DOI: 10.51745/najfnr.9.19.137-150

REVIEW ARTICLE

Infant, Child, and Adolescent Nutrition

Anthropometric, dietary, and nutritional outcomes of vegetarian and vegan diets in childhood: A narrative review and recommendations for adequate nutrition

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ABSTRACT

Background: The adoption of plant-based diets, including vegetarian and vegan variations, is experiencing a notable increase among pediatric populations, driven by ethical, environmental, and health considerations. However, the appropriateness of these dietary patterns, particularly in relation to nutritional sufficiency, remains a subject of scholarly discourse.

Aims: This narrative review aims to synthesize the anthropometric, dietary, and nutritional aspects of vegetarian and vegan diets in children and to provide evidence-based guidelines for ensuring nutritional adequacy while adhering to a vegetarian lifestyle.

Methods: A comprehensive literature search was conducted across PubMed, Science Direct, Embase, Scopus, Web of Science, and Google Scholar up to February 2024. Search terms included variations of "vegetarian" and "vegan" in conjunction with "infant," "child," "anthropometric," and "nutritional intake." Studies were selected based on their relevance to dietary intake, nutritional status, and health, while excluding investigations focused on macrobiotic dietary patterns.

Results: A total of 278 articles were initially identified, of which 38 underwent full-text review. Sixteen studies met the inclusion criteria. Anthropometric data indicated that vegetarian and vegan children generally exhibit similar growth patterns to their omnivorous peers, though some studies show slightly lower height and weight percentiles. Dietary intake analysis revealed a tendency for vegetarian diets to exhibit higher consumption of fruits, vegetables, and fiber but potentially lower intakes of calorie energy, protein, and critical micronutrients such as iron, zinc, and calcium. Despite some deficiencies, the availability of contemporary food products and nutritional supplements have contributed to improved nutrient availability.

Conclusions: While vegetarian dietary patterns can support healthy growth and development in children, meticulous dietary planning is essential to avoid the risk of nutritional deficiencies. The availability of specialized vegetarian products and fortified foods has enhanced dietary outcomes. Sustained professional guidance from healthcare professionals is crucial for optimizing nutritional intake and ensuring that vegetarian diets meet the developmental needs of children. Future research should persist in addressing knowledge gaps and refining dietary recommendations.

Keywords: Anthropometry, Child Nutrition, Dietary Intake, Nutritional Status, Vegetarian Diet, Veganism.

ARTICLE INFORMATION

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Received: September 25, 2024
Revised: January 10, 2025
Accepted: Mars 18, 2025
Published: April 03, 2025

Article edited by:
Prof. Khaled Méghit Boumédiène
Article reviewed by:
Dr. Basil H. Aboul-Enein
Dr. Karen Cordovil

Cite this article as: Gómez Ramirez D.B., Rivas N.A.M., & Caro-Roldán M. Á. (2025). Nutritional outcomes of vegetarian diets in childhood: Addressing controversies and formulating recommendations for adequate nutrition. *The North African Journal of Food and Nutrition Research, 9* (19): 137 – 150. https://doi.org/10.51745/najfnr.9.19.137-150

1 INTRODUCTION

Plant-based dietary regimens, including vegetarian and vegan modalities, exhibit considerable heterogeneity. Variations within these dietary patterns include the consumption of specific animal-derived products, such as lacto-vegetarians (who include dairy), ovo-vegetarians (who include eggs), ovo-lacto-vegetarians (who consume both eggs and dairy), and pesco-vegetarians (who incorporate fish). Other variations include flexitarians or semi-vegetarians, who occasionally consume animal products, including diverse types of meat (Cayllante, 2014; Fraser, 2009). The most restrictive form of vegetarianism is veganism, which entails the complete

avoidance of all animal products. Within veganism, further subcategories exist, such as raw vegans, who abstain from heating food above 60°C, and fruitarians, whose dietary intake consist predominantly of fruits and vegetables (Cayllante, 2014).

The motivations underlying the adoption of these dietary practices are varied, including ethical, moral, religious, environmental, personal preference, sustainability, and health-related considerations. In the context of childhood, however, these motivations are typically circumscribed to familial adherence (Schürmann *et al.*, 2017), and the prevalence of plant-based diets among children appears to be increasing (Peretti *et al.*, 2020). European estimates suggest that the proportion of vegetarians ranges from 1.2% in Portugal to 7% in the United Kingdom and 10% in Germany, although the proportion of vegans is significantly lower (1–3%) (Redecilla-Ferreiro *et al.*, 2020). In Germany, 2% of boys and 6% of girls aged 14 to 17 identify as vegetarians, and 3.3% of children aged 6 to 11 adhere to a vegetarian diet (Rudloff *et al.*, 2019; Newby, 2009). In the United States, a survey conducted by the Vegetarian Resource Group indicated that approximately 4% of children aged 8 to 18 are vegetarian, and 1% are vegan (Pawlak & Bell, 2017; Vegetarian Resource Group, 2014).

An ongoing discourse persists regarding the appropriateness of raising children on a vegetarian or vegan diet (Baroni *et al.*, 2019; Fewtrell *et al.*, 2017; Scaglioni *et al.*, 2017). This concern is particularly relevant for restrictive dietary regimens that do not meet the criteria for being well-planned (Schürmann *et al.*, 2017). Scholarly inquiry into the dietary intake patterns of contemporary vegetarian diets in children and adolescents remains limited.

In adult populations, dietary surveys have demonstrated considerable diversity in food intake patterns among individuals identifying as vegetarians (Alexy *et al.*, 2017). The majority of studies focusing on pediatric populations date back to the 1980s and 1990s, thereby not reflecting current dietary habits, characterized by the widespread availability of a diverse array of vegetarian and vegan products (Rudloff *et al.*, 2019). Concomitant with the increasing prevalence of vegetarianism, a growing number of families are adopting these dietary practices and raising their children accordingly from infancy.

