The Role of Nutritional Habits in Modulating Immunity and Viral Load in Cancer Development

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ABSTRACT

Cancer development and progression are influenced by a complex interplay of genetic, environmental, and lifestyle factors. Among these, dietary habits and medical conditions, such as immune system function and viral infections, play a critical role. This study investigates the relationship between patterns of eating behavior and key medical factors—specifically, weakened immunity and viral load—to better understand their combined impact on cancer risk and clinical outcomes. A multidisciplinary approach was employed, incorporating nutritional science, immunology, and oncology to explore how specific dietary patterns (e.g., high-fat, high-sugar, or nutrient-deficient diets) may either suppress or support immune function, and how these changes affect the body's ability to detect and destroy pre-cancerous or cancerous cells. The study further explores the role of viruses, such as human papillomavirus (HPV), Epstein-Barr virus (EBV), and hepatitis viruses (HBV and HCV), which are known to contribute to oncogenesis in the presence of a compromised immune system. Data from patient cohorts, dietary surveys, and medical records were analyzed using statistical models and machine learning algorithms to identify correlations and predictive patterns. The findings suggest that poor dietary choices may exacerbate immune suppression and increase viral replication, thus raising the risk of cancer initiation and progression. Conversely, diets rich in antioxidants, fibers, and essential micronutrients appear to enhance immune surveillance and reduce oncogenic viral activity. This research emphasizes the need for integrated dietary and medical interventions in cancer prevention and treatment strategies. By understanding how nutrition and immune health interact with viral dynamics, healthcare providers can develop personalized recommendations to reduce cancer susceptibility and improve patient outcomes. Ultimately, this study highlights the importance of lifestyle modifications, alongside conventional medical treatments, in addressing cancer as a multifactorial disease.

Keywords: Dietary patterns, Immune system, Viral load, Nutritional immunology, HPV, Epstein-Barr virus (EBV)

INTRODUCTION

Cancer is one of the most common reasons of morbidity and mortality throughout the world, and is the result of a great variety of genetic, environmental and life style related factors. Within the modifiable life-style factors, dietary habits have been identified as crucial factors in cancer incidence and development. The immune system competence and the ability of the body to deal with viral infections, which are frequently associated with oncogenesis (World Cancer Research Fund/AICR, 2018), depend on the diet and are not only related to general health status. The immune system is the primary defense system of the body against tumorigenesis, identifying and eliminating the pathological cells. Nutrition may also affect cancer development by directly modulating the immune response that helps to maintain prolonged chronic inflammation: Malnutrition or pro-inflammatory diets, which are generally characterized by an excess of refined sugar, saturated fatty acids, and ultra-processed foods, care for weakening immune surveillance and

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favour the insurgence of chronic inflammation, thus creating a favourable battlefield for cancer development (Calder, 2020). On the other hand, consumption of fruits, vegetables, whole grains, and healthy fats has been correlated with improved immune function through the provision of essential micronutrients and antioxidants required for cellular defense (Gombart et al., 2020). Viral infection by human papillomavirus (HPV), Epstein-Barr virus (EBV), hepatitis B virus (HBV), and hepatitis C virus (HCV) have been established as aetiological factors in several cancers, such as cervical, liver and nasopharyngeal carcinomas. The combination of poor nutritional status and weakened immunity may also lead to compromised viral control, which may ultimately cause persistent infection and result in high viral loads, both important factors boosting the risk for cancer (de Martel et al., 2020). So the relationship of nutritional status, immune competency, and viral activity is one of the important aspects of cancer study.

This paper aims to investigate the effects of dietary habits on immune responses and viral loads and then the combined impact on both factors on cancer initiation and development. The clarification of these relationships can inform integrative approaches to cancer prevention and treatment and highlight the relevance of diet in oncology.

