Update of the DGE position on vegan diet

Position statement of the German Nutrition Society (DGE)

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Abstract

This update of the DGE position statement on vegan diet evaluates new data on the health effects of a vegan diet. Additionally, and as an expansion of the former position statements, scientific literature regarding the effects on other target dimensions of a more sustainable diet (environment, animal welfare and social aspects) was examined. To identify relevant publications, an umbrella review and an additional systematic review were carried out. If necessary, further publications were considered. However, the existing approaches for assessing the impact of vegan diets on animal welfare and social aspects are not yet well-established, or comprehensively applied, so these were not included.

A vegan diet has been found to have potential advantages and disadvantages for health compared to other diets. For the general population, a vegan diet, like other diets, can be health-promoting, provided that vitamin B_{12} is supplemented, the food selection is balanced and well-planned, and the nutrient requirements of potentially critical nutrients are sufficiently covered (possibly also via further nutrient supplements).

For vulnerable groups, i.e. children, adolescents, pregnant women, breastfeeding mothers and elderly people, the DGE cannot make a clear recommendation either in favour of or against a vegan diet due to limited available data. Due to the risk of potential, possibly irreversible consequences if not implemented properly, vegan diets in vulnerable groups require particularly well-founded nutritional knowledge. Therefore, for these groups nutritional counselling by qualified specialists is strongly recommended for adequate implementation.

A vegan diet is particularly environmentally friendly and is a recommended measure to reduce the environmental impact of food systems.

Taking into account both health and environmental aspects, a diet with a significant reduction in animal-based foods is recommended.

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Introduction

The German Nutrition Society (DGE) generally recommends a diet consisting of a large proportion of foods of plant origin that is supplemented by foods of animal origin. It is important that the choice of food ensures a sufficient supply of nutrients. Plant-based diets are more sustainable to the environment and the climate than the usual diet in Germany, and also beneficial for health [1]. The DGE position statements on a vegan diet from 2016 [2] and 2020 [3] were formulated with a focus on nutrient supply. In the DGE position statement from 2016, the DGE concluded that following a vegan diet an adequate supply of nutrients without supplementation of (potentially) critical nutrients is not possible or only possible with difficulties. For adults who wish to follow a vegan diet, the DGE has derived recommendations for the implementation of a nutrient-adequate vegan diet. In the position statement from 2016, the DGE pointed out that the risk of nutrient deficiencies, and thus health problems, are increased. Therefore a vegan diet was not recommended for pregnant women, breastfeeding mothers, children and adolescents. The update to the position for population groups with special nutritional requirements i.e. children from infancy through the entire growth phase to adolescents, pregnant women and breastfeeding mothers published in 2020 [3] re-evaluated the available evidence on vegan diet and nutrient adequacy. The DGE position on vegan diets for these groups remained unchanged due to continuing insufficient data. It was also stated that healthcare professionals should draw attention to the risks of a vegan diet, point out options for action and offer the best possible support in implementing a nutrient-adequate vegan diet [3].

In the position statement on a more sustainable diet from 2021 [4], the DGE declared that the future work will explicitly consider environmental, social and animal welfare dimensions in addition to the health dimension. This is in alignment with the objectives of a more sustainable diet as set out in the report by the Scientific Advisory Board on Agricultural Policy, Nutrition and Consumer Health Protection at the Federal Ministry of Food and Agriculture (*Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz beim Bundesministerium für Ernährung und Landwirtschaft, WBAE)* [5].

Glossary for the update of the DGE position on vegan diet	
Biodiversity	The diversity of ecosystems, animal and plant species and genetic diversity.
Certainty of Evidence (CoE)	Describes the confidence of effect estimates; the higher the CoE, the higher the confidence that the calculated effect estimate is close to the true effect.
Eutrophication	Enrichment of nutrients in originally nutrient-poor waters, which can lead to the excessive growth of algae and aquatic plants and thus deprive other plant species, many microorganisms and animals of their basis of life.
Heterogeneity	Describes the inconsistencies in the effect estimates and between study results and the extent of overlap of the confidence intervals in a meta-analysis. High heterogeneity can be explained by differences in study populations, interventions/exposures, outcomes or in methodological approaches. When heterogeneity is high and unexplained, the certainty of evidence (CoE) needs to be rated down.
Intermediate parameters	Parameters that can be clearly linked to the development of diseases, e.g. blood lipids as an intermediate parameter for cardiovascular diseases.
Mean difference	The difference between the mean values of an outcome under consideration for an exposure and the comparison group, e.g. vegan and omnivorous diet.
Ratio of means	Alternative measure to the (standardised) mean difference, representing the ratio of the mean values of two groups. This has advantages in very heterogeneous study populations, e.g. when summarising different age groups.
Random effects model	The random effects model is a model used in meta-analyses to summarise the individual results of the primary studies to an overall effect estimate. This model takes into account both, the variance within a primary study and between the studies, e.g. due to differences in the characteristics of the study populations.
Standardised mean difference	Corresponds to the mean difference divided by the standard deviation. Used when different scales (e.g. different measurement methods) have been used for the same parameters in the underlying studies in a meta-analysis.
Umbrella Review	A type of systematic review that summarises the evidence on a specific research question from several previously published systematic reviews into a clearly structured study and providing the highest level of evidence. Systematic reviews with or without meta-analyses can be considered.

Based on the four target dimensions of a more sustainable diet, this update of the DGE position on a vegan diet will for the first time include the target dimensions of environment, social and animal welfare in addition to an evaluation of new health-related study results with a focus on health and environment. The health dimension now also includes, in addition to nutrient intake and status, further health-related parameters including the risk of diet-related diseases. The scope of the statement was also extended from the general population to vulnerable population groups (children, adolescents, pregnant women and breastfeeding mothers). Furthermore, for the first time elderly people were included as a vulnerable population subgroup. For the environmental target dimension, the environmental impact of a vegan diet is evaluated based on life cycle assessments (LCA) and model calculations and compared to other diets. Only specific key aspects for social and animal welfare target dimensions are addressed, resulting in a different structure of these chapters compared to the other chapters.

Health dimension

Methodology for the health dimension

To identify relevant publications, we conducted an umbrella review (UR), i.e. a systematic review of systematic reviews (SR) with and without meta-analysis (MA). This UR was based on a UR published by Selinger and Neuenschwander et al. [6] in 2023, in which SRs with MA were considered. For the present UR, the search term from Selinger and Neuenschwander et al. [6] was used to identify new publications, as well as SRs without MA and studies on vulnerable population groups, which were additionally taken into account in the UR for the DGE position statement.

It was determined that an additional SR of primary studies will be conducted if the UR does not provide comprehensive information for the vulnerable population groups. The literature search for this SR was limited to primary studies from January 2020 onwards, as an SR for these groups has already been conducted as part of the update to the DGE position statement on vegan diets in population groups with special nutritional requirements in 2020 [3]. Data from primary studies that were already considered in the UR, as well as endpoints for which data were already available from the UR, were not considered again.

The searches were conducted in PubMed, Web of Science, Cochrane Library and Epistemonikos on 7 March 2023 (UR) and 30 May 2023 (SR on vulnerable population groups). PubMed alerts (until mid-August 2023) were used to search for relevant new publications. The search strategies are listed in ◆ eSupplement Table e1 and e2. The PICOS (Population, Intervention, Comparison, Outcomes, Study design) framework for both systematic literature searches are shown in ◆ eSupplement Table e3 and e4. All steps of the UR and SR were performed independently by two researchers. Data extraction was performed by one researcher and checked for accuracy by another researcher. If several SRs on the same outcome, in the same population group and with the same study design were available, the SR with the largest number of primary studies was included. SRs with MA were preferred to those without MA. To identify further relevant publications, the reference lists of the included publications were screened and experts were contacted. If a pooled estimate for vegan and vegetarian study participants was given in an MA, an estimate was recalculated exclusively for the vegan group using a random effects model, if possible. The certainty of evidence (CoE) was determined using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach [7].

Results for the health dimension

After removal of duplicates, 446 publications were identified within the UR, of which 217 full texts were screened and 28 SRs were included (◆ eSupplement Tables e5 and Figure e1). Three further SRs were included via PubMed alerts and contact with experts. In total, 31 SRs on vegan diets were included, out of which 20 SRs provided MA. In total, 10 SRs with and without MA contained results on nutrient intake/status, four on nutrition-related diseases, and 21 on other health-related parameters (including anthropometric parameters and cardiovascular risk factors).

We identified one comprehensive SR with MA on vegan diets and nutrient intake/status and other health-related outcomes in children and adolescents [8]. However, for other vulnerable population groups, we did not identify an SR, and thus, evidence was insufficient. In the SRs identified for pregnant and breastfeeding women, only individual primary study results were presented. No SR could be found for the group of elderly people according to the eligibility criteria. Therefore, no comprehensive SR was identified for the other vulnerable population groups.

