

# Diet and growth of vegetarian and vegan children

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## ABSTRACT

The prevalence of plant-based diets, that is, vegetarian (without meat and fish) and vegan (plant foods only) diets, is increasing also among children and adolescents, and energy and nutrient requirements are highest during this age. Hence the question emerges whether and, if so, how much animal-source food should be included in a healthy and sustainable diet. Recent studies, published 2018–2023, mostly showed comparable anthropometrics between omnivore and vegetarian children, however, fat mass was lower in vegetarians or vegans. Results on marker of iron status were inconsistent. Vitamin B12 status was lower without supplementation, but did not differ between groups when supplementation prevalence was high. Blood lipid profile seems to be more favourable in plant-based groups. Bone mineral density was lower in vegetarians and vegans, but differences attenuated after adjustment. Nevertheless, the long-term clinical relevance of these results remains unclear. Energy intake did not differ between groups and was in the recommended range, although protein intake was lower in vegetarians and vegans. Reported calcium intakes did not differ or were lower in vegetarians compared with omnivores, and were lowest in vegans. More favourable intakes in subjects on plant-based diets were found for fibre, sugar, folate, magnesium and iron. All but one study were cross-sectional, and longitudinal studies of both vegetarian and vegan children/adolescents are required to prospectively examine associations of plant-based diets with health. Professional societies should develop country-specific food-based dietary guidelines adapted to the special dietary habits for children on plant-based diets.

## INTRODUCTION

There is currently controversy about whether and, if so, how much animal-source food should be included in a healthy and sustainable diet.<sup>1 2</sup> This issue is particularly relevant for children.<sup>3 4</sup> Due to growth and development, energy and nutrient requirements per kg body weight are higher than in later, less vulnerable stages of life and malnutrition can impair growth and development, sometimes irreversibly. The suitability of plant-based diets, especially vegetarian (without meat and fish) and vegan (plant foods only) diets, in this age group, is, therefore, an unsolved issue. Hence, this review aims to describe the current evidence on growth, health and

nutrient adequacy of vegetarian and vegan diets during growth.

## PREVALENCE AND MOTIVES

There is an increasing prevalence of individuals consuming a vegetarian or vegan diet in high-income countries.<sup>2 5–7</sup> In the general adult population, it is estimated that around 10% follow a vegetarian diet, and around 1%–2% a vegan diet.<sup>2</sup> The prevalence among children and adolescents is not clear.<sup>2</sup> In Germany, results from the 2015–2017 EsKiMo II study showed a total of 3.4% vegetarians (1.5% among 6–11-year-olds; 5.1% among 12–17-year-olds). This is a clear increase over the first EsKiMo I study conducted in 2006 (1.6% vegetarians among the 12–17-year-olds; no data available for younger children). Vegetarian diets were more prevalent among girls and in children from families with high economic status.<sup>8</sup> These sociodemographic characteristics are consistent with data from studies of adults.<sup>7 9</sup>

Among adults, animal rights/welfare and ethics is one main motive to follow a plant-based diet, but also health and concerns for environmental sustainability.<sup>10</sup> This is in accordance with a German cross-sectional study, in which children and adolescents were asked for their primary motive to consume a vegetarian or vegan diet. The vast majority reported ethical, that is, animal rights motives (ie, rejection of mass farming, right to life for animals or an emotional attachment to animals) as the most important motive for choosing their diet (vegetarians: 70%, vegans: 69%). Environmental reasons (eg, climate protection, resource conservation) were the primary motive for only 7% of vegetarians and 5% of vegans, whereas health played a role as the primary motive for 11% of vegans (vegetarians: 2%). At least 14% of vegetarians and 13% of vegans stated that the motive for their diet was ‘because the parents eat this way’. Those participants indicating the parental diet as the primary motive were significantly younger (8.2±2.2 years),



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whereas those indicating ethics as the primary motive were slightly older ( $12.9 \pm 3.7$  years) than those indicating other motives.<sup>11</sup>

### POSITIONS OF PROFESSIONAL HEALTH ASSOCIATIONS

In some countries, vegetarian and especially vegan child nutrition is seen rather critically. In Germany and Switzerland, a carefully planned vegetarian diet is considered feasible even at growing age, but a vegan diet is not recommended.<sup>12 13</sup> The German Society for Paediatric and Adolescent Medicine recommended a balanced, omnivore diet with a moderate consumption of meat, fish and dairy because nutrient requirements are most easily and most likely met.<sup>9</sup> Other professional societies conclude that an appropriately planned (or balanced) vegetarian, including vegan, diet is (or can be) healthy and nutritionally adequate in childhood and adolescence, for example, the Academy of Nutrition and Dietetics,<sup>7</sup> the Italian Society of Human Nutrition<sup>14</sup> or the Canadian Paediatric Society.<sup>15</sup> However, these professional societies also list potentially critical nutrients and provide detailed guidance on how to ensure that intakes meet requirements.

