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Preventing Micronutrient Deficiencies in Vegan and Vegetarian Populations: Strategies for Effective Dietary Management and Health Promotion

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Abstract

Background: Micronutrient deficiencies pose significant health risks, particularly among vegan and vegetarian populations, where the absence of animal-source foods can lead to inadequate intake of essential vitamins and minerals. This issue is critical during periods of rapid growth, such as infancy and adolescence.

Methods: A comprehensive literature review was conducted using databases like PubMed, EMBASE, Google Scholar, and the Cochrane Library from 1980 to 2023. The search employed keywords including 'micronutrients,' 'vegetarian,' 'vegan,' 'deficiencies,' and various life stages such as 'infant' and 'adolescent.' Studies included original research, reviews, meta-analyses, and authoritative position papers.

Results: The review identified that vegan and vegetarian diets often lack critical nutrients such as vitamin B12, iron, zinc, and iodine, which are predominantly found in animal-source foods. For example, studies revealed that a significant percentage of vegan children exhibited vitamin B12 deficiency, leading to adverse health outcomes like anemia and developmental delays. Additionally, while some vegetarian diets showed adequate intakes of vitamins A, C, and E, the overall risk of micronutrient inadequacy remained high, particularly in strict vegan populations.

Conclusion: The findings underscore the importance of nutritional education and monitoring for individuals following vegan or vegetarian diets, especially among vulnerable groups like pregnant women, infants, and adolescents. Tailored dietary strategies, including supplementation and food fortification, are essential to mitigate the risks of deficiencies. Health professionals should advocate for well-structured diets that ensure adequate micronutrient intake to promote optimal health outcomes.

Keywords: Micronutrients, Vegetarian Diets, Vegan Diets, Deficiencies, Nutritional Education

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1. Introduction

Micronutrients are vitamins and minerals required in minimal quantities for health (mg or μg/day), facilitating the body's production of enzymes, hormones, and other chemicals vital for optimal growth and development. Micronutrients are particularly essential during periods of fast growth and development in infancy, including the first 1000 days and the first years of life, as well as throughout adolescence [1]. Micronutrient deficiencies may result in harmful health concerns, as well as less apparent issues including diminished academic performance and heightened illness susceptibility [2-5]. Conversely, there is growing evidence that dietary habits throughout infancy and adolescence might influence health in later life [6]. The World Health Organization's (WHO) Ambition and Action in Nutrition 2016–2025 sought to establish a suitable nutrition plan and referenced resolution WHA 37.18 concerning the prevention and treatment of micronutrient malnutrition.

Micronutrients must be obtained from the diet, and deficits in children without preexisting conditions are attributable to dietary sources. Micronutrient content is generally richer, more diverse, and more bioavailable in animal-source foods (ASF), such as meat, fish, eggs, dairy products, and animal-derived components, compared to foods of plant origin (FPO) [6,7,8]. Animal-sourced foods are the primary dietary sources of vitamin B12 and vitamin D, with potential additions from some mushrooms and yeasts. ASF serves as a significant supply of highly bioavailable vitamin A (retinol), iron, and zinc. Additionally, they provide a daily supply of riboflavin, choline, and vitamin E. Alternatively, vegetable oil and almonds may provide the primary sources of vitamin E. Iodine intake from diet mostly relies on iodized salt, with additional contributions from animal source foods (ASF) and, to a lesser degree, from food plant origins (FPO), contingent upon the iodine levels in the local soil and water.

Populations with little or no consumption of animal-source foods, i.e., adhering to a vegetarian diet, face the risk of deficiency in some or all of these nutrients based on their amount of animal-source food intake [9]. The extent of ASF limitations and the types of authorized meals delineate the various vegetarian patterns [10-13]. All designs include extended nursing where feasible. The lacto-ovo-vegetarian diet (LOV), sometimes conflated with a vegetarian diet, is mostly adopted and avoids all forms of meat, fish, and shellfish, while including dairy products, eggs, honey, and a diverse array of plant foods. Lacto-vegetarians omit eggs, pollotarians eat chicken, pescatarians ingest fish and shellfish, and ovo-vegetarians may consume eggs but not dairy products. Flexitarians will intermittently and variably consume meat or fish. Veganism is far more restricted, excluding all animal-sourced foods, as well as goods containing substances obtained from animal sources and all things of animal origin (e.g., wool, silk, leather). A macrobiotic diet mostly consists of grains, legumes, vegetables, seaweed, and soy products, with the potential inclusion of seafood.