The additional systematic literature search for primary studies identified eight observational studies (◆ eSupplement Table e6 and Figure e2): three studies investigated a vegan diet during pregnancy, three during breastfeeding and two in elderly people. Primary studies on a vegan diet and nutrient intake/status could only be identified for pregnant women and breastfeeding mothers. Further studies investigated associations between a vegan diet and

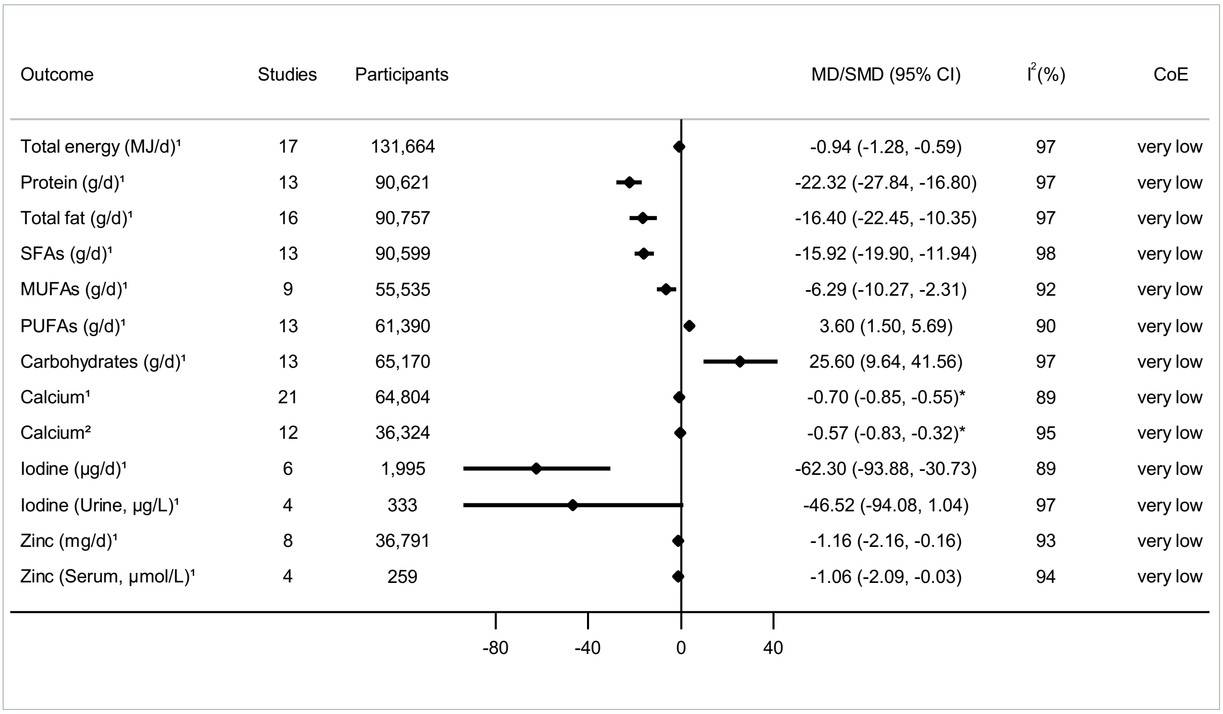

Fig. 1: **Nutrient intake/status of a vegan diet compared to an omnivorous or vegetarian diet in the general population ([standardised] mean differences with 95% confidence intervals)**
CI: Confidence Interval, CoE: Certainty of Evidence, I^2: Measure of Heterogeneity, MD: Mean Difference, SMD: Standardised Mean Difference
[1] Compared to an omnivorous diet
[2] Compared to a vegetarian diet
* SMD was only given for calcium, all other values as MD
All included studies are cross-sectional studies

pregnancy outcomes. In the two studies on elderly people, only a small number of elderly people following a vegan diet were considered, and only descriptive characteristics were given, meaning that no conclusions can be drawn from them.

Nutrient intake/status

Vegan diets in the general population The results of the SRs with MA on nutrient intake/status in vegan diets compared to non-vegan diets for the adult general population are shown in ◆ Figure 1 and ◆ eSupplement Table e7 and the results of the SRs without MA are shown in ◆ eSupplement Table 8. All SRs with MA showed a very high heterogeneity (I^2) between the study results and a very low CoE was found for all identified associations on nutrient intake/status.

A vegan diet was associated with a lower intake of energy, total fat and protein, as well as a higher intake of carbohydrates, compared to an omnivorous diet (◆ Figure 1) [9]. In addition, differences in the fatty acid composition were observed: a lower intake of saturated, as well as monounsaturated fatty acids, but a higher intake of polyunsaturated fatty acids was observed for a vegan diet compared to an omnivorous diet [9]. Furthermore, a vegan diet was associated with a lower intake of calcium, iodine and zinc compared to a non-vegan diet [10–12]. In an SR without MA [13] comparing omnivorous, vegetarian and vegan diets, a vegan diet was associated with a higher mean intake of n-3 fatty acids, α-linolenic acid, fibre, vitamin E, vitamin B_1, vitamin B_6, folate, vitamin C, magnesium and iron compared to a vegetarian or omnivorous diet. For vitamin A, vitamin B_2, niacin and phosphorus, similar intakes were observed for all three diets. The observed intake of docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA) and vitamin B_{12} was lower in a vegan diet than in an omnivorous diet [13]. In studies that took into account the intake of vitamin B_{12} supplements, a lower intake was also observed for a vegan diet than for an omnivorous diet [13].

A vegan diet was associated with lower intakes of vitamin D and selenium as well as higher intakes of copper compared to a non-vegan diet [14]. According to the authors of the SR, the results on sodium intake were heterogeneous: in some included studies, a lower sodium intake was observed in people following a vegan diet, while in further studies a higher sodium intake was observed in people on a non-vegan diet [14].

In addition to dietary intake, some SRs also included information on nutrient status based on biomarkers. SRs with MA indicated a lower vitamin B_{12} [15] and zinc concentration [14] in the serum (see ◆ Figure 1 and ◆ eSupplement Table e7) of people following a vegan diet compared to an omnivorous diet. For people on a vegan diet, lower serum vitamin B_{12} concentrations have been observed compared to people on a vegetarian diet [15]. The studies included in one SR mainly looked at people who did not take vitamin B_{12} supplements [15]. In SRs without MA [13, 14], higher vitamin B_1 and vitamin C statuses were observed in people on a vegan diet than in people on a vegetarian or omnivorous diet. The nutritional statuses of vitamin A (beta-carotene and retinol), vitamin E, vitamin B_6 and magnesium were similarly high in all groups. The statuses of vitamin D and iron (ferritin in serum or plasma) were similar in a vegan diet as in a vegetarian diet, but lower than in an omnivorous diet. In addition, insufficient supply of vitamin D and iron were observed more frequently in the vegan group than with a vegetarian or omnivorous diet. In a primary study included in an SR, a lower niacin status was found in vegan diets compared to vegetarian and omnivorous diets [13].

Vegan diets in vulnerable population groups (children, adolescents, pregnant women, breastfeeding mothers, elderly people) An SR with MA by Koller et al. [8] was included on the nutrient intake/status of children and adolescents comparing a vegan diet with an omnivorous diet. Depending on the nutrient investigated, between two and five cross-sectional studies were included. The wide age range of the children and adolescents in the primary studies used for the MAs by Koller et al. [8] (0–18 years) should be noted. In view of these age differences, the ratio of means was calculated as this parameter is less age-dependent than other common absolute or relative measures used to describe mean differences [16–18]. The results are shown in ◆ Figure 2 [8] and ◆ eSupplement Table e9. For the other vulnerable population groups, only SRs without MA were identified, some of the results being based on a single primary study. A very low CoE was found for all identified associations with nutrient intake/status in the vulnerable population groups (◆ Figure 2 and ◆ eSupplement Table e9 and e10).

Compared to an omnivorous diet, a vegan diet in children and adolescents was associated with lower relative intakes of protein and saturated fatty acids and lower absolute intakes of protein, monounsaturated fatty acids, vitamin B_2 and calcium in relation to energy intake (◆ Figure 2). In contrast, a vegan diet was associated with higher relative intakes of carbohydrates, fibre and polyunsaturated fatty acids compared to an omnivorous diet. Additionally, a vegan diet was associated with higher absolute intakes of fibre, folate, vitamin C, vitamin E, magnesium, potassium and total iron compared to an omnivorous diet. With regard to selenium and iodine intake, the SR with MA showed a tendency towards a lower intake on a vegan diet. The vitamin B_{12} concentration in serum was higher in children and adolescents on a vegan diet compared to children and adolescents on an omnivorous diet, due to the observed frequent intake of vitamin B_{12} supplements. In contrast, lower ferritin levels were observed [8].

In a primary study with pregnant women [19], the vitamin B_{12}, folate and iron statuses in blood and umbilical cord blood of the women were analysed, and no differences were observed between the diets (◆ eSupplement Table e14).

With regard to breastfeeding women, only SRs without MA based on single primary studies and other primary studies analysing the composition of the breast milk could be included (◆ eSupplement Table e14). One SR identified a primary study showing that a vegan diet in breastfeeding women was associated with a lower total fat concentration in breast milk compared to breast milk from breastfeeding women on a vegetarian or omnivorous diet [20]. Based on two primary studies, differences in the proportion of various fatty acids in breast milk were also observed. In vegan breastfeeding mothers the breast milk contained a lower proportion of DHA and a higher ratio of linoleic to α-linolenic acid, as well as a lower concentration of trans fatty acids compared to breast milk from vegetarian or omnivorous breastfeeding mothers [20]. In another primary study reported in an SR [21], the vitamin B_{12} concentration in breast milk was analysed in breastfeeding women on omnivorous, ovo-lacto-vegetarian or vegan diets, and no differences were found between the diets. There was also a positive correlation between the intake of vitamin B_{12} supplements and its concentration in breast milk. Compared to breastfeeding women on an omnivorous or ovo-lacto-vegetarian diet, breastfeeding mothers on a vegan diet more often used vitamin B_{12} supplements [21]. In a study from the USA, no difference was found between the diets for the concentration of most minerals in breast milk (calcium, copper, iron, potassium, magnesium, manganese, sodium, phosphorus and zinc) or for lead (as a contaminant in food) [22]. A vegan diet was associated with a higher selenium concentration in the breast milk compared to a vegetarian or omnivorous diet. In this publication, no difference in iodine concentration was observed [22], while in another publication the concentration of

iodine in the milk of women on a vegan diet was lower compared women on a vegetarian or omnivorous diet [23].
No study on the nutrient intake/status of elderly people on a vegan diet could be identified.