According to the German Nutrition Society (Deutsche Gesellschaft für Ernährung, DGE), the complete elimination of animal products from the diets of infants, children, and adolescents is not recommended due to the potential risk of unavoidable nutrient deficiencies in the absence of supplementation (Lemale *et al.*, 2019). However, the American Academy of Nutrition and Dietetics (Melina *et al.*, 2016) supports well-planned vegetarian and vegan diets for children and adolescents that contain the required nutrients. Current research, predominantly conducted in developed countries, yields inconclusive findings regarding the nutritional status and dietary intake of vegetarian and vegan children. Therefore, further investigation on the nutritional status, including anthropometric measurements and food intake, of children adhering vegetarian or vegan diets, as well as the formulation of recommendations to ensure adequate nutrition.

This paper aims to review the anthropometric, dietary, and nutritional aspects of vegetarian children and to provide evidence-based recommendations for maintaining a balanced diet while adhering to a vegetarian lifestyle. The findings of this review are intended to contribute to better clinical practice regarding the nutrition of vegetarian children.

2 METHODS

2.1 Literature search strategy

For this narrative review, a comprehensive and strategic literature search was conducted to identify relevant studies examining the nutritional outcomes of vegetarian diets during childhood. The following electronic databases were interrogated: PubMed, Science Direct, Scopus and Embase, along with the search engines Web of Science and Google Scholar. Studies published in English and Spanish up to February 2024 were considered eligible for inclusion. The initial search strategy employed the following Boolean-connected keywords:

- (vegetarian OR vegan) AND (infant OR child OR infancy OR childhood) AND (anthropometric OR macronutrient intake OR micronutrient intake).

Additionally, a second search was conducted using the following terms:

- (vegetarian OR vegan) AND (infant OR child OR infancy) AND (recommendations for food OR recommendations for nutrient consumption).

These search terms were strategically selected to capture a broad range of scholarly literature related to dietary intake, health outcomes, and recommendations for appropriate nutrition in children adhering to vegetarian and vegan dietary regimens.

2.2 Study selection

Upon retrieval of the search results, the titles and abstracts of the identified studies were meticulously reviewed to determine their relevance to the research topic. Duplicate records were removed, and the remaining studies were subjected to screening based on the inclusion and exclusion criteria summarized in Table 1. The study selection process,

including the rationale for excluding specific articles, is detailed in Figure 1, a PRISMA flow diagram (Page *et al.*, 2021) that provides a transparent and coherent overview of the methodology employed to refine the final corpus of included articles.

Table 1. Inclusion and exclusion criteria

Inclusion	Exclusion
- Studies focused on children between the ages of 0 and 18 years. - Studies examining vegetarian or vegan diets, or comparisons between vegetarian and omnivorous diets. - Studies that provided data on dietary intake, nutritional status, health outcomes, and/or recommendations for the proper implementation of vegetarian diets. - The study types included position statements, guidelines, case reports, and experimental studies.	- Studies focusing on macrobiotic diets, as they were considered outside the scope of this review.

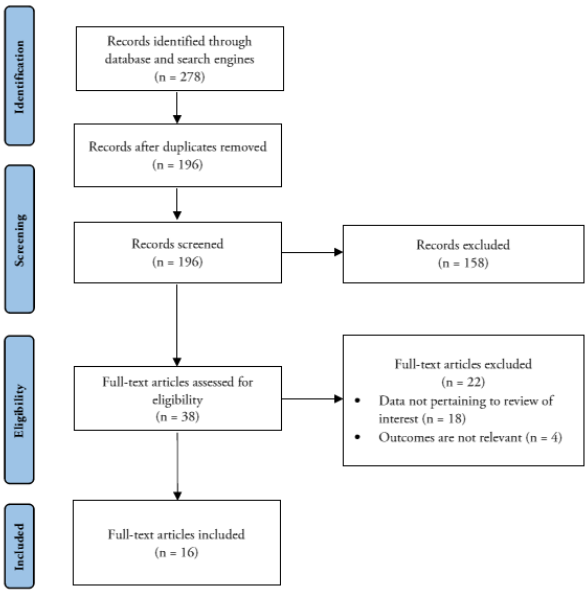

Figure 1. PRISMA Flow diagram of the article's selection process and exclusion reasons

2.3 Data synthesis

Given the narrative synthesis approach adopted for this review, the extracted data were synthesized qualitatively. Key findings from the included studies were thematically organized to reflect the principal aspects of vegetarian diets in childhood, such as anthropometric parameters, macronutrient and micronutrient intake, potential nutritional deficiencies (e.g., vitamin B12, iron, calcium), and the associated health implications of these dietary patterns. Additionally, studies providing evidence-based recommendations for ensuring adequate nutrition in vegetarian children were particularly emphasized.

The synthesis process focused on identifying areas of controversy or lacunae within the existing body of literature, as well as providing research-based recommendations for nutrition practitioners and caregivers. Findings were discussed in relation to the health outcomes and growth of children adhering to vegetarian diets, with particular attention directed towards the most commonly observed nutritional challenges.

2.4 Limitations of the review

As a narrative review, this study was not designed to provide a systematic or exhaustive meta-analysis of the extant literature. The methodological approach allowed flexibility in the selection of studies based on their relevance and methodological rigor; consequently, it is possible that some pertinent articles may have been excluded. Furthermore, no formal quality assessment of the included studies was conducted. Despite these inherent limitations, this review aimed to provide a comprehensive and accessible overview of the current state of knowledge regarding vegetarian diets in childhood, with a focus on nutrition and health outcomes.