It is important to recognize that in some regions, particularly in Asia, humans have thrived for millennia on diets devoid of meat, achieving both survival and longevity. This diet persists in these nations' cultural and religious traditions mostly out of reverence for all living creatures. Moreover, the avoidance of ASF is gaining traction in developed nations owing to heightened concerns over animal welfare, sustainable development, health, and the socioeconomic ramifications of animal product consumption. In homes, children's dietary behaviors are influenced by parental food purchases, modeling behaviors, and the desire for children to adopt their views and eating practices [14-16]. Conversely, an increasing number of institutions, including kindergartens, schools, universities, restaurants, and hospitals, are offering vegetarian choices at least once or twice weekly for educational and environmental purposes. This raises the issue of the hazards and benefits associated with vegetarian diets throughout infancy. The dangers associated with inadequate micronutrient consumption are a significant concern [17-22]. This narrative review seeks to evaluate and analyze the significance of micronutrient insufficiency risk based on the existing evidence.

2. Research Methodology

A thorough literature review using PubMed, EMBASE, Google Scholar, and the Cochrane Library was performed from 1980 to January 2023. The used keywords included: 'micronutrients', 'vitamin', 'mineral', 'vegetarian', 'vegan', 'pregnancy', 'lactation', 'breastfeeding', 'newborn', 'infant', 'toddler', 'child', 'adolescent', 'dietary intake', and 'deficiencies. Additionally, a search was conducted to locate pertinent papers cited in previously recognized publications. Included were original publications, reviews, meta-analyses, position papers, and recommendations issued by authoritative scientific institutions or societies. Articles in English including pertinent English abstracts, as well as those in French, were chosen. When pertinent data were detected in a different language, an online translator was used to ensure that information was not disregarded. Upon reviewing the titles and abstracts of the selected papers, duplicate references were eliminated.

3. Vitamins

FPO may serve as a substantial source of antioxidant vitamins, including vitamin C (ascorbic acid), E (tocopherol), provitamin A carotenoids, and vitamin K (phylloquinone), in addition to vitamin B1 (thiamine), B2 (riboflavin), B3 (niacin, PP), B5 (pantothenic acid), B6 (pyridoxine), B7 (biotin), and B9 (folates) [23-26]. Nonetheless, the influence of cooking (heating and leaching) and processing on the accessible vitamin content must not be overlooked [27]. In comparison to the vitamin intakes of omnivorous children, research indicate that those of vegetarians and vegans are often equivalent or even superior, particularly among vegans [28-33]. Children adhering to a macrobiotic diet have been shown to have a reduced intake of vitamin B2 in comparison to omnivores [34]. No research evaluated the consumption of vitamin K or vitamin B5.

Conversely, dietary sources of vitamin D are somewhat restricted, mostly coming from newborn and young child formulae, with minor contributions from certain fatty fish and even fewer from certain mushrooms [35-38]. In comparison to omnivorous children, studies revealed no change in the consumption of vegetarian children, but one research indicated a reduced intake among vegan children [39-44]. The primary concern with vegetarian diets is the complete absence of vitamin B12 in FPO [45]. The only potential plant source of vitamin B12 may be some algae, but with limited bioavailability [46].

Vitamin B12 is crucial for human metabolism, functioning as a coenzyme in the conversion of methylmalonyl-CoA to succinyl-CoA during propionate metabolism and in the transmethylation of homocysteine to methionine. Following an examination of established dietary reference values, the European Food Safety Authority (EFSA) recommends an adequate dietary intake of cobalamin of 4.5 μg/d for pregnant women, 5 μg/d for lactating women, 0.5 μg/d for infants under 7 months, 1.5 μg/d for infants aged 7–11 months and children aged 1–6 years, 2.5 μg/d for children aged 7–10 years, 3.5 μg/d for teenagers aged 11–14 years, and 4 μg/d for adolescents aged 15–17 years. The symptoms and long-term prognosis of cobalamin insufficiency in children are contingent upon the degree and duration of the deficit [47]. The diagnosis may be challenging in moderate cases and in the absence of particular indicators, perhaps resulting in a significant delay that might adversely affect prognosis. Practitioners should recognize this potential in newborns born to vegetarian moms and youngsters adhering to a vegetarian diet who do not use supplements.