### POTENTIAL CRITICAL NUTRIENTS

Restrictive diets, excluding animal source foods, have an increased risk of inadequate nutrient intakes, not only because a lower dietary diversity generally decreases the likelihood of adequate nutrient supply. Animal source foods are good sources of some nutrients, for example, for high-quality protein (meat, fish, dairy), riboflavin and calcium (dairy), iodine (fish, dairy), long-chain n-3 fatty acids (fatty fish), selenium (animal-source food) and bioactive compounds including creatine or taurin.<sup>1 16</sup> In particular, animal-source foods are the only natural source of vitamin B12.<sup>6 9</sup> The bioavailability of some nutrients is also higher from animal-source foods. First, because nutrients are in a readily absorbable form, such as haem iron in meat.<sup>1 2 6</sup> Furthermore, some plant foods contain anti-nutritive substances that impair absorption, such as phytates that inhibit the absorption of iron and zinc.<sup>1 2 9</sup> However, animal-source foods are also major sources of saturated fatty acids and cholesterol, contribute little to the supply of potassium, magnesium and folate, and lack many health-promoting ingredients such as dietary fibre and phytonutrients (secondary plant compounds).<sup>1 2 17</sup>

With a vegetarian diet, special attention should therefore be paid to a sufficient supply of iron and zinc, with a vegan diet additionally to protein, long-chain n-3 fatty acids, calcium, iodine, selenium and in particular vitamin B12 (table 1).

### ACTUAL STUDIES ON VEGETARIAN AND VEGAN CHILD NUTRITION

In their 2017 review on vegetarian and vegan diets during childhood, Schürmann *et al* listed 24 publications from 16

studies published from 1988 to 2013.<sup>18</sup> Only two studies were found examining vegan-fed children separately. With the exception of studies in the Adventist setting, which may have some sampling bias, the samples were small and most studies were cross-sectional. Outcomes were heterogeneous. Overall, the growth and body weight of children on plant-based diets were found within the lower reference range. Studies indicated lower or similar biomarkers of iron status in vegetarians compared with omnivore groups.<sup>18</sup> However, since these studies were conducted, substantial changes in the food market occurred: the range of foods offered has increased, including with respect to plant-based meat and dairy alternatives.<sup>7 19</sup> More dietary supplements are available on the market, and the world wide web has developed into an important source of information about noteworthy aspects of a plant-based diet. However, only a few studies on modern vegetarian and vegan child nutrition have been published so far (table 2).

There was only one longitudinal study (follow-up: 3 years) with a sample of young children (6 months to 8 years) in Canada, conducted between 2008 and 2019.<sup>5</sup> The type of diet was self-reported by parents. Of 8907 children, 248 (2.7%) were categorised as vegetarian, of whom 25 were vegan (0.3% of the total sample). The small number of vegan children precluded a separate analysis. Although vegetarian participants were more likely to have Asian ethnicity, mean body mass index (BMI)-z-score and BMI-z-score growth rates did not differ between diet groups. Nevertheless, vegetarian-fed children were slightly less tall than the control group. However, the effect size was small and was estimated to be 0.3 cm for a 3-year-old child. Serum ferritin, 25(OH) vitamin D and serum lipids did not differ between groups. The authors concluded that there were no meaningful differences in growth or the biochemical measures assessed in this study between vegetarian or omnivore children.<sup>5</sup>

In a small Finnish study, 40 young children from daycare centres, including 24 omnivore, 10 vegetarian and 6 vegan participants, were examined cross-sectionally in 2017.<sup>20</sup> No differences in anthropometric measurements (z-scores of heights, BMI and mid-upper arm circumference) were found between groups, although protein intake (% of energy intake), calculated from 4-day estimated dietary records, was lower among vegans. In contrast, fibre and folate intakes were higher in vegans than in omnivores. Blood lipids were lower in the vegan group, vitamin A status was insufficient, but erythrocyte folate was higher. The serum concentration of vitamin B12 was adequate, and no group difference of urinary iodine concentration was found. Furthermore, untargeted metabolomics analysis showed lower concentrations of essential amino acids and docosahexaenoic acid (DHA). The authors conclude that given the observed metabolic differences, the health consequences of a vegan diet in childhood need to be clarified.<sup>20</sup>

Two studies on vegan and vegetarian diets in Germany were conducted by a working group to which the author of