3 Results

3.1 Results of the Search

The comprehensive literature search conducted up to February 2024 across the designated electronic databases (PubMed, Science Direct, Embase, Web of Science), and search engine (Google Scholar) yielded a total of 278 potentially relevant articles. Following the removal of 82 duplicate records, the titles and abstracts of the remaining studies were screened for eligibility. A total of 158 records were excluded as they did not meet the pre-defined selection criteria outlined for this narrative review. The full-text articles of 38 studies were retrieved and assessed for eligibility. Following this second screening, 22 studies were excluded due to reasons such as the absence of relevant dietary data, a primary focus on macrobiotic diets, or the exclusion of childhood participants. The final selection of studies was included in the qualitative synthesis. A PRISMA flow diagram (Page *et al.*, 2021) illustrating the selection process is presented in Figure 1, and a summary of the anthropometric and dietary intake results extracted from the included articles is provided in Table 1.

3.2 Anthropometric data in vegetarian diets for infants

The available body of anthropometric reports concerning vegetarian and vegan children is relatively limited. Studies conducted in the 1990s analyzed growth and anthropometric parameters; however, their results may no longer possess the same degree of contemporary relevance due to significant

improvements in vegetarian and vegan diets, particularly with the increased availability of specialized food products tailored for this population, including formulations designed for infants and young children (Rudloff *et al.*, 2019; Weder *et al.*, 2019). The study by O'Connell *et al.* (1989), which examined 404 vegetarian children aged 4 months to 10 years in the United States, concluded that height-for-age, weight-for-age, and weight-for-height percentiles fell within the 25th to 75th percentile range according to U.S. reference data. However, both height and weight for age were lower compared to the reference population. Height was between 0.2 and 2.1 cm shorter, and weight was between 0.1 and 1.1 kg lower than the reference averages. The most pronounced height difference was observed in children aged 1 to 3 years. By the age of 10, the vegetarian children in the study were, on average, 0.7 cm shorter and 1.1 kg lighter than the median reference values (O'Connell *et al.*, 1989).

More recent investigations suggest that children following omnivorous, vegetarian, and vegan diets exhibit comparable growth trajectories in terms of height and weight, consistent with WHO references. However, some vegetarian children have been observed to exhibit stunted growth and thinness, potentially associated with energy intakes below recommended levels (Weder *et al.*, 2019).

Schürmann *et al.* (2017) report that when comparing the growth of vegetarian and omnivorous children of the same age, similar growth patterns are generally observed in terms of height, weight, and body mass index (BMI). However, studies from the 1980s and 1990s documented lower weight and BMI values among vegetarian children compared to those following omnivorous diets (Hebbelinck *et al.*, 1999; Nathan *et al.*, 1997; Sanders, 1988). Sabaté & Wien (2010) also reported a tendency for vegetarian children to be leaner than their omnivorous counterparts, with the difference becoming more pronounced during adolescence, aligning with earlier studies identifying the largest differences among adolescents.

In the study conducted by Ambroszkiewicz *et al.* (2007), similar anthropometric parameters were observed in terms of weight, height, and BMI between vegetarian and normal-weight omnivorous children; however, the vegetarian children exhibited lower fat reserves ($p < 0.05$) and a lower fat mass-to-lean mass ratio ($p < 0.05$). These anthropometric results are partially attributable to food consumption patterns in vegetarian diets, that may involve lower caloric density, higher dietary fiber intake, and reduced consumption of added sugars and fats (Alexy *et al.*, 2021b). Some researchers view this leanness may represent a potential advantage of vegetarian or vegan diets in preventing the onset of obesity in childhood, as well as conferring associated benefits in reducing the risk of prevalent diseases in adulthood (Schürmann *et al.*, 2017).

3.3 Dietary intake data in vegetarian diets for infants

On average, individuals adhering to vegetarian diets exhibit a higher consumption of grains, legumes, vegetables, fruits, nuts, and seeds (Alexy *et al.*, 2022; Haddad & Tanzman, 2003; Sabaté & Wien, 2010) and lower intake of fats, added sugars, snacks, and beverages (Orlich *et al.*, 2014), resulting in an overall healthier diet (Alexy *et al.*, 2022; Krajčovičová-Kudláčková *et al.*, 1997b; Leung *et al.*, 2001). However, instances of highly restrictive diets in children and adolescents have been documented to result in inadequate nutrient provision, particularly with respect to energy intake (Baroni *et al.*, 2019). Lower calorie intakes have been reported in vegetarian children and adolescents, specifically 7597 kJ/day (1815 kcal) for vegetarians and 8039 kJ/day (1921 kcal) for omnivores (Schürmann *et al.*, 2017). Nevertheless, the Vegchi study demonstrated no significant differences in energy intake among vegan, vegetarian, and omnivorous children, although omnivorous diets exhibited higher energy density due to a greater consumption of total fats and free sugars (Weder *et al.*, 2019; Weder *et al.*, 2022a). Plant-based diets, characterized by a higher content of vegetables, fruits, fiber, and water, and possess a lower energy density (Sabaté & Wien, 2010). Additionally, approximately 10% of children and adolescents following vegetarian diets do not consume lunch at school (Patelakis *et al.*, 2019), and the limited availability of vegetarian options may contribute to reduced school meal intake and consequently lower calorie consumption in some vegetarian children (Weder *et al.*, 2019).

