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THE EFFECT OF VEGETARIAN AND VEGAN DIET IN CHILDREN'S GROWTH AND DEVELOPMENT. A systematic review

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RESUM

Propòsit: Un creixent interès pel vegetarianisme i el veganisme ha cridat una atenció considerable, i amb això la prevalença de dietes vegetarianes i veganes en els nens.

En general, les dietes vegetarianes es consideren saludables i alguns beneficis s'han demostrat en la població adulta, no obstant això, hi ha certes preocupacions sobre si poden satisfer els requisits dietètics durant la infància i l'adolescència per a un creixement i desenvolupament adequat.

A causa de la manca de dades actualitzades disponibles, l'objectiu d'aquesta revisió sistemàtica és avaluar els riscos i beneficis potencials d'una dieta vegetariana o vegana sobre l'estat de salut, el creixement i la ingesta de nutrients en nens i adolescents fins als 18 anys.

Mètodes: Es van utilitzar les bases de dades del PubMed i Web of Science per a la cerca bibliogràfica. Els criteris d'inclusió es van centrar en estudis observacionals, comparatius, de cohorts i clínics que investiguen la ingesta dietètica i els resultats de salut en nens i adolescents que segueixen una dieta vegetariana o vegana. Es van excloure estudis sense una definició adequada de la dieta vegetariana i informes de casos, revisions i guies.

Resultats: 17 estudis publicats entre el 2000 i el 2023 van complir els nostres criteris. El creixement i el pes corporal eren generalment normals en nens amb dietes vegetarianes i veganes, tot i que alguns estudis es va informar d'una alçada més baixa per a l'edat i un augment del risc de fracàs antropomètric, especialment a les regions amb una diversitat dietètica limitada. No hi ha un benefici clar sobre el perfil lipídic, ja que tant el C-LDL com el C-HDL són baixos, però hi ha un benefici per a una ingesta més baixa de colesterol total. La ingesta de calci, vitamina D, seleni, iode i vitamina B12 va ser menor en nens vegetarians i vegans sense tenir en compte la suplementació, mentre que la ingesta de zinc, antioxidants, fibra, ferro i folats va ser més alta.

Les ingestes d'àcids grassos saturats, EPA i DHA eren més baixos en nens vegetarians i vegans, però tenien una ingesta més alta d'àcids grassos mono i poliinsaturats, ALA i LA en comparació amb els omnívors.

Conclusions: a causa de l'heterogeneïtat dels estudis, la variabilitat en l'edat i la qualitat dels estudis, és difícil treure conclusions fermes sobre els possibles beneficis i riscos. Tanmateix, les dietes vegetarianes i veganes poden donar suport a un creixement i desenvolupament normal en nens i adolescents si estan ben planificades i suplementades. Hi ha alguns riscos de deficiències nutricionals, i per això és important planificar i controlar aquestes dietes per garantir una ingesta adequada de nutrients crítics. A més, és necessari que els professionals sanitaris entenguin aquestes necessitats nutricionals especials i proporcionin orientació i suport a les famílies amb nens vegans i vegetrians.

Paraules clau: dieta vegetariana, dieta vegana, nens, adolescent, ingesta dietètica, creixement, desenvolupament.

ABSTRACT

Purpose: An increasing interest in vegetarianism and veganism has attracted considerable attention, and with it the prevalence of vegetarian and vegan diets in children.

In general, vegetarian diets are considered to be healthy and some benefits have been shown in the adult population, however, there are concerns about whether the dietary requirements during childhood and adolescence can be met for a proper growth and development.

Due to the lack of update data available, the objective of this systematic review is to assess the potential risks and benefits of a vegetarian or vegan diet on health status, growth and nutrient intakes in children and adolescents aged up to 18 years.

Methods: PubMed and Web of Science databases were used for the literature search. Inclusion criteria focused on observational, comparative, cohort and clinical studies investigating dietary intake and health outcomes in children and adolescents following a vegetarian or vegan diet. Studies without an adequate definition of the vegetarian diet and case reports, reviews and guidelines were excluded.

Results: 17 studies published between 2000 and 2023 met our criteria. Growth and body weight were generally normal in children on vegetarian and vegan diets, although some studies reported lower height for age and an increased risk of anthropometric failure, especially in regions with limited dietary diversity. There is no clear benefit on the lipid profile, as both LDL-C and HDL-C are lower, but there is a benefit for lower intakes of total cholesterol. Intakes of calcium, vitamin D, selenium, iodine and vitamin B12 were lower in vegetarian and vegan children without taking into account supplementation, whereas intakes of zinc, antioxidants, fiber, iron and folates were higher. Saturated fatty acids, EPA and DHA intakes were lower in vegetarian and vegan children, but they had higher intakes of mono and polyunsaturated fatty acids, ALA and LA compared to omnivores.

Conclusions: Due to the heterogeneity of the studies, the variability in age, and the quality of the studies, it is difficult to draw firm conclusions about the potential benefits and risks. However, vegetarian and vegan diets can support normal growth and development in children and adolescents if they are well planned and appropriately supplemented. There are some risks of nutritional deficiencies, and it's important to plan and monitor these diets to ensure adequate intakes of critical nutrients. In addition, it's necessary for healthcare professionals to understand these special nutritional needs and provide guidance and support to families with children on vegan and vegetarian diets.

Keywords: vegetarian diet, vegan diet, children, adolescent, dietary intake, growth, development.

1. INTRODUCTION

In the last decade, vegetarianism and veganism have gained considerable attention as dietary choices for individuals seeking healthier and more sustainable lifestyles, and with it an increasing number of children and adolescents opting these diets, as members of a vegetarian family or on their own initiative (18).

A study conducted by Ipsos made in 2018 found that around 8% of the world's population consider themselves vegetarians, of which 2% are self-identified as vegan (19). Building upon this global perspective, Lantern's 2017 report "The Green Revolution" indicated that approximately 7.8% of the Spanish population identified as vegans or vegetarians, primarily adhering to vegetarian diets while sporadically consuming meat or fish. Subsequent updates to its report in 2019 revealed a 27% increase over two years, setting the number of vegetarians at 9.9% of the population. In the most recent iteration of the report, published in 2021, the vegetarian population has grown another 34% to reach 13% of the Spanish population (20).

Families opt for vegetarian or vegan diets for a variety of reasons, typically with ethics emerging as the primary motivator. Moreover, ecological and environmental concerns are also gaining importance, alongside with health-related factors (18).

The vegan diet avoids consuming any animal-derived products including fish, meat, dairy, eggs, and honey, as well as those products that have been tested on animals. In contrast, a vegetarian diet excludes only meat and fish, but includes dairy products and eggs (21).

Vegetarian diets are rich in fiber, magnesium, ferric iron, folic acid, vitamins C and E, n-6 polyunsaturated fatty acids, carotenoids, flavonoids, and other phytochemicals and antioxidants. But they tend to be lower in total fat, n-3 polyunsaturated fatty acids, cholesterol, iodine, zinc, ferrous iron, and vitamins B12 and D (22). The average intake of energy and protein meets the recommendations with an adequate proportion of macronutrients and fiber (22). However, the risk of deficiency is particularly notable in the most restrictive diets, especially vegan diets, and special attention should be paid to critical nutrients (22).

Iron deficiency may arise as plant-based iron is less readily absorbed compared to iron from animal sources. Foods such as legumes, dark green leafy vegetables, fortified cereals, and dried fruits can help address this concern (23).

Since some sources of calcium, like milk and dairy products may not be included in these diets, alternative sources such as green leafy vegetables, fortified tofu, fortified plant milks, and fortified fruit juices should be incorporated (24). Additionally, Vitamin B12 is mainly found in animal-derived foods, therefore vegetarians and vegans are at risk of deficiency without supplementation. It is

important to get enough vitamin B12 through fortified foods or supplements, due to the risk of irreversible neurological damage in infants (20).
Omega-3 fatty acids, zinc, iodine, vitamin D are also essential nutrients for proper growth and development, on that account, they require special monitoring to prevent deficiency (23,24).

However, the potential risks or benefits of these diets remain controversial. While the European Society for Pediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) and The American Academy of Nutrition and Dietetics support well-planned vegetarian and vegan diets at all stages of life, including childhood and adolescence. On the other hand, the German Nutrition Association and the French Hepatology, Gastroenterology, and Nutrition Group (GFHGNP) do not recommend vegan diets for infants, children and adolescents due to the risk of nutrient deficiencies, which are inevitable without supplementation (25).

Several benefits have been shown in the adult population following a vegetarian or vegan diet, such as lower risk of cardiovascular disease, diabetes, hypertension, obesity and more weight loss (26).
Furthermore, with the increase of the interest in vegetarianism, there are recent publications of systematic reviews reporting that vegetarian diets in children could be related to a lower body weight or fat body mass, and have inadequate growth with some cases of stunting and wasting. Besides, some micronutrients could be affected with a poorly planned diet with lower intakes of vitamin D, calcium and iron status (27,28).
Due to the association based on a not recent studies of these reviews, the aim of the present study is to systematically review the literature on vegetarian or vegan diets in children and adolescents from birth to 18 years and to analyse the potential risks and benefits on health status, growth, and the nutrient intakes.

2. METHODS

2.1 Databases and search strategy

PubMed and Web of science databases were used for the search. The search query used was: ("vegan diet" OR "vegetarian diet" OR "plant-based diet"). Second, we combined this with specific search terms related to general health outcomes, such as deficiencies and growth parameters. The initial search date was June 2023 and the last update was August 2023. Details of the search strategy and filters used can be found in the appendix.