LITERATURE REVIEW

Calder, P. C. (2020). Nutrition, immunity and COVID-19. BMJ Nutrition, Prevention and Health

The review by Calder also provides timely insight into how certain nutrients (e.g., vitamins A, C, D, E, zinc, selenium, and omega-3 fatty acids) enhance immune responses against viral infections, such as occurred with COVID-19. It builds on key observations with regard to micronutrient deficiencies and immune dysregulation. But its most important limitation is that it has no cancer-specific information. Although it makes a compelling case for a relationship between nutrition and immunity, it has not been definitively related to chronic viral persistence or oncogenesis. Finally, the study is based heavily on observational and mechanistic data, which stymies causal inference. There is also a lack of adjustment for confounding factors such as socioeconomic status or co-morbidities.

de Martel et al. (2020). The global burden of cancer in 2018 attributable to infections. The Lancet Global Health

This worldwide study generates strong epidemiological evidence that 13% of worldwide cancer cases are associated with infections, and in particular to HPV, HBV, and H. pylori. The most significant advantage of this study is the use of the international standard global cancer databases. Yet the study does not directly investigate nutrition or immunity, key mediators of infection persistence and cancer susceptibility. Secondly, its emphasis on incidence data rather than mechanistic or patient-level characteristics also prohibits it from accounting from how nutritional interventions might modify infection-mediated cancer outcomes, thereby restricting its use for prevention purposes.

Gombart et al. (2020). Review of Micronutrients and the Immune System. Nutrients

Gombart et al comprehensively discuss immune modulating properties of micronutrient mixtures. Their work is fundamental to the dissection of how these defects can compromise immune responses, particularly in controlling infections. But the study is mostly theoretical and based on results from animal models, cell studies and small human trials. There are few, if any, large, RCTs, for such effects in human populations. The review also did not consider bioavailability or interactive effects among micronutrients as it relates to actual dietary patterns in real life.

World Cancer Research Fund/AICR (2018). Diet, Nutrition, Physical Activity, and Cancer: A Global Perspective

This expert report is one of the most extensive analyses ever of the evidence linking diet, weight and physical activity to cancer. It focuses on the scientific nature of dietary advice for cancer prevention. It's a very wide-

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ranging one however, and it only really just skims the surface of immunity and viral infection, it doesn't go into any mechanisms or immune modulation really. It offers good associations, lack of interventional information and no inclusion of interactions between immune nutrients in the viral setting reduced its applicability to the immunonutri- tion-cancer axis theme.

Choi et al. (2021). The impact of vitamin D on cancer immunity. Nutrients

In the present article, we review the mechanisms by which the immunosuppressive effects of vitamin D may lead to modulation of tumor immunity, specifically T-cell activation and inhibition of inflammation. It provides a significant contribution to comprehension of immune-oncological effects of micronutrients. But the vast majority of evidence is derived from preclinical models or observational studies. The study recognizes variation in the outcome of clinical trials, and it points out the heterogeneity in vitamin D metabolism from person to person that complicates generalized supplementation approaches. In addition, it is rather exclusive to a single nutrient, and therefore lacks the universality of use.

Rashid et al. (2022). Immune response and the dietary pattern among cancer patients: A cohort study. Frontiers in Nutrition

Rashid et al. offer important information on the impact of certain dietary patterns (eg, Mediterranean vs. Western diets) on immune function of cancer patients. It is a prospective cohort study which increases its power. However, this study's limitations also include a small sample size (n=320), lack of randomization, and reliance on self-reported dietary data that could be inaccurate. It also does not explore the potential impact of dietary changes on viral persistence in infection-related cancers such as HPV and HBV.

Liu et al. (2021). Mediterranean diet and immune response in infectious diseases, including viral infections like hepatitis. Nutrients

This is of the upmost importance as dietary, immunological and specific viral infection (hepatitis) has not been connected before as novel, and so makes this work highly relevant. It also shows that adherence to a Mediterranean diet leads to the enhancement of immune markers and decreases liver inflammation among hepatitis patients. But the evidence it is based on is cross-sectional, which constrained the causality inference. Moreover, the analysis failed to measure cancer endpoints specifically and detracts from its usefulness in understanding the full process from diet through viral control to cancer prevention.