In the context of vegetarianism, especially for children, specific nutrients are considered critical, such as iron, zinc, iodine, selenium, long-chain omega-3 fatty acids (eicosapentaenoic acid [EPA], docosahexaenoic acid [DHA]), and vitamin D, with additional concerns about vitamin B12, calcium, riboflavin (B2), and protein in vegan diets (Melina *et al.*, 2016; Richter *et al.*, 2016; Weder *et al.*, 2022a). However, the increasing prevalence of plant-based diets has prompted the food industry to develop a wide range of meat substitutes, plant-based dairy alternatives, and nutritional supplements tailored for this population, which are now widely consumed and contribute to nutrient intake (Weder *et al.*, 2019).

Regarding protein intake, studies have indicated lower protein consumption in vegetarian children compared to their omnivores counterparts (Weder *et al.*, 2019; Yen *et al.*, 2008), with reports of hypoalbuminemia (38%) and protein deficiency (12%) in vegetarian children (Krajčovičová-Kudláčková *et al.*, 1997a). Research by Weder *et al.* (2019) demonstrated that a greater inclusion of animal-based foods correlated with higher total protein intake. Both plant-based

and omnivorous children consumed protein levels approximately 2.3–2.5 times higher than the German reference intake (1g protein/kg body weight/day), which fell within the acceptable macronutrient distribution range.

Iron represents one of the most extensively investigated micronutrients in vegetarian children. Leung *et al.* (2001) assessed ferritin levels, a key marker of iron storage, in 51 ovo-lacto-vegetarian children and reported that the prevalence of iron deficiency ranged from 4.3% with ferritin levels below 10 µg/L to 8.5% with ferritin levels under 15 µg/L in Chinese vegetarian children—prevalence rates not considered low. In contrast, another study reported a higher prevalence of iron-deficiency anemia in vegetarians (58%), compared to omnivores (9%) (Krajčovičová-Kudláčková *et al.*, 1997a).

Cobalamin (vitamin B12) is an essential nutrient for DNA synthesis and the development of brain and nervous system. High folate intake in vegetarian individuals can mask the hematological manifestations of cobalamin deficiency, but advanced deficiency can lead to irreversible neurological symptoms (Romero-Velarde *et al.*, 2016). Given that maternal B12 stores may be insufficient for the infant, it is crucial that all breastfed vegan infants receive regular B12 supplementation (0.4 µg/day for the first 6 months, 0.5 µg/day from 6 months onward), unless the mother's diet is consistently supplemented with B12 or includes B12 from fortified food sources (Mangels & Messina, 2001).

Zinc plays a vital role in proper growth and development, functioning as a cofactor for nearly 100 enzymes and participating a role in protein synthesis and immune function. The bioavailability of zinc is reduced by phytates, which are commonly found in legumes and whole grains (Romero-Velarde *et al.*, 2016). Some studies have reported lower zinc intake in vegetarian children compared to omnivores (84% of reference levels in vegetarians versus 94% in omnivores) (Schürmann *et al.*, 2017).

Calcium is necessary for bone and tooth formation, muscle contraction, vasodilation, nerve impulse transmission, and secretion of hormones and enzymes (Kirby & Danner, 2009). In a study by Ambroszkiewicz *et al.* (2007) examining the diet of 50 vegetarian children aged 2 to 10 years, calcium intake was approximately 50% lower in vegetarians compared to omnivores, and serum vitamin D levels were found to be twice as low in the vegetarian group.

In conclusion, the currently available data does not permit definitive generalizations regarding dietary intake in vegetarian children, especially considering the wide range of vegetarian and vegan food products now commercially available. Figure 2 highlights the discrepancies between findings from studies conducted in the 1980s and 1990s and current research regarding vegetarian diets in childhood.

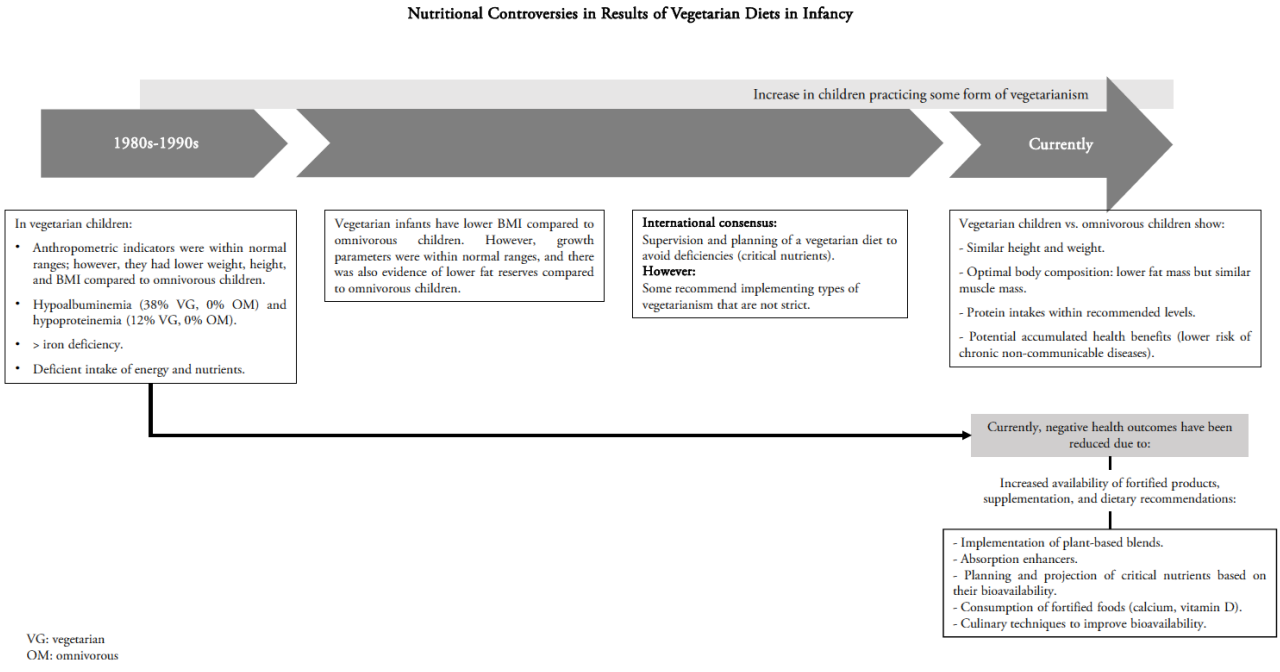

Figure 2. Nutritional controversies in results of vegetarian diets in infants

Table 1: Summary of anthropometric and intake results in vegetarian and vegan children

