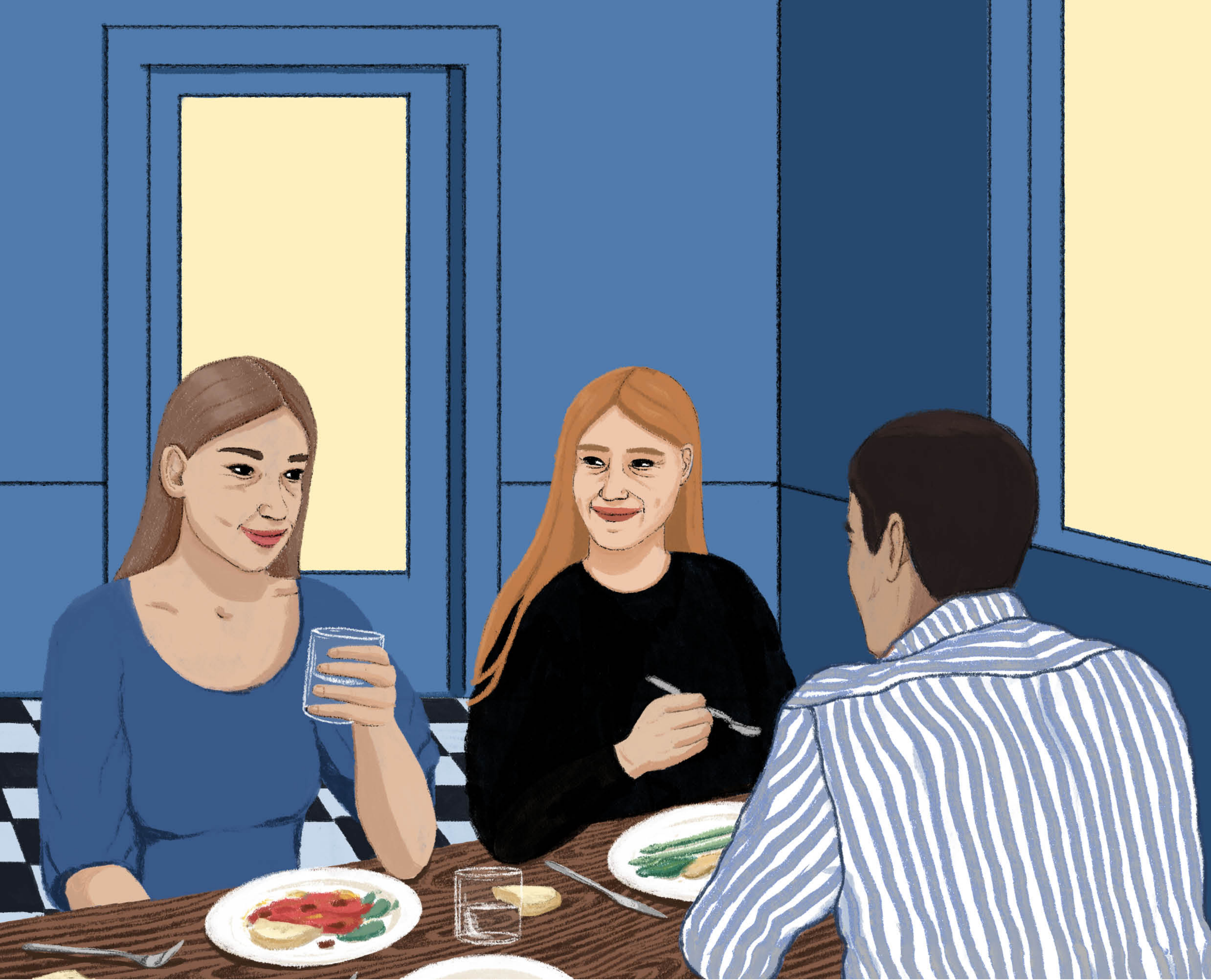
Nordic Council of Ministers

NORDIC NUTRITION RECOMMENDATIONS 2023

INTEGRATING ENVIRONMENTAL ASPECTS



This new edition of the Nordic Nutrition Recommendations makes a powerful link between healthy people and a healthy planet. We must work to promote and protect both. Focusing only on one could result in nutritionally inadequate diets or large environmental impacts.

DR TEDROS ADHANOM GHEBREYESUS, DIRECTOR-GENERAL OF THE WORLD HEALTH ORGANIZATION

NNR2023 is an impressive piece of work. The key information is very accessible, and covers a wide range of topics, some not considered before despite being very important. The results of the considerable amount of work that has gone into this report will be very informative for a wide range of stakeholders and provides a great foundation for evidence-based policymaking. Now it needs to be adopted into policy.