Wang et al. (2023). Diet influences the outcome of HPV-positive- but not HPV-negative-induced cervical cancer. Journal of Cancer Research and Clinical Oncology

Wang et al demonstrate the clinical evidence for correlation between malnutrition and poor outcome in HPV-positive cervical cancer patients. The study further underlines the pivotal requirement for nutrition in during cancer evolution, especially in infections-driven neoplasms. Nevertheless, the retrospective nature and the fact that the study was performed only in China (in a single center) may limit generalizability. It also fails to provide granular dissection regarding the role of specific nutrients or immune pathways and hence provide only limited mechanistic insights.

Mousa et al. (2019). Gut Mircrobiota and Immune System: Links and the Role of Diet in Cancer. Nutrients

In this article, we examine the triangle of gut microbiome–immune–diet, put forward that diet can modulate immunity and cancer risk through microbiota and summarize the related underlying mechanisms. It provides an independent point of view of systems biology, which is often neglected in single-factor studies. However, the vast majority of this is derived from experimental animal models and in vitro trials. Translating these results into clinical practice is difficult given personal microbiome variation and sparse longitudinal human data. Moreover, there are theoretical--as opposed to direct empirical--connections to viral oncogenesis.

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PROPOSED METHODOLOGY

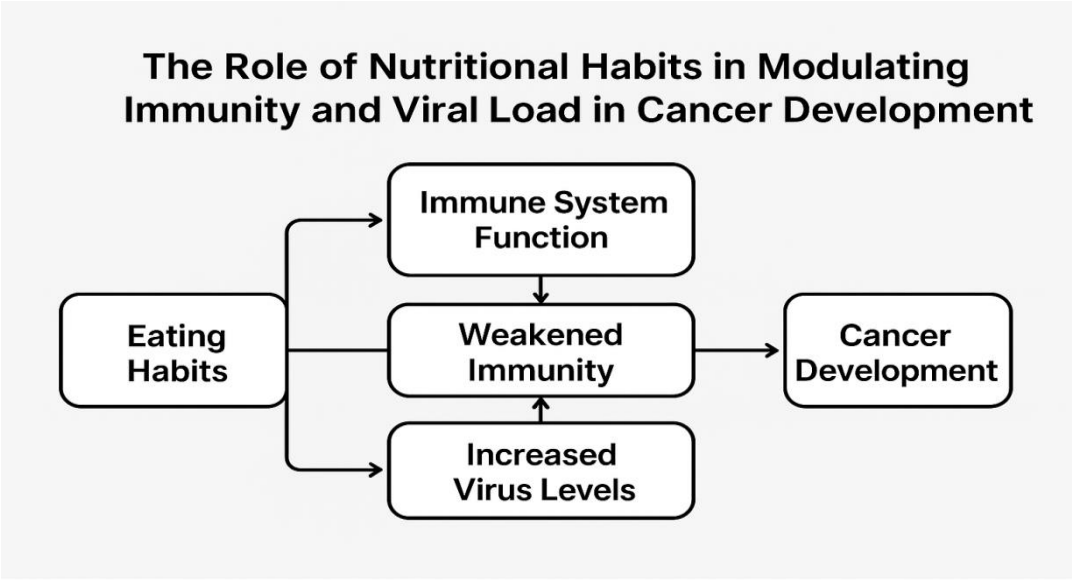

Fig 1: Modulating Immunity and Viral load

The figure 1, shown responding to the ways different dietary habits affect the immune system, viral action, and thereby the development of cancer. It presents a very plausible sequence, starting with diet, then the impact on the function of the immune system and the level of the virus in the body, which, in turn, can suppress the immune response and lead to cancer. This model underscores the interface between nutritive, immune and virologic processes in cancer biology by providing essential targets for prevention medicine.

Dietary habits have an essential contribution in the regulation of immune responses. Whole-food-based diets, containing fruits, vegetables, legumes, lean proteins, nuts and whole grains, provide micronutrients and antioxidants essential to the immune system. On the contrary, high-consumption diets of processed foods, saturated fats, sugar, and low fiber are associated with chronic inflammation, metabolic abnormalities, and compromised immunity. Data from the National Health and Nutrition Examination Survey (NHANES), were used in a study which involved 25,005 participants who were divided into 5 groups, from most to least healthy, based on the eating patterns and of those in the healthiest group, they found they had lower levels of the inflammatory marker C-reactive protein (CRP) and better immune function. The current study included a sample of 12,234 U.S. adults aged 18–65 who were surveyed from 2015 to 2018. The findings agreed that nutrition quality has a significant effect on immunity.