Outcome	Studies	Participants	Ratio of means (95% CI)	I^2(%)	CoE
Total energy	5	762	0.99 (0.91, 1.08)	79	very low
Protein	3	393	0.78 (0.68, 0.89)	94	very low
Total fat	4	638	0.94 (0.87, 1.02)	81	very low
SFAs	3	578	0.57 (0.48, 0.67)	83	very low
MUFAs	2	548	0.99 (0.76, 1.28)	95	very low
PUFAs	2	548	1.85 (1.75, 1.96)	7	very low
Carbohydrates	3	608	1.09 (1.01, 1.18)	92	very low
Sucrose	2	184	0.75 (0.53, 1.07)	88	very low
Fibre	2	184	1.87 (1.57, 2.24)	71	very low
Vitamin B1	2	363	1.08 (0.80, 1.46)	88	very low
Vitamin B2	2	363	0.59 (0.42, 0.82)	88	very low
Vitamin B6	2	363	1.10 (0.93, 1.30)	73	very low
Folate	4	517	1.96 (1.44, 2.67)	95	very low
Folate (Blood)	4	398	0.96 (0.56, 1.65)	98	very low
Vitamin B12	2	363	0.91 (0.00, 7322.95)	100	very low
Vitamin B12 (Blood)	2	121	1.21 (1.02, 1.42)	0	very low
Holotranscobalamin (Blood)	3	368	1.14 (0.95, 1.36)	38	very low
Vitamin C	3	487	1.56 (1.33, 1.84)	64	very low
Vitamin A (Retinol equivalents)	3	393	0.92 (0.83, 1.02)	0	very low
β-Carotene	2	427	1.30 (0.85, 2.01)	82	very low
Vitamin D	4	517	0.88 (0.35, 2.22)	92	very low
Vitamin D (Blood)	3	401	0.85 (0.64, 1.13)	94	very low
Vitamin E	2	363	1.67 (1.36, 2.07)	76	very low
Calcium	3	487	0.60 (0.36, 1.00)	96	very low
Magnesium	3	487	1.55 (1.23, 1.96)	93	very low
Potassium	2	363	1.08 (1.02, 1.15)	0	very low
Iron	4	517	1.53 (1.39, 1.70)	62	very low
Ferritin (Blood)	3	401	0.82 (0.74, 0.90)	5	very low
Iodine	3	417	0.48 (0.17, 1.34)	79	very low
Selenium	2	363	0.54 (0.20, 1.45)	89	very low
Zinc	3	393	0.96 (0.64, 1.44)	95	very low

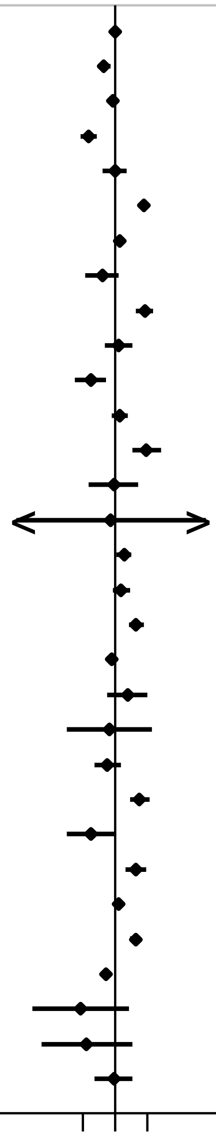

Fig. 2: **Nutrient intake/status with a vegan diet compared to an omnivorous diet in children and adolescents (age 0–18 years)** (ratio of means with 95% confidence intervals)
CI: Confidence Interval, CoE: Certainty of Evidence, I^2: Measure of Heterogeneity
All included studies are cross-sectional studies; the data on proteins, carbohydrates, fat and fatty acids are based on relative intake values (% of energy intake).

Risk of nutrition-related diseases and other health-related parameters

Vegan diets in the general population The results on nutrition-related diseases and other health-related parameters are shown in ◆ Figures 3 and 4. In randomised controlled trials (RCT) rated with moderate CoE, a vegan diet led to greater weight loss (–2.52 kg; 95% CI: –3.06, –1.98) compared to non-vegan dietary interventions. A very low or low CoE was found for the other parameters analysed in the general population (see ◆ eSupplement Table e11 and e12).

In RCTs, the vegan dietary interventions led to lower total and LDL cholesterol [24], but also lower HDL cholesterol [25], apolipoprotein B [26] and lower fasting glucose [9] than in respective comparison groups. A vegan diet was also associated with lower LDL [9] and HDL cholesterol [25] in cross-sectional studies. A score for the risk prognosis of coronary heart disease in the next 10 years (10-year CHD score) was also lower in RCTs including vegans than in the comparison group [26]. In an SR with MA based on cross-sectional studies, a lower body weight was observed for a vegan diet compared to lacto-vegetarian and omnivorous diets [27]. People on a vegan diet also showed a tendency towards lower height [27], a lower body mass index (BMI) and a lower waist circumference in other SRs with MA [9].

In cross-sectional studies, lower triglyceride concentrations were observed in people on a vegan diet compared to people on omnivorous diets [9]. In RCTs, however, no difference was shown between the diets [24]. For systolic and diastolic blood pressure there were no differences between the diets [25, 28]. Here, the estimation was very imprecise, meaning that no clear difference could be derived. Likewise, no difference was observed between the diets in HOMA-IR (Homeostasis Model Assessment Insulin Resistance) [9].

Outcome	Studies	Participants	MD (95% CI)	I^2(%)	CoE
Weight loss (kg)[1]	8 RCT	836	-2.52 (-3.06, -1.98)	3	moderate
Body weight (kg)[2]	3 CS	479	-5.45 (-12.23, 1.33)	94	very low
Body height (cm)[2]	3 CS	479	-1.90 (-3.45, -0.34)	41	very low
BMI (kg/m²)[3]	27 CS	175,897	-1.99 (-2.73, -1.25)	98	very low
Waist circumference (cm)[3]	5 CS	49,965	-3.10 (-5.51, -0.69)	85	very low
Systolic blood pressure (mmHg)[4]	11 RCT	1,078	-1.33 (-3.50, 0.84)	30	low
Diastolic blood pressure (mmHg)[4]	11 RCT	1,078	-1.20 (-3.06, 0.65)	54	low
Systolic blood pressure (mmHg)[3]	3 CS	132	-2.19 (-10.77, 6.39)	76	very low
Diastolic blood pressure (mmHg)[3]	3 CS	132	-2.00 (-7.22, 3.22)	75	very low
Triglycerides (mmol/L)[5]	9 RCT	690	0.03 (-0.07, 0.13)	22	low
Triglycerides (mmol/L)[2]	19 CS	51,043	-0.20 (-0.32, -0.08)	91	very low
Total cholesterol (mmol/L)[5]	9 RCT	690	-0.42 (-0.61, -0.22)	59	very low
LDL cholesterol (mmol/L)[5]	8 RCT	679	-0.48 (-0.75, -0.21)	87	very low
LDL cholesterol (mmol/L)[3]	22 CS	53,032	-0.51 (-0.65, -0.36)	91	very low
HDL cholesterol (mmol/L)[5]	9 RCT	690	-0.10 (-0.20, -0.00)	31	low
HDL cholesterol (mmol/L)[3]	3 CS	138	-0.10 (-0.18, -0.02)	0	very low
Apolipoprotein B (µmol/L)[6]	7 RCT	609	-0.19 (-0.23, -0.15)	61	low
Fasting glucose (mmol/L)[3]	10 CS	50,823	-0.25 (-0.39, -0.11)	61	very low
HOMA-IR[3]	3 CS	153	-0.04 (-0.36, 0.28)	0	very low
10-year CHD risk (%)[6]	5 RCT	537	-1.34 (-2.19, -0.49)	54	very low
BMD lumbar spine (g/cm²)[3]	6 CS	630	-0.07 (-0.12, -0.03)	69	very low
BMD femoral neck (g/cm²)[3]	5 CS	600	-0.06 (-0.09, -0.02)	73	very low
BMD whole body (g/cm²)[3]	3 CS	301	-0.05 (-0.10, -0.00)	68	very low

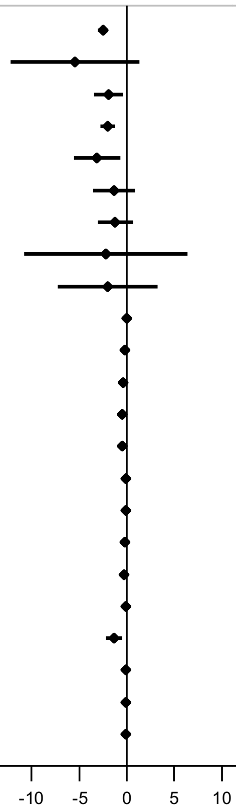

Fig. 3: **Anthropometric and other health-related parameters of a vegan diet compared to an omnivorous diet in the general population** (mean differences with 95% confidence intervals)

BMD: Bone Mineral Density, BMI: Body Mass Index, CHD: Coronary Heart Disease, CI: Confidence Interval, CoE: Certainty of Evidence, CS: Cross-Sectional Study, HDL: High Density Lipoprotein, HOMA-IR: Homeostasis Model Assessment Insulin Resistance, I^2: Measure of Heterogeneity, LDL: Low Density Lipoprotein, RCT: Randomised Controlled Trial

Compared to: [1] omnivorous diet, dietary interventions with defined macronutrient content, diabetes diet, habitual diet; [2] lacto-vegetarian or omnivorous diet; [3] omnivorous diet; [4] diets recommended by professional societies; diet with portion control; [5] omnivorous diet, diet recommended by the American Diabetes Association; [6] a dietary intervention according to the National Cholesterol Education Programme

In SRs with MA (◆ Figure 4), the relative risk for cancer [29] and ischemic heart disease [30] was lower in people on a vegan diet compared to people on an omnivorous diet. There was also a trend towards lower all-cause mortality in people with a vegan diet compared to those with an omnivorous diet [29]. For the incidence of cardiovascular disease and stroke [30], and the prevalence of type 2 diabetes [31], the SRRs were imprecisely estimated and the CoE very low, so that no clear differences could be derived [29–31]. An association was found between a vegan diet and a lower bone mineral density in the lumbar spine and femoral neck (◆ Figure 3), as well as a higher fracture incidence (◆ Figure 4) compared to an omnivorous diet [32].