Reference	Objective	Participant Characteristics	Key Findings	
			Anthropometry	Intake/Consumption
Weder *et al.* (2022b)	Evaluate the intake and adequacy of micronutrients and fats in vegetarian, vegan, and omnivorous children.	The study included 430 infants (127 vegetarian, 139 vegan, and 164 omnivorous) aged 1 to 3 years.	The study by Weder *et al.* (2019) describes the anthropometric component	Children on plant-based diets had higher intake of monounsaturated and polyunsaturated fatty acids compared to their counterparts. Additionally, saturated fat and cholesterol intakes were lower in this group. Vegan children (VN) exhibited higher intake of vitamins E, K, B1, B6, C, folate, potassium, magnesium, and iron compared to the other groups. However, VG-VN children presented lower intake of vitamin B2, and all groups were below the reference for vitamin D.
Alexy *et al.* (2022)	Compare the food group consumption of vegetarian and vegan children and adolescents aged 6 to 18 years with an omnivorous control group.	The study was conducted on 390 children and adolescents (145 VG, 110 VN, and 135 OM) aged 6 to 18 years.	*	Children on VG and VN diets had a higher consumption of legumes, nuts, and dairy and meat alternatives. Additionally, VN had lower intake of fats and sweets.
Alexy, *et al.* (2021)	Examine the nutritional status and dietary intake of vegetarian, vegan, and omnivorous adolescents aged 6 to 18 years in Germany.	The study analyzed 401 children and adolescents (149 VG, 115 VN, and 137 OM) aged 6 to 18 years.	*	The three groups exhibited similar energy intakes; however, the energy density was lower in VN. Low intake of vitamin B12 was observed in vegans, although biomarkers did not indicate deficiency. Additionally, calcium intake was below the reference level in all groups.
Weder *et al.* (2019)	Examine the energy and macronutrient intake, as well as the anthropometry, of 430 vegetarian, vegan, and omnivorous children (1 to 3 years old) in Germany.	The study included 430 infants (127 vegetarian, 139 vegan, and 164 omnivorous) aged 1 to 3 years.	There was similarity between the groups in height and weight, in accordance with WHO references. However, some vegetarian children showed stunted growth and underweight.	Energy intake was lower in vegan and vegetarian children compared to omnivores, primarily due to higher consumption of total fats and free sugars. There was a high fiber intake in vegan and vegetarian children due to greater consumption of plant-based foods.
Schürmann *et al.* (2017)	Evaluate studies on the dietary intake and nutritional or health status of vegetarian infants, children, and adolescents.	The study analyzed 24 publications from 16 studies conducted between 1988 and 2013 that assessed children with vegan diets aged 0–18 years.	Growth in VG and OM children of the same age was found to be in accordance with WHO references; however, body fat mass was found to be lower in VG-VN diets.	Lower caloric intake in VG children and adolescents.

Table 1: (Continued)

Reference	Objective	Participant Characteristics	Key Findings	
			Anthropometry	Intake/Consumption
Sabaté & Wien (2010)	Explore the effects of vegetarian diets on health and the potential biological reasons for the protective effects of plant-based foods in the context of preventing childhood overweight and obesity.	The review suggests that following a plant-based diet from childhood may reduce the risk of developing obesity.	They reported that VG children are thinner than omnivorous children, and this difference increases during adolescence.	Plant-based diets, being richer in vegetables, fruits, fiber, and water, have low energy density.
Yen *et al.* (2008)	Evaluate and compare the dietary intake and nutritional status of preschool vegetarian and omnivorous children and their parents.	A total of 42 vegetarian (VG) participants were recruited (Children: 21 VG and parents: 19 VG, 2 VN) and 56 omnivorous (OM) participants (Children: 18 and parents: 28). The age group of interest was between 2-6 years.	No statistically significant differences were found between the groups of children for BMI, height, and weight.	Protein intake was lower in VG children compared to OM children. It was found that VG children had better intake of fiber and vitamin C, with no differences observed between the groups in energy consumption, or in vitamins E, B1, B2, calcium, and zinc intake.
Ambroszkiewicz *et al.* (2007)	Analyze the blood markers of bone formation in prepubertal vegetarian children.	50 children on vegetarian diets and 50 on omnivorous diets, aged 2 to 10 years, participated.	In vegetarian children, weight, height, and BMI are similar to those of their omnivorous counterparts.	Calcium intake was lower in VG children. Both groups had intakes below the recommended levels of vitamin D; however, serum vitamin D levels were twice as low in VG children.
Haddad & Tanzman (2003)	Compare the nutrient intake and eating patterns of self-identified vegetarians in the Continuing Survey of Food Intake by Individuals (CSFII) database with those of the general non-vegetarian population.	Data from 13,313 participants over 6 years old from the CSFII 1994–1996, 1998 were used to compare dietary patterns between VG and OM.	VG children had lower BMI than omnivorous children; however, the differences were not statistically significant.	VG children have healthier habits, as they consume more cereals, legumes, vegetables, fruits, nuts, and seeds.
Leung *et al.* (2001)	Investigate the nutritional status of Chinese ovo-lacto-vegetarian children aged 4 to 14 years.	The study included 51 VG (ovo-lacto-vegetarian) children aged 4 to 14 years.	The growth was found to be comparable to that of the general omnivorous (OM) population.	Protein consumption was 1.6 ± 0.6 g/kg of body weight, meeting the recommended dietary intake in the United States. However, some children were found to have iron deficiency and anemia.