After reading the title and abstracts of the identified articles, duplicate references were removed and relevant studies were selected based on the following criteria.

2.2 Inclusion Criteria

Observational studies, comparative studies, cohort studies and clinical trials. Data on dietary consumption and nutritional or health status.

Study population ranged in age from birth to 18 years.

Studies comparing vegetarian diets (vegan, lactovegetarian, vegetarian) with omnivorous diets.

2.3 Exclusion Criteria

Studies conducted in populations not meeting the criteria defined in the PICOs (adult population, children not on adhering to a vegetarian or vegan diet, etc).

Case reports, reviews and guidelines.

Studies without a proper definition of the vegetarian diet (patterns based solely on increased consumption of plant-based foods).

Studies that did not report the outcomes of interest.

Studies during pregnancy or exclusive breastfeeding.

Studies not available in English (published in Polish journals).

The PICO questions are shown in Table 1.

2. 4 Data synthesis

Data was synthesized based on the outcomes examined in each study, with results and numerical values summarised in the results table. In addition, a bias table was created to assess the quality of the included studies.

3. RESULTS

Literature search

Fig.1 shows the flow of the literature search and article selection. We identified 259 reports from different databases and other sources, of which 31 were excluded for being duplicated records. Out of the 228 reports assessed for eligibility, 204 reports were excluded for different reasons, which are listed in Fig.1. Finally, 17 studies were included in the review.

Study outcomes were heterogeneous in terms of collection methods, age and dietary groups. Anthropometric data, dietary intake, plasma levels of selected nutrients, lipid profile, and fatty acids were assessed. An overview of the relevant results are displayed in table 2.

Growth and development

The predominant findings across numerous studies indicated that the body weight, height, BMI, and mid-upper circumference of children and adolescents following a vegan or vegetarian diets, fell within the normal range or were comparable to the omnivorous control group (1,2,4,5,9,10,12,14,16). However, two studies reported a lower z-score for height in the vegetarian group compared to the omnivorous group. One study reported an increased risk of 0.57, corresponding to a decrease of 3.15 cm, while the second study reported a risk of 0.8, corresponding to a decrease of 0.3 cm (14,17).

Some studies identified an increased risk of anthropometric failures, including stunting, wasting, and underweight. A vegetarian diet compared with an omnivorous diet in children from Hong Kong aged 4 to 14 years found a 2% of stunted growth (1). Similar results were found in another study, a cross-sectional study of children aged 1 to 3 years in Germany, which found that 3.6% of the vegan children had stunting and wasting, 2.4% of vegetarian children had stunting and 0.6 % of omnivores had wasting. But in contrast, omnivorous children had the highest prevalence of overweight with 23%(16). Furthermore, a study examining the association between the adequacy level of the vegetarian diet and the risk of anthropometric failure in children aged 6 to 23 months in India, found an increased risk of 20-30% of stunting, wasting and underweight. And a direct association between the minimum adequacy (four food groups, but not including dairy) with an average OR: 1.47 of these anthropometric failures compared to a maximum adequacy (more than four food groups, including dairy) (11).

Two studies examining body composition and skinfold measurements, in vegetarian and vegan children, found a lower fat mass and FM/LM ratio than in omnivores (5), along with a lower fat mass index, thigh and hip z scores, and suprailiac and triceps skinfolds (17). However, in the last article, there were no significant differences in lean mass index, biceps and subscapular skinfolds and waist circumference between vegetarians and omnivores (17).

Opposite to these findings, other studies found no significant differences in lean or fat mass (10).

Findings on bone health can be synthesized. One study found no significant differences in bone mineral density (BMD) of the spine in the studied girls, aged 4 to 14, on vegetarian diet compared with an omnivorous diet (1), another study in a similar age group reported no differences in bone mineral content (BMC) or BMD between vegetarians and omnivores (10). In contrast, one study found a decrease of 3.7% in BMC of the total body minus the head and a 5.6% in BMC of the spine (L2-L4) in vegans compared to omnivores (17).

Macronutrients and cholesterol

In terms of macronutrient intake, there is variability across the studies collected. Some studies reported no significant differences in dietary energy from carbohydrate, protein, and total fat (2, 5, 8).

At the same time, most of the studies were compared with the daily intake recommendations and showed that the energy from carbohydrates, protein and total fats, were within the intervals (3,6,9,10).

On the other hand, other studies showed lower intakes of protein and added sugars in plant-based diets compared with omnivores and higher intakes of carbohydrates and fibre in vegans in comparison with omnivores and vegetarians (16,17).

Regarding cholesterol intake, three studies found higher intakes of total cholesterol among omnivores compared with vegans and vegetarians (4,15,17).

Calcium

Overall the findings suggest varied adherence to calcium intake recommendations among the dietary groups.

One study found no significant differences in calcium intakes among vegetarians in different age groups (1). Another study, reported calcium intakes ranging from 105 mg to 600 mg in lactovegetarian adolescents girls (4).

Meanwhile, two other studies compared calcium intake between vegetarian, vegan, and omnivorous diets, with different results. The first study showed insufficient dietary intake in both vegetarian and omnivorous groups (5-10 years), averaging 548 ± 315 mg/day and 596 ± 222 mg/day, respectively (10). However, a higher percentage of omnivorous children (64%) met the recommended daily intake for calcium compared with vegetarian children (55%) (10). In the second study, without supplementation, less than 50% of vegan children (1-3 years) reached the recommended daily intake for calcium in Germany (320 mg/day) and vegetarians and omnivores were above the h-AR (Germany) with 399 mg/day and 445 mg/day, respectively (15).

Vitamin D

There are a variety of intake, serum plasma and supplementation results for this micronutrient.

Starting with intakes, we found four articles, one of which showed that vegetarian children had lower vitamin D levels (1.1±1.1 µg) compared with the recommended daily intake (6). Two other articles compared intakes between vegan participants and omnivorous participants and found lower vitamin D intakes in vegans compared with the omnivorous group (17). At the same time, both groups had an insufficient intake of vitamin D (1.74 and 2.01 μg/day, vegetarians and omnivores, respectively)(10). Only 38% of vegetarians and 45% of omnivores meet the recommended daily intake for vitamin D (10). The last article on intakes compared three types of groups and noted significant differences in this vitamin (15). With supplementation, vegans were the group with the highest intake (12.9 µg/day), followed by vegetarians (2.1 µg/day) and finally the omnivores (1.7µg/day) (15).

Plasma levels were also compared on five occasions (6,10,12,14,17). One article mentioned that vegetarian children were below the reference values (13,7±6.6 µL)(6). Two other articles showed no evidence of an association or no significant differences in plasma levels of total-25(OH)D between vegetarian and omnivorous diets (10,14). Another work compared the serum plasma levels between vegans and omnivores, being the first group with lower levels of total-25(OH)D (12). Finally, an article that took into account the supplementation or not of the participants. Vegans and vegetarians had lower plasma levels of total-25(OH)D compared with omnivores (a decrease of 13.2 in vegans and 7.1 in vegetarians), without taking supplementation into account (17). In contrast, when supplementation was considered, total-25(OH)D levels were higher in vegetarians (9.2µL) than in omnivores (17).

Vitamin D supplementation was followed in two articles (14,17), in which 41.9 % of omnivores and 49.6% of vegetarians took vitamin D supplements (14). And in the second, 37.5% of omnivores, 33.3 % of vegetarians and 32.7% of vegans took vitamin D supplements (17)

Zinc

Two studies found no significant differences in zinc intakes and plasma levels among the dietary groups (7,12). However, one of them reported a higher intake of zinc in vegans compared to omnivores (12).

The median intake reported in one study was 4,02 mg/day for vegetarians and 5,44 mg/day for omnivores (7), while in the second study was 7,62 mg/day for omnivores, and 8,05 mg/day for vegetarians and 8,72mg/day for vegans (12).

Selenium

Only one study reported data on selenium intakes, a cross-sectional study conducted in children aged 1-3 years (13).

With regard to selenium intake, we can distinguish two possible results. First, the unadjusted model showed intakes of 22 µg/day for omnivores, 19 µg/day for vegans and 17 µg/day for vegetarians (13). However, in the adjusted model, a higher selenium intake was found for the omnivore group (3.05 µg/day) in comparison with vegans (2.78 µg/day) (13).

There were 52% of vegetarians, 47% of vegans and 28% of omnivores who were below the harmonized average requirements (< 17µg/day). Moreover 39% of vegetarians, 36% of vegans and 16% of omnivores were below 15 µg/day (13). And in a few cases, 2% of vegetarians and 6% of vegans had intakes above the harmonized upper limit (60 g/day) (13).

Regarding supplements, only a minority of participants took selenium supplements (2% of vegetarians, 12% of vegans and 1% of omnivores participants), although the specific amounts were not known (13).

Iodine

Information regarding this mineral has been obtained from two articles. The first article indicated no differences in urine iodine levels between the dietary groups (158 µg in omnivores, 148 µg in vegetarians, 104 µg in vegans)(12). Additionally, it was observed that omnivores had the highest iodine intake, compared with vegetarians and vegans (47 µg/day vs 33 µg/day and 31 µg/day, respectively)(15).

Iron

In four of our included studies, no significant differences in iron intake were found between dietary groups in children and adolescents (1,7,8,9). One of these studies showed that vegetarians and omnivores had lower intakes of iron compared with the Recommended Dietary Allowance (RDA), 5.99 mg/day and 5.88 mg/day, respectively (8). On the contrary, three other studies reported higher intakes of iron in vegetarians and vegans compared with omnivorous children (12,15,17).