For some disease outcomes, only SRs without MA could be identified. These only described a few individual primary studies (◆ eSupplement Table e12). In these SRs, a lower risk of prostate [33] and colorectal cancer [34], as well as a lower incidence of type 2 diabetes [35] and metabolic syndrome [36], were reported for vegan diets compared to the other diets. In a primary study reported in an SR, people on a vegan diet had lower hand strength than those on an omnivorous diet [37]. In an SR [37], a greater decrease in fat-free mass was found in a vegan diet in an RCT and a lower fat-free mass in a cross-sectional study than in the respective comparison groups (◆ eSupplement Table e12).

A positive association between a vegan diet and orthorexia nervosa pathology was observed as compared to an omnivorous diet, in most studies of an SR including mostly cross-sectional studies. For disordered eating behaviour in general, the vast majority of studies showed no diet-related associations [38]. In one SR analysing several dental clinical parameters, it was concluded that people on a vegan diet had good overall oral health [39].

Vegan diets in vulnerable population groups (children, adolescents, pregnant women, breastfeeding mothers, elderly people) Studies on nutrition-related diseases in children and adolescents following a vegan diet are limited to some intermediate parameters, e.g. blood lipids (◆ Figure 5). For the MAs of primary studies on children and adolescents [8], the CoE was low to very low (◆ Figure 5 and ◆ eSupplement Table e9). The primary studies, included due to a lack of SRs on the other vulnerable population groups, had a consistently very low CoE (◆ eSupplement Table e14).

In the MAs by Koller et al. (◆ Figure 5, [8]), no differences in BMI or weight were observed between children and adolescents on vegan versus omnivorous diets. In contrast, an association of slightly lower height was observed among children and adolescents on a vegan diet compared to an omnivorous diet. Sensitivity analyses suggested that this difference was mainly due to the results of one primary study in which children and adolescents on a vegan diet were younger, without adjustment for age [40]. Furthermore, compared to the reference group, lower levels of HDL, LDL and total cholesterol in serum were observed in children and adolescents following vegan diets [8]. No diet-related difference was found for triglycerides [8]. Only one cross-sectional study on bone health in children could be identified in the SR [8]: here, lower bone mineral contents (measured by dual X-ray absorptiometry, DXA) were observed in vegan compared to omnivorous diets.

In two primary studies, pregnant women on a vegan diet were compared with pregnant women on a non-vegan diet with regard

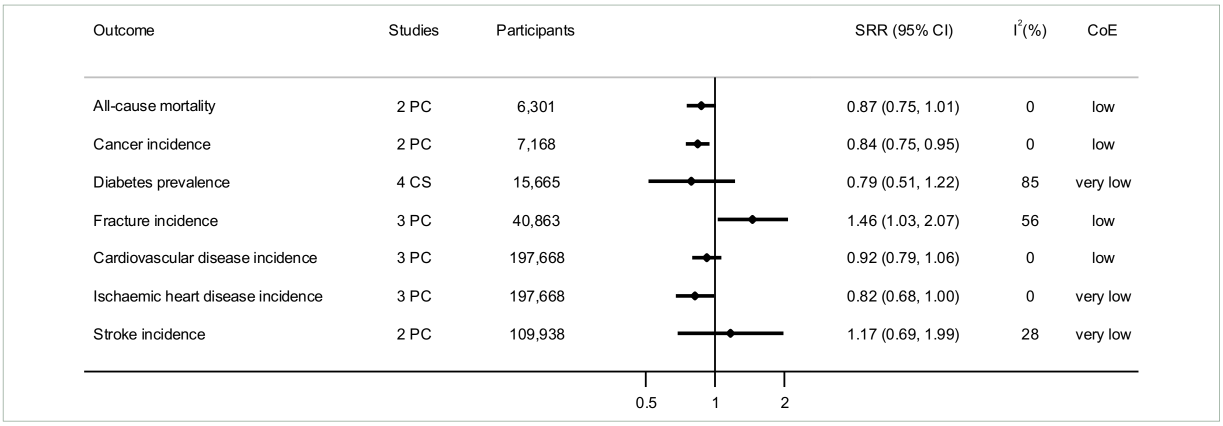

Fig. 4: **All-cause mortality and the risk of nutrition-related diseases with a vegan diet compared to an omnivorous diet in the adult general population** (Summary risk ratio with 95% confidence intervals)
CI: Confidence Interval, CoE: Certainty of Evidence, CS: Cross-Sectional Study, I^2: Measure of Heterogeneity, PC: Prospective Cohort Study, SRR: Summary Risk Ratio

Outcome	Studies	Participants	Ratio of means (95% CI)	I^2(%)	CoE
Total cholesterol	2	154	0.74 (0.64, 0.86)	88	very low
HDL cholesterol	3	401	0.87 (0.76, 1.00)	90	very low
LDL cholesterol	3	401	0.72 (0.56, 0.92)	90	very low
Triglycerides	2	371	1.04 (0.97, 1.11)	0	very low
BMI	3	8,175	1.03 (0.98, 1.08)	30	low
Height	5	8,670	0.97 (0.96, 0.98)	0	low
Body weight	5	8,670	0.95 (0.91, 1.00)	73	very low
Birth weight	2	465	1.07 (1.03, 1.11)	0	very low

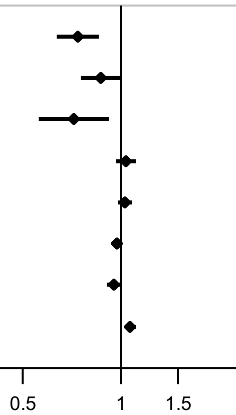

Fig. 5: **Health-related parameters of a vegan diet compared to an omnivorous diet in children and adolescents (age 0-18 years)** (ratio of means with 95% confidence intervals)
BMI: Body Mass Index, CI: Confidence Interval, CoE: Certainty of Evidence, HDL: High Density Lipoprotein, I^2: Measure of Heterogeneity, LDL: Low Density Lipoprotein;
birth weight of children whose mothers where on a vegan diet during pregnancy;
all included studies are cross-sectional studies

to anthropometric parameters [41, 42]. A vegan diet was associated with a lower weight gain during pregnancy compared to an omnivorous diet [41, 42]. The relative risk of a small-for-gestational-age newborn was higher with a vegan diet than with an omnivorous diet [41, 42]. In one of the primary studies, no difference was found in the incidence of large-for-gestational-age newborn between the diets [42]. In the SR with MA by Koller et al. [8], an association between a vegan diet in pregnancy and higher birth weight was observed in an MA based on two studies. In a primary study included in an SR and in two further primary studies (◆ eSupplement, Tables e13 and e14), no differences were found with regard to the frequency of preterm births depending on the diet [21, 41, 42]. No difference was observed between the diets with regard to the incidence of complications due to high blood pressure [41]. In one primary study, there was an inverse association between a vegan diet and gestational diabetes compared to an omnivorous diet [42], while in the other primary study no differences were observed between the groups [41].

Two studies that examined elderly people could be identified. These only included a small number of elderly people on a vegan diet and reported descriptive characteristics, meaning that no conclusions can be drawn from them (◆ eSupplement, Table e14).

Discussion for the health dimension

The results presented from the health dimension, with predominantly very low and low CoE, indicate that, particularly in the general population, there are potential advantages as well as disadvantages for a vegan diet compared to other diets. The potential benefits include cardiometabolic health, while the potential drawbacks include associations with potentially poorer bone health. For the vulnerable groups, especially pregnant women, breastfeeding mothers and elderly people, there are still only few studies with a limited number of endpoints on the differences between people with vegan and omnivorous diets.

When evaluating the relevance of the results, it must be taken into account that the MAs are based on observational studies and only analyse differences between diets, mostly vegan diets compared to omnivorous diets. This means that no statement can be made about the design of the respective diets and the health status of the comparison groups in the individual studies. It cannot be ruled out that a comparison of a health-conscious group with a less health-conscious group on a different diet could distort the results due to unsystematic recruitment.

In the MAs based on RCTs, vegan dietary interventions are compared with omnivorous dietary interventions (e.g. a diet based on the recommendations of professional societies).

For results from both observational studies and RCTs, it must be taken into account that the transferability to an everyday vegan or omnivorous diet is limited, as the design of the diets is of central importance for the evaluation.

In the UR for the general population and the SR for the vulnerable population groups, vegan diets were generally compared with omnivorous diets, as described previously. The results are categorised below.

Critical nutrients in a vegan diet

In order to assess the physiological relevance of the differences in the nutrient supply of different diets, a comparison with reference values is necessary. In the SR without MA by Neufingerl and Eilander [13], the results were compared with the Estimated Average Requirement (EAR) of the National Academy of Medicine (formerly Institute of Medicine) [43, 44]. This value represents the average daily nutrient intake, which is estimated to cover the requirements of half the healthy individuals of one sex in a defined population group. According to the authors, it can be assumed that with an average intake at or below the EAR, a significant proportion of the population could be at risk of deficiency [13]. In the Nutritional Evaluation (NuEva) study (omnivorous n = 65, flexitarian n = 70, ovo-lacto-vegetarian n = 65, vegan n = 58), a comparison of the median intake data with the DGE/ÖGE reference values for nutrient intake was carried out in a cross-sectional survey [45]. Depending on the scientific data available and the physiological role of the nutrients, the DGE/ÖGE reference values provide a recommended intake, estimated values or guiding values. The recommended intake is the nutrient intake that is sufficient to cover the needs of almost all healthy individuals (97.5%) in a defined population group. Thus, comparing the median intake (50th percentile) with the recommended intake (98th percentile) overestimates the proportion of people with insufficient intake [46]. The use of biomarkers for nutrient status is only possible to a certain extent for a few (potentially) critical nutrients since some used markers are suboptimal, e.g. vitamin B_{12}, zinc, calcium or vitamin A [46].