Table 1: (Continued)

Reference	Objective	Participant Characteristics	Key Findings	
			Anthropometry	Intake/Consumption
Hebbelinck *et al.* (1999)	Evaluate the daily energy intake and determine selected anthropometric measures, puberty ratings, and physical fitness measures of vegetarian children, adolescents, and young adults, and compare these variables with reference data.	They evaluated different age groups; however, for this review, the groups of interest are: A: girls aged 6 to 9 years (n=9) and boys aged 6 to 11 years (n=9) B: girls aged 10 to 15 years (n=10) and boys aged 12 to 17 years (n=10)	Weight and BMI were lower in VG-VN children and adolescents compared to OM diets. Additionally, they had skinfold thickness measurements lower than the reference mean.	Lower energy intake in VG-VN children and adolescents.
Nathan et *al.* (1997)	Evaluate the ability of a meat-free diet to support normal growth in children.	50 VG children and 50 OM children, aged 7 to 11 years, were evaluated.	Growth (weight-for-age) was similar between groups and close to the 50th percentile. Additionally, arm circumference and skinfold thickness were found to be similar in both groups.	*
Krajčovičová-Kudláčková *et al.* (1997a)	Evaluate the plasma fatty acid profile in a group of vegetarians (lacto-ovo-vegetarian), vegan, and semi-vegetarian children.	The study included 32 children (7 vegan, 15 vegetarian, and 10 semi-vegetarian) aged 11 to 15 years, and the results were compared with data from 19 omnivorous children.	*	Children with alternative diets had lower saturated fat content, and the levels of n-3 polyunsaturated fatty acids in vegans (VG) were identical to those in omnivores (OM). However, the content of EPA and DHA was lower in vegans (VN).
Krajčovičová-Kudláčková *et al.* (1997b)	Evaluate the health and nutritional status of children with two different dietary habits.	They evaluated 26 VG children (lacto and ovo-lacto vegetarians) and 32 OM children in the age range of 11 to 14 years.	*	58% of the VG children, compared to 9% of the OM children, had anemia due to iron deficiency. Hypoalbuminemia and hypoproteinemia were observed in 38% and 12% of the VG children, respectively, compared to 0% in the OM children.
O'Connell *et al.* (1989)	Examine the effects of a vegetarian diet on child growth.	Evaluated 404 vegetarian children aged 4 months to 10 years.	Differences in height-for-age and weight-for-age indicators compared to the reference ideal: ▪ Height ranged between 0.2 and 2.1 cm shorter, and weight between 0.1 and 1.1 kg less than the reference mean. ▪ 2. Greater differences in height were observed in children aged 1–3 years.	*
Sanders (1988)	Examine the growth and development of British vegetarian-vegan children.	39 VG and VN children, aged 1 to 7 years, were evaluated, and the results were compared with English standards.	VG-VN children exhibited normal growth; however, they were shorter in height and lighter in weight compared to population standards.	VG-VN children showed low intake of calories, calcium, vitamin D, B2, and B12. Regarding energy consumption, most children had intake levels below the UK recommended daily dose, with this being more evident in vegan children than in vegetarians.

*Note: VG: vegetarian, VN: vegan, OM: omnivorous. *: The study does not report data on the compon*

4 Discussions

This review highlights the persistent heterogeneity in the available information concerning vegetarian diets in childhood, particularly with respect to nutritional status, food consumption, and macro- and micronutrient intake. However, longitudinal trends suggest an improvement in the nutritional profile of these diets over time, characterized by the increased availability and consumption of products specifically formulated for this population and a more comprehensive data addressing the topic. These advancements have contributed to enhanced health and nutrition outcomes in vegetarian infants, especially within industrialized countries.

Theoretically, vegetarian, and especially vegan, dietary regimens can pose a potential risk of nutritional deficiencies, particularly in vulnerable life stages such as infancy, adolescence, and pregnancy (Peretti *et al.*, 2020). However, these dietary patterns could reduce cardio-metabolic risk, though this benefit has not yet been definitively demonstrated in pediatric populations, despite accumulating positive evidence in adults. According to Sutter and Bender (2021), the pathogenesis of atherosclerosis initiates in childhood, suggesting that an early adoption of a vegan diet could further reduce the risk of cardiovascular disease. Furthermore, the consumption of reduced amounts of red meat, primarily replaced by poultry and fish, a dietary pattern often referred to as flexitarianism or semi-vegetarianism, may represent an interesting approach to reducing cardiovascular disease risk without necessarily increasing the risk of nutritional deficiencies (Peretti *et al.*, 2020).

The review by Louzada *et al.* (2023) supports the notion that vegetarian diets can provide infants and children with a higher intake of dietary fiber, magnesium, vitamins C and E, which could benefit growth and development. However, they may also be associated with deficiencies in essential amino acids, calcium, iron, zinc, iodine, omega-3 fatty acids, and certain B vitamins, all of which are crucial for proper development.

This essential duality contributes to the ongoing debate surrounding vegetarianism in childhood. While these diets can provide higher amounts of certain important micronutrients, the adequacy of others may be compromised. It is important to note, however, that lower intakes of certain micronutrients do not necessarily indicate clinical deficiency, as these may be framed within the context of physiological adaptations that can occur in response to lower nutrient availability (Louzada *et al.*, 2023). This perspective contrasts with the findings of Hovinen *et al.* (2021), who, through metabolomic analyses and the assessment of nutritional status biomarkers in infants, identified notable metabolic differences compared to omnivores, indicating that the metabolism of certain micronutrients may indeed be affected in vegan children. For this reason, Desmond *et al.* (2024) highlight the need for harmonized dietary recommendations for plant-based diets in children, given the heterogeneity of current research findings.