The need for vitamin B12 rises during pregnancy and breastfeeding due to tissue growth and the provision for the fetus and baby [48,49]. In a study of pregnant women sticking to vegetarian diets for a minimum of three years without supplementation, 22% were found to be deficient in vitamin B12 [50]. Maternal vitamin B12 insufficiency correlates with low birth weight and a heightened risk of pregnancy problems [51]. The cobalamin status in the first six months of life is contingent upon the maternal cobalamin status during gestation [52]. Infants born to mothers lacking in vitamin B12 are often asymptomatic at birth but may exhibit clinical symptoms between 4 to 6 months of age [53]. Symptoms may include megaloblastic anemia, eating challenges, failure to thrive, irritability, muscle hypotonia, tremors, seizures, and potentially permanent poor neurodevelopment [54].

The cobalamin content in breast milk corresponds to the maternal cobalamin concentration in blood [55]. The primary nutritional deficiency in breast milk from vegetarian and vegan moms is vitamin B12. A vegetarian diet in the mother is the primary cause (64% of cases) of vitamin B12 insufficiency in breastfed newborns [56]. In India, which has the greatest frequency of vegetarians, 63.7% of 149 exclusively breastfed newborns (3.1 ± 1 mo) had low blood vitamin B12 levels (<200 pg/mL), while only 21% of these children had a vegetarian mother [57]. Symptoms of cobalamin insufficiency in breastfed newborns often emerge between 4 to 8 months of age. Many breastfed newborns of vegetarian or vegan mothers have been shown to have significant vitamin B12 insufficiency, resulting in anemia, failure to grow, hypotonia, developmental delays, microcephaly, and brain atrophy [58-63].

Numerous investigations have substantiated the presence of vitamin status shortage in children by demonstrating reduced blood cobalamin levels and/or elevated plasma methylmalonic acid or homocysteine levels [35,64,65]. Conversely, other individuals did not achieve comparable outcomes, perhaps owing to neglecting potential supplements or the short period of the restricted diet [39,43,63,66]. Vitamin B12 insufficiency progresses gradually due to the vitamin's storage in the liver. The observed incidence of vitamin B12 insufficiency was 62% in pregnant vegetarians, 25–85% in vegetarian children, and 21–41% in vegetarian adolescents. Deficiency was more prevalent among vegans and those who had followed a vegetarian diet from birth. Approximately 40% of 210 ostensibly healthy Indian toddlers aged 6–23 months have vitamin B12 deficiency (<210 pg/mL), particularly due to the absence of cow's milk consumption for a minimum of 6 months (OR 2.6, 95% CI 1.4–4.6) [67]. In Italy, a case of severe vitamin B12 deficiency necessitating hospitalization was recorded in youngsters adhering to a vegan diet [68]. In a macrobiotic society, 55% of children had vitamin B12 deficiency as shown by their urine methylmalonic acid levels [69]. In summary, the deficient symptoms are identical to those previously outlined for newborns [70]. Indian research including 27 young infants (6–27 months) revealed that 83% had anemia, all showed developmental delay or regression, and brain shrinkage was seen in the 9 children who underwent neuroimaging [84]. An accurate diagnosis of vitamin B12 insufficiency often relies on the presence of megaloblastic anemia and neurological problems. Nevertheless, as folate consumption is often elevated among vegetarians, the distinctive hematologic features of vitamin B12 insufficiency may be obscured.

4. Minerals

FPO is comparatively abundant in certain minerals like potassium and magnesium, although exhibits varied levels of zinc, copper, and selenium, and exclusively includes non-heme iron, which has low bioavailability [10,31,32]. The absorption of iron, zinc, and calcium is diminished by phytates and/or oxalates, which are prevalent in unrefined cereals, whole grains, and legumes. Calcium is not classified as a micronutrient because of its prevalence in the human body. The primary cause of insufficiency is insufficient consumption and/or low absorption of certain microminerals [71].

Iron's primary function in the body is to facilitate the oxygen-carrying capacity of hemoglobin and to promote tissue oxygenation. This publication has lately addressed the current understanding about iron homeostasis, dietary consumption, and the prevention of iron insufficiency [72]. Insufficient consumption of bioavailable iron may result in diminished body reserves and iron insufficiency, which can be evaluated by blood ferritin testing in the absence of inflammation. Children are more susceptible to iron deficiency because of their accelerated development. Iron deficiency will precede the development of iron deficiency anemia, potentially resulting in impaired neurodevelopment. Dietary iron consumption and absorption are the primary determinants of bodily iron status, in conjunction with blood loss. Most FPO contain modest levels of inorganic iron, which has limited bioavailability (1–12%), without accounting for potential iron leaching during cooking [86,88]. Iron bioavailability is reduced by dietary fiber and phytate, whereas it is enhanced by vitamin C. Documented intakes were often similar to or exceeded those of omnivorous children among individuals adhering to vegetarian, vegan, or macrobiotic diets [35,36-44,46].

