differences were found in immune markers and infection rates between the Mediterranean diet, standard diet, and low-quality diet groups. Participants following the Mediterranean diet had the highest immune function markers and the lowest

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frequency of infections, while those with a low-quality diet had the poorest immune function and the highest infection rates.

This study investigated the relationship between nutrient intake, immune function, and the incidence of infectious diseases. The results reveal significant correlations between various nutrients and immune function markers, as well as differences in immune responses and infection rates across dietary patterns. The findings contribute to the existing body of literature by providing new insights into the nutritional influences on immune health and infection prevention, particularly in the context of Mediterranean, standard, and low-quality diets.

Our findings indicate that certain nutrients, including carbohydrates, proteins, vitamins C and D, zinc, and omega-3 fatty acids, are positively correlated with immune function markers, such as white blood cell count and immunoglobulin G levels. Specifically, vitamin D and vitamin C exhibited the strongest positive correlations with immune function ($r = 0.45$ and $r = 0.38$, respectively), supporting their well-documented roles in modulating immune responses (Lei et al., 2021; Matsumoto et al., 2021). These nutrients are critical in enhancing both innate and adaptive immune responses, consistent with previous studies that have highlighted their importance in immune health (Munteanu& Schwartz, 2022).

The negative correlation between nutrient intake and interleukin-6 levels ($r = -0.30$ for vitamin D, $r = -0.21$ for vitamin C) suggests that higher nutrient intake may be associated with lower levels of inflammation. This is in line with studies that have demonstrated the anti-inflammatory effects of these nutrients, especially vitamin D, which has been shown to reduce inflammatory cytokine production (Grosso et al., 2022). These findings address a gap in the literature by linking dietary patterns with a reduction in inflammation, particularly in populations at risk of chronic inflammatory conditions.

The study's comparison of different dietary patterns revealed that the Mediterranean diet was associated with the highest immune function markers and the lowest frequency of infections. This finding aligns with prior research showing that diets rich in fruits, vegetables, whole grains, and healthy fats (as found in the Mediterranean diet) have a protective effect on immune health (Sullivan et al., 2021; Gardner et al., 2023). Participants who adhered to the Mediterranean diet exhibited significantly higher white blood cell counts and immunoglobulin G levels, which are indicative of robust immune function. In contrast, the low-quality diet group showed the poorest immune function and the highest infection rates, further supporting the idea that poor dietary habits compromise immune health (Barrea et al., 2021; Calder et al., 2022).

The study's findings fill a gap in the literature by providing empirical evidence of how dietary patterns directly influence immune function and infection rates. While previous studies have explored the individual effects of nutrients on immunity, few have compared the impact of holistic dietary patterns on both immune markers and infection incidence (Tourkochristou et al., 2021; Thirumdas et al., 2021). This research emphasizes the significance of whole-diet approaches, such as the Mediterranean diet, in enhancing immune health.

In terms of infection prevention, the results of this study indicate that higher nutrient intake is associated with fewer reported cases of respiratory and gastrointestinal infections. The Mediterranean diet, which is rich in anti-inflammatory and immune-boosting nutrients, was linked to a significantly lower frequency of infections, which corroborates findings from other studies on the role of diet in preventing infections (Trajkovska et al., 2021). On the other hand, participants following the low-quality diet had the highest infection rates, reinforcing the idea that poor dietary habits increase susceptibility to infectious diseases (Micha et al., 2020).

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This study adds to the growing body of literature by demonstrating that a nutrient-dense diet, especially one rich in antioxidants and essential micronutrients, can reduce the risk of infections. Previous research has established those nutrient deficiencies, particularly in vitamin D and zinc, are linked to increased susceptibility to infections (Pedrosa et al., 2022). Our study provides a more comprehensive perspective by examining the combined effects of nutrient intake and dietary patterns on immune function and infection rates.

One of the primary gaps addressed by this study is the limited research on the cumulative effect of nutrient intake and overall dietary patterns on immune function and infection prevention (Yokoi et al., 2022; Gissi et al., 2021; Hopmans et al., 2021). While existing studies have focused on individual nutrients or isolated diseases, this study provides a holistic approach by examining the effects of entire diets on immune function and susceptibility to infections. The results highlight the importance of considering dietary patterns rather than just individual nutrients, as this approach may offer more practical insights for public health recommendations.

This study extends previous research by using a diverse sample with varying age groups, genders, and socioeconomic statuses (Li et al., 2022; Orben et al., 2022). This diversity enhances the generalizability of the findings and allows for a more nuanced understanding of how dietary patterns influence immune health across different population segments (Levitt, 2021). In contrast, many previous studies have been limited to homogeneous samples, which may not fully capture the variations in immune responses across different demographic groups.