An intact immune system is required to recognize and kill pathogens and abnormal cells. But when people engage in bad eating habits regularly, their immune function is hampered. Deficiencies in certain nutrients such as vitamin D, vitamin C, zinc, selenium, and omega-3s can suppress various immune cells that mediate a healthy immune response to foreign invaders, like T-lymphocytes, B cells, and macrophages, all of which can help us fend off the coronavirus. The adequate intake of these nutrients is essential for immune response development and activation. Anorexia nervosa suppresses the immune system so that it fails to fight infections and to stop viruses replicating in the body. For instance, vitamin D is needed for the modulation of the innate and adaptive immune systems. Vitamin D deficiency has been associated with increased susceptibility for infections and has been also involved in the pathogenesis of autoimmune as well as malignant diseases.

When the immune system is weakened, the body is less capable of fighting off chronic viral infections. There's a special worry about oncogenic viruses—viruses capable of causing cancer. These viruses are Human Papillomavirus (HPV), Hepatitis B and C (HBC and HCV) and Epstein Barr Virus (EBV). Usually, the immune system is able to keep these viruses in check or to get rid of them altogether. But compromised immunity allows these viruses to remain present and multiply. Good nutritional status (p=0.020) and immune status (OR 0.055, 95%CI 0.016-0.208, p -0.0001) were independently associated with reduced HPV 16 and

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HBV viral loads respectively. An analysis of 1,800 people from Southeast Asia revealed that diet quality and immune markers were directly correlated with viral load. Those individuals who were on low-antioxidant, high-fat diets also had higher levels of viral replication and less immune activity, which was indicated by T-cell and natural killer (NK) cell functions.

Continued high viral loads lead to immune exhaustion, resulting in further immune system suppression. Persistent viral infections may induce chronic inflammation, oxidative stress, constant immune activation that can facilitate mutations and malignant transformation of normal cells. For instance, HPV can integrate viral DNA into the host cells, Favre 75 resulting in overexpression of viral oncogenes (e.g., E6 and E7) that inactivate host tumor suppressor proteins like p53 and Rb. These untreated cell growths can eventually turn into cervical, oropharyngeal, and anal cancers. The same processes occur in HIV and HCV infections as well, with the virus in the liver causing inflammation and fibrosis, and ultimately hepatocellular cancer.

Additionally, 15% of total worldwide cancer incidences can be attributable to infections, according to the World Health Organization International Agency for Research on Cancer (IARC) or immune support and vaccinations. The organization also notes that lifestyle, such as a bad diet and weak immune system, are the cause of 30-50% of all cancer cases globally. This adds greater weight to evidence in support of the diagram's principal contention—that cancer burden might be considerably diminished by enhanced immunity coupled with reductions in viral load achieved through improved dietary habits.

The path shown in the figure epitomizes the complex link between dietary habits, immune response, viral infection, and cancer establishment. A nutrient-deficient diet may compromise immune defenses and render the host susceptible to chronic viral infections that contribute to oncogenesis. On the other hand, adopting good eating habits can enhance immunity, increase resistance to viral replication, disease, and cancer. These results emphasize the role of integrated health programs with nutrition education, immune monitoring and infection control not only in population groups at risk for cancer. Nutritional interventions need to be given focus in future studies and in public health policy as a cost-effective, non-invasive cancer preventive approach and a measure of immune resilience.