PROFESSOR SUSAN FAIRWEATHER-TAIT, NORWICH MEDICAL SCHOOL, UK, MEMBER OF EXPERT COMMITTEES ON NUTRIENT REQUIREMENTS FOR FAO, WHO, EFSA AND UK HEALTH AUTHORITIES

The Nordic Nutrition Recommendations forms an important scientific basis for Sweden's dietary guidelines as well as our front-of-pack labelling "the Keyhole". The NNR impacts our food choices in very concrete ways by guiding the composition of school meals and other public meals, as well as the Swedish citizens to make healthy and sustainable food choices.

ANNICA SOHLSTRÖM, DIRECTOR-GENERAL, SWEDISH FOOD AGENCY

NNR2023 is really a tremendous amount of work and well done. I especially appreciate the inclusion of all of the analytic frameworks, this adds to the transparency of the work. This will be a huge resource for authorities across the world undertaking development of Food based dietary guidelines. The stepwise consideration of health and environment is a commendable addition to the many considerations when making dietary guidelines.

AMANDA MACFARLANE, CHAIR OF THE CANADA-US JOINT DIETARY REFERENCE INTAKES (DRIS) WORKING GROUP (2013-2022)

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Secretary General's Preface – NNR2023

Food is a central part of our everyday life. It plays a pivotal role for our health and wellbeing. Food is a part of our culture and through food we express our creativity and celebrate our holidays. We simply cannot overstate the importance of food in our lives and our societies. The right to adequate food is a human right that most countries strive to uphold for their citizens. Beyond affecting our personal health, our food choices also have long lasting impact on our climate and environment.

We in the Nordics have a long-standing collaboration when it comes to food. The Nordic Nutrition Recommendations (NNR) is the proudest example of our joint efforts. Since 1980 we have funded accomplished scientists and experts in their work to compile the best available data on nutrition. The resulting NNR publications have served as reference texts internationally and have guided the design and development of national food based dietary guidelines in the Nordic and Baltic countries. These guidelines influence the nutrition labels that in turn inform consumer food choices. They also guide school meals and the food we serve in our hospitals and other care facilities. Serving the healthiest food possible to our children, and to those who are vulnerable and frail, is made easier through the hard work that has gone into the NNR.

This new edition, the NNR2023, is our bravest step yet. It will present the best available data for how to eat for the health of our bodies and for our planet. The decision to let this edition integrate environmental aspects is well aligned with our global commitments, and with the Nordic Vision to be the most sustainable and integrated region by 2030. We cannot, and will not, turn a blind eye to the scientific evidence of how our consumption impacts our planet.

Being mindful of how we use our resources is a global common goal. It is my sincere hope that in making NNR2023 freely available to download and use, we in the Nordics support knowledge sharing on healthy and sustainable food choices well beyond our own region. It is a pioneering body of work for the

Nordic region, a labour of love for the several hundred scientists and experts who have given years of their lives to this publication, and a personal highlight for me to introduce the Nordic Nutrition Recommendations 2023. The change towards a healthy and sustainable Nordic region starts with our food.

Karen Ellemann
Secretary General
Nordic Council of Ministers

OVERALL DIET RECOMMENDATION

Overall, we recommend a predominantly plant-based diet rich in vegetables, fruits, berries, pulses, potatoes and whole grains, ample amounts of fish and nuts, moderate intake of low fat dairy products, limited intake of red meat and poultry, and minimal intake of processed meat, alcohol, and processed foods containing high amounts of added fats, salt and sugar.

INTRODUCTION

Preface

In 2016, the Nordic Council of Ministers took the initiative to update the scientific foundation for national nutrient recommendations and dietary guidelines in the Nordic and Baltic countries. The present NNR2023 report has been developed according to the project description and describes the science advice to the authorities in the Nordic and Baltic counties.

The scientific foundation for the NNR2023 report consists of approximately 100 qualified systematic reviews, including 9 *de novo* qualified systematic reviews, and 57 *de novo* background reviews on nutrients, food groups, meal- and dietary patterns, physical activity, body weight, food and nutrient intakes, and burden of diseases in Nordic and Baltic countries. In addition, several *de novo* papers on principles, methodology and environmental impact of food consumption are also essential parts of the scientific foundation of NNR2023 report. Many scientists have contributed to the NNR2023 project as authors of these background papers, served as referees or participated in reference groups. All papers will be available at the website of the Nordic Council of Ministers, and as part of the extended NNR2023 report. While the NNR2023 Committee highly appreciates and acknowledges the considerable and essential contributions and suggestions by these scientists, the present NNR2023 report is the sole responsibility of the NNR Committee.

The NNR2023 report has developed science advice based on the health effects of foods and response to the country-specific public health challenges and burden of diseases, food consumption patterns, as well as the country-specific environmental impacts of food consumption.

The NNR2023 report has not formulated advice on country-specific priorities such as food production and accessibility (e.g., agricultural methods, import and export, self-sufficiency, food security) and sociocultural aspects (e.g., animal welfare) of food consumption. Such topics are briefly discussed in background papers and in relevant sections of NNR2023, but must be dealt with nationally.