According to the SR by Neufingerl and Eilander [13], people on a vegan diet achieved intakes at or above the EAR for almost all nutrients, with the exception of vitamin D and, in men, the bioavailability-adjusted EAR for zinc. An intake of vitamin D below the EAR was observed for all diets [13]. Vitamin D has a special position among the vitamins due to the own synthesis of the body under UVB exposure. In general, the intake from the regular diet is often low and if endogenous synthesis is lacking or insufficient it might be beneficial to take vitamin D supplements [47]. Nevertheless, the SR showed a tendency towards a lower vitamin D status (25[OH]D) and more frequent inadequate supply (25[OH]D $< 20\ \mu g/L$) and vitamin D deficiency (25[OH]D $<10\ \mu g/L$) in people on a vegetarian or vegan diet compared to the respective comparison groups [13].

In the vegan group, the mean intake of vitamin B_{12} met the EAR when the intake via nutrient supplements was considered [13]. Since plant-based foods do not contain significant amounts of bioavailable vitamin B_{12}, people following a vegan diet need to rely on supplements to meet their nutritional requirements [48].

The National Academy of Medicine provides an Acceptable Macronutrient Distribution Range (AMDR) for EPA and DHA, which represents a value for energy-providing nutrients linked to a lower risk of chronic diseases. In contrast, for α-linolenic acid an Adequate Intake (AI) is given, i.e. a value derived from the healthy population [49]. In people on a vegan diet, the mean reported intake for α-linolenic acid was above the AI, while EPA and DHA were below the lower value of the AMDR [13]. According to Neufingerl and Eilander [13], the lower EPA and DHA status in the blood, despite a higher intake of α-linolenic acid indicates that the endogenous conversion of α-linolenic acid to EPA and DHA might be insufficient in both vegetarian and vegan diets. Furthermore, based on the hypothesis introduced earlier in this section, the authors conclude that with an average intake both below and at the level of the EAR a significant proportion of the population may be at risk of deficiency. Therefore, a vegan diet may increase the risk of insufficient intake of EPA, DHA, calcium, zinc, iodine and iron (in women) [13].

Neufingerl and Eilander [13] further concluded that the lower bioavailability of iron from plant-based foods is not fully compensated by the higher intake often seen in vegan diets. This conclusion is based on the more frequent occurrence of a lower iron status (as measured by plasma or serum ferritin), ferritin deficiency ($<15\ \mu g/L$) and anaemia (haemoglobin $<120/130$ g/L in women/men), in vegetarian or vegan diets compared to omnivorous diets. In the same SR, the EAR for calcium was not met in some studies, regardless of diet, though a vegan diet tended to be associated with lower calcium intake compared to a vegetarian or omnivorous diet [13]. The results of the most comprehensive SR with MA [11] from the UR (◆ Figure 1) also indicate that calcium intake could be lower in vegan diets compared to vegetarian or omnivorous diets. In the NuEva study, a vegan diet was associated with a lower mean reported intake of protein, polyunsaturated fatty acids, in particular n-3 fatty acids, pantothenic acid, vitamin B_2, vitamin B_{12}, vitamin A, vitamin D, calcium, potassium, iron (in women) and zinc compared to the respective DGE/ÖGE reference values [45]. Both Neufingerl and Eilander, as well as the authors of the publication on the NuEva study, thus identified many of the same nutrients as critical, despite different comparative values (EAR or DGE/ÖGE reference values) and different data sources [13, 45]. While Neufingerl and Eilander [13] conducted an SR, the NuEva study is a German cross-sectional survey with a small sample size (vegans n = 58) [45].

Due to a lack of data, differences in the prevalence rates of nutrient deficiencies between diets were generally not analysed. Neufingerl and Eilander [13] describe biomarker data used to assess adequate nutrient supply, but no statements were drawn regarding symptoms of nutrient deficiency. No publications addressing this outcome could be identified.

The assessment of **vitamin A** intake in a vegan diet is complicated by different methods used to calculate the conversion of provitamin A carotenoids into retinol. The DGE/ÖGE reference value for vitamin A is based on the use of retinol activity equivalents (RAE, conversion rate 12–24:1), whereas the included publications used retinol equivalents (RE, conversion rate 6–12:1) [8, 13, 45, 46]. Using RE leads to higher calculated retinol intake from provitamin A carotenoids than the use of RAE, which limits the comparability with the reference value. In principle, an adequate supply of vitamin A with a vegan diet is possible through the sole intake of provitamin A carotenoids by conversion to vitamin A; provided there are no disorders in fat digestion, absorption, or enzyme activity for conversion to retinol. In addition, a conscious choice of foods is required. Particularly in vulnerable population groups, implementation can be difficult due to the relatively high quantities of provitamin A-containing foods required, increasing the risk of deficiency [46]. Additionally, the individual variance in provitamin A metabolism is poorly researched with several factors influencing the conversion rate [50]. Overall, due to the uncertainties, vitamin A may be another potentially critical nutrient in vegan diets. This needs further investigation.

The results of the UR show that a vegan diet is associated with a lower **iodine** intake and a tendency towards a poorer iodine supply compared to an omnivorous diet [12, 13]. The included SR with MA on iodine intake in children and adolescents showed a tendency towards lower iodine intake in a vegan diet, with two of the three primary studies showing lower intake in vegans, while the third study showed no difference [8]. In the MAs in both adults as well as children and adolescents, the confidence intervals (CI) were wide, which does not permit a precise estimate of the effect size. Two primary studies were available on iodine status in children and adolescents, but these were not directly comparable since only one of the studies standardised for creatinine in urine. While no difference in iodine status (iodine-creatinine quotient in spontaneous urine) was observed in the smaller study (vegan n = 6) [51], in the other study (vegan n = 75) a vegan diet in children and adolescents was associated with a lower iodine status (iodine content in spontaneous urine) [52]. Further primary studies, which compared intake between groups as well as intake with reference values, pointed to an overall iodine intake and iodine status that was frequently too low. In the NuEva study, average urinary iodine excretion was less than 100 μg/L for all diets [45], and therefore falling below the World Health Organisation (WHO) cut-off values for iodine deficiency [45, 53]. In the NuEva study, people on a vegan diet had the lowest iodine excretion [45]. Another German cross-sectional study showed similar results for iodine intake [54]. The results are consistent with further German studies that identified iodine as a critical nutrient in adults, as well as in children and adolescents [55, 56].

According to calculations by Nicol et al. [57], the iodine intake for a plant-based diet with reduced animal products, such as the reference diet of the EAT-Lancet Commission (Planetary Health Diet, PHD), is around 128 μg per day. The main sources of iodine in this calculation were animal foods, such as cow's milk and cow's milk products, eggs and fish. If cow's milk is not replaced by iodine-enriched plant-based milk alternatives, the calculated intake was only 54 μg per day [57]. In a market sample by the Consumer Association of North Rhine-Westphalia (Verbraucherzentrale NRW) in 2021, only two of the 71 plant-based milk alternatives were iodine-fortified [58]. Since other relevant iodine sources eggs and fish [57], are not consumed in a vegan diet, even lower iodine intake can be expected. Regarding the iodine intake data, neither the studies analysed nor the calculation by Nicol et al. [59] generally accounted for the use of iodised salt at home or the intake from foods processed with salt, nor do they take this into account quantitatively [8, 12, 60]. Approximately half of the recommended daily iodine intake of around 200 μg can be covered by iodised salt with a salt intake of up to 6 g per day in accordance with the DGE guideline value.[1] However, iodised salt is not widely used either in households or in food production [63, 64]. Algae with a moderate and declared iodine content can contribute to meet the requirement. Algae can lead to an excessive iodine intake (> 500 μg per day) due to their highly variable iodine content, which can cause health problems, especially in those with low habitual iodine intake. Therefore, algae cannot be recommended without restriction [65, 66]. Data on the actual contribution of algae to iodine requirements in a vegan diet are not yet available.

Since the study results in an SR are summarised independently of the country in which the study was conducted, the contribution of fortified foods to the nutrient supply in the UR cannot be clearly identified. Therefore the transferability of the results to the nutrient supply in Germany is limited.

When assessing the nutrient supply, the fortification of foods with nutrients should be considered. An example of major international differences is the fortification of flour. Over 90 countries worldwide have legislation requiring the fortification of at least one type of industrially milled cereal [67]. In Europe, the UK is the only country where fortification of wheat flour with calcium carbonate (min. 235, max. 390 mg/100 g), iron (min. 1.65 mg/100 g), thiamine (min. 0.24 mg/100 g), niacin or niacinamide (min. 1.6 mg/100 g) is mandatory [68]. In North and South America, for example, the fortification of wheat flour and further cereal flours e. g. with calcium, iron or folic acid is in many cases mandatory [69]. In addition, there is a voluntary fortification practice for example in the US where the level of fortification is at the discretion of the manufacturer and is only regulated in specific cases [70].

Relationships between a vegan diet and the risk of nutrition-related diseases

- For several endpoints, a tendency towards a lower risk was observed with a vegan diet compared to the reference diets.
- Effect estimates were available for all-cause mortality, cancer incidence and ischaemic heart disease, which indicate benefits of a vegan diet.
- No clear associations could be derived for the incidence of total cardiovascular disease, stroke and diabetes prevalence (◆ Figure 4).
- The greatest difference between vegan and omnivorous diets was observed in fracture incidence, with an increased relative risk with vegan diets.

Overall, there is only a very low or low CoE for these associations and the number of underlying studies is small, which means that the results should be interpreted with caution. There was also a tendency towards lower **bone mass density** (◆ Figure 3) in vegan compared to omnivorous diets.

However, in two of the three underlying studies, many potential confounding factors were not taken into account. In their SR, Neufingerl and Eilander [13] also observed higher values for bone remodelling and bone resorption parameters in vegan diets compared to omnivore and vegetarian diets. One possible reason for the association between bone health and a vegan diet is that calcium intake and vitamin D status tend to be lower. People on a vegan diet also often have a lower BMI, which is associated with lower bone density and an increased fracture risk [71–73]. In a large prospective cohort study (EPIC-Oxford), the association of a vegan diet with a 30% increased fracture risk was no longer observed when only participants with a calcium intake of at least 525 mg per day were considered, regardless of their diet [71]. In a more recent analysis of the EPIC-Oxford study, the association between a vegan diet and an increased fracture risk, particularly for hip fractures, was observed. This association remained even after adjusting for potentially relevant confounders such as sex, BMI, protein and calcium intake. It is therefore possible that there are further relevant influencing factors [72].