**Table 1** Potential critical nutrients in vegetarian and vegan diets during childhood and plant-food sources

Nutrient	Plant food source
Vegetarian	
Iron*†	Legumes, whole grains, pseudo-grains (eg, quinoa, amaranth), nuts, seeds, green leafy vegetables <sup>6*</sup>
Zinc*	Nuts, seeds, whole grains, soy (tofu, tempeh) <sup>7</sup>
Vegetarian and vegan	
Protein	Grain and legumes (at the best in combination to enhance protein quality), soy (attention must be paid to a sufficient energy supply) <sup>7</sup>
Long chain n-3 fatty acids	Plant oils fortified or supplements with DHA from single cell/micoralgae oils, or single-oil-DHA-supplements (if applicable), optimise conversion by a ratio of linoleic acid and linolenic acid of 4:1 <sup>7</sup>
Calcium‡	Tofu calcium-set, tempeh, sesame seeds and tahini, low-oxalate green leafy vegetables (kale, brokkoli, bok choy (pak choy), mustard greens, okra), certain beans, peas, lentils, almonds and calcium-enriched beverages, <sup>16 45</sup> as well as calcium rich mineral water <sup>6</sup> ; oxalate-rich vegetables (eg, spinach) are not a good source of calcium, even if the content of this mineral is high <sup>2 45</sup>
Iodine	Iodised table salt, sea vegetables <sup>7</sup>
Vitamin B <sub>12</sub> §	Fortified foods
Vitamin D¶	Fortified foods (eg, plant-based milk alternatives)
Selenium	Brazil nuts
*Phytate content in legumes and whole grains, inhibiting absorption, can be reduced by baking, fermenting, soaking, leavening and germination. <sup>2 7</sup>	
†Organic acids (ie, vitamin C, citric, malic, lactic acid) increase bioavailability. <sup>2</sup>	
‡Potentially critical in vegetarian diets when little dairy is consumed.	
§ Only regular supplementation ensures an adequate intake.	
¶Supplementation might be needed depending on sunlight exposure and skin pigmentation. <sup>2 17</sup>	
DHA, docosahexaenic acid.	

this article belongs: The VeChi-Diet study examined between 2016 and 2018 the diet of 430 children (127 vegetarian, 139 vegan, 164 omnivorous) aged 1–3 years using dietary records.<sup>21–23</sup> Although mean z-scores of parental-reported body weight and height did not differ between diet groups, a slightly higher percentage of vegan (3.6%) compared with vegetarian (2.4%) and omnivore (0%) were classified as stunted, and 3.6% of vegan, 0.6% of omnivore and no vegetarian child were classified as wasted.<sup>22</sup> Neither energy intake nor energy density differed between diet groups. Protein intake was lowest among vegans and highest among omnivores, but all groups exceeded the dietary reference value of 1g/kg body weight per day by 2.3–2.5-fold. Added sugar was the lowest and fibre intake was highest among vegans.<sup>22</sup> Micronutrient intakes showed a significant difference between groups.<sup>21</sup> Vegan children had the highest intakes of folate, magnesium and iron, followed by vegetarians. Including dietary supplements, the intake of vitamin B12 was the highest too.<sup>21</sup> In a separate evaluation, selenium intake was estimated using a food composition database provided by the European Food Safety Authority. Although vegetarian and vegan children consumed less selenium than omnivorous children, on average, all three groups met the harmonised average requirement for selenium of 17µg/day.<sup>23</sup>

Nevertheless, these results were only based on self-reported dietary intake, which is prone to bias social desirability and inaccuracies of food composition database. Hence, the VeChi-Youth-Study (conducted 2017–2019) also examined biomarkers of potential critical nutrients and blood lipids in a sample of 401 German children and adolescents aged 6–18 years.<sup>11 24 25</sup> In this study, the SD score of BMI did not differ between vegetarian, vegan and omnivore participants.<sup>24</sup> Vegans had no higher rates of iron deficiency anaemia, but ferritin levels were slightly lower,<sup>24</sup> which might be beneficial for long-term health.<sup>2</sup> Vegans had the lowest non-high-density lipoprotein (non-HDL) and low-density lipoprotein (LDL) concentrations in comparison to vegetarians and omnivores. A high prevalence (>30%) of 25-OH vitamin D3 and vitamin B2 concentrations below reference values were found irrespective of the diet group.<sup>24</sup> The food intake pattern of vegan children and adolescents was characterised by higher intakes of whole grains, legumes, nuts and plant-based milk alternatives than those of vegetarians. However, vegetarians in this study also consumed significantly less dairy than the omnivore control group.<sup>11</sup> As the affordability of such a plant-based food pattern is repeatedly debated, a further evaluation estimated the food costs of the three diet groups using