Rune Blomhoff, *professor, head of NNR2023 Committee*,
University of Oslo and Oslo University Hospital

Abbreviations

AI: Adequate intake

AR: Average requirement

BEE: Basal energy expenditure

BMI: Body mass index

CDRR: Chronic disease risk reduction

CO_2eq: Carbon dioxide (CO_2) equivalents

CRC: Colorectal cancer

CV: Coefficient of variation

CVD: Cardiovascular disease

DALY: Disability-adjusted life years

DRV: Dietary reference value

E%: Energy percentage, i.e., percentage of total energy intake

EFSA: European Food Safety Authority

EK-FJLS Executive and Food: Nordic Committee of Senior Officials for Fisheries, Aquaculture, Agriculture, Food and Forestry. Nordic Council of Ministers

FAO: Food and Agriculture Organization of the United Nations

FBDG: Food-based dietary guideline

GHG: Greenhouse gases

HSSD: Healthy, Safe and Sustainable Diet, Nordic Council of Ministers

IOM: Institute of Medicine, USA

IPCC: Intergovernmental Panel on Climate Change

kJ: Kilojoule (1 kJ = 0.239 kcal)

kcal: Kilocalorie (1 kcal = 4.184 kJ)

LCA: Life Cycle Assessment

LNCSB: Low- and no-calorie sweetened beverages

MJ: Megajoule (1 MJ = 239 kcal)

NASEM: National Academies of Sciences, Engineering, and Medicine, USA

NCM: Nordic Council of Ministers

NNR: Nordic Nutrition Recommendations

NNR2023: The sixth edition of the Nordic Nutrition Recommendations (2023)

PAL: Physical Activity Level

PLP: Pyridoxal 5′-phosphate

Provisional AR: provisional average requirement

qSR: Qualified Systematic Review

REE: Resting energy expenditure

RI: Recommended intake

SD: Standard deviation

SDG: The UN Sustainable Developmental Goals (United Nations, 2015)

SR: Systematic review

SSB: Sugar-sweetened beverages

T2D: Type 2 diabetes

UL: Tolerable Upper Intake Level, corresponds to Upper Intake Level and Upper Level

UN: United Nations

UPF: Ultra-processed foods

WHO: World Health Organization

Glossary

Added sugars: Refined sugars such as sucrose, fructose, glucose, starch hydrolysates (glucose syrup, high-fructose syrup), and other isolated sugar preparations used as such or added during food preparation and manufacturing.

Baltics or Baltic countries: The three Baltic countries (Estonia, Latvia, and Lithuania).

Carbon dioxide equivalents: For assessing the short-term global warming potential of different greenhouse gases by converting them to the equivalent amount of CO_2 with the same global-warming potential and the total amount is then summed.

DALY: The overall burden of disease is assessed using the disability-adjusted life years.

Free sugars: Added sugars plus sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates.

Indicator: A central step in setting DRVs or FBDGs is identifying and selecting indicators of adequate and excessive intakes. An indicator broadly refers to clinical endpoints, biomarkers, surrogate markers, and chronic disease risk factors. A qualified biomarker is often used as an indicator to derive DRVs for nutrients.

Life cycle assessment: An ISO-standardized environmental management tool to quantitatively assess and compare the overall environmental performance of products, services and technologies.

Life-stage group: The DRVs are expressed as reference values for groups defined by age, sex, pregnancy and lactation.

Monoculture: Intensive large-scale cropping systems with low diversity.

Net zero: GHG emission regimes that do not produce further warming, i.e., no increase in total radiative forcing from atmospheric greenhouse gases.

Nordics or Nordic countries: The five Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden).

Physical activity level: The physical activity level is used to express a person's total daily physical activity, and is used for estimating total energy expenditure.

Plant-based diet: In this report, the terms plant-based diet is defined as a diet that mostly contain plant foods such as vegetables, fruits, whole grains, pulses, nuts and seeds. Animal foods such as fish, white meat (poultry), red meat, and low-fat dairy can make up a moderate amount of the foods in a plant-based diet.

Qualified biomarker: When a biomarker is qualified, it means that it has been accepted by the NNR2023 committee as a valid basis for deriving DRVs or FBDGs.

Qualified systematic review: A systematic review defined by the inclusion and exclusion criteria set by the NNR2023 Committee. A qualified systematic review may be used to inform the setting of DRVs or FBDGs.

Ultra-processed foods: Foods in category 4 of the NOVA classification system.

Vegetarian diets: (sometimes referred to as lacto-ovo vegetarian) includes eggs and dairy foods, but no meat, poultry, fish, or seafood.

Vegan diets: includes no animal-source food.

Updating scientific evidence used to set DRVs and formulate FBDGs

Qualified Systematic Reviews are considered as the preferred method to evaluate causality

More than 3 million nutrition science papers published in scientific journals can be retrieved when searching in standard library databases. The study quality varies considerably in these papers, similarly to all other scientific and medical disciplines. When setting DRVs and formulating national FBDGs, only adequately designed studies of high quality should be utilized.