Interestingly, the results from the studies by Weder *et al.* (2022b) and Neufingerl and Eilander (2023) indicate that inadequate intakes of vitamin D, iodine, calcium, and fatty acids such as EPA and DHA are not exclusive to vegetarian-vegan children and can also be prevalent in omnivorous children. The VeChi Youth study demonstrated that urinary iodine excretion in vegetarians, vegans, and omnivores was, on average, lower than the established reference value, with significantly lower levels observed in vegans (Alexy *et al.*, 2021a). Additionally, the study by Weder, *et al.* (2022b) reported that 39% of vegetarians, 36% of vegans, and 16% of omnivores consumed less than 15 µg of selenium per day, which is below the adequate intake level for children aged 1 to 3 years as defined by the European Food Safety Authority (EFSA). This finding highlight that the risks of nutritional deficiency are not exclusive to any particular type of diet, aligning with the conclusions of the review by Neufingerl and Eilander (2023).

The American Academy of Nutrition and Dietetics states that well-planned lacto-ovo-vegetarian, lacto-vegetarian, ovo-vegetarian, and vegan diets are appropriate for all stages of the life cycle, including infancy and adolescence (Melina *et al.*, 2016). However, poorly planned vegetarian or vegan diets, such as any imbalanced diet, can have detrimental consequences for health and growth (Redecilla Ferreiro *et al.*, 2020). The European Society for Pediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) emphasizes the importance of ensuring adequate nutrient intake in vegetarian or vegan diets, particularly when they become more restrictive (Redecilla-Ferreiro *et al.*, 2020).

Lacto-vegetarian and lacto-ovo-vegetarian diets can be fully adequate during infancy and childhood. For infants weaned onto vegan diets, careful dietary planning is essential to guarantee adequate caloric intake, essential fatty acids, proteins, calcium, iron, zinc, and vitamin B12 from fortified foods or supplements (Scaglioni *et al.*, 2017). Scaglioni *et al.* also emphasizes that proper professional guidance is essential for vegetarian and vegan diets to ensure adequate nutrition for children.

In our review, we identify analyses consistent with those of Alexy (2023) regarding the anthropometric aspect, indicating comparability to omnivorous children, although the long-term clinical relevance of these results remains to be fully elucidated, necessitating further longitudinal studies. These dietary choices are also embedded within ethical and cultural debates, as Kiely, (2021) suggests, with parents often framing these diets as a logical extension of their ethical or

environmental values. However, concerns have been raised that imposing these dietary restrictions could potentially limit children's future autonomy or expose them to unnecessary risks if the diet is not managed appropriately. Consequently, the provision of comprehensive information for parents or caregivers becomes crucial for effective planning, aiming to avoid nutritional deficiencies (Table 2). Additionally, the support of healthcare personnel and regular evaluations of nutritional status are key elements in ensuring optimal development.

Table 2. Nutritional recommendations for vegan infants according to research guidelines (Baroni *et al.*, 2018; Fewtrell *et al.*, 2017; Kirby & Danner, 2009; Mangels & Messina, 2001; Redecilla-Ferreiro *et al.*, 2020)