Regarding iron status, one study found that serum levels of iron, ferritin, and transferrin were within the reference range in vegetarian children (6). In addition, four other studies found no significant differences in mean values of iron, hemoglobin and transferrin levels between vegetarian and omnivorous diets (8,9,12,17). One of these studies also found no difference in ferritin levels (12). Likewise, another study found no association between a vegetarian diet and ferritin levels below 14 ng/mL (14).

In contrast, some studies observed lower levels of ferritin in vegetarian children in comparison with omnivores (8,9). One study also found lower levels of ferritin, hemoglobin and hematocrit in vegan children compared with omnivorous children. But not in vegetarians compared to omnivores (17).

Three other studies observed an average of 4% iron deficiency without anemia in vegetarians (1,7,8) compared with 11% in omnivores (7,8). Another study found that 23% of vegetarians and 4.6% of omnivores had ferritin levels below 15 ng/ml in children (9). One of these studies also found a prevalence of 8.5% anemia in vegetarians(1), while the other two studies found 4.5% anemia and

9% iron deficiency in vegetarians versus 5.6% anemia in omnivores (7,8). One study found similar results, with 2% of vegetarians and 2% of vegans with moderate iron deficiency having anemia (17). The average iron intake of the included studies in vegetarian children and adolescents was 8.49mg/day for 1-6 years, 9mg/day for 7-11 years and 8.89 mg/day for 12-17 years.

Vitamin B12 and homocysteine

In two studies in children, comparing the vegetarian intakes with the recommended values, found vitamin B12 within the reference range (1.6 ± 1.3 µg/day). However, it was noted that 28% of the vegetarian children had vitamin B12 intakes below the recommended values (<1µg/day) (3,6). Furthermore, two different studies with a similar age range, found no differences of vitamin B12 intake between the vegetarian and omnivorous diet (9,12). One study found intakes of 1.7 µg/day in vegetarians and 1.8 µg/day in omnivores(9). The other study, without taking into account supplementation, reported intakes of 3.2 µg/day in vegans, 2.7 µg/day in vegetarians, and 3.5 µg/day in omnivores (12). Interestingly, when supplementation was taken into account, significant differences were found between vegans with an intake of 43µg/day versus omnivores with an intake of 3.5µg/day.

In contrast, three studies revealed discrepancies in vitamin B12 intake between dietary groups. One study found lower intake of vitamin B12 among vegetarians compared to omnivores (1.36µg/day and 2.51µg/day, respectively) (10). Another study, comparing intakes to the harmonized average requirement (h-AR), found a lower vitamin B12 intake in the group of vegetarians and vegans without supplemented, compared to omnivores (0.6µg/day and 0.2 µg/day vs 1.5 µg/day respectively). Furthermore, less than 50% of vegans met the h-AR for vitamin B12 (0,7µg/day) and vegetarians also fell below the h-AR (15). But when supplementation was taken into account, significant differences were observed between the different diets (71.4µg/day in vegans > 1.3 µg/day in vegetarians >1.6 µg/day in omnivores) (15). The latest study found similar results when supplementation was taken into account, with significant differences between vegans and omnivores (0.5 µg/day and 2.7 µg/day, respectively). However, without taking into account supplementation, no differences were found (1.2 µg/day vs 2.7 µg/day) (17).

The average of vitamin B12 intake in the included studies, without taking into account supplementation, in vegetarians and vegans children was 1.68 µg/day from 1-6 years and 1.47 µg/day from 7-10 years.

In relation to plasma levels of vitamin B12, two studies comparing vegetarian diets with nutritional recommendations in children, observed levels within the reference range (548.6±144.4pg/mL) (3,6). When comparing vegetarian, vegan and omnivorous children, no significant differences were found between them (>128 pmol). In this study, 17% of omnivores, 40% of vegetarians, and 83% of vegans took vitamin B12 supplements (12)

On the other hand, two studies found significant differences between dietary groups in children. One study found that 4% of vegetarians had levels <160 pmol/L of vitamin B12 (1). The other study identified a decrease in plasma levels of vitamin B12 of 217.6 pmol/L in vegans and 90.9 pmol/L in vegetarians without supplementation compared to omnivores (17). When food fortification was taken into account, only vegans experienced a decrease in plasma levels of 139.8pmol/L compared to omnivores. In this study, 16% of omnivores, 19% of vegetarians, and 40% of vegans were found to have a possible B12 deficiency (17).

To monitor vitamin B12 status, plasma homocysteine levels are also taken into account. Of the three studies that analyzed it, two of them found plasma levels within the reference values (6.1±1.2 µmol/L) (3.6), and in one of them also found no significant differences between vegetarians and omnivores (6.13 µmol/L vs. 5.45). µmol/L) (6). The latter study found an inverse correlation between plasma homocysteine and vitamin B12 levels, specifically with elevated homocysteine levels and low vitamin B12 levels in vegetarians and vegans compared to omnivores (17).

Folates, vitamin B2, vitamin B6

In most of the included studies, folate intake in vegetarian and vegan children and adolescents was higher than omnivores (3,4,12,15,17) or was within the recommended intake (6). Only one study reported no significant differences in folate intake between vegetarians and omnivores (7).

Plasma levels of folate were generally within the normal range in most studies (1,3,6), whereas one study noted higher levels in vegans compared to omnivores, with four out of six vegans having levels above the reference range 208–972 nmol/l (12)

For vitamin B6 intake, one study found no significant differences between vegetarians and omnivores (7), while another found higher intakes in vegans compared to omnivores (15).

Alternatively, for B2 intake one study observed a lower intakes in vegan and vegetarian children compared to omnivores. Less than half of the vegans reached the h-AR for vitamin B2 (500µg/day), with vegetarians also falling below, reporting intakes of 429µg/day in vegans and 461 µg/day in vegetarians (15).

Fatty acids

A total of three studies reporting on fatty acid intake in children found lower intakes in vegans and vegetarians of saturated fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) compared to omnivores (12,15,17). On the contrary, they had a higher intake of mono and polyunsaturated fatty acids, alpha-linolenic acid (ALA) and linoleic acid (LA) compared to omnivores

(12,15,17). In addition, one study found a lower intake of arachidonic acid (AA) in vegans and vegetarians (15). The other study showed different results for mono unsaturated fatty acids, with a lower intake in the vegan group, contrary to the findings of the other two studies (17).

The intakes of EPA and DHA of the studies in children varied, one study in children with a median age of 3.5 years found intakes of 48 mg in omnivores and 0 mg in vegans and vegetarians for EPA and 116 mg in omnivores, 17 mg in vegetarians and 0 mg in vegans for DHA (12). The other study in children aged 5-10 years, found intakes of 3.8mg/day in vegans, 1.4mg/day in vegetarians and 10.7 mg/day in omnivores for EPA and 18.4 mg/day in vegans, 16.6 mg/day in vegetarians and 35.4 mg/day in omnivores for DHA (15).

Only one study reported plasma levels of fatty acids, and found lower levels of DHA in vegans compared to omnivore children (12).

Lipids

In most studies, vegetarian and vegan children tended to have a lower lipid profile. With lower levels of total cholesterol, High-Density Lipoprotein (HDL-C), Low-Density Lipoprotein (LDL-C) compared to omnivorous children (2,12,17). Among these studies, one specifically found lower levels of LDL in vegans, but not in vegetarians compared to omnivores (17)

Similarly, a study comparing a vegetarian diet to nutrition recommendation found lower plasma levels of total cholesterol and LDL-C, but within the reference range (155.1±25.8 mg/dL TC, reference range <170 mg/dL; 91 ± 24.5 LDL-C, <110 mg/dL). HDL-C levels were close to the lower limit (53.7±8.3, reference range 52-72 mg/dL) (3).

In contrast, some studies revealed no differences between the dietary groups in plasma levels of lipids (5,14). One of the studies compared vegetarians with omnivores and the interaction of milk consumption on the lipid profile and found no evidence of an association between vegetarian diet and serum lipids. However, observed that cow's milk consumption modified the relationship between vegetarian diet and serum lipids. Vegetarian children who consumed little or no cow's milk had lower lipid levels than omnivorous children. On the contrary, children who consumed the recommended two cups of milk a day, regardless of diet, had similar lipid levels, specifically HDL-C, LDL-C and total cholesterol (14).

Regarding triglycerides (TG), one study found plasma levels in vegetarians within the reference range of 50-100 mg/dL(3). Other studies found no significant differences were seen between vegetarians and omnivores (2,5). Although one study found high plasma levels of TG and low-density lipoprotein (VLDL) in vegetarians compared to omnivores (17).

The prevalence of lipid abnormalities was investigated across several studies. One study found a 6.4% prevalence of hyperlipidemia in vegetarians (1), another study found that 13% of omnivores and 6% of vegetarians had high pediatric LDL-C levels (≥ 130 mg/dL). Additionally, 7% of omnivores, 15% of vegetarians, and 26% of vegans had low HDL levels (< 45 mg/dL) (17).

Antioxidants

Regarding vitamin A, one study found that the vegetarian group exceeded the recommended daily intake, with a mean value of 1245.4 ± 911.3 μRE (6). However, serum vitamin A levels in the vegetarian group were within the reference values and no significant difference was found compared with the omnivores (6). Two other studies found no differences in vitamin A intakes between vegetarians and omnivores (7,12).