In general, systematic reviews (SRs) are considered the method with highest quality for synthesizing original scientific evidence. The Enhancing the QUAlity and Transparency Of health Research (EQUATOR) network has formulated requirements that must be met in reporting SRs (Liberati et al., 2009; Page et al., 2021). Several SRs have been published in the field of diet, nutrition and health. However, the quality varies and control of risk of bias does often not meet the standard needed to inform national recommendations.

Due to sponsorship from commercial entities and ideological organizations, concerns have been raised about bias in the results of such SRs. For example, evidence for substantial bias has been identified in conclusions of industry-sponsored systematic reviews. It has been suggested that industry-sponsored research will result in higher likelihood of a favourable conclusion, compared with government-sponsored research (Hansen et al., 2019; Lundh et al., 2017). While industry-sponsored research is likely to be important for nutrition research also in the future, it is fundamentally important that industry sponsors should have no role in project design, implementation, analysis, or the interpretation of results. This independence minimizes the potential for bias.

The NNR2023 project has considered all SRs. However, to reduce the risk of bias, NNR2023 did not consider SRs commissioned or sponsored by industry or organizations with a business or ideological interest as qSRs. Only SRs commissioned by national food or health authorities, or international food and health organizations, were used as the foundation for setting DRVs and formulating national FBDGs. To evaluate bias and other quality aspects, we developed a guide for working with systematic reviews and formulated specific inclusion and exclusion criteria that had to be met for SRs to qualify as main science base in the NNR2023 project (Arnesen et al., 2020a, b; Høyer et al., 2021). SRs that met all inclusion and exclusion criteria were designated "qualified SRs" (qSRs) The qSRs identified are shown in Appendix 2.

The following eight steps had to be included when developing qSRs for the NNR2023 project:

1. Precise definition of the research question
2. Development of protocol with predefined criteria
3. Adequate literature search
4. Screening and selection of studies according to protocol requirements
5. Data extraction according to protocol requirements
6. Assessing risk of bias following specific procedures
7. Synthesis and grading of total strength of evidence following specific procedures
8. Reporting according to standardized criteria

Details of these steps are described in Arnesen et al. (Arnesen et al., 2020a, b). For example, for the NNR *de novo* qSRs on randomized controlled trials, a modified version of the Cochrane's 'Risk of bias 2.0' tool (Sterne et al., 2019) was used to critically appraise internal validity, i.e., bias. For non-randomized trials, the risk of bias assessment tool was based on the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) instrument (Sterne et al., 2016), and for observational studies (prospective cohort studies, case-cohort studies, or case-control studies), the recently developed 'Risk of Bias for Nutrition Observational Studies' (RoB-NObS) tool, developed by the US Department of Agriculture's (USDA) Nutrition Evidence Systematic Review (NESR) team (Nutrition Evidence Systematic Review, 2019), was used. These tools, or various other tools of similar quality, were used in all qSRs identified in the present NNR report.

Global collaboration between health authorities

NNR2023 should ideally build on recent qSRs of highest quality for all associations between nutrients and food groups and every relevant health-related outcome. A complete set of qSRs may include the following:

- qSRs for each of the indicators used to set Average Requirement (AR) for each of the 36 nutrients included in NNR2023
- qSRs for each of the indicators used to set Upper Limit (UL) for each of the 36 nutrients included in NNR2023
- qSRs for assessing indicator dose-response and additional candidate indicators for AR and UL
- qSRs for each of the candidate indicators used to formulate science advice for healthy FBDGs for all the 15 food groups, meal and dietary patterns assessed in NNR2023. A number of indicators should be assessed for each food group, such as various types of cardiovascular diseases and cancers, type 2 diabetes and other relevant chronic diseases. Often, there is also a need for qSRs on several subcategories within each food group.

Thus, recent qSRs of several hundred possible exposure-outcome pairs would be needed in the ideal situation. However, due to the high cost and resources involved in developing qSR, no national authorities have the resources and competence for completing the task on their own. This calls for international harmonization and collaboration between national authorities (Allen et al., 2020; NASEM, 2018; Yaktine et al., 2020). The NNR project is a long-standing example of international harmonization and collaboration.

Such global harmonization is possible since foods and nutrients have identical health effects across nations and regions. Scientific human studies conducted in regions outside the Nordic and Baltic countries are therefore equally relevant as human studies conducted within the Nordic and Baltic countries. There are a few noteworthy exceptions, but many studies on health effects are universally applicable. All exceptions to this general rule were carefully considered in each relevant section in this report. When developing national DRVs and FBDGs, several country-specific issues need to be considered (see discussion later in the report).