Recommendation Topic	Key Findings
Breastfeeding and Formula Feeding	▪ Exclusive breastfeeding is recommended for the first six months of life. ▪ If breastfeeding is not feasible, commercially prepared soy-based infant formulas or other fortified plant-based protein formulas constitute appropriate alternatives for vegan infants. ▪ Plant-based beverages such as rice, almond, and soy milk, even when fortified with calcium, are not adequate substitutes for bovine milk during infancy. The use of infant formula or soy formula is recommended. ▪ During the period of complementary feeding, continued breastfeeding or the provision of at least 500 mL of infant formula daily is recommended to ensure adequate calcium intake, or through fortified foods.
Complementary Feeding	▪ The introduction of complementary feeding should occur at the same developmental stage (not before 17 weeks or after 26 weeks) and following the same principles as for omnivorous infants, with specific attention to strategies for preventing nutritional deficiencies. ▪ Vegetarian complementary feeding should be carefully planned by a pediatrician or registered dietitian. Regular monitoring of the child's growth trajectory, neurological development, and nutritional habits is essential. ▪ Caregivers should offer a variety of foods to infants to facilitate the development of varied flavor preferences (Scaglioni *et al.*, 2017). ▪ Consuming large quantities and a wide variety of plant-based foods (legumes, cereals, tubers, fruits, vegetables, nuts) is important, with an emphasis on minimally processed foods. ▪ Particular attention should be paid to ensuring adequate caloric intake, as vegetarian diets, due to high volume and fiber content, and sometimes lower caloric density, may lead to early satiety, especially in children under the age of five years (Kirby & Danner, 2009).
Proteins	▪ Legumes, as a natural substitute for meat in vegetarian diets, should be introduced starting at six months of age. For infants consuming purees and porridges, pureed vegetables with legumes or tofu can be offered. Ovo-lacto-vegetarians may occasionally substitute legumes with eggs or dairy. For families preferring a direct transition to solid foods, options such as hummus (prepared from chickpeas or other legume spreads), cooked and crumbled tofu, and peas or lentils mixed with rice are suitable. Unsweetened soy yogurt, with or without fruit, can also be introduced occasionally from six months of age. ▪ The combination of legumes with cereals at each meal is crucial to complement amino acid profiles (Gibson *et al.*, 2014). A higher protein intake, up to 35% of total caloric value, is also recommended for children (Mangels & Messina, 2001); therefore, the inclusion of foods such as tofu, fortified cereals, legumes, fermented soy products (e.g., tempeh), and soy yogurt is suggested. The consumption of whole grains should be encouraged. Once these foods are well-tolerated, nuts and seeds can be introduced in their ground or pureed form. After the first year of life, a wide variety of plant-based foods, including legumes, grains, nuts, and seeds should be consumed regularly.
Iron	▪ Foods rich in iron, such as legumes, should be consistently included in the diet to prevent the risk of iron deficiency. ▪ Iron deficiencies are a significant concern in vegetarian diets due to the absorption of non-heme iron and the presence of antinutrients in plant-based iron sources that can inhibit bioavailability. To compensate for this, an 80% increase in iron intake is recommended for vegetarian and vegan diets (Kirby & Danner, 2009). Additionally, the absorption of non-heme iron can be enhanced by concurrent consumption of vitamin C-rich foods. ▪ The diet should include foods rich in vitamin C and provitamin A in main meals to promote iron absorption and provide carotenoids, with sufficient fruit and vegetable consumption. Spinach, Swiss chard, beets, arugula, and other green leafy vegetables, as well as seaweed, should be avoided until the first year of life due to their high nitrate and iodine content.
Vitamin B12	▪ Vitamin B12 supplementation is recommended for ovo-lacto-vegetarians, and especially for vegans, to ensure adequate intake and prevent deficiency. ▪ For children up to three years, a daily dose of 5 µg or 250 µg twice weekly is recommended. For children aged four to ten years, 25 µg daily or 500 µg twice weekly, and for those over ten years, 50 µg daily or 1000 µg twice weekly (Redecilla-Ferreiro *et al.*, 2020). Ideally, supplements should be in the form of cyanocobalamin, which is the most studied and demonstrates the best bioavailability (Del Bo *et al.*, 2019).
Calcium and Vitamin D	▪ Calcium intake is a potential concern for vegans due to the high oxalate content in certain vegetables, which can impede calcium absorption, necessitating the consumption of large portions to meet requirements. Fortified foods and increasing calcium intake by 20% above recommendations is suggested (Kirby & Danner, 2009). ▪ Vitamin D deficiency and nutritional rickets have been associated with non-supplemented diets or inadequate consumption of fortified foods and lack of sun exposure (Kirby & Danner, 2009). Dairy products and eggs, which provide vitamin D, calcium, and protein may be included depending on the specific type of vegetarian diet (Baroni *et al.*, 2019). ▪ Opt for tofu or soy yogurts that are fortified with calcium and vitamin D. Fortified plant-based beverages can be utilized in cooking but should not serve as the primary beverage until the child is at least 2–3 years of age (Redecilla-Ferreiro *et al.*, 2020).

Table 2. (Continued)

Recommendation Topic	Key Findings
Zinc	▪ Zinc intake in vegetarian diets deserves careful consideration in pediatric populations due to lower zinc content in several plant-based foods and absorption limitations. An increase of 50% above the recommended zinc intake for strict vegetarians is recommended (Kirby & Danner, 2009).
Omega-3	▪ The inclusion of foods rich in omega-3 fatty acids, such as canola oil, soy, flaxseed, chia, and sacha inchi, is recommended (Kirby & Danner, 2009). These seeds can be introduced based on tolerance and appropriate timing of introduction within the infant's or child's developmental stage.
Culinary Treatments	▪ Culinary treatments including sprouting, soaking, cooking, roasting, homogenizing, or fermenting are important in vegetarian diets as they reduce antinutrients and enhance the bioavailability of critical macro and micronutrients.

5 Conclusions

In conclusion, the extant body of research regarding the nutritional adequacy of vegetarian and vegan diets for children presents a heterogeneous yet evolving landscape. While seminal studies from the 1980s and 1990s suggested potential nutritional deficiencies and growth concerns, recent advances in vegetarian food options and more informed dietary planning strategies have improved the nutritional profiles of these dietary regimens. The evidence suggests that with meticulous planning and appropriate supplementation, plant-based diets can support healthy growth and development in pediatric populations. However, specific nutrients such as vitamin B12, iron, calcium, and omega-3 fatty acids require particular attention to ensure that children adhering to these diets receive adequate nutrition. As the prevalence of plant-based diets continues to rise, ongoing rigorous research and updated evidence-based dietary guidelines will be essential for optimizing health outcomes in vegetarian and vegan children.

It is observed that while the reviewed data exhibit heterogeneity in anthropometric outcomes and food consumption among vegetarian infants, current outcomes may be improved due to the availability of products specifically formulated for this population and the implementation of more effective dietary management strategies. The guidance and support of healthcare professionals with appropriate recommendations are crucial to empower families raising vegetarian children to effectively plan their diets in a manner that support optimal development and health, while also respecting their dietary preferences. Additionally, establishing appropriate dietary habits during these stages is of significant importance, as they can influence dietary practices and health trajectories in adulthood. Thus, a well-planned vegetarian diet initiated in infancy may contribute to the adoption of beneficial long-term dietary behaviors and health benefits associated with vegetarianism.

Acknowledgment: not applicable.
Source of funding: not applicable
Previous submissions: None.
Authors' Contribution: BDGR contributed to the literature search, data acquisition and analysis, manuscript writing, and approval of the final version. AMNR contributed to the literature search, data acquisition and analysis, manuscript writing, and approval of the final version. MACR contributed to the manuscript writing and approval of the final version. All authors critically reviewed this and previous versions of the paper
Conflicts of Interest: All authors declare that they have no conflicts of interest.
Preprint deposit: Authors did not share this manuscript as a preprint deposit.

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