Only in one situation did vitamin A status, as assessed by retinol-binding protein (RBP), showed insufficient vitamin A status in vegans, despite the adequate intake of vitamin A (12). The RBP levels reflect the actively available vitamin A and are used as a vitamin A biomarker (12).

For vitamin C, studies reported higher intakes in vegetarians and vegans compared with omnivores (7,8,9,15, 17). One study also found no significant differences in intake between vegetarians of different age groups (1).

Vitamin E intakes also tended to be higher in the vegan and vegetarian groups compared with the omnivore group (15). However, in another study, serum vitamin E levels were lower in vegetarians compared with omnivores, but both were within the recommended reference values (6).

4. DISCUSSION

This systematic review highlights the lack of evidence regarding the risks and benefits of a vegan or vegetarian diet in children and adolescents. The importance of the review's findings in informing decision-making and guiding future research efforts is emphasized.

4.1 Growth and Development

Due to the low level of scientific evidence, consisting mainly of observational studies, with both cohorts and cross-sectional design, many of which included infants older than one year. Although some have followed a vegan diet since birth, it is not possible to state with certainty that infants on a vegetarian diet do not exhibit a different growth pattern compared to infants on an omnivorous diet.

This review found mixed results regarding the growth and development of children on vegetarian and vegan diets. Most of the studies observed a body weight, height and BMI within the normal range. However, some studies reported a lower height for age and risks of anthropometric failures such as wasting, stunting and underweight. One of the studies reporting anthropometric failures, had some limitations, including the indirect collection of anthropometric data, which may affect the accuracy of the results (16). Another study, used Hong kong reference growth charts, which differ from WHO reference growth charts, influencing the validity of the findings(1).

In the Vechy study, which involved a larger sample size, there was only a minimal prevalence in vegans and vegetarians of stunting and wasting (16). In contrast, a study conducted with a sample of 5772 vegetarian children aged 6–23 months from India, found an increased risk (20-30%) of anthropometric failures. In India, although nutritional conditions are improving, anthropometric status is still a critical issue (13). This and the lack of dietary diversity, could explain the higher prevalence of anthropometric failures. Highlighting the importance of dietary quality and diversity in preventing growth problems and demonstrating different results depending on the geographical area (13).

These discrepancies suggest that while well-planned vegetarian and vegan diets can support normal growth, there may be cases where inadequate planning leads to suboptimal growth outcomes.

The variation in these findings underscores the need for meticulous dietary planning in vegetarian and vegan diets in children. And further research, particularly longitudinal studies with standardized dietary assessments and growth measurements, is essential to provide more definitive conclusions on the impact of vegetarian and vegan diets on child growth and development.

4.2 Health Implications in Lipid Profile

In most of the studies reviewed, vegan and vegetarian children tended to have a lower lipid profile, characterised by lower levels of total cholesterol, LDL-C and HDL-C.

Lower levels of total cholesterol and LDL-C could have some long-term health benefits, such as preventing the development of cardiovascular disease (CVD) (29). Diet is one of the most important factors related to cardiovascular risk and a dietary patterns that limit the intake of unprocessed foods and saturated fat, such as vegan and vegetarian diets with higher intakes of unsaturated and polyunsaturated fats, along with whole grains, legumes, more fibre, etc., appear to have a protective effect against cardiovascular disease (29). Atherosclerosis, for example, starts in childhood and progresses in adulthood, so maintaining these dietary patterns into adulthood could have benefits in terms of CVD risk (29).

In contrast, some studies found lower levels of HDL-C, this reduction may not be entirely favorable. HDL-C has a cardiovascular protection effect due to its role in transporting excess cholesterol from peripheral tissues to the liver, and lower levels of HDL-C are associated with atherosclerosis and CVD (30). Therefore, it is necessary to ensure adequate levels of HDL-C in an optimal range of > 45 mg/dL (31)

In contrast, some studies found no differences in serum lipids between the dietary groups. One of these, which looked at the interaction of cow's milk in the lipid profile of the dietary groups, found that consumption of cow's milk in vegetarian diet modified serum lipids, especially HDL-C, LDL-C and total cholesterol. Those who consumed the recommended two cups of milk per day, regardless of the diet, had similar lipid levels. This suggests that the addition of cow's milk to the vegetarian diet, if not consumed, may help to increase serum lipids with a similar lipid profile to the vegetarian diet.

In relation to TG and VLDL the findings are escas and different, so makes it difficult to draw conclusions and more research into the influence of TG and VLDL in children need to be done.

4.3 Micronutrient intake

The review presented significant variability in micronutrient values among children on vegetarian, vegan and omnivorous diets. The main nutrients that were likely to be deficient in children on vegetarian and vegan diets were identified:

Iron

The average of iron intake in the studies reviewed among vegetarian and vegan children and adolescents showed an adequate intake for all age ranges with a higher intake compared to the average requirement (AR) of the EFSA (1-6 years: 5mg/day, 7-11 years: 8mg/day and 12-17 years: 7 mg/day in girls, 8 mg/day in boys).

Of the included studies on iron intake, most found no significant differences between the dietary groups and another majority reported higher intakes. Only one study found lower intakes than the RDA in vegetarians and omnivores. These results suggest that vegetarians and vegans can easily achieve the recommended intakes. However, the bioavailability of the iron must be considered, as non-heme iron from plant-sources tends to be less readily absorbed than the heme iron from animal sources(32). Around 12% of iron from plant sources is absorbed, which is attributed to the indigestibility of cellular constituents such as chloroplasts and mitochondria (32). It is therefore clear that a higher intake of iron is not reflected to a better iron status.

In contrast, to assess the risk of iron deficiency, ferritin needs to be considered as a specific biomarker to assess iron deficiency (ID). Low levels of ferritin are defined by the WHO as <12µg/L in children, but in clinical practice ID could be diagnosed when ferritin levels are below 30 µg/L (33). Transferrin saturation (TSAT) levels below 20% are also diagnostic for ID(33). In our review, there are mixed results reporting ferritin levels but not TSAT, some studies reported lower ferritin levels but in contrast other studies found no differences in ferritin levels or no association between the vegetarian diet and low ferritin levels. On the other hand, there was a prevalence of iron deficiency with and without anemia in several studies, although in two studies the prevalence was higher in the omnivorous diet. These findings highlight the importance of monitoring iron status, not only in vegetarian and vegan children but also in omnivorous children. Because of to the risk of iron deficiency and iron deficiency with anemia, with consequences such as poor cognitive, motor and neurophysiological development (34)

Vitamin B12, B, homocysteine

The average of vitamin B12 intake in the included studies, without taking into account supplementation, in vegetarian and vegan children showed an adequate intake for children aged 1-6 years, but at the lower limit compared to the EFSA Adequate Intake (AI) (1.5 µg/day). And an inadequate intake for children aged 7-10 years compared to AI of the EFSA AI (2.5 µg/day).

These results suggest that without supplementation, vegetarian or vegan diets are unlikely to achieve the recommended intakes.

In our review, some studies found no significant differences between vegetarian and vegan diets compared to omnivorous diets, but most studies that didn't consider supplementation found lower intakes or lower than the recommended intakes in vegetarians and vegans, with a prevalence of vitamin B12 deficiency in some cases. Twenty-eight per cent of vegetarians in two studies were below the recommended levels of <1µg/day and another study found that less than fifty percent of vegans met the h-Ar of 0.7µg/day. Considering that these reference values are already very low compared to the EFSA AI, and that a statistically significant number of vegans and vegetarians tend to fall below them, indicates the importance of supplementation, especially in vegans. This is consistent with the results found when supplementation was considered at higher intakes in these dietary groups.

Vitamin B12 is synthesised by soil-dwelling bacteria. It can't be synthesised by fungi, plants or animals (35), and is mainly concentrated in the bodies of animal predators (36). Animal foods such as milk, meat, eggs and fish are the main principal sources of vitamin B12, which is why vegetarians and vegans are at higher risk of vitamin B12 deficiency due to the low contribution or absence of this vitamin from plant food (36). Vitamin B12 deficiency provokes hyperhomocysteinemia that it is a characteristic factor for risk development of atherothrombotic and neuropsychiatric disorders (36), in children, research has found an association between vitamin B12 deficiency and higher levels of homocysteine, that impacts negatively on cognitive function (37).

Regarding plasma levels of vitamin B12 and homocysteine levels in our results, interestingly one study analysing the relationship between the two of them found an inverse correlation between plasma homocysteine levels and vitamin B12 levels, in vegetarian and vegan children. However, when food fortification was taken into account, only vegans experienced a decrease in plasma vitamin B12 levels, and when supplementation was taken into account, none of them did. This again highlights the importance of supplementation in these dietary groups for a proper vitamin B12 levels and a correct neurocognitive development.

Concerning the B vitamins, folate intake is generally higher in vegetarians and vegans than in omnivores in most of the included studies. Along with plasma levels in the normal range or higher. Vitamin B6 intakes also don't raise concerns about meeting requirements.

In contrast, riboflavin (vitamin B2) causes more concern, with one study reporting lower intakes of vitamin B2, with less than half of vegans meeting the h-AR, and vegetarians also falling below. And compared to the EFSA AI (0.5mg/day) intakes are inadequate. Riboflavin deficiency can reduce the metabolism of other B vitamins, particularly folate and vitamin B6 (38). Adequate intake of this vitamin is also important for adequate absorption of other B vitamins and for proper neurodevelopment (37).

Vegetarians and vegans with a diversified diet containing different fruits and vegetables can avoid deficiency, although intakes may be lower than omnivores (38).