Since around 2010, national health authorities and international organizations have gradually started to use qSRs as the preferred method for evidence-based evaluation of causal relations between nutrient or food exposures and health outcomes. Close to 100 SRs (Table 1-2 and Appendix 2) fulfilled the inclusion and exclusion criteria for qSRs and were used as a main fundament when setting DRVs and formulating FBDGs in the NNR2023 project. The Institute of Medicine (IOM), National Academies of Sciences, Engineering, and Medicine (NASEM) (IOM was renamed to NASEM in 2011), the European Food Safety Authority (EFSA) and Nordic Council of Ministers (Nordic Council of Ministers, 2014) are among the authorities that contributed to developing these qSRs.

Table 1 Qualified systematic reviews used for nutrients
A) Macronutrients

Nutrient	Reference	Published/commissioned by
Energy	WCRF/AICR (WCRF/AICR, 2018b, f)	WCRF/AICR
Fat and fatty acids	Fogelholm et al. (2012), Schwab et al. (2014), Wolfram et al. (2015), de Souza et al. (2015), Brouwer (2016), Mensink (2016), Balk et al. (2016), Newberry et al. (2016), Te Morenga and Montez (2017), Abdelhamid et al. (2018, 2020), Naude et al. (2018), Brown et al. (2019), Hanson et al. (2020), Hooper et al. (2020a, b), Brainard et al. (2020), Snetselaar et al. (2020a), Donovan et al. (2020a), Deane et al. (2021), Bärebring et al. (2022), Nwaru et al. (2022), Reynolds et al. (2022)	NNR2012, DGE, WHO, AHRQ, DGAC2020, NNR2023
Carbohydrates	Hauner et al. (2012), Sonestedt et al. (2012), Fogelholm et al. (2012), WHO (2015), SACN (2015), Reynolds et al. (2019), Mayer-Davis et al. (2020), EFSA (2022)	DGE, NNR2012, WHO, SACN, DGAC2020, EFSA
Dietary fibre	Fogelholm et al. (2012), Hauner et al. (2012), SACN (2015), Reynolds et al. (2019), Dierkes et al. (2023), WCRF/AICR (2018j)	NNR2012, DGE, SACN, WCRF/AICR, WHO, NNR2023
Protein	Fogelholm et al. (2012), Hörnell et al. (2013), Pedersen et al. (2013), Pedersen and Cederholm (2014), Hengeveld et al. (2022), Arnesen et al. (2022), Lamberg-Allardt et al. (2023b)	NNR2012, Health Council of the Netherlands, NNR2023

Abbreviations: AHRQ: Agency for Healthcare Research and Quality; DGAC2020: 2020 Dietary Guidelines Advisory Committee; DGE: Deutsche Geschellschaft für Ernährung (German Nutrition Society); EFSA: European Food Safety Authority; NNR: Nordic Nutrition Recommendations; WCRF/AICR: World Cancer Research Fund/American Institute of Cancer Research; WHO: World Health Organization.

B) Micronutrients

Nutrient	Reference	Published/commissioned by
Vitamin A	Olsen et al. (2023)	EFSA
Vitamin D	Lamberg-Allardt et al. (2013), Newberry et al. (2014), Dewey et al. (2020), Lamberg-Allardt et al. (2023a)	NNR2012, AHRQ, DGAC2020, EFSA
Riboflavin	Buijssen et al. (2014)	EFSA
Niacin	Eeuwijk et al. (2012)	EFSA
Vitamin B_6	Eeuwijk et al. (2012), EFSA (2023a)	EFSA
Folate	Donovan et al. (2020b), Åkesson et al. (2023)	DGAC 2020, EFSA
Vitamin B_{12}	Bärebring et al. (2023)	NNR2023
Biotin	Eeuwijk et al. (2012)	EFSA
Calcium	Uusi-Rasi et al. (2013), Newberry et al. (2014)	NNR2012, AHRQ
Phosphorus	Eeuwijk et al. (2013)	EFSA
Sodium	WHO (2012), Eeuwijk et al. (2013), Neale and Clark (2017), Newberry et al. (2018), EFSA (2019b), NASEM (2019)	WHO, EFSA, Australian Department of Health and New Zealand Ministry of Health, AHRQ, NASEM
Potassium	(Aburto et al., 2013), Newberry et al. (2018), NASEM (2019)	WHO, AHRQ, NASEM
Iron	Domellöf et al. (2013), Dewey et al. (2020)	NNR2012, DGAC2020
Iodine	Gunnarsdottir and Dahl (2012)	NNR 2012
Selenium	EFSA (2023b)	EFSA
Copper	Bost et al. (2012)	EFSA
Phytochemicals and antioxidants	WCRF/AICR (2018a), O'Connor et al. (2022)	WCRF/AICR, AHRQ

Abbreviations: AHRQ: Agency for Healthcare Research and Quality; DGAC2020: 2020 Dietary Guidelines Advisory Committee; EFSA: European Food Safety Authority; NASEM: National Academies of Science, Engineering, and Medicine; NNR: Nordic Nutrition Recommendations; WCRF/AICR: World Cancer Research Fund/American Institute of Cancer Research; WHO: World Health Organization.