In addition to the general population, Selinger and Neuenschwander et al. [6] also considered studies on **high-risk populations** which had an increased risk of diet-related diseases, for example cardiovascular diseases, e.g. persons with type 2 diabetes or obesity. They found similar correlations as in the general population. In addition, people with an increased risk of nutrition-related diseases appear to benefit more from a vegan diet than healthy adults.

One possible procedure for assessing the **physiological relevance** of health-related parameters, e.g. serum lipids, is to consider the mean difference in relation to the respective reference values[2] [74]. Based on this, there are physiologically relevant lower values for BMI, HDL, LDL and total cholesterol, as well as fasting glucose, in the general population on a vegan diet. For systolic and diastolic blood pressure, the differences in regard to the reference values are too small to be considered physiologically relevant. The results of the MAs by Koller et al. [8] show similar tendencies for blood lipids. With the exception of the lower HDL cholesterol, the serum lipid profile and the lower fasting glucose are favourable in view of the risk of cardiovascular disease [75]. Underlying possible physiological mechanisms were described by Selinger and Neuenschwander et al. [6].

[1] With an average iodine content of 20 μg/g in iodised salt, assuming that all salt used in the household and supplied via processed products is iodised, a maximum of 120 μg iodine per day is supplied via iodised salt if the recommended upper limit of 6 g per day is adhered to (20 μg/g x 6 g/day = 120 μg/day) [61, 62].

[2] The minimum required difference is a deviation of +/– 2.5% of the reference value [74].

"Healthy" vs. "unhealthy" vegan diets

A vegan diet is generally associated with a high proportion of health-promoting and minimally processed foods such as fruit and vegetables, whole grains, pulses, nuts and seeds. However, less recommended foods such as refined grain products, sugar-sweetened beverages, snacks and confectionery can also be included in a vegan diet [76]. To date, little research has been conducted into the various types of vegan diets. Two dietary pattern analyses [77, 78] showed that vegan and omnivorous diets can differ in terms of food selection and nutritional quality. While some people on a vegan diet tended to make health-conscious food choices, others included a high proportion of highly processed foods in their diet [77, 78].

With increasing supply and demand, **plant-based milk and meat alternatives**, which are often highly processed, are particularly gaining in importance [79–81]. These can have both potentially favourable and potentially unfavourable nutritional aspects [82, 83]. Plant-based milk and meat alternatives are a heterogeneous group whose products can strongly differ in terms of their ingredients, the degree of processing and the content of nutritionally unfavourable ingredients, such as salt or saturated fatty acids. It is therefore not possible to draw a definitive conclusion regarding the consumption of plant-based milk and meat alternatives.

Limitations of the UR for the health dimension

Within the scope of the conducted UR, only the SR with the most primary studies was included for each outcome and population group. It is therefore possible that the selected SR do not represent every primary study that considers the respective outcome. However, the overlap of the primary studies in the SRs was very high, meaning that no major deviations in the results of different SRs are expected. The additional systematic literature search for primary studies for the vulnerable groups for which no comprehensive data was available in the UR (pregnant women, breastfeeding mothers, elderly people) nevertheless made it possible to map the current scientific evidence. The results for children and adolescents by Koller et al. [8] are given as ratios of means due to age differences in the collectives. This means that a comparison with reference values or with the results of studies that determined other statistical parameters is not possible.

Another limitation is the lack of a standardised definition of a vegan diet in the underlying studies. While some studies referred to a strictly vegan diet, i.e. a diet with a consistent avoidance of animal products, in other studies people who had a very low consumption of animal foods (e.g. milk and eggs less than once a week or month) were assigned to the vegan group [6]. The data on dietary habits are generally based on self-report, so that the diets are not clearly separated from each other in many studies, e.g. vegetarian diet from pescetarian diet [84].

Furthermore, a large part of the SRs are based on non-representative cross-sectional studies, which can only reflect the potential short or long-term effects on nutrient intake/status and other health-related endpoints to a limited extent, e.g. if the duration of the vegan diet is not taken into account or not taken into account sufficiently. This can potentially lead to misjudgements in the sense of an over- or underestimation of health effects. These points limit the generalisability of the results. In contrast, for disease endpoints predominantly prospective cohort studies were identified (◆ Figure 4). Furthermore, in some of the SRs confounding factors (e.g. sex, age, BMI, physical activity, socioeconomic status) were not taken into account when analysing the studies, meaning that a distortion of the results cannot be ruled out. It is debated whether the potential health benefits of a vegetarian or vegan diet observed in studies are due to the often more health-conscious lifestyle. Many studies do not record or control for these factors [85].

Conclusion for the health dimension

The results of the UR show favourable associations in adults in the general population with regard to cardiometabolic health with low CoE, while indications of an increased relative risk of poorer bone health with a vegan diet were identified. For the vulnerable groups, only a comprehensive SR on vegan diets in children and adolescents could be identified. No comprehensive SRs were available for all further vulnerable population groups. The few primary studies for these groups do not provide any information on many relevant parameters. Future studies could change this.

In addition to vitamin B_{12}, iodine also takes an exceptional position among the potentially critical nutrients. Iodine is considered critical in the German general population, regardless of diet. However, the supply in vegan diets appears to be worse. The supply of vitamin A in vegan diets must be investigated further in the future. Vitamin A could be another potentially critical nutrient in vegan diets.

> **A vegan diet, like other diets, cannot be universally assessed. For all types of diets, the risk of inadequate nutrient intake increases with larger restrictions in food choices and less variety in the diet.**

These differences in the organisation of the diet are often not taken into account in primary studies, but are important for the interpretation of the data and the implementation of a vegan diet.

Dimension Environment

Methodology for the environment dimension

The environmental effects of a vegan diet were also comprehensively mapped as part of the UR for the assessment of health effects. The most recent SR was included [86] and thus older reviews with less information content and those that did not explicitly deal with vegan diets were excluded [86–89]. In addition, two primary studies with model simulations (food system models) were included in the second step [90, 91]. Scarborough et al. [91] used dietary data from the UK from 1993–1999 and linked them to the current characterisation factors, i.e. coefficients on individual potential environmental effects per product unit from a study by Poore & Nemecek [92]. The diets were classified according to their consumption of animal foods, and the effect of a vegan diet on the environment compared to a diet with a high meat consumption was calculated (reduction effect). O'Malley et al. [90] used consumption data from the USA from 2005–2010 and linked these with data from Heller et al. [93] on greenhouse gas emissions from food groups. The results on the reduction effect in ◆ Table 1 refer to the comparison with the average diet from the sample mentioned above.

While the nutrient intake and health effects of a vegan diet can be manifested and observed in the human individual, the environmental effects can only be derived from model calculations. As in the primary studies mentioned above, potential environmental impacts are usually calculated in the studies using life cycle assessments by multiplying the consumption quantities by the characterisation factors mentioned. These studies [91, 94, 95] reflect the environmental impacts of specific foods, but can only depict linear relationships, i.e. without dynamic adjustments in the agricultural and food system. For this reason, additional studies showing the environmental impacts of reductions in the production and consumption of animal-based foods using model calculations were used to classify the results [90, 91]. These studies should be seen as complementary to the SRs mentioned above, as they can depict the environmental impacts and complex ecological and economic relationships within the agricultural and food system in a more differentiated way. This is particularly relevant when discussing a vegan diet for large sections of the population. However, model simulations can generally only describe food groups and not individual foods.

Results for the environment dimension

The results of the SR [86] and the two modelling studies [90, 91] (◆ Table 1) show that a vegan diet is clearly associated with a lower environmental impact than conventional omnivorous diets with regard to almost all indicators. However, the studies come to different conclusions regarding the size of their reduction potential for some indicators.

With regard to the greenhouse gas emissions indicator, all studies indicate a relatively consistent reduction level of 69–81% [86, 90, 91]. The CIs of the three studies presented are relatively narrow and the estimate is therefore quite precise. In contrast, a much more heterogeneous picture emerges for the further environmental indicators. According to Jarmul et al. [86], land use can only be reduced by 3%, while Scarborough et al. [91] assume an average reduction of 75% [86, 91]. With regard to water use, Jarmul et al. [86] even reported a 13% increase, while Scarborough et al.

Environmental impact	Jarmul et al. 2020 Systematic review	Scarborough et al. 2023 Primary study UK[1]	O'Malley et al. 2023 Primary study US
Greenhouse gas emissions	–81% (–87%; –75%)	–75% (–63%; –85%)	–69% (NA)
Land use	–3% (–16%; 11%)	–75% (–56%; –93%)	
Water use	13% (–12%; 38%)	–54% (–19%; –79%)	
Eutrophication		–73% (–60%; –81%)	
Nitrogen use	–18% (–26%; –9%)		
Phosphorus use	–11% (–26%; 3%)		
Biodiversity loss		–66% (–35%; –88%)	

Tab. 1: **Reduction potential[1] (95% CI) of a vegan diet compared to omnivorous diets.** Data according to the most recent systematic review (Jarmul et al. 2020 [86]) and primary studies from the USA (O'Malley et al. 2023 [90]) and UK (Scarborough et al. 2023 [91]) (mean values and 95% confidence interval [CI])
[1] Compared to a diet with high meat consumption

[91] calculated a reduction of 54% [86, 91]. At 73%, the reduction in eutrophication potential according to Scarborough et al. [91] is also significantly higher than the reductions in nitrogen and phosphorus use calculated by Jarmul et al. [86] (18% and 11% respectively) [86, 91]. Scarborough et al. [91] also stated the loss of biodiversity, measured by the number of extinct species. This was given as a reduction of 66% for a vegan diet.