**Table 2** Studies with vegetarian (VG), vegan (VN) and omnivore (OM) children and adolescents (2018–2023)

Reference	Study sample (design)	Methods	Main results
Ambroszkiewicz <i>et al</i> <sup>28</sup>	n=76 (4–9 years), thereof n=51 VG, n=25 OM (cross-sectional)	Anthropometric measurements, dietary recalls, blood samples: amino acid concentrations, 25(OH)D, parathormone, marker of bone metabolism, albumin, prealbumin	VG had comparable energy intake and lower intake of protein, amino acids and calcium, intake of fibre was higher. Blood concentrations of albumin, valine, lysine, leucine, isoleucine were lower, of C-terminal telopeptide of collagen type I (CTX-I) higher in VG; no difference was found in parathormone, IGF-I and osteocalcin concentrations.
Ambroszkiewicz <i>et al</i> <sup>29</sup>	n=105 (5–9 years), thereof n=55 VG, n=50 OM (cross-sectional)	Anthropometric measurements, DXA, dietary recalls, blood samples: myocine, adipokine	Comparable body weight and height, but lower fat mass in VG, similar intakes of energy and calcium, lower intake of energy from protein in VG, no difference in concentrations of myocines and adipokines, lower leptin concentrations in VG, no difference in bone mineral content.
Ambroszkiewicz <i>et al</i> <sup>27</sup>	n=106 (5–10 years), thereof n=53 VG, n=53 OM (cross-sectional)	Anthropometric measurements, pubertal stage, dietary recalls, DXA, blood sample: 25-OH-Vitamin D, marker of bone metabolism and leptin	Comparable body weight and height; lower % body fat, leptin and bone mineral density z-scores in VG, comparable concentrations of adiponectin, osteocalcin and C-terminal telopeptide of collagen (CTX), higher parathormone concentrations, lower protein intake in VG, similar intake of calcium.
Ambroszkiewicz <i>et al</i> <sup>30</sup>	n=117 (5–10 years), thereof n=62 VG, n=55 OM (cross-sectional)	Anthropometric measurements, pubertal stage, dietary records, blood sample: adipokines	Comparable body weight and height, but lower fat mass index in VG, comparable energy intake, lower protein intake of VG, lower ratio of leptin to soluble leptin receptors and higher adiponectin/leptin ratio, higher omentin/leptin ratio in VG, no significant differences in the ratios of adiponectin/resistin, omentin/resistin, vaspin/leptin and vaspin/resistin.
Alexy <i>et al</i> <sup>11 24 25</sup>	n=401 (6–18 years), thereof n=149 VG, n=115 VN, n=137 OM	Anthropometric measurements, 3day-weighted dietary records, blood (haemoglobin, ferritin, folate, vitamin B2, 25(OH)D, HOLO-TC, MMA, blood lipids)	No difference of BMI, vitamin B2, 25(OH)D, triglycerides between groups, higher folate and MMA, but lower HOLO-TC in VG than in OM, lowest non-HDL and LDL in VN compared with VG and OM, highest ferritin in OM; >30% of 25-OH vitamin D3 and vitamin B2 concentrations below reference values independent from group, <sup>24</sup> highest intakes of vegetables, whole grain, legumes, nuts and milk alternatives in VN, less dairy intake in VG than in OM, <sup>11</sup> lowest estimated food costs in VG. <sup>25</sup>
Desmond <i>et al</i> <sup>26</sup>	n=187 (5–10 years), thereof n=63 VG, n=52 VN, n=72 OM (cross-sectional)	Anthropometry, deuterium dilution, DXA and carotid ultrasound	VN had lower body fat indices but similar lean mass, VG and VN had lower bone mineral content and vitamin D-status, and serum B12 (both without supplementation). Supplementation resolved low B-12 and 25(OH)D status.
Elliott <i>et al</i> <sup>5</sup>	n=8907 (age 2.2±1.5 years at baseline), thereof n=248 VG <sup>1</sup> , n=8659 OM (longitudinal: 2.8±1.7 years follow-up)	Anthropometric measures, Vitamin D status, lipoproteins	No evidence of an association between VG diet and z-BMI, height-for-age z-score, serum ferritin, 25-OH-Vitamin-D, or serum lipids, but higher odds of underweight among VG.
Hovinen <i>et al</i> <sup>20</sup>	n=40 (median age 3.5 years), thereof n=10 VG, n=6 VN, n=24 OM (cross-sectional)	4-day food records, anthropometric measures, blood and urine samples	VN had higher intake of fibre and folate and lower intakes of energy from protein and saturated fatty acids than OM. Status of vitamin D, DHA and cholesterol (including total, LDL and HDL) of VN children were lower than those of OM, no difference in Vitamin B12 status and urinary iodine excretion.