Table 2 Qualified systematic reviews used for FBDGs

Food group	Qualified SR	Published/commissioned by
Breastfeeding	Victora et al. (2016), WCRF/AICR (2018b), Güngör et al. (2019a, b, c, d, e)	WHO, WCRF/AICR, DGAC2020
Complementary feeding	Obbagy et al. (2019a, b, c), English et al. (2019a, b, c) Spill et al. (2019), EFSA (2019a), de Silva et al. (2020), Arnesen et al. (2022); Padhani et al. (2023)	DGAC2020, EFSA, EAACI, NNR2023, WHO
Beverages	Sonestedt et al. (2012), WHO (2015), SACN (2015), WCRF/AICR (2018g), Mayer-Davis et al. (2020a), Mayer-Davis et al. (2020b), EFSA (2022), Rios-Leyvraz and Montez (2022), Rousham et al. (2022)	NNR2012, WHO, SACN, WCRF/AICR DGAC2020
Cereals (grains)	Fogelholm et al. (2012), Hauner et al. (2012), Åkesson et al. (2013), SACN (2015), WCRF/AICR (2018b, j), Reynolds et al. (2019)	NNR2012, DGE, WHO, WCRF/AICR
Vegetables, fruits and berries	Fogelholm (2012), WCRF/AICR (2018j), Stanaway et al. (2022)	NNR2012, WCRF/AICR, GBD
Potatoes	Åkesson et al. (2013), SACN (2015)	NNR2012
Fruit juice	SACN (2015), WCRF/AICR (2018b), Mayer-Davis et al. (2020a)	SACN, WCRF/AICR, DGAC2020
Pulses (legumes)	SACN (2015), WCRF/AICR (2018j), Lamberg-Allardt et al. (2023b), Thórisdottír et al. (2023)	SACN, WCRF/AICR, NNR2023
Nuts and seeds	Arnesen et al. (2023)	NNR2023
Fish and seafood	WCRF/AICR (2018e), Snetselaar et al. (2020b, c), Norwegian Scientific Committee for Food and Environment (2022)	WCRF/AICR, DGAC2020, Norwegian Scientific Committee for Food and Environment
Red meat	Fogelholm et al. (2012), WCRF/AICR (2018e), Lescinsky et al. (2022)	NNR2012, WCRF/AICR, GBD
White meat	WCRF/AICR (2018e), Ramel et al. (in press)	WCRF/AICR, NNR2023
Milk and dairy products	Åkesson et al. (2013), WCRF/AICR (2018e), Lamberg-Allardt et al. (2023b)	NNR2012, WCRF/AICR, NNR2023
Sweets and confectioneries	EFSA (2022), Mayer-Davis et al. (2020b), WHO (2015), Rousham et al. (2022)	EFSA, DGAC2020, WHO
Alcohol	WCRF/AICR (2018h), Mayer-Davis et al. (2020), Canadian Centre on Substance Use and Addiction (CCSA) (2023)	WCRF/AICR, DGAC2020, Health Canada
Dietary patterns	2020 Dietary Guidelins Advisory Committee (2020), Boushey et al. (2020a, b, c, d, e, f, g)	DGAC2020
Meal patterns	Heymsfield et al. (2020a, b, c)	DGAC2020

Abbreviations: DGAC2020: 2020 Dietary Guidelines Advisory Committee; EAACI: European Academy of Allergy and Clinical Immunology; EFSA: European Food Safety Authority; GBD: Global Burden of Disease; NNR: Nordic Nutrition Recommendations; SACN: Scientific Advisory Committee on Nutrition; WCRF/AICR: World Cancer Research Fund/American Institute of Cancer Research; WHO: World Health Organization.

These qSRs, some with overlapping topics, have been published in the period 2012-2023. While use of qSRs constitutes the most solid fundament available, it is important to independently review the literature to identify new significant and relevant evidence published after the publication date of a qSR. A key role of the background papers for the 36 nutrients, 15 food groups, and meal and dietary patterns, is to ascertain that NNR2023 is up to date with the most recent scientific evidence.

Selection of topics for de novo qualified systematic reviews

An important aspect of the NNR2023 project was to select the most relevant topics for updating DRVs and FBDGs that had not been covered in a previous recent qSR. The NNR2023 Committee selected 9 topics for development of qSRs by the NNR2023 SR Centre (see "Organization of the NNR2023 project"). In an open call, scientists, health professionals, national food and health authorities, food manufacturers, other stakeholders and the general population in the Nordic and Baltic countries were invited to suggest SR topics. A total of 45 nominations with suggestion for more than 200 exposure–outcome pairs were received in the public call. The process of selecting topics is described in Høyer et al. (2021).