Discussion for the environment dimension

The results show that a vegan diet can be expected to have a lower environmental impact than current omnivorous diets; the results are only inconsistent when it comes to water consumption. In general, the lower the proportion of animal products in the diet, the lower the environmental impact [87, 91]. However, the quantitative data on the reduction potential must be interpreted with caution. Life cycle assessments are based on relatively rigid assumptions regarding product and region-specific emission parameters or land-use coefficients. Comprehensive model simulations are also able to depict the dynamic changes in the entire food system in the event of a major change in dietary patterns. However, LCAs are better at modelling product-specific environmental impacts, while model simulations usually consider food groups. In order to better assess the existing uncertainties, a wide range of methodological approaches were included in the assessment.

◆ Box 1 addresses some methodological aspects that must be taken into account when interpreting the quantitative results:

Finally, it should be emphasised that the results presented are based on the linear models mentioned above, which multiply the quantity of food consumed by its characterisation factors. This means that various aspects that would be relevant if large sections of the population were to switch to a vegan diet are not taken into account. In particular, the use of grassland resources for human nutrition and the utilisation of food waste and by-products for animal feed must be considered as addi-

Box 1: Methodological challenges in calculating the environmental impact of different diets

- To convert the **climate impact of methane and nitrous oxide** into CO_2 equivalents, the global warming potential (GWP) over a period of 100 years is usually used, which is also in line with the emission reduction targets of the Paris Agreement of 2015 [96]. Other calculation methods for the GWP would primarily change the assessment of methane and the assessment of food from ruminant husbandry [97], but have so far been difficult to implement in modelling. However, even on the basis of these alternative GWP methods, methane emissions would have to be significantly reduced to limit global warming to a maximum of 1.5 degrees in the next 30 years.
- When calculating **land use**, it is also assumed that products from grassland-based ruminant systems in particular, which account for around two-thirds of the world's agricultural land, are penalised, as they partly develop non-arable, relatively unproductive land for human consumption [98]. The modelling of grassland-based production systems is still a major challenge for existing models [99]. For example, it must be taken into account that the productivity of livestock and fodder production, as well as the composition of fodder, varies greatly from region to region and between production systems. This also explains the existing range of uncertainty in the estimation of total land use changes due to dietary changes on a larger scale.
- The results regarding **water use** are not very meaningful, as the data from Jarmul et al. [86] are based on only three observations and are also very widely dispersed. In addition, a geographically explicit calculation that takes into account local water scarcity is increasingly gaining acceptance, for which no differentiation is made in the calculations carried out by Jarmul et al. [86]. There are also improved modelling approaches that explicitly take into account the spatially heterogeneous availability of water resources and can estimate water scarcity more accurately [100, 101].
- Finally, with regard to product-related effects on **biodiversity**, there is currently no method that has become established [102], which is why the results of Scarborough et al. [91] should also be relativised. The method used there [103] mainly takes into account the fact that cultivated land is usually less species-rich than its natural state. As feed production requires a lot of land, vegan diets perform much better. Overall, the values from Scarborough et al. [91] overestimate the reduction potential because a vegan diet is compared to a diet with high meat consumption (≥ 100 g/day) [91]. According to Scarborough et al. [91], if a vegan diet is compared to a diet with medium meat consumption (50–99 g/day), a reduction of 47% in water consumption and 65% in greenhouse gas emissions can be expected [91].

tional protein sources that would be completely eliminated in the case of a vegan diet [98, 104-108]. However, **model calculations** suggest that a strongly plant-based diet with up to around 9g of protein per person per day from foods of animal origin that do not compete for land with direct human nutrition [98, 105] has a similarly positive environmental balance as a purely vegan diet [98, 105, 109-111].

Conclusion for the environment dimension

Compared to the currently usual omnivorous diets, a vegan diet can be considered particularly environmentally friendly. In particular, the high potential for reducing greenhouse gas emissions has been proven. However, diets with a low proportion of foods of animal origin are also significantly more environmentally friendly than the current diet in Germany.

Social dimension

When recording and evaluating the social dimension, aspects along the value chain, i.e. in food production, have to be considered. Social norms, social cohesion and social participation, e.g. with regard to the impact of the social dimension on consumers through food prices, also play a role. Compared to the target dimensions health and environment, there is currently less consensus among the public, scientists and politicians concerning which goals should be achieved and how the situation should be assessed [5]. There are publications that define the framework for this target dimension. However, these have not yet been widely or explicitly applied to vegan diets [104, 112]. Some aspects relevant to this target dimension are highlighted below.

In the social dimension of nutrition, **affordability**, e.g. on the basis of per capita expenditure on food, is relevant. It is often argued that a vegan diet is more expensive than an omnivorous diet. One of the arguments used here is that the price of plant-based dairy or meat alternatives is currently often higher than that of the animal equivalent. In addition to the differences in the VAT rate (19% for plant-based milk and meat alternatives vs. 7% for milk, meat and their products 113]), this could also be due to the fact that these products are currently still produced in much smaller quantities [114]. A market survey on plant-based meat alternatives conducted by the consumer advice centre Germany (Verbraucherzentrale) also shows significant price differences between conventionally and organically produced goods. While the price of conventionally produced goods is significantly higher for plant-based meat alternatives than for comparable meat products, this trend is reversed for organically produced goods [114]. If plant-based diets become more widespread and demand develops accordingly, production costs could fall significantly in the future [115, 116]. The market for vegan meat and dairy alternatives is currently developing very dynamically. It is therefore not yet possible to predict how the relative prices between animal and plant-based foods will change in the future. If an ambitious climate and environmental policy is implemented, plant-based alternatives to animal products could become competitive with animal foods in the future.

- In a secondary analysis as part of the Vegetarian and Vegan Children and Youth Study (n = 410, 6-18 years; 2017–2019), the food expenditure for a vegetarian, a vegan and an omnivorous diet was compared within the study group with predominantly high socioeconomic status [117]. A vegetarian diet was associated with the lowest food expenditure, while expenditure on omnivorous and vegan diets differed only slightly [117].
- In a study by Kabisch et al. [118], cost comparisons were drawn up on the basis of modelled diet plans for different diets[3] and the prices in German supermarket chains. Compared to an omnivorous diet with a high proportion of freshly cooked meals, the modelled vegan diet was 16% more expensive, while the Mediterranean diet was 23% more expensive and an omnivorous diet with a high fat and moderate carbohydrate content was 67% more expensive. The ovo-lacto-vegetarian diet was the most favourable diet in the modelling [118]. None of the modelled diet plans could be financed with a budget of €150 per person per month, corresponding to the monthly rate of *„Arbeitslosengeld II“* (unemployment benefit, as of 2021) provided for food. The authors conclude that "healthy" food in particular is less affordable in low-income households [118].

The WBAE also states that nutritionally more beneficial foods, such as fruit, vegetables, fish or lean meat, are more expensive on average (per 100 kcal) than energy-dense foods with a high proportion of added sugar and fat [5]. According to the WBAE,

[3] All diets meet the DGE/ÖGE reference values for nutrient intake; (1) omnivorous diet with a high proportion of highly processed foods; (2) omnivorous diet with a high proportion of freshly cooked meals; (3) low-protein vegan diet; (4) low-fat ovo-lacto-vegetarian diet; (5) low-fat omnivorous diet; (6) Mediterranean diet; (7) high-fat moderate-carbohydrate diet [118]

a change in eating habits, in the sense of a reduction in the consumption of animal products, is nevertheless more likely to save consumers money [5]. The political framework also plays an important role here, i.e. the extent to which the hidden environmental and health costs of various foods are reflected in retail prices [116, 119]. If these external costs are taken into account, a heavily plant-based diet results in significantly lower food expenditure compared to an omnivorous diet [116, 120, 121]. However, model simulations indicate that a strong reduction in animal husbandry would require significantly less labour in agriculture. This can lead to social problems in rural areas, at least in a transitional period [115].

Overall, the social aspects of a vegan diet are complex and difficult to analyse, both at an individual level and along the value chain. The effects have so far been insufficiently mapped and are generally not recognisable to consumers [5]. Future developments, e.g. in food prices, and the establishment of systems for measuring the social impact of vegan diets are crucial for assessment in this context.

Animal welfare dimension

The Vegan Society [122], which first coined the term "vegan" in connection with nutrition in 1944, defined veganism as a "philosophy and way of living which seeks to exclude – as far as is possible and practicable – all forms of exploitation of, and cruelty to, animals [...]" [123].
In a German survey, people who followed a vegan diet (n = 329) were asked about their underlying motivation in an open question. Most people (82%) stated several motives. At almost 90%, animal-related motives, such as animal welfare or animal rights motives or other ethical aspects relating to animals, were most frequently mentioned. This was followed by health-related and environmental motives (69% and 47%, respectively) [124]. In an international cross-sectional survey (n = 7914; vegan n = 424), attitudes towards animal welfare were recorded by students in 22 countries using a questionnaire. The greatest variance in attitudes towards animal welfare was explained by diet, with a vegan diet being associated with higher attitudes towards animal welfare than an omnivorous diet [125].
The consumption of food and the use of products of animal origin, which are avoided in a vegan diet, raise questions of animal ethics in the discussion about animal welfare. Animal ethics deals with questions of appropriate, fair or good treatment of animals by humans. The animal welfare movement sees animal husbandry for the purpose of meat consumption as justified and aims to reform in the interests of animal welfare. A well-known representative of the animal welfare movement in Germany is the German Animal Welfare Association *(Deutscher Tierschutzbund e. V.)*. The animal rights movement, which includes organisations such as PETA (People for the Ethical Treatment of Animals), on the other hand, strives for a vegetarian/vegan diet and questions the basic principles of livestock farming. According to the WBAE, the animal welfare movement is generally more accepted in society than the animal rights movement, and organisations such as the *Deutscher Tierschutzbund e. V.* cooperate with the industry to improve conditions in livestock farming [126].