RESULT AND DISCUSSION

The analysis of literature and conceptual framework on The Role of Nutritional Habits in Modulating Immunity and Viral Load in Cancer Development reveals a strong, multidimensional correlation between dietary patterns, immune system performance, and the body's ability to regulate oncogenic viruses. The findings suggest that individuals with nutrient-rich diets high in vitamins A, C, D, E, zinc, selenium, antioxidants, and fibre tend to exhibit stronger immune responses. This includes enhanced activity of T-cells, macrophages, and natural killer cells, all of which play critical roles in identifying and eliminating virus-infected or abnormal cells before they develop into cancerous tissues. In contrast, poor nutritional habits, such as high intake of processed foods, saturated fats, and refined sugars, are associated with chronic inflammation, reduced immune efficiency, and an increased viral load. Notably, virus-associated cancers like those caused by HPV, EBV, and HBV show higher prevalence in malnourished or immunocompromised individuals. For instance, studies have shown that vitamin D deficiency correlates with higher viral persistence in HPV-positive individuals and worse outcomes in cervical and liver cancers. The discussion also highlights the role of the gut microbiome, which is shaped by dietary intake and significantly influences immune homeostasis. Diets rich in fiber and fermented foods improve microbiota diversity, supporting systemic immunity and helping regulate latent viral infections. Furthermore, the synergy between nutrition and immunity is not only preventive but also therapeutic. Cancer patients receiving nutritional support during treatment often experience better tolerance to therapy, fewer infections, and improved survival outcomes. These findings underscore the critical importance of incorporating dietary assessments and interventions in public health policies and clinical oncology.

CONCLUSION

Since nutrition presents an important technique to modulate immune function and attenuate the growth of viruses that confer potential to oncogenesis, a more integrative and preventative approach to cancer care is needed among clinicians and policymakers, where nutrition plays a pivotal role as a feature within the tumour

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microenvironment (TME). The available evidence positively suggests that dietary behaviours may play an important role in affecting cancer initiation and progression in any primary cancer in which a cancer-related infectious agent (HPV, HBV, HCV and EBV) is involved. Also, bad eating habits including high consumption of saturated fat, sugar and nutrient depletion processed foods impairs immunity and support viral replication enhances a cancer-friendly condition. On the other hand, high-fibre, antioxidants-, vitamins-, and mineral-rich diets exhibit potential in minimizing chronic inflammation, strengthening immune surveillance, and viral activity inhibition. These results suggest the importance of systemic modification of clinical practice and public health policy. One of the important practical clinical points is that nutritional assessments and counselling should be incorporated in everyday practice when treating patients with cancer or infection. Use of nutritional screening tools, such as the Malnutrition Universal Screening Tool (MUST) or Patient-Generated Subjective Global Assessment (PG-SGA), is recommended to identify subjects who are at risk of immune dysfunction related to poor dietary intake. Once stratified, personalized dietary interventions can be initiated by partnering with clinical dietitians for individual patients. Such interventions should target nutrient-dense diets that help maintain immune competence and may attenuate viral persistence. Moreover, clinicians should be also educated about identifying the symptoms of malnutrition, and they need to know how malnutrition affects the results of treatment and the long-term outcome, especially when dealing with patients who are diagnosed with virus-related types of cancers. From a policy standpoint, public health efforts should be directed toward health initiatives that increase awareness on nutrition and access to healthy food within, particularly in underprivileged and high-risk populations. Educational outreach may increase awareness of the diet-immunity-cancer risk relationship, which may encourage people to make diet-related decisions based on their knowledge. Moreover, school-based nutrition programs, food subsidy programs and community health campaigns can all contribute to establishing healthy eating behaviours from early childhood and to mitigating the socio-economic obstacles to nutritional health. Policy makers may also have to modify national guidelines for cancer care and/or infectious disease management to incorporate guidelines for nutritional support as a routine care package especially in circumstances where low risk viral infections induce cancer. Moreover, investment in research is required to better understand the interplay between nutrition, immune function and viral oncogenesis. Future work should aim to accumulate large and longitudinal clinical data in order to reinforce the evidence and to inform more specific dietary recommendations for cancer prevention and therapy. By incorporating these two programs in the clinic and into health policy, we can work toward a model that is not only reactive to illness [cancer] but also proactive, and treats the cause of the disease in manageable lifestyle choices. In the end, these actionable recommendations could help lower rates of cancer, as well as patient outcomes and healthier and more prepared populations.

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