In addition, to search for "hot topics" relevant for setting DRVs and FBDGs, the NNR2023 Committee developed scoping reviews (ScRs) for 36 nutrients, 15 food groups, meal patterns and dietary patterns aimed at identifying potential SR topics. After considering approximately 15,000 review papers, several topics were identified. The NNR2023 Committee shortlisted 52 exposure-outcome pairs based on the call and the ScRs.

The following nine top prioritised topics for *de novo* SRs were then selected by the NNR2023 Committee in a comprehensive Delphi process (Høyer et al., 2021):

1. Protein intake in children and growth and risk of overweight or obesity: A systematic review and meta-analysis (Arnesen et al., 2022)
2. Legume consumption in adults and risk of cardiovascular disease and type 2 diabetes: A systematic review and meta-analysis (Thórisdottír et al., 2023)
3. Animal versus plant-based protein and risk of cardiovascular disease and type 2 diabetes: A systematic review of randomized controlled trials and prospective cohort studies (Lamberg-Allardt et al., 2023b)
4. Quality of dietary fat and risk of Alzheimer's disease and dementia in adults aged ≥ 50 years: A systematic review (Nwaru et al., 2022)

5. Intake of vitamin B12 in relation to vitamin B12 status in groups susceptible to deficiency: A systematic review (Bärebring et al., 2023)
6. White meat consumption and risk of cardiovascular disease and type 2 diabetes: A systematic review and meta-analysis (Ramel et al, 2023)
7. Supplementation with long chain n-3 fatty acids during pregnancy, lactation, or infancy in relation to risk of asthma and atopic disease during childhood: A systematic review and meta-analysis of randomized controlled clinical trials (Bärebring et al., 2022)
8. Nuts and seeds consumption and risk of cardiovascular disease, type 2 diabetes, and their risk factors: A systematic review and meta-analysis (Arnesen et al., 2023)
9. Dietary fibre and growth, iron status and bowel function in children 0-5 years old: A systematic review (Dierkes et al., 2023)

The target group for DRVs and FBDGs in NNR2023

Previous editions of NNR and most other national nutrient and diet recommendations (reviewed in NASEM (2022)) have described the "healthy population" or the "apparently healthy population" as the target population, without specifying in detail who are included and who are excluded. In the fifth edition of NNR, it was stated that the DRVs in NNR2012 were intended for the "general population", "healthy population" and "apparently healthy population" (Nordic Council of Ministers, 2014). In NNR2012, it was also decided that the DRVs were not intended for groups or individuals with diseases or other conditions that affect their nutrient requirements.

A process to more precisely define the target population for nutrient recommendations has recently been described (NASEM, 2022). In line with NASEM and EFSA, the NNR2023 defines the target population as the general population. The general population encompasses all age groups (i.e., infants, children and adolescents, adults, the elderly, pregnant and lactating women). The target population includes individuals that may absorb or metabolize nutrients from food components to various degrees, or have sensitivities because of specific genetic background, conditions or diseases. While DRVs and FBDGs are intended for most of these individuals, some subpopulations may be excluded. If not identified and excluded specifically in NNR2023, such subpopulations must be considered case-by-case by appropriate health authorities or practitioners.

The DRVs cover increased requirements such as during short-term mild infections or medical treatments. The DRVs are usually not suited for long-term infections, malabsorption and various metabolic disturbances (Christensen et al., 2020).

A significant proportion of the population in the Nordic and Baltic countries are at risk of developing chronic diseases or have already been diagnosed with a chronic disease (e.g., cardiovascular diseases, hypertension, cancers and type 2 diabetes) or with a risk factor (e.g., hypercholesterolaemia, hypertension, or hyperglycaemia) associated with development of these chronic diseases. Chronic disease risk factors and the use of medications are common, particularly among middle-aged and older adults. Individuals with chronic diseases or chronic disease risk factors should be considered as part of the general population unless there is an effect of the disease and/or medications on nutritional status that would alter normal physiologic requirements. In contrast, individuals with diseases, conditions or medications that clearly alter nutrient metabolism or requirements, should not be included in the general population for the DRVs specific to those nutrients. Similarly, individuals undergoing procedures that may alter gastrointestinal function and nutrient absorption might also need to be excluded.

Importantly, people with overweight or obesity, which represent a large segment of most life-stage groups, are also included in the target population. However, when individuals have severe comorbidities caused by overweight and obesity, they may be excluded from the target population if there is evidence that their condition or medications alter their energy or other nutrient requirements.

For FBDGs, individuals with food allergies, which occur when the immune system reacts with certain components in food, are excluded from the guideline related the specific foods. The same is true for specific foods causing food intolerance, such as irritable bowel syndrome, which is a broad term that is used to describe a wide range of adverse reactions to foods.

Developing background reviews for 36 nutrients and food components and 15 food groups, meal patterns and dietary patterns

The present edition of NNR builds on the solid foundation of the comprehensive and well-recognized previous editions of NNR, including the nutrient reviews (in the form of nutrient *chapters* in NNR2012 (Nordic Council of Ministers 2014)). Due to a substantial and rapidly developing production of new scientific evidence, all nutrient background papers have been updated in NNR2023. Additionally, since the present edition aimed to develop science advice for setting FBDGs in the Nordic and Baltic countries, new papers were developed for 15 food groups. In addition, papers were added for meal patterns and dietary patterns.