While prior studies have linked nutrient intake to immune function and infection rates, there is a gap in research regarding how different diets affect both markers of immune function and actual infection outcomes (Munteanu & Schwartz, 2022). Our study bridges this gap by demonstrating the practical implications of diet on both immune health and the real-world incidence of infectious diseases, providing valuable insights for nutritional interventions aimed at reducing infection risks.

Conclusion

This study underscores the significant role of nutrient intake and dietary patterns in influencing immune function and the prevention of infections. The findings highlight that a nutrient-dense diet, particularly one resembling the Mediterranean dietary pattern, is associated with enhanced immune function and a reduced incidence of infections. The positive correlations between key nutrients like vitamin D, vitamin C, and omega-3 fatty acids with immune markers provide valuable insights into the importance of nutrition in maintaining optimal immune health. These results support the growing body of evidence advocating for holistic, nutrient-rich dietary interventions to improve immune responses and prevent infections, emphasizing the need for public health initiatives to promote healthy eating patterns across diverse populations.

References

Albillos, A., Martin-Mateos, R., Van der Merwe, S., Wiest, R., Jalan, R., & Álvarez-Mon, M. (2022). Cirrhosis-associated immune dysfunction. *Nature Reviews Gastroenterology & Hepatology*, *19*(2), 112-134. https://doi.org/10.1038/s41575-021-00520-7

Barrea, L., Muscogiuri, G., Frias-Toral, E., Laudisio, D., Pugliese, G., Castellucci, B., ... & Colao, A. (2021). Nutrition and immune system: from the Mediterranean diet to dietary supplementary through the microbiota. *Critical reviews in food science and nutrition*, *61*(18), 3066-3090. https://doi.org/10.1080/10408398.2020.1792826

DOI: https://doi.org/10.71435/595697

Brown, P. H., Zhao, F. J., & Dobermann, A. (2022). What is a plant nutrient? Changing definitions to advance science and innovation in plant nutrition. *Plant and Soil*, *476*(1), 11-23. https://doi.org/10.1007/s11104-021-05171-w

Calder, P. C., Ortega, E. F., Meydani, S. N., Adkins, Y., Stephensen, C. B., Thompson, B., & Zwickey, H. (2022). Nutrition, immunosenescence, and infectious disease: an overview of the scientific evidence on micronutrients and on modulation of the gut microbiota. *Advances in Nutrition*, *13*(5), S1-S26. https://doi.org/10.1093/advances/nmac052

Gardner, C. D., Vadiveloo, M. K., Petersen, K. S., Anderson, C. A., Springfield, S., Van Horn, L., ... & American Heart Association Council on Lifestyle and Cardiometabolic Health. (2023). Popular dietary patterns: alignment with American Heart Association 2021 dietary guidance: a scientific statement from the American Heart Association. *Circulation*, *147*(22), 1715-1730. https://doi.org/10.1161/CIR.0000000000001146

Gissi, E., Manea, E., Mazaris, A. D., Fraschetti, S., Almpanidou, V., Bevilacqua, S., & Katsanevakis, S. (2021). A review of the combined effects of climate change and other local human stressors on the marine environment. *Science of the Total Environment*, *755*, 142564. https://doi.org/10.1016/j.scitotenv.2020.142564

Godswill, A. G., Somtochukwu, I. V., Ikechukwu, A. O., & Kate, E. C. (2020). Health benefits of micronutrients (vitamins and minerals) and their associated deficiency diseases: A systematic review. *International Journal of Food Sciences*, *3*(1), 1-32. https://doi.org/10.47604/ijf.1024

Grosso, G., Laudisio, D., Frias-Toral, E., Barrea, L., Muscogiuri, G., Savastano, S., & Colao, A. (2022). Anti-inflammatory nutrients and obesity-associated metabolic-inflammation: state of the art and future direction. *Nutrients*, *14*(6), 1137. https://doi.org/10.3390/nu14061137

Hopmans, J. W., Qureshi, A. S., Kisekka, I., Munns, R., Grattan, S. R., Rengasamy, P., ...& Taleisnik, E. (2021). Critical knowledge gaps and research priorities in global soil salinity. *Advances in agronomy*, *169*, 1-191. https://doi.org/10.1016/bs.agron.2021.03.001