Continued

Table 2 Continued

Reference	Study sample (design)	Methods	Main results
Weder <i>et al</i> <sup>21 22</sup>	n=430 (1–3 years), thereof n=127 VG, n=139 VN, n=164 OM (cross-sectional)	Dietary records, self-reported data on body weight and height	Body weight and height z-scores did not differ between groups, but more VG and VN were classified as stunted or wasted. Macronutrient pattern differed between groups, and comparison of intake with dietary references indicated vitamin D, iodine and DHA as potential critically for all participants, as well as vitamin B2, vitamin B12, calcium and iron for VG and VN children, only.

BMI, body mass index; DHA, docosahexaenic acid; DXA, dual-energy X-ray absorptiometry; HDL, High density lipoprotein; HOLO-TC, holotranscambalamin; IGF-I, insulin-like growth factor 1; LDL, Low density lipoprotein; MMA, methylmalonic acid; non-HDL, non-High density lipoprotein.

retail food prices.<sup>25</sup> It could be shown that the vegetarian food pattern was the least expensive compared with the omnivore and vegan diet pattern and food costs did not differ significantly between omnivores and vegans.<sup>25</sup>

In Poland, Desmond *et al*<sup>26</sup> cross-sectionally examined children aged 5–10 years (63 vegetarians, 52 vegans, 72 omnivores) using anthropometry, deuterium dilution, DXA, carotid ultrasound, fasting blood samples, dietary intake and accelerometry data. Vegetarians (–2 cm) and vegans (–3 cm) were shorter than omnivores, but the difference for vegetarians was not significant. However, height z-scores were >0 in all groups, indicating sufficient overall longitudinal growth. Also bone mineral content was lower in both plant-based groups than in omnivores, but the cardiovascular risk profile was healthier in vegans. Furthermore, vegans had lower serum vitamin B12 and 25(OH) vitamin D concentrations, but this difference was not evident in those subgroups using supplements. With respect to iron status, vegans, but not vegetarians had lower haemoglobin and ferritin levels than omnivores.<sup>26</sup>

Another Polish working group repeatedly recruited vegetarian and omnivore children attending a mother and child health facility and examined several aspects of metabolic health.<sup>27–30</sup> The most recent paper described amino acid levels and bone markers in n=51 vegetarian (of whom 9% were vegans) and n=25 omnivorous children aged 4–9 years. Apart from the bone resorption marker CTX-I (C-terminal telopeptide of collagen type I, lower levels among vegetarians), bone markers (parathormone, Insulin-like growth factor 1, osteocalcin and osteoprotegerin) did not differ significantly between the groups. Protein intake (12.8% of energy intake) was lower but adequate among vegetarians, and blood concentrations of some amino acids (ie, valine, lysine, leucine and isoleucine) were lower too.<sup>28</sup>

An additional study of 53 vegetarian and 53 omnivore pre-pubertal children examined the aforementioned bone markers and additionally bone mineral density in the lumbar spine by dual-energy X-ray absorptiometry (DXA). Vegetarian children had a lower percentage of fat mass and leptin concentrations. Total and lumbar spine bone mineral density z-scores were lower, and

parathormone concentrations were higher than omnivores. Notably, bone mineral density z-scores were positively associated with anthropometric parameters.<sup>27</sup>

In another Polish sample of pre-pubertal children (53 vegetarian and 50 omnivore children, 5–10 years), there were no significant differences between adipokines (adiponectin, visfatin and omentin).<sup>27</sup> Also, serum levels of myokines (myostatin, irisin) did not differ between 55 vegetarian and 50 omnivore children aged 5–9 years. The observed lower leptin levels among vegetarians reflected the lower percentage of body fat.<sup>29</sup>

Considering all this, studies showed comparable anthropometrics between omnivore and vegetarian children.<sup>5 20 24 27 29 30</sup> In one study, height was lower among vegans,<sup>26</sup> whereas others found no difference between groups.<sup>5 20 22 24 27 29 30</sup> However, especially in the youngest sample, higher prevalence of wasting and stunting than in omnivore children was observed in vegetarian and vegan children<sup>22</sup> but the prevalence was nonetheless low, and the longitudinal study found higher odds of being underweight in vegetarians.<sup>5</sup> Fat mass was lower in vegetarians<sup>27 29 30</sup> or vegans,<sup>26</sup> but not in all studies.<sup>30</sup> Accordingly, observed leptin concentrations were lower in vegetarians.<sup>27 29</sup> Haemoglobin levels were comparable<sup>24</sup> or lower in vegans,<sup>26</sup> whereas ferritin was lower in vegetarians<sup>24</sup> and vegans<sup>24 26</sup> or did not differ.<sup>5</sup> Also, results of vitamin D status (lower in vegans<sup>20</sup> and without supplementation,<sup>26</sup> no difference between groups<sup>5 24 27 28</sup> or with supplementation<sup>26</sup>) and vitamin B12 status (lower without supplementation,<sup>26</sup> no difference between groups<sup>20 24 26</sup> or with supplementation<sup>26</sup>) were inconsistent. Blood lipid profile seems to be more favourable in plant-based groups,<sup>20 24 26</sup> but this was not observed in all studies.<sup>5</sup> Mean values of total bone mineral density z-score were significantly lower in vegetarian than in omnivore children,<sup>27</sup> but the authors did not adjust for differences in anthropometrics. In another study, bone mineral content was lower in vegetarians and vegans,<sup>26</sup> after adjustment for body height and weight z scores, as well as bone area, these differences attenuated to the null in vegetarians and to –3.7% in vegans.<sup>26</sup> Osteocalcin concentrations did not differ between groups,<sup>27 28</sup> and results on parathormone