Nevertheless, none of these investigations accounted for iron bioavailability. Consequently, the evaluation revealed diminished iron storage [35-39,42,44]. Despite the recognition that iron absorption is heightened during iron deficiency, resulting in hepcidin suppression [73]. Several investigations indicated reduced hemoglobin concentration [36,38]. Infrequent instances of iron deficiency anemia attributed to a vegetarian diet have been documented [41,44]. The likelihood of iron deficiency increases under adverse socio-economic conditions [74].

Zinc serves as the prosthetic group for several enzymes that facilitate key metabolic processes and is integral to the receptor proteins for vitamins A and D, along with thyroid and steroid hormones [75]. Globally, it is estimated that 17% of the population may experience insufficient zinc intake, with a lower prevalence in high-income nations compared to low-income areas [76]. In this sample, the average zinc consumption from animal source foods (ASF) was 34.8 ± 20%. The greatest zinc concentration is present in oysters, shellfish, and red meat, while the foremost sources of zinc include whole grains, fortified cereals, pulses, nuts, and seeds [76]. Nonetheless, the high levels of phytate, oxalate, or fiber in FPO may hinder zinc absorption. Total dietary phytate and the phytate/zinc molar ratio exhibited a significant correlation with the risk of insufficient zinc consumption ($r = 0.62$ and 0.92, respectively; $p < 0.01$) [77].

The reported dietary intakes of vegetarian or vegan youngsters were comparable to those of their omnivore counterparts in the majority of these investigations [37,39,40,42], exhibiting similar plasma zinc concentrations [39,47]. In three investigations, vegetarian children exhibited decreased consumption levels compared to omnivorous children [36,41,46]. None of these investigations documented the clinical manifestations of zinc deficiency; nevertheless, some case reports exist concerning young vegan infants who were provided with plant milk [78]. Zinc deficiency in a clinical context may manifest as diminished appetite and anorexia, reduced development velocity, heightened vulnerability to infections, diarrhea, depressive symptoms, and skin rashes at mucosal surfaces [79].

Iodine is an essential structural and functional component of thyroid hormones, playing a significant role in growth, neurological development, and cognitive functioning. The concentration of iodine, in the form of iodide, in water and food is very varied. The primary sources of iodine are sea goods, eggs, milk, and iodized salt. The iodine level in meats and FPO is contingent upon the soil fertility of the food producing area [80]. Adults who exclude iodine-rich items from their diets have a heightened risk of iodine shortage [81]. Research evaluating iodine consumption in vegetarian youngsters is limited. German research revealed that youngsters following a lacto-ovo-vegetarian diet had a reduced consumption compared to omnivores [49]. This was absent in many Finnish young vegan youngsters who had iodine urine concentrations comparable to those of omnivores [47].

Despite being inconsistently supplied by plants, the intake of these microminerals in vegetarian youngsters has hardly been assessed. In addition to ASF, they are mostly sourced from cereals, legumes, and seeds, contingent upon soil composition [32]. Two studies have shown that copper consumption in vegetarian children is comparable to or exceeds that of their non-vegetarian counterparts [37]. Adolescents following a Canadian LOV diet exhibited greater manganese consumption compared to their omnivorous peers [37]. The selenium consumption of Swedish vegan teenagers was lower than that of omnivorous adolescents [41]. Aside from these limited investigations, no other research was identified specifically concerning the use of chromium or molybdenum.

The knowledge of nutrition among parents and teenagers, together with their habits and attitudes, influences their food choices depending on the availability of certain foods and the resulting nutritional adequacy of a particular plant-based diet. This underscores the need for health experts to educate and counsel families adhering to a limited diet. Pregnant women, babies, toddlers, and teenagers adhering to a vegetarian diet need medical supervision. The fundamental issue is the prevalent lack of understanding about the intricacies of these diets and the corresponding treatments that should be offered. This outcome stems from insufficient nutritional education and training in medical schools and postgraduate programs [82-84].