The recruited background paper authors followed an "Instruction to authors" (Nordic Nutrition Recommendations 2022) developed by the NNR2023 Committee. Authors were asked to use the corresponding chapter in NNR2012 and the ScR described above (i.e., scoping reviews for identification of topics for *de novo* qSRs (Høyer et al. 2021)) as a starting point. Authors were responsible for developing appropriate literature searches and assess significant new relevant evidence published since NNR2012. When available, qSRs were used as the main fundament in the background papers. For exposure-outcome pairs not covered by qSRs, the authors assessed other reviews or original papers. These sections have, as a minimum, fulfilled the requirements for scoping reviews from the EQUATOR network (Tricco et al. 2018). If any of these papers were used as main fundament for setting DRVs or formulating FBDGs, the quality of papers was assessed following standard procedures for randomized controlled trials and observational studies. For quality assessment of systematic reviews that included randomised or non-randomised studies and/or observational studies we adapted a modified version of AMSTAR2 (Shea et al., 2017) (Appendix 3). All background papers were peer-reviewed and submitted to public consultation.

The original search strategy and date is reported in each background paper. The NNR2023 Committee updated all searches on April 15th, 2023. If the NNR2023 Committee considered the new papers especially relevant, it is cited and added to the assessment in the nutrient and food group sections in this report. Of special interest, some new qSRs were identified. These are also incorporated in the assessment in the nutrient and food group sections below.

These background reviews constitute the main scientific update since NNR2012. Especially, they inform about the current status of the specific indicators used in setting DRVs and FBDGs, whether any new indicators should be considered, and they also discuss new qSRs. They also discuss any new recommendations available from EFSA and NASEM since NNR2012.

Table 3. NNR2023 background papers on nutrients

Nutrient	Authors
Fluid and water balance	Iversen and Fogelholm (2023)
Energy	Cloetens and Ellegård (2023)
Fat and fatty acids	Retterstøl and Rosqvist (2023)
Carbohydrate	Sonestedt and Øverby (2023)
Dietary fibre	Carlsen and Pajari (2023)
Protein	Geirsdóttir and Pajari (2023)
Vitamin A	Olsen and Lerner (2023)
Vitamin D	Brustad and Meyer (2023)
Vitamin E	Hantikainen and Lagerros (2023)
Vitamin K	Lyytinen and Linneberg (2023)
Thiamin	Strandler and Strand (2023)
Riboflavin	Lysne and Strandler (2023)
Niacin	Freese and Lysne (2023)
Pantothenic acid	Freese, Aarsland and Bjørke-Monsen (2023)
Vitamin B_6	Bjørke-Monsen and Ueland (2023a)
Folate	Bjørke-Monsen and Ueland (2023b)
Biotin	Solvik and Strand (2023)
Vitamin B_{12}	Bjørke-Monsen and Lysne (2023)
Vitamin C	Lykkesfeldt and Carr (2023)
Choline	Obeid and Karlsson (2023)
Calcium	Uusi-Rasi and Torfadóttir (2023)
Phosphorus	Itkonen and Lamberg-Allardt (2023)
Magnesium	Henriksen and Aaseth (2023)

Sodium	Jula (2023)
Potassium	Toft, Riis and Jula(2023)
Iron	Domellöf and Sjöberg (2023)
Zinc	Strand and Mathisen (2023)
Iodine	Gunnarsdóttir and Brantsæter (2023)
Selenium	Alexander and Olsen (2023)
Copper	Henriksen and Arnesen (2023)
Chromium	Henriksen and Bügel (2023)
Manganese	Kippler and Oskarsson (2023)
Molybdenum	Oskarsson and Kippler (2023)
Fluoride	Kjellevold and Kippler (2023)
Phytochemicals and antioxidants	Myhrstad and Wolk (2023)

Table 4. NNR2023 background papers on food groups, meal patterns and dietary patterns

Food group	Authors
Breastfeeding and complementary feeding	Hörnell and Lagström (2023)
Beverages	Sonestedt and Lukic (2023)
Cereals	Skeie and Fadnes (2023)
Vegetables, fruits, and berries	Rosell and Fadnes (2023)
Potatoes	Rosell and Deslisle (2023)
Fruit juice	Rosell and Delisle (2023)
Pulses (legumes)	Torheim and Fadnes (2023)
Nuts and seeds	Fadnes and Balakrishna (2023)
Fish and seafood	Ulven and Torfadóttir (2023)
Meat and meat products	Meinilä and Virtanen (2023)
Milk and dairy products	Holven and Sonestedt (2023)
Eggs	Virtanen and Larsson (2023)
Fats and oils	Rosqvist and Niinistö (2023)