Although there are currently some assessment frameworks for recording animal welfare at the level of individual animal species, approaches for assessing the impact of diets on animal welfare are not yet well established and have not yet been comprehensively applied to vegan diets [127]. Nevertheless, it can be assumed that a vegan diet would perform best here.

Reduced pressure to intensify animal husbandry would open up new opportunities for a greater prevalence of species-appropriate forms of husbandry. If the reduction in demand were to go hand in hand with the selection of food of animal origin from species-appropriate husbandry, this could lead to greater animal welfare [4]. Future developments could show whether this might be realisable in practice.

Conclusion and recommendations for action

In this DGE position statement on vegan diet, not only health aspects were considered, but also the additional dimensions of a more sustainable diet, namely environmental, social and animal welfare. However, the approaches for evaluating the impact of diets on the social and animal welfare target dimensions are not yet sufficiently established and have not been comprehensively applied. Therefore, the position statement on vegan diet focuses on the health and environmental dimensions. Nevertheless, previous approaches suggest that the growing adoption of vegan diets could have positive long-term effects on social aspects

and animal welfare, although future adjustments and developments will be necessary for both dimensions.
The systematic literature review and assessment for the health dimension show evidence for a preventive potential of a vegan diet for cardiometabolic diseases and cancers in the general population. However, there is also evidence for an increased risk of reduced bone health associated with a vegan diet. Nevertheless, the number of underlying studies and sample sizes were often small, the study populations were heterogeneous, and in some cases there was a risk of bias. This is reflected in the low or very low certainty of the evidence, meaning future large, well-designed studies could change the current findings.
As with other types of diets, a vegan diet cannot be universally assessed. The choice of food and whether (potentially) critical nutrients (e.g. through supplements) are supplied in sufficient quantities are important considerations when assessing the effects on health. In addition to vitamin B_{12}, for which long-term and reliable supplementation is crucial, iodine is particularly notable as a potentially critical nutrient. Iodine is considered critical in the German general population, regardless of diet. However, the umbrella review and primary studies indicate that the iodine supply in vegan diets is even more inadequate compared to other groups.
In addition to vitamin B_{12} and iodine, protein, long-chain n-3 fatty acids[4], vitamin D, vitamin B_2, calcium, iron, zinc, selenium and possibly vitamin A are considered (potentially) critical nutrients in a vegan diet.

Based on the current state of knowledge, for the healthy adult general population, a vegan diet, like other diets, can be health-promoting, provided that vitamin B_{12} is supplemented, the food selection is balanced and well-planned, and the nutrient requirements of potentially critical nutrients are sufficiently covered (possibly through further nutrient supplements).

There is limited evidence for a vegan diet in children and adolescents based on one systematic review with meta-analysis. In contrast, for pregnant women and breastfeeding mothers only individual primary studies could be identified, and no comprehensive survey could be identified explicitly for elderly people. It should be noted that the group of elderly people, is particularly heterogeneous, encompassing a wide range of ages and health statuses with varying nutrient requirements. It includes individuals who are healthy as well as those with multimorbidity or frailty [46]. Therefore, it is even more difficult to draw generalised conclusions for this population group.
In children and adolescents, similar correlations were found as in the healthy adult general population. Overall, the few studies on vulnerable groups did not identify any clear negative associations between a vegan diet and health-related outcomes. However, these cannot be ruled out due to the limited data available.

- **For the vulnerable groups of children, adolescents, pregnant women, breastfeeding mothers and elderly people, the DGE cannot make a clear recommendation either in favour of or against a vegan diet due to the limited data available. Due to the risk of potential, possibly irreversible consequences if not implemented properly, vegan diets in vulnerable groups require particularly well-founded nutritional knowledge. Reliable supplementation of vitamin B_{12} and possibly further potentially critical nutrients is crucial. Additionally, a balanced and well-planned food selection using nutrient-dense foods is even more important than in the healthy adult general population.**

- **Nutritional counselling by qualified specialists is urgently recommended for adequate implementation.**

For recommendations on how to implement a health-promoting vegan diet, see ◆ Box 2.

For various environmental indicators, the analysed publications show clear advantages of a vegan diet compared to an omnivorous diet. A vegan diet is a recommended measure for reducing the environmental impact of the food system. A plant-based diet with very low consumption of animal-based foods (i.e. up to about 9 g protein per person per day from animal sources that do not compete with direct human nutrition for land) [98, 105] offers similar benefits in terms of environmental indicators. A plant-based diet in line with the DGE recommendations also helps to reduce the environmental impact of nutrition [1].

[4] This applies particularly to pregnant women, breastfeeding mothers, children and adolescents

Box 2: Recommendations for a health-promoting vegan diet

- People following a vegan diet must supplement with vitamin B_{12}. The DGE recommends regular and reliable use of a vitamin B_{12} supplement for individuals following a vegan diet. As clinical deficiency symptoms often only develop after several years of low or no vitamin B_{12} intake, people on a vegan diet should have their vitamin B_{12} levels checked regularly. People who belong to vulnerable groups should pay particular attention to this.
- In addition, vegans should pay particular attention to ensuring adequate iodine intake. The use of iodised salt in the household, the consumption of foods prepared with iodised salt or iodine-fortified foods, e.g. plant drinks, can help meet the requirements. Regular consumption of algae with a declared iodine content is also beneficial to meet requirements. If insufficient iodine-rich foods are consumed, adults should take a daily iodine supplement of 100 µg in consultation with a physician. This measure can support the adequate supply. This dosage complies with the maximum recommended daily intake for food supplements issued by the Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung, BfR) [128]. For children and adolescents, supplementation should be individually assessed in consultation with a paediatrician. For all groups, algae and algae preparations without labelled iodine content are not recommended due to their highly fluctuating iodine levels. The use of iodised salt alone is insufficient.
- Further nutrients that in an omnivorous diet predominantly come from animal foods (protein, long-chain n-3 fatty acids, vitamin D, vitamin B_2, calcium, iron, zinc, selenium and possibly vitamin A), must be obtained from plant sources. This can be achieved through a well-chosen selection of foods, possibly complemented by fortified foods or nutrient supplements.
- Regardless of the type of diet, a healthy and varied food selection based on fruit and vegetables, wholegrain cereals, wholegrain products, potatoes, pulses, nuts and the use of vegetable oils, as well as low salt and sugar should be implemented. Vegetable oils high in α-linolenic acid (canola oil and walnut oil) should be favoured over oils high in linoleic acid (corn oil, sunflower oil). No definitive conclusion can be drawn for the consumption of plant-based milk and meat alternatives. Checking the ingredient list and the nutritional information can help in making a nutritionally favourable decision. Overall, it is important to consider the entire food selection when planning a diet.
- The recommendations for vulnerable population groups are in line with the recommendations for action "Nutrition and physical activity in children from 1–3 years old" of the Germany-wide "Healthy Start Network" [129]. In addition, the following recommendations of the "Healthy Start Network“ apply to pregnant women, breastfeeding mothers and infants [129–131]:
  - In addition to the general recommendation to supplement folic acid before conception and during the first trimester of pregnancy as well as iodine throughout the entire pregnancy, pregnant women following a vegan diet should take a vitamin B_{12} supplement on a permanent basis. Furthermore, they should also ensure an adequate intake of potentially critical nutrients in particular and, if necessary, use fortified foods and, after consulting a physician, consider further nutrient supplements [130].
  - It is recommended that pregnant and breastfeeding women following a vegan diet supplement with 200 mg DHA per day since they do not regularly consume oily sea fish [130, 131]. Regardless of their diet, breastfeeding mothers should use iodised salt and take a daily supplement of 100 µg of iodine [131].
  - In the case of vegan-fed infants, i.e. both breastfed infants whose mothers follow a vegan diet and infants who receive vegan infant formula and/or exclusively vegan complementary foods, the supply of essential nutrients must be ensured on a permanent basis. This can be achieved through fortified foods or a nutrient supplement containing vitamin B_{12} and possibly further critical nutrients (e.g. iodine, iron). If infants are not or not exclusively breastfed, they should receive an infant formula and follow-on formula that meet the legal standards as a substitute for breast milk. Conventional products are typically based on cow's milk; however, infant formula based on soy protein, enriched with essential nutrients is available as a vegan alternative. This formula should also be used to prepare the milk cereal porridge [131]. Plant-based milk alternatives such as soy or oat drinks are not an adequate substitute for breast milk and should not be used to prepare milk cereal porridge. Additionally, all infants receiving exclusively home-made baby food should be supplemented with approximately 50 µg iodine per day [131].
- Health and nutrition professionals should maintain an open attitude towards people who want to adopt a vegan diet, either for themselves or their children. They should offer the best possible support in implementing a balanced and well-planned vegan diet.
- Increasing the availability of well-planned vegan meals in communal catering can further support both a healthy and environmentally friendly diet. Both individual health and the environment benefit from a more frequent choice of vegan meals.

Taking into account both health and environmental aspects, a diet with a significant reduction in animal-based foods is recommended.

Need for Research

To better assess the nutritional advantages and disadvantages of a vegan diet, more high-quality, larger-scale studies with longer follow-ups and low risk of bias are needed across all life stages. The multicentre COPLANT study (Cohort Study on Plant-Based Diets), which examines around 6,000 people following vegan, ovo-lacto-vegetarian, pescetarian or omnivorous diets started in 2024, can help to address existing data gaps [132]. Due to the rising prevalence of vegan diets, their inclusion in German representative dietary surveys is also increasing. In the future, these surveys could potentially also provide low-biased information on vegan diets. In addition, well-designed RCTs are needed, for example to assess the effects of vegan diets on intermediate markers and to support the findings from observational studies. Further research should investigate the bioavailability of (potentially) critical nutrients, as well as the role of plant-based alternatives to milk, meat, fish and other convenience products in the current vegan diet.

To support consumers who wish to adopt a vegan diet and make health- and environmentally-optimised food choices, the DGE plans to successively provide adapted food-based dietary guidelines for further diets, including a vegetarian and vegan diet, as well as different population groups.

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