Fatty acids

The intakes of EPA and DHA reported in two studies in vegetarian and vegan children were below the EFSA AI for all age groups (EPA + DHA: 250mg/day). Omnivorous children also failed to meet the recommended intakes.

Our findings on fatty acid intakes in three studies on vegetarian and vegan children showed lower intakes of saturated fatty acids, EPA and DHA. But instead a higher intakes of monounsaturated and polyunsaturated fatty acids, ALA and LA. Reducing saturated fatty acids and increasing intake of monounsaturated and polyunsaturated fatty acids has health benefits, such as preventing the development of CVD (29), as we have previously mentioned in the lipid profile. On the other hand, lower levels of essential fatty acids (EPA and DHA) during childhood and adolescence have some risks, may be associated with lower processing speed, affect cognitive functions and have a lower neuropsychological capacity later in adulthood (39).

The main source of EPA and DHA is fish oil, but adequate amounts can be found in plant sources, mainly in nuts, seeds or linseed oils, chia, hemp and soya and their derivatives (40). A handful of walnuts or one tablespoon of any of these seeds could cover the requirements (40). The EPA and DHA play a special role in the development and maintenance of the brain and memory, have ant-inflammatory and antioxidant properties and are involved in the immune system (40). Therefore, we need to pay particular attention to these essential fatty acids, which can be deficient in a plant-based diet if the proportion of plant sources is not sufficient to ensure an adequate minimum, and if necessary, supplementation or fortification could be considered.

Selenium and zinc

Regarding selenium, the only available study showed lower average selenium intake in vegetarians and vegans compared to omnivores. Only the unadjusted model exceeded the EFSA selenium recommendation (15 µg/day for children aged 1-3 years). This unadjusted model is less reliable and accurate because it includes fewer variables than the other model. Despite dietary differences, the majority of the children in the studies did not reach the recommended selenium intake, but omnivorous children usually had higher selenium intakes compared to vegetarians. This is due to the large number of animal based foods that have a high content of this mineral. Some examples are seafoods, eggs, grains, poultry, meat and organ meats (42).

Selenium is an essential element involved in numerous metabolic processes, control of the immune system, thyroid hormones, male infertility, neoplasms, cardiovascular disease and DNA synthesis. It also possesses antioxidant qualities (41). And the lack of selenium in children can impact their growth and cognitive development, weaken their immune system, and make them more susceptible to infections (41).

In contrast, a small proportion of children, mainly those consuming Brazil nuts, exceed the upper intake limit for selenium. Excessive selenium intake can lead to toxicity, characterised by gastrointestinal disorders, hair loss and nerve damage (42). Thus, it is necessary to monitor selenium intake to ensure it remains within recommended limits.

Two studies reported zinc intakes, the first one involved participants aged 2 to 18 years and the EFSA's requirements for this age range from 3,6 mg/day to 9,9 mg/day. So perhaps the average intakes in this article are on the low side, and probably half of the population studied is deficient in zinc, including vegetarian and vegan children, even the omnivorous participants (7).

In the second article, the intakes are higher and quite appropriate considering that the average age was 3.5 years (12). We can confirm that 100% of the children reached the minimum recommended levels.

Zinc deficiency causes a variety of health problems, especially in young people. It can cause diarrhea, stunting and lack of appetite, as well as some future reproductive problems, hair loss and some infections (43). Although zinc is not a nutrient that is usually deficient in plant-based diets, it is important to consider.

Iodine

Another micronutrient, although not as prominent, is iodine. In the vast majority of cases it is more often to find deficiencies in vegans or vegetarians than omnivores. Iodine is crucial to the production of thyroid hormones, which are vital for brain development and growth in early childhood and adolescence, especially the second ones (44). The EFSA recommendation for iodine is 90 µg/day for children aged 1 - 10 years, so as in both articles included children in this age range (12,15), we can state that in the first article all children are above the adequate reference, whereas in the second article no of them reaches the minimum levels and there is a deficiency.

Nevertheless, ensuring adequate iodine intake remains crucial and can be achieved through fortified foods (such as iodized salt) and careful dietary planning to include iodine-rich sources.

Calcium, vitamin D and bone health

Calcium intake varied according to diet. A higher percentage of omnivores were above the recommendations (h-AR), but not significantly, compared to vegetarian children. Nevertheless, almost a third of the population was deficient in calcium (10,15) compared with the EFSA values for 4-10 year olds, which are at least 680 mg/day.

In another study, less than a half of the vegan children reached the German h-AR recommended calcium intake (320 mg/day) (15). The average requirements for calcium in children aged 1- 3 years by the German harmonised average requirements were similar to the EFSA values (390 mg/day).

These findings showed that a large proportion of the participants, regardless of their diet, did not meet the recommended calcium requirement. The lower percentage of vegans meeting the h-AR indicates the need for targeted dietary advice and possible supplementation.

On the other hand, the articles on vitamin D intake had participants aged between 5 and 10 years old (6, 17), with the exception of two articles in which participants were aged between 6 months to 8 years and 1 to 3 years old (14,15). The EFSA recommendations for adequate intake is the same for both groups (15 µg/day), so we can affirm that the majority of intakes were deficient in this vitamin.

Given the high prevalence of calcium and vitamin D deficiency in vegan and vegetarian diets, these two parameters have a very strong correlation with bone mineral health and can cause serious health problems and long-term consequences for bone growth and health (45,46).

Vitamin D is important for calcium absorption and bone health in general (46). Many studies showed insufficient vitamin D intake in vegetarian and vegan diets without supplementation, with median intakes ranging from 0 to 12,9 µg/day, falling below the minimum levels in accord with EFSA.

The minimum target level for vitamin D for the whole population is 50 nmol/L (47) and most of the population tends to fall below this reference value, with vegans and vegetarians having more difficulty achieving the minimum intake and plasma levels of vitamin D. It’s therefore necessary to find methods, such as supplementation or fortified foods, to reach the minimum in this population.

In relation to bone health, as we mentioned in the results, there were two different conclusions for bone health. The first opinion was that there were no significant differences between BMD in different dietary patterns (10,17), so this evidence suggests that a vegetarian diet may be as effective as an omnivorous diet in maintaining bone health in childhood. However, another study had a different perspective due to a decrease in vertebral BMC in vegans compared to the general population (17). The evidence from this study suggests that a strict vegan diet may be associated with a lower bone density.

4.4 Evidence and quality levels of studies

In this systematic review, we assessed the quality of the evidence obtained in our studies, including various levels of scientific evidence according to the number and types of bias. The articles present a variety of levels of evidence ranging from level 2- to level 2++.

Most of the articles included in this review were rated at level 2- and 2+, while some were rated at level 2++.

Taking into account the quality of the scientific evidence shown in the previous sections is a major limitation of our review, as we have rated nine out of seventeen studies as level 2- and most of our studies almost regularly have major biases. Specifically, level 2- studies present more methodological limitations, such as poorly controlled designs or selection of the participants' bias problems. These studies have a less reliable evidentiary force compared to level 2++ studies.

On the contrary, six out of seventeen are rated with level 2+ and only two articles are rated with 2++. These types of studies have a more robust design, so they have adequate controls and fewer bias problems, making them more reliable and increasing confidence in the six conclusions. Level 2++ studies are particularly valuable as they provide more solid evidence on the causal relationships between diet and micronutrient levels.

4.5 Strengths and limitations

A great strength in our work is the use of a systematic methodology. Systematic reviews are considered the most reliable sources of evidence for decision-making as they employ explicit methods to identify, select, and critically appraise relevant primary research, and to extract and analyze data from the studies that are included (48).

While the diversity of findings may enrich global understanding, it also presents challenges to draw firm conclusions. The variation in results across different studies requires us to consider multiple perspectives and factors, reflecting the complexity of the reality under study.

Another limitation of our study was the limited information found for some of the micronutrients included, such as selenium, zinc and iodine. In order to obtain more accurate and reliable results for those minerals, the source of the results would have to be broader.

Also the studies do not have a homogeneous age population but contain a lot of variability in age, in other words, some studies have a very wide age range and it is difficult to compare them with the average references.

5. CONCLUSION

In conclusion, this review highlights the potential risks of micronutrient deficiencies in children and adolescents on vegan or vegetarian diets. Although well-planned plant-based diets have health benefits, they also present challenges in meeting the essential nutrients requirements for growth and development.

Healthcare professionals need to understand these unique nutritional needs and provide guidance and support to families with children on vegan and vegetarian diets. Adequate intakes of critical nutrients such as vitamin B12, iron, zinc, calcium, omega-3 fatty acids, and vitamin D are essential for proper growth and prevent deficiencies.

Further research, particularly longitudinal studies, is needed to better understand and guide clinical practice regarding the long-term health outcomes of children and adolescents on vegan diets. In addition, comparative studies are needed to assess the effectiveness of interventions, such as providing dietary advice in one group compared with no dietary advice in the other.

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APPENDICES

Search strategy: (((vegan diet[Title/Abstract]) OR (vegetarian diet[Title/Abstract]) OR (plant-based diet[Title/Abstract])))AND(((growth[Title/Abstract]) OR (obesity[Title/Abstract]) OR (nutrients[Title/Abstract]) OR (deficiency[Title/Abstract]) OR (development[Title/Abstract]))). Filters were applied for language (Catalan, English, Spanish), age group (Child: birth-18 years), species (Humans) and publication year (2000-2023).