Lei, B., Cui, J., Newman, C., Buesching, C. D., Xie, Z., Macdonald, D. W., & Zhou, Y. (2021). Seed dispersers shape the pulp nutrients of fleshy-fruited plants. *Proceedings of the Royal Society B*, *288*(1953), 20210817. https://doi.org/10.1098/rspb.2021.0817

Levitt, H. M. (2021). Qualitative generalization, not to the population but to the phenomenon: Reconceptualizing variation in qualitative research. *Qualitative psychology*, *8*(1), 95. https://psycnet.apa.org/doi/10.1037/qup0000184

Li, F., Luo, S., Mu, W., Li, Y., Ye, L., Zheng, X., & Chen, X. (2021). Effects of sources of social support and resilience on the mental health of different age groups during the COVID-19 pandemic. *BMC psychiatry*, *21*, 1-14. https://doi.org/10.1186/s12888-020-03012-1

Mantzioris, E. (2020). Macronutrients. In *Nutrition for Sport, Exercise and Performance* (pp. 49-73). Routledge.

Matsumoto, M., Saito, A., Okada, C., Okada, E., Tajima, R., & Takimoto, H. (2021). Consumption of meals prepared away from home is associated with inadequacy of dietary fiber, vitamin C and mineral intake among Japanese adults: Analysis from the

DOI: https://doi.org/10.71435/595697

2015 National Health and Nutrition Survey. *Nutrition Journal*, *20*, 1-13. https://doi.org/10.1186/s12937-021-00693-6

Munteanu, C., & Schwartz, B. (2022). The relationship between nutrition and the immune system. *Frontiers in nutrition*, *9*, 1082500. https://doi.org/10.3389/fnut.2022.1082500

Munteanu, C., & Schwartz, B. (2022). The relationship between nutrition and the immune system. *Frontiers in nutrition*, *9*, 1082500. https://doi.org/10.3389/fnut.2022.1082500

Orben, A., Przybylski, A. K., Blakemore, S. J., & Kievit, R. A. (2022). Windows of developmental sensitivity to social media. *Nature Communications*, *13*(1), 1649. https://doi.org/10.1038/s41467-022-29296-3

Pedrosa, L. F., Barros, A. N., & Leite-Lais, L. (2022). Nutritional risk of vitamin D, vitamin C, zinc, and selenium deficiency on risk and clinical outcomes of COVID-19: A narrative review. *Clinical nutrition ESPEN*, *47*, 9-27. https://doi.org/10.1016/j.clnesp.2021.11.003

Sullivan, V. K., Petersen, K. S., Fulgoni III, V. L., Eren, F., Cassens, M. E., Bunczek, M. T., & Kris-Etherton, P. M. (2021). Greater scores for dietary fat and grain quality components underlie higher total Healthy Eating Index–2015 scores, while whole fruits, seafood, and plant proteins are most favorably associated with cardiometabolic health in US adults. *Current Developments in Nutrition*, *5*(3), nzab015. https://doi.org/10.1093/cdn/nzab015

Thirumdas, R., Kothakota, A., Pandiselvam, R., Bahrami, A., & Barba, F. J. (2021). Role of food nutrients and supplementation in fighting against viral infections and boosting immunity: A review. *Trends in food science & technology*, *110*, 66-77. https://doi.org/10.1016/j.tifs.2021.01.069

Tourkochristou, E., Triantos, C., & Mouzaki, A. (2021). The influence of nutritional factors on immunological outcomes. *Frontiers in immunology*, *12*, 665968. https://doi.org/10.3389/fimmu.2021.665968

Trajkovska Petkoska, A., & Trajkovska-Broach, A. (2021). Mediterranean Diet—A Healthy Dietary Pattern and Lifestyle for Strong Immunity. *Analysis of Infectious Disease Problems (Covid-19) and Their Global Impact*, 279-305. https://doi.org/10.1007/978-981-16-2450-6_13

Venter, C., Eyerich, S., Sarin, T., & Klatt, K. C. (2020). Nutrition and the immune system: A complicated tango. *Nutrients*, *12*(3), 818. https://doi.org/10.3390/nu12030818

Witkamp, R. F. (2021). Nutrition to optimise human health—how to obtain physiological substantiation?. *Nutrients*, *13*(7), 2155. https://doi.org/10.3390/nu13072155

Yokoi, R., Watari, T., & Motoshita, M. (2022). Future greenhouse gas emissions from metal production: gaps and opportunities towards climate goals. *Energy & Environmental Science*, *15*(1), 146-157. https://doi.org/10.1039/D1EE02165F

DOI: https://doi.org/10.71435/595697