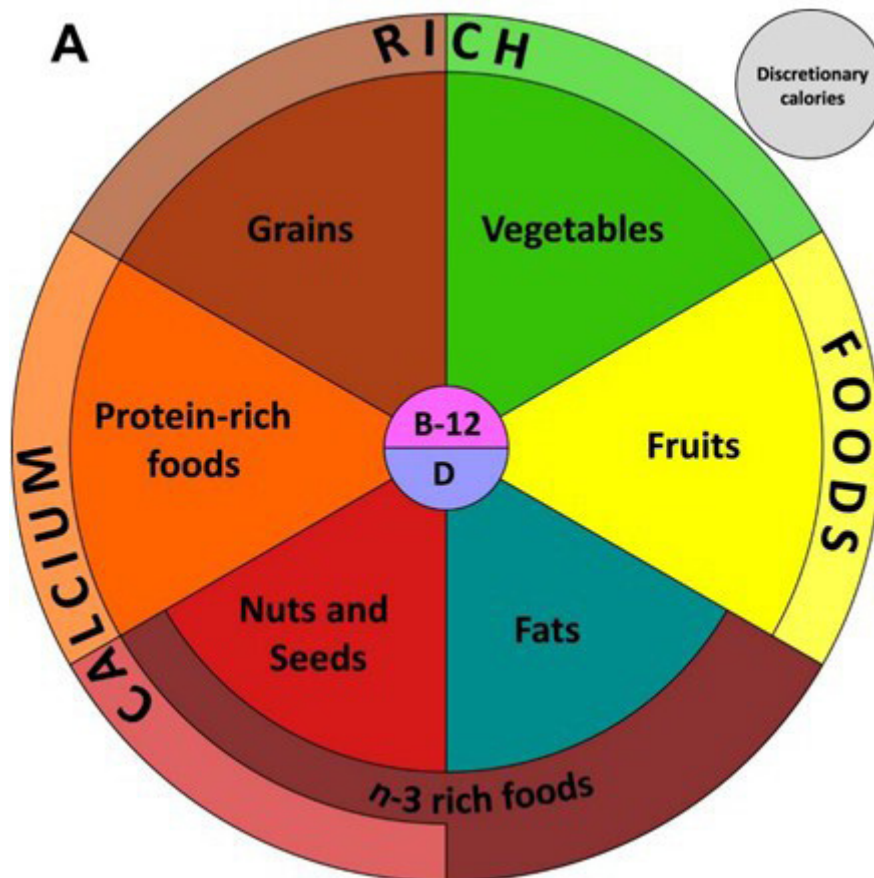
were inconsistent.<sup>27 28</sup> However, the long-term clinical relevance of these results remains unclear. Energy intake did not differ between groups<sup>22 24 26 29</sup> and was in the recommended range,<sup>27 30</sup> but protein intake was lower in vegetarians<sup>24 26 27 29 30</sup> and vegans.<sup>20 24 26</sup> More favourable intakes in subjects on plant-based diets were found for fibre, sugar, folate, magnesium and iron.<sup>20 21 26</sup> Reported calcium intakes did not differ<sup>27 29</sup> or were lower<sup>28</sup> in vegetarians compared with omnivores, and were lowest in vegans.<sup>24 26</sup>

It must be mentioned that none of these studies was representative of the population at large. This could bias the results, as families who participate voluntarily in scientific studies may have better health awareness than the overall population. However, due to the low prevalence of vegetarian and in particular vegan diets, conducting a representative study would be not feasible and too expensive. Furthermore, only randomised trials could detect the causal effects of plant-based diets on nutrient adequacy and health, but such studies are not possible in children for ethical and compliance reasons. It would be desirable to have more data from prospective, longitudinal studies, as currently, only one longitudinal study with vegetarian-fed children is available. In addition, not all studies presented here distinguished between vegetarian and vegan diets. For the development of science-based

food-based dietary guidelines (FBDGs), the development of public health measures for vegetarian and vegan families, and to elucidate divergent results of nutritional status between studies, the description of food intake patterns and supplementation habits would be useful. Studies on vegetarian or vegan diets during weaning are lacking up to now.