Table 1. PICO questions

Population	Human, pediatric population (Child: birth-18 years)
Intervention	Vegan diet, vegetarian diet or plant-based diet
Comparator	Not applicable or omnivorous diet.
Outcomes	Growth, Obesity, Nutrients, Deficiency and Development
Type of study	Observational study, comparative study and cohort Study.
Limits	Year publication between 2000-2023 Languages: English, Spanish, Catalan

Figure 1. Flow chart.

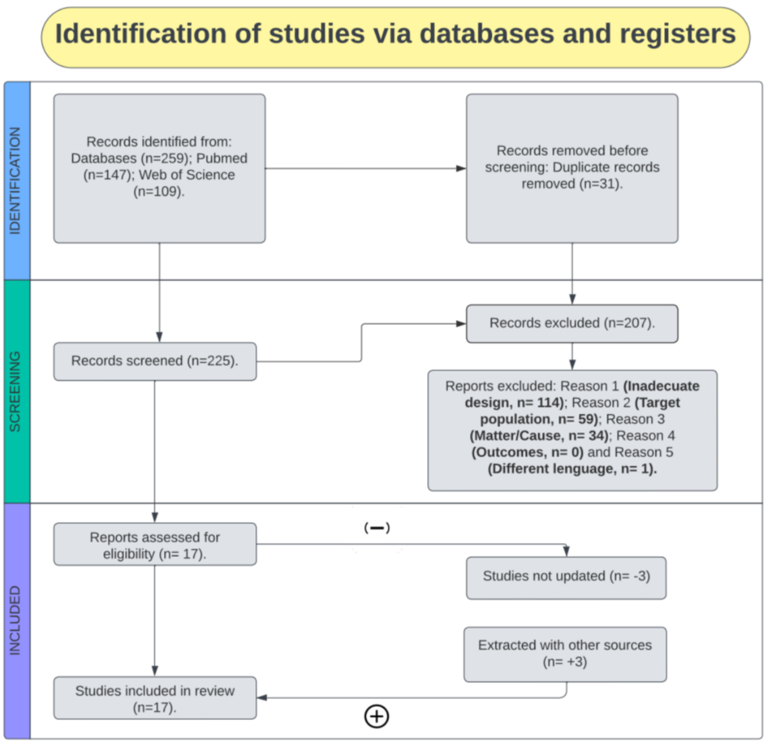

Table 2: Extraction of results

Author, year	**Study design and Participants**	**Diet assessed/ compared**	**Assessed outcomes**	**Results**
Leung SSF (2001) (1)	Descriptive observational (cross-sectional) n= 51 Chinese children lacto-ovo-vegetarian (for at least 1 year), age 4-14 years .	Vegetarian diet compared to the local omnivorous. Dietary intake: from 7 day food record and analyzed by a computer program, previously used for a local population	Anthropometry: (weight for age, weight for height, height for age, BMI, and prevalence of obesity) Analyzed using Hong Kong reference charts. Bone status: BMD of the spine (L2-L4). Intakes of Ca, Vitamin C, Iron. Serum lipids, hematological data, iron, Vit B12 and folate status. Venous blood sample (10ml) after overnight fasting.	Weight, height, weight for age, weight for height, BMI (19.37 -21.20) of diet groups within the normal range 2% had stunting (-2.36SD). 20% had of obesity (BMI >90th percentile of Hong Kong reference) *Bone status* BMD of the studied girls within mean ± 2 SD of local curves for girls. No reference curve for boys. *Intakes* NO significant differences in Ca, Iron and Vitamin C between age groups. *Serum/plasma levels (results of 47 subjects)* 8,5 % had anemia (Hb < 3th percentile curve). 4% had iron deficiency without anemia (serum ferritin < 10 mg/L). 6,4% had hiperlipidemia (above total-C 4,4 mmol/L and LDL 2,84 mmol/L). Folate within the normal range (>7 nmol/L) 4% had < 160 pmol/L of Vit B12.
Ambroszkiewicz J, et al. (2004) (2)	Comparative Observational n= 35 children, age 2-10 years from Poland. 22 vegetarians (13 lacto-ovo-vegetarians, 2 lacto-vegetarians and 7 vegans) and 13 omnivores (control group)	Vegetarian diet compared to omnivorous diet. Dietary intake: analyzed using the program Dietetyk2. Methodology not reported	Anthropometry (BMI height, and weight). Total energy, macronutrients intake, and fiber. Serum concentrations of lipids (TC, HDL-C, LDL-C, and TG) Venous blood sample after overnight fasting.	NO significant differences between the diet groups in height, weight, and BMI. *Intakes* VG vs OM: NO significant differences in dietary energy, CH (E%), P (E%) and F(E%). VG> fiber than OM. *Serum concentrations* VG< TC, HDL-C, LDL-C than OM. No significant difference in TG between the diet groups.

Ambroszkiewicz J, et al. (2006) (3)	Observational study. n= 32 vegetarian children, age 2-10 years from Poland. 21 Lacto- ovovegetarians, 1 lacto vegetarian, 5 ovovegetarians and 5 vegans.	Vegetarian diet compared to nutrition recommendations. Dietary intake: analyzed using the program Dietetyk2 Methodology Not reported	Total energy and macronutrients intake. Intakes of folate and Vit B12. Serum concentrations of lipids (TC, HDL-C, LDL-C and TG), homocysteine, folate, and Vit B12**.** Venous blood sample after overnight fasting	*Intakes* Average daily energy, P(E%), F(E%) and CH(E%) similar to the recommended amounts. ↑folate (195.7±78.0 µg/day) and Vit B12 in the reference range (1.6±1.3 µg/day). 28% of VG below the recom-mended values of Vit B12 (<1 µg/day). *Serum/plasma levels* ↓TC (155.1±25.8 mg/dL), LDL-C (91±24.5) but in the reference range. HDL-C close to the lower limit of the reference range (53.7±8.3) . TG (80.4 ± 58.4mg/dL), homocysteine (6.1±1.2 mol/L), folate (12.8±3.4 ng/L) and Vit B12 (548.6±144.4 pg/mL) in the physiological range.
Chiplonkar SA, et al. (2010) (4)	Cross-sectional study n= 630 girls lacto-vegetarian (not ill or had in the recent past any illness, without medical treatment or taking multivitamin mineral supplements), age 10- 16 years from Pune city, India.	Lacto-vegetarian diet compared to Adolescent Micronutrient Quality Index (AMQI) based on I on Indian dietary guidelines and US dietary recommendations. Dietary intake: from 24-hour recall on 3 nonconsecutive days, multiple-pass approach.	Anthropometry (BMI height, and weight). Total energy and macronutrients intakes. Intakes of calcium, iron, zinc, vitamin C, folic acid , cholesterol. Plasma levels of vitamin C, beta carotene, and zinc Venous blood sample after overnight fasting.	24% were < 5th percentile of the Indian reference BMI for age. 2.1% were > the 85th percentile of the Indian reference BMI for age. *Intakes* 67.8% had energy intake < 75% of the Indian RDI for adolescent girls. 50-70% of the average micronutrient < than the Indian RDIs. Ca: between 105 mg to 600 mg. Q3 > Q1 intake of calcium, iron, zinc, vitamin C, folic acid. 95% had a cholesterol intake < 200 mg/day. *Serum/plasma levels* Levels of Zn, VitC, and β-carotene significantly positively correlated with the AMQI. *Supplementation* Without taking multivitamin mineral supplements, as an exclusion criteria.

Ambroszkiewicz J, et al (2011) (5)	Observational study n= 90 prepubertal children (without any endocrine disorders, genetic syndromes, or taking medications), age 4-10 years from Poland. 30 vegetarians (15 lacto-ovo-vegetarians, 2 lacto-vegetarians, and 4 vegans), 30 normal-weight omnivores, and 30 obese omnivores (simply obesity)	Vegetarian diet compared to omnivorous diet. Dietary intake: from a 3-day food record (2 weekdays and 1 weekend day), analyzed using the program Dietetyk2	Anthropometry (zBMI, FM (Kg), LM (Kg), Body fat (%), Ratio FM/LM) Total energy and macronutrients intake. Serum concentrations of lipids (TC, HDL-C, LDL-C and TG) Venous blood sample after overnight fasting.	VG vs OM normal-weight: NO significant differences in body weight, height, BMI, lean mass, and body fat values. VG < fat mass, FM/LM ratio than OM normal-weight. *Intakes* VG vs OM normal-weight: NO significant differences in dietary energy, CH(E%, g), P(E%, g) and F(E%, g) intakes. *Serum/plasma levels* VG vs OM normal-weight: NO significant differences in TC, LDL-C, HDL-C and TG than OM.
Laskowska-Klita, T (2003) (6)	Comparative study. n= 50 children, age 5-11 years from Poland. 32 vegetarians (21 lacto-ovo vegetarians, 1 lactovegetarian, 5 vegans) and 18 omnivores (control group).	Vegetarian and omnivorous diet compared to nutrition recommendations. Dietary intake: analyzed using the program Dietetyk 2. Methodology Not reported	Total energy and macronutrients intake. Intake and serum status of Vit B12, folate, vitamins A, E and D, Concentrations of homocysteine, folate and iron balance Venous blood sample after overnight fasting	*Intakes* Dietary energy, CH (E%), P (E%) and F(E%) within the recommended daily intake. VG> CH (221.3± 64.5g), folate (195.7±78.0μg) vitamin A (1245.4 ± 911.3 μRE) than recommended daily intake. VG< F (50.9±19.2g), and vitamin D (1.1±1.1μg) than recommended daily intake. VG: Vit B12 in the reference range (1.6±1.3μg). 28% were below the lower recommended value (<1.2μg) *Serum/plasma levels* VG: Vit B12, folate, vitamins A and E within the reference values. VG <vitamin D (13,7±6.6μL) than reference values. VG vs OM: NO significant difference on homocysteine, and vitamin A. VG< vitamin E than OM VG: iron, ferritin , and transferrin within the reference values.

GorczycA, D et al. 2013 (7)	Comparative study. n= 40 healthy children (without previous replacement therapy or recent illness and chronic diseases), age 2 to 18 years from Poland. 22 vegetarians (for at least 1 year) and 18 omnivores (control group).	Vegetarian diet compared to omnivorous diet. Dietary intakes from 7 day food records and analyzed by computer program Dieta 4.0 (National Food and Nutrition Institute, Poland)	Intakes of iron, zinc, vitamin C, vit B6 and B9. Serum concentrations of Iron, total iron-binding, ferritin Prevalence of anemia, iron deficiency (ID) and iron deficiency anemia (IDA). Venous blood sample after overnight fasting.	*Intakes* No significant differences in iron, zinc, vitamin A, Vitamin B6 and folate between the diet groups. VG > vit C than OM. *Serum/ plasma levels* 4,54% of VG, and 5.6% of OM had anemia (Hb < 11g/dL). 36% of VG and 11% of OM had ID (serum ferritin < 12 g/L for 1-3 y.o, and *<15.0g/L for > 3 y.o*) 9% of VG had IDA (Hb < 11g/dL with ID)
GorczycA, D et al. 2013 (8)	Comparative study n= 40 healthy children (without previous replacement therapy or recent illness and chronic diseases), age 2 to 18 years from Poland. 22 vegetarians (for at least 1 year) and 18 omnivores (control group)	Vegetarian diet compared to omnivorous diet Dietary intake from 7 day food records and analyzed by computer program Dieta 4.0	Total energy, protein, vitamin C and iron intake. Serum concentrations of iron, iron status, ferritin and total iron-binding capacity Prevalence of anemia, ID and IDA. Venous blood sample after overnight fasting.	*Intakes* VG vs OM: NO significant differences of total daily energy, P(g) and iron. VG > Vit C than OM. VG and OM: Median iron (5.99mg/day and 5.88mg/day) lower than RDA. *Serum/plasma levels* 4,5% of VG, and 5.6% of OM had anemia (Hb < 11g/dL). 36% of VG and 11% of OM had ID (serum ferritin < 12 g/L for 1-3 y.o, and *<15.0 .g/L for > 3 y.o*) 9% of VG had IDA (Hb < 11g/dL with ID) VG vs OM: NO significant differences in Hb, haematocrit, red blood cells, mean corpuscular Hb, and iron levels. VG < MCV and median ferritin than OM.
Ambroszkiewicz J, et al. 2017. (9)	Comparative study n= 89 healthy prepubertal children, age 4.5- 9.0 years from Poland. 43 lacto- ovo- vegetarians and 46 omnivores (without any effect in iron metabolism, altered liver function, inflammation, eating disorders or constipation).	Vegetarian diet compared with omnivorous diet and Polish recommendations. Dietary intake from 10- day food diary record, three (2 weekdays and 1 weekend day). Calculated using the program Dieta5® (National Food and Nutrition Institute, Warsaw).	Anthropometry: BMI, height, weight. Total energy and macronutrients intake. Intakes of iron, Vit B12, and vitamin C. Serum concentrations of ferritin, iron, and hematological data Venous peripheral blood sample after overnight fasting (3ml)	No differences between the diet groups in height, BMI, and weight. *Intakes* Average daily energy and macronutrients within the recommended daily intake. VG< P (E%) than OM VG> CH (E%, vitamin C than OM VG vs OM: NO significant differences in iron and Vit B12 *Serum/plasma levels* VG vs OM: NO significant differences in mean value of iron, transferrin, Hb and MCV. VG< ferritin than OM. 23.3% of VG and 4.6% of OM had ferritin < 15 ng/mL

				25.6% VG and 15.2% of OM had decreased Iron concentration.
Ambroszkiewicz J (2018) (10)	Comparative study n= 130 healthy prepubertal children, age 5–10 years from Poland. 70 vegetarians (from birth) and 60 omnivores (without history of low birth weight ,GI diseases with malabsorption, history of chronic renal failure or any chronic infection or drugs consumption).	Vegetarian diet and omnivorous diet compared to the current recommendations for Polish children. Dietary intake from a 10-day food diary record, three consecutive days (2 weekdays and 1 weekend day). Calculated using the program Dieta5®	Anthropometry: zBMI, FM, LM. Bone status: BMC, BMD in the total body (TBMD) and at the lumbar spine (BMD L1-L4). Total energy and macronutrients intake. Intakes of vitamin D, Vit B12, Ca. Venous blood sample after overnight fasting Serum concentrations of total-25(OH)D.	No differences between the diet groups in height, BMI, weight, LM, FM, BMC and BMD. *Intakes* Average daily energy intake in both groups within recommendations. VG < P (E%), Vit B12 (1.36µ g/day) than OM. VG > CH (E%) than OM. VG and OM: insufficient dietary intake of Ca (548 ± 315 and 596 ± 222 mg/day), and vitamin D (1.74 and 2.01 μg/day) 55% of VG and 64% of OM follow the recommended daily intake for calcium. 38% of VG and 45% of OM follow the recommended daily intake for vitamin D. *Serum concentrations* VG vs OM: NO significant differences of total- 25(OH) D.
Sakshi Pandey M.Tech (2021) (11)	Cross-sectional study. n= 5772 vegetarian children, age 6–23 mo from India.	Association between dietary adequacy level (maximum, medium and minimum) of a vegetarian diet and anthropometric failure Dietary intake: from 24-hour dietary recall, data collected from the NFHS-4 questionnaire.	Anthropometric Failures (Stunting, Wasting, Underweight) using WHO Z-scores.	35% had stunting, 20 % had wasting and 27% underweight. Minimum adequacy OR: 1.37 stunting, 1.37 wasting, and 1.7 underweight compared to maximum adequacy. Medium adequacy OR: 1.2 underweight than maximum adequacy. Significant increase in risk of underweight & wasting without dairy intake.
Topi Hovinen (2021) (12)	Cross-sectional study. n= 40 Finnish children, media age 3.5 years. 6 vegans (since birth), 10 vegetarians (since birth) and 24 omnivores from the same daycare centers.	Vegetarian and omnivorous diet compared to the current Finnish growth references. Dietary intake: from estimated 4-day food record filled in by the parents and daycare personnel. Dietary habits from questionnaires filled by	Anthropometry: zBMI, height, mid-upper arm circumference. Total energy and macronutrients intake. Intakes of fatty acids, iron, zinc, folate, Vit B12 and Vit A. Serum concentrations TC, HDL-C, LDL-C, fatty acids, vitamin D,	No differences between the diet groups in the z-scores of height, BMI, or mid-upper arm circumference. *Intakes* VN < protein (E%), SFA, EPA, DHA than OM VN > mono- and polyunsaturated fatty acid, LA, ALA, fiber, iron, zinc and folates than OM. VG < OM secondary statistical analysis suggests lower Zn concentration. No differences between the diet groups in Vit A and B12 (without supplementation). VN (43µg/day)> VG (3.6µg/day)>OM (3.5µg/day) (with supplementation)

		parents.	vitamin A, vitamin B12, folate, zinc, iron, and iodine. Venous blood samples of 15 ml after overnight fasting	*Serum/plasma levels* VN < DHA, TC, LDL-C, HDL-C, RBP, Vit D3, total-25(OH)D than OM. VN> ALA, long-chain fatty acid and folates (n=4 folates above the reference range 208–972 nmol/l) than OM. VN: Vit A status insufficiency (RBP). No differences between the diet groups in Vit B12, zinc, iron, ferritin, transferrin receptor, and urine iodine. *Supplements* 17% of OM, 40% of VG and 83% of VN took vit B12 supplements. 87% of OM, 90% of VG, and 100% of VN took vit D supplements .
Weder S, et al. (2022) (13)	Cross-sectional study. n= 430 healthy children, age 1–3 years from Germany. 139 vegans, 127 vegetarians, and 164 omnivores.	Selenium intakes of vegetarian, vegan, and omnivorous diet compared to the %H-AR: 17 g/day based on the EAR. Selenium intake from 3-day food diary record (not including supplements) and food selenium concentrations provided by EFSA.	Selenium intake.	*Intakes* Median selenium intake unadjusted model: OM (22 µg/day) > VN (19 µg/day) > VG (17 µg/day) Median selenium intake adjusted model: OM (3.05 µg/day) > VN (2.78 µg/day). 52% of VG, 47% of VN and 28% of OM < H-AR of 17 µg/day. 39% of VG, 36% of VN, and 16% of OM < 15 µg/day. 2% of VG and 6% of VN > H-UL of 60 g/day (by 110-775%) *Supplements* 2% of VG, 12% of VN, and 1% of OM took a selenium (or selenium-containing) supplement. The amounts of selenium not known.
J Elliott L, et al. (2022) (14)	Longitudinal Cohort Study. n= 8907 children without chronic illnesses, age 6 mo to 8 years from Canada, who participated in Target Kids cohort. 248 vegetarians (including 25 vegans) and 8659 omnivores.	Vegetarian diet compared with omnivorous diet and the cow's milk interaction. Dietary intake from3-day food diary record.	Anthropometry: zBMI, height-for-age z-score, weight status category, n=8794. Serum concentrations of ferritin, total-25(OH)D, and lipids (HDL-C, TC, LDL-C). n=4673.	<u>Primary analysis:</u> No differences in mean zBMI or zBMI growth rates between the diet groups. VG: OR: 1.87 underweight <u>Secondary analysis:</u> VG: 0.8 < zHeight, equivalent to 0.3 cm for a 3-year-old child. *Serum/plasma levels.* Not evidence of association between VG diet and serum ferritin, total- 25 (OH)D or serum lipids. Cow's milk consumption ↑ serum lipids for VG diet. VG & OM: similar serum lipids in both diets consuming the recommended volume of cow's milk/day (2 cups). *Supplements* 5.6% of OM and 10.6% of VG took iron supplements. 41.9 % of OM and 49.6% of VG took vitamin D supplements.