5. Conclusions

The incidence of vegetarian diets among children is increasing in developed nations, mostly influenced by parental dietary choices. Adhering to a vegetarian diet might be arduous. The risk of micronutrient deficit in vegetarian children is challenging to determine because to the present limits of information stemming from the absence of well-structured trials. This necessitates the need for more robustly powered studies to more effectively uncover any issues, which are challenging to execute.

Nonetheless, the potential for vitamin B12 insufficiency should be acknowledged in neonates of vegan or macrobiotic mothers and children with significant limitations on animal-source foods. Iron deficiency, along with iodine and zinc levels, must be evaluated on an individual basis in vegan youngsters. To this end, some suitable tests may be conducted, considering that a more restricted diet in ASF correlates with an increased risk. An LOV diet exposure poses little danger, if it incorporates a highly diverse diet with enough dairy consumption and particularly specialized formulas for newborns and young children. Many deficiencies may be mitigated by nutritional counsel and adherence to a well-structured diet with a variety of foods, along with food fortification and supplementation where necessary. Conversely, it is advisable to refrain from vegan and macrobiotic diets during pregnancy and infancy. Nevertheless, particular emphasis should be placed on the micronutrients vitamin B12, iron, zinc, iodine, and vitamin D. Parents and adolescents must be made aware of the significant repercussions of neglecting dietary supplement guidance and the need for ongoing medical and nutritional oversight.

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الوقاية من نقص العناصر الغذائية الدقيقة في السكان النباتيين والنباتيين: استراتيجيات لإدارة غذائية فعالة وتعزيز الصحة

الملخص

الخلفية :تمثل نقص العناصر الغذائية الدقيقة مخاطر صحية كبيرة، خاصة بين السكان النباتيين والنباتيين، حيث يمكن أن تؤدي غياب الأطعمة الحيوانية المصدر إلى تناول غير كافٍ من الفيتامينات والمعادن الأساسية. هذه القضية تكون حرجة خلال فترات النمو السريع، مثل مرحلة الطفولة والمراهقة.

الطرق :تم إجراء مراجعة شاملة للأدبيات باستخدام قواعد بيانات مثل PubMed و EMBASEو Google Scholarو Cochrane Libraryمن عام 1980 إلى 2023. استخدمت عملية البحث كلمات رئيسية مثل "العناصر الغذائية الدقيقة"، "نظام غذائي نباتي"، "نظام غذائي نباتي صرف"، "نقص"، ومراحل الحياة المختلفة مثل "الرضيع" و"المراهق". شملت الدراسات أبحاثًا أصلية، ومراجعات، وتحليلات شاملة، ومقالات موثوقة.

النتائج :حددت المراجعة أن الأنظمة الغذائية النباتية والنباتية غالبًا ما تفتقر إلى العناصر الغذائية الحيوية مثل فيتامينB12 ، والحديد، والزنك، واليود، والتي توجد بشكل أساسي في الأطعمة الحيوانية المصدر. على سبيل المثال، أظهرت الدراسات أن نسبة كبيرة من الأطفال النباتيين تعاني من نقص في فيتامينB12 ، مما أدى إلى نتائج صحية سلبية مثل فقر الدم وتأخر النمو. بالإضافة إلى ذلك، بينما أظهرت بعض أنظمة الغذاء النباتي تناولًا كافيًا من الفيتامينات A و CوE، إلا أن الخطر العام لنقص العناصر الغذائية الدقيقة ظل مرتفعًا، خاصةً في السكان النباتيين الخالصين.

الاستنتاج :تؤكد النتائج على أهمية التعليم الغذائي والمراقبة للأفراد الذين يتبعون أنظمة غذائية نباتية أو نباتية صرف، وخاصةً بين الفئات الضعيفة مثل النساء الحوامل، والرضع، والمراهقين. تعد الاستراتيجيات الغذائية المخصصة، بما في ذلك المكملات الغذائية والتغذية المدعمة، ضرورية لتقليل مخاطر النقص. ينبغي على المتخصصين في الرعاية الصحية الدعوة إلى نظم غذائية محكمة لضمان تناول كافٍ من العناصر الغذائية الدقيقة لتعزيز نتائج صحية مثلى.

الكلمات المفتاحية :العناصر الغذائية الدقيقة، الأنظمة الغذائية النباتية، الأنظمة الغذائية النباتية الصرفة، نقص، التعليم الغذائي.