### DIETARY SUPPLEMENTS

Although dietary supplements, in particular vitamin B12, are recommended in a vegetarian and specifically vegan diet both among adults and children, data on the prevalence of use within plant-based diets are scarce. Sutter and Bender stated that a third to a half of all vegans use supplements,<sup>17</sup> and awareness about vitamin B12 is assumed to have strongly increased over the last decades.<sup>6</sup> Nevertheless, only very few studies with paediatric samples reported exact data on supplementation practices, even when nutrient status was the main aim.<sup>31</sup> In some studies, the use of supplements was even an exclusion criterion in recruitment.<sup>18</sup> In one recent Polish study<sup>26</sup> (table 2), analyses of vitamin D and vitamin B12 status were presented among vegetarian and vegan children stratified by the use of supplements. Accordingly, 44% of vegans and 34% of vegetarians supplemented vitamin B12, and 32% of



**Figure 1** The VegPlate Junior as an example for a vegan Food Based Dietary Guideline for children and adolescents as published by Baroni and Battino.<sup>32</sup>

vegetarians and 33% of vegans supplemented vitamin D.<sup>26</sup> In German studies, the supplementation rate in particular of vitamin B12 was substantially higher: In the German Vechi Youth study, the vast majority of participants supplemented vitamin B12 (vegans: 88%, vegetarians: 52%), and a substantial part of the sample also vitamin D (vegans: 54%, vegetarians: 27%).<sup>24</sup> In the Vechi Diet study with a younger sample, 97% of vegans and 35% of vegetarians, reported the use of vitamin B12 supplements.<sup>21</sup> In Finland, 83% of vegans and 40% of vegetarians reported the intake of vitamin B12 supplements (vitamin D: 90% of vegetarians and 100% of vegans).<sup>20</sup> The reasons for the different study results are unclear. It is possible that families in different countries have different levels of information about the need for supplementation, or this is the result of selection bias.

However, there is a lack of scientific knowledge about the optimal dosage of vitamin B12-supplements in a vegetarian or vegan diet due to the high variability of absorption attributable to the frequency of intakes.<sup>32</sup> The Italian Society of Human Nutrition suggests vitamin B12 either one daily single dose of 5 µg (6 months to 3 years), 25 µg (4–10 years) and 50 µg from 11 years onwards. Alternatively, daily multi-doses of 2×1 µg (<4 years), 2×2 µg (4–10 years) and 3×2 µg (>11 years) are suggested.<sup>14</sup> The Canadian Paediatric Society suggests 5 µg to 10 µg of a daily supplement for infants, children and adolescents,<sup>15</sup> whereas the German Society for Paediatric and Adolescent Medicine recommended 5–25 µg/day, depending on a person's vitamin B12 status and age.<sup>9</sup> Although there is no upper limit on vitamin B12-intake and excessive vitamin B12 intake is generally considered safe,<sup>6</sup> a maximum limit in dietary vitamin B12-supplements of 25 µg was proposed for adults.<sup>33</sup> An alternative supplementation strategy, the use of vitamin B12-fortified toothpaste, has been validated in adults,<sup>34</sup> but not in children.

### PLANT-BASED DIETS AND LONG-TERM HEALTH

Studies on the long-term health of vegetarian and vegan-fed children are lacking because of the long latent period of non-communicable disease. However, it is well accepted that atherosclerosis starts in childhood.<sup>35</sup> Compared with omnivore diets, plant-based diets have been associated with substantial reductions in modifiable risk factors in adults, including atherogenic lipoprotein concentrations, blood glucose, inflammation and blood pressure.<sup>2</sup> The obesity risk is also reduced,<sup>2</sup> with differences in BMI at least partially attributable to an overall healthier lifestyle.<sup>16</sup> This evidence among adults is consistent with the results of some of the studies listed in [table 2](#), which reported lower fat mass percentages<sup>26 27 29</sup> and more favourable blood lipids<sup>20 24 26</sup> among vegetarian and vegan than in omnivore children.