Weder S, et al. (2022) (15)	Cross-sectional study. n= 430 healthy children, age 1–3 years from Germany. 139 vegans, 127 vegetarians, and 164 omnivores.	Vegetarian, vegan and omnivorous diets compared to the %H-AR of micronutrients intakes, based on the EAR. Dietary intake from 3-day weighed diary record during consecutive days (weekdays and weekends).	Intake of vitamins B, vitamin D, folate, calcium, iodine, iron, fatty acids, and cholesterol.	*Intakes* <u>Without supplements:</u> VN > Vit E, B6, folate, vitamin C, iron, PUFA, LA and ALA than OM OM > Vit B2, B12, calcium, iodine, SFA, AA, EPA, DHA, and cholesterol than VN. VG < Vit B12, Vit B2 and iodine than OM. VG > Vit E, and iron than OM. VN > DHA than VG. < 50% of VN reached the h-AR for calcium (320 mg/day), Vit B2 (429µg/day) and B12 (0.2 µg/day). VG, VN and OM < vitamin D than the h-AR ((10 µg/day) VG: vitamins B2 (461µg/day) and B12 (0.6µg/day) < the h-AR. VG: calcium (399 mg/day) > the h-AR OM: calcium (445 mg/day) and vitamin B2 (639µg/day)>h-AR <u>With supplements:</u> Significant differences in VitB12 and VitD between the diets groups: VN (71.4µg/day, 12.9 µg/day) > VG (1.3 µg/day, 2.1 µg/day) > OM (1.6 µg/day, 1.7µg/day). Significant differences in EPA and DHA between the diets groups: EPA: OM (10.7mg/day) >VN (4.4mg/day) >VG (1.6 mg/day) DHA: OM (35.4 mg/day) >VG (19.5 mg/day)> VN (19.1 mg/day) *Supplements* 97.1 % of VN, 35.4 % of VG and 7.9% of OM took Vit B12 supplements.
Weder S, et al. (2019) (16)	Cross-sectional study. n= 430 healthy children, age 1–3 years from Germany. 139 vegans, 127 vegetarians, and 164 omnivores.	Vegetarian and vegan diet compared to omnivorous diet. Dietary intake from 3-day weighed dietary record during consecutive days (weekdays and weekends).	Anthropometry: Median weight-for-height,height-for-age, and weight-for-age z-scores. Prevalence of wasting, stunting and overweight. Total energy, macronutrients intake and fiber.	NO significant differences in weight-for-height, height-for-age, and weight-for-age z-scores between the diet groups. 3.6% of VN and 2.4% of VG had stunting. 3.6% of VN and 0.6% of OM had wasting. 23.2% of OM, 18.1% of VG and 18% of VN had overweight. *Intakes* OM > P(g/Kg) and added sugars (%E) than VG and VN. VN > CH (%E) and fiber than VG and OM. Significant differences in added sugar between VN (2.1 %E) and OM (4.8 %E).
Desmond MA, et al. (2021) (17)	Cross-sectional study. n= 187 healthy children (without treatment or	Vegetarian and vegan diet compared to omnivorous diet (reference group).	Anthropometry: zHeight, zBMI, LMI, FMI, Waist skinfolds (Biceps, suprailiac, subscapular, triceps) and girths (waist, hip,	No significant differences in LMI, biceps and subscapular skinfold, and waist circumference between the diet groups. VG< thigh z score than OM VN< zHeigh (∆ - 0.57, corresponded to -3.15cm) than OM

	condition that could affect growth or development), age 5-10 years from Poland. 63 vegetarians, 52 vegans, and 72 omnivores.	Dietary intake from 4-day food diary record, during consecutive days (including 2 weekend days).	thigh). Bone status: TBLH BMC, L2-L4 BMC, BMAD. Total energy, macronutrients intake and fiber. Intake of Vit B12, vit D, folate, Iron, vitamin C, and cholesterol. Serum concentrations of iron status, Vit B12, total- 25(OH)D, and lipids (HDL-C, TC, LDL-C, VLDL-C, TG). Venous blood samples of 15 ml after overnight fasting	VN < thigh z score, BMI, FMI, suprailiac and triceps skinfold, and hip z scores than OM VN < TBLH BMC (Δ - 3.7%), L2-L4 BMC (Δ - 5.6%) than OM . *Intakes* VN< P, total F, saturated and monounsaturated F, cholesterol, Vit B12 and Vit D than OM VN > CH, fiber, polyunsaturated F, folate, carotenoids, Vit C, and Iron than OM VG > Ca than VN and OM. *Serum/plasma levels.* VN < TC, HDL-C, LDL-C than OM. VG<TC, HDL-C than OM. VG> VLDL-C, TG than OM No significant differences of iron status between VG and OM VN<RCBS, Hb, hematocrit, and ferritin than OM VN and VG (without supplement) < Vit B12 (Δ-217.6pmol/L and Δ- 90.9pmol/L) than OM. VN (without supplement)> homocysteine, MCV than OM. VG (without supplement) >homocysteine than OM VN (fortification only)< Vit B12 (Δ-139.8pmol/L) than OM. VG and VN (without supplementation)<25(OH)D (Δ-7.1 and Δ-13.3 nmol/L) than OM. VG (with supplementation) > 25(OH)D than OM. 16% of OM, 19% of VG, and 40% of VN had possible Vit B12 deficiency. 2% of VG, and 2% of VN had moderate iron deficiency anemia. 13% of OM, and 6% of VG had abnormal pediatric LDL-C high (≥ 130 mg/dL) 7% of OM, 15% of VG, and 26% VN had HDL low (> 45 mg/dL) *Supplements* 7% of OM, 35 % of VG and 44.2 of VN took Vit B12 supplements. 37.5% of OM, 33.3 % of VG and 32.7% of VN took vitamin D supplements.

VG = vegetarian; VN = vegan; OM = omnivorous

Table 2: Extraction of results

Bone status: Bone mineral content (BMC), Bone mineral density (BMD), BMC for the total body minus the head (TBLH BMC), BMC of the L2-L4 region (L2-L4 BMC), Bone mineral apparent density (BMAD)

Macronutrients: protein (P), fat(F), carbohydrates (CH).

Iron status: iron deficiency (ID) and iron deficiency anemia (IDA).

Amino acids and fatty acids: Polyunsaturated Fatty Acids(PUFA), saturated fatty acids (SFA), linoleic acid (LA), alpha-linoleic acid (ALA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), arachidonic acid (AA).

Lipids: total cholesterol (TC), Low-Density Lipoprotein Cholesterol (LDL-C), High-Density Lipoprotein CholesteroL (HDL-C), Very-Low-Density Lipoprotein Cholesterol (VLDL-C), triglycerides (TG)

Anthropometry: BMI z-score (zBMI), Height z-score (zHeight), fat mas index (FMI), lean mas index (LMI), fat mas/lean mas retio (FM/LM ratio)

Vitamin D: 25-hydroxyvitamin D (total-25(OH)D)

Harmonized average requirement (%H-AR).

Table 3. Bias and level of evidence of the included studies.

	Confounding	Exposure measurement	Participant selection	Data missing	Outcome measurement	Outcome reporting	Study quality
Leung SSF (2001) (1)							2-
Ambroszkiewicz J, et al. (2004) (2)							2-
Ambroszkiewicz J, et al. (2006) (3)							2-
Chiplonkar SA, et al. (2010) (4)							2-
Ambroszkiewicz J, et al (2011) (5)							2-
Laskowska-Klita, T (2003) (6)							2-
GorczycA, D et al. 2013 (7)							2-
GorczycA, D et al. 2013 (8)							2+
Ambroszkiewicz J, et al. 2017. (9)							2++
Ambroszkiewicz J (2018) (10)							2-
Sakshi Pandey M.Tech (2021) (11)							2+
Topi Hovinen (2021) (12)							2+
Weder S, et al. (2022) (13)							2+
J Elliott L, et al. (2022) (14)							2-
Weder S, et al. (2022) (15)							2-
Weder S, et al. (2019) (16)							2-
Desmond MA, et al. (2021) (17)							2++

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Table 3. Green: No bias; Red: Bias present; Yellow: Partial bias.

Confounding bias: Variables such as age range, gender, etc.

Exposure measurement bias: Considered studies where diets (vegetarian and vegan) were not differentiated.

Participant selection bias: Considered the method used to select study participants, including specified inclusion or exclusion criteria.

Data missing bias: Considered data sources where extraction methods are unclear or missing.

Outcome measurement bias: Considered studies lacking specified result extraction methods (e.g., R24h, QFCA) or employing irregular or inaccurate measurements.

Outcome reporting bias: Considered factors such as selective result reporting for convenience.