However, one potential long-term risk with a plant-based diet is bone health. In a recent review, a meta-analysis of 20 studies including 37134 participants indicated that vegetarians and vegans had lower bone mineral density

at the femoral neck and lumbar spine compared with omnivores. Furthermore, vegans had higher fracture rates, indicating clinical relevance.<sup>36</sup> Although at least in part the results might be attributable to differences in anthropometric variables,<sup>37 38</sup> particular attention should be paid to nutrients that are relevant for bone health and potentially critical in vegetarian and vegan diets, such as protein, calcium and vitamin D.<sup>39</sup> This is especially important for children and adolescents, as bone mass accumulation reaches its maximum during early adolescence (9–14 years among girls and 11–16 years among boys) and a high peak bone mass is protective against later osteoporosis and fractures.<sup>39</sup>

In adults, fracture incidence was reduced regardless of a dietary pattern when calcium intake was at least equal to the estimated average requirement of 525 mg/day.<sup>40</sup> Adequacy of vitamin D status supports the absorption of calcium. Whether vegetarian or vegan children should routinely take a vitamin D supplement is not yet answered conclusively.<sup>2 17</sup> In the Adventist Health Study 2, a combination of both calcium and vitamin D supplementation, the elevated risk for bone fractures among vegans disappeared.<sup>41</sup> Nevertheless, bone health is affected by more than these two nutrients, for example, protein intake and dietary acid load. Repeated bone density measurements in children and adolescents who have been consuming a plant-based diet for a longer period would be desirable.

### FOOD-BASED DIETARY GUIDELINES

Not every plant-based food pattern is healthy<sup>42</sup> and provides sufficient energy and the full spectrum of nutrients. Deficiencies can occur when vegetarian or vegan diets are not well planned, specifically in the paediatric population. Hence, food based dietary guidelines (FBDG) are necessary to inform families about the selection and combination of plant foods and dietary supplements, if necessary, in particular as motivations to follow a plant-based pattern are not necessarily health-based. Nevertheless, only few plant-based dietary guidelines for children and adolescents exist up to now.<sup>43</sup>

The VegPlate Junior ([figure 1](#))<sup>32</sup> provides recommendations for six plant food groups (ie, grains, vegetables, fruits, fats, nuts and seeds and protein-rich foods). On a second level, emphasis was laid on n-3-rich-foods and calcium-rich foods. Supplementation of vitamin B12 and vitamin D is mentioned, too. The VegPlate Junior is based on a selection of the most representative plant foods from the Mediterranean tradition. Dairy and eggs are considered optional. This FBDG was designed to fulfil the Italian and US Dietary Reference Intakes and hence meet all the criteria defining a vegetarian or vegan diet as well-planned.<sup>32</sup>

The Canadian governmental health recommendations take a different approach and issue one guideline from the age of 2 years<sup>44</sup> which can result both in omnivore, vegetarian, or vegan dietary patterns. The Canadian food guidance plate comprises only three segments: vegetables

and fruits (half of the plate), whole grain foods and protein foods (a quarter of the plate each). In the protein food group, legumes (beans, peas and lentils), nuts and seeds, as well as fortified soy beverages, tofu and other soy products, are equal to animal-source foods (eggs, lean meat, fish, dairy).<sup>44</sup>

## CONCLUSION

To stop or at least mitigate climate change, a transformation of the diet in Western countries is necessary. Above all, the consumption of meat must be reduced. Further studies are necessary to accompany this transformation and to investigate the long-term effects on nutritional status and health, especially in children. The current studies show that a vegetarian, but also a vegan diet, can ensure sufficient growth. However, especially in young children, height and weight should be monitored regularly to ensure that growth retardation is immediately diagnosed. On the other hand, a vegetarian and vegan diet might be a protective factor against overweight and obesity, not only among adults but also among children.<sup>17</sup> Some experts also call for medical supervision of physiologic parameters.<sup>2 15</sup> For this purpose, paediatricians should be provided with recommendations regarding the nutrients to be examined, including the appropriate biomarkers, as well as age-specific examination intervals. The limited data on the use of dietary supplements show large differences between countries. The goal must be that all children on vegan diets receive vitamin B12 supplements regularly, and vegetarian-fed children at least occasionally.

A vegetarian but especially a vegan diet for children should be well planned. However, it is important to acknowledge that even poorly planned omnivore diets, for example, a 'Western Style' dietary pattern comprising large amounts of animal-source foods, refined grains, salt and sugar, are not without risk<sup>16</sup> as the high prevalence of overweight and obesity already during the growing age show. By a combination of a wide range of plant foods and the use of supplements, energy and nutrient intake in children's diets can also be achieved by partially or even completely avoiding animal foods. Just as with omnivore diets, families need evidence-based and practical information on how a vegetarian and/or vegan diet should be composed for their children. For this, further education in the context of evidence-based FBDG is necessary. For this purpose, professional societies should develop country-specific FBDGs adapted to the respective dietary habits and the regional food market for children on plant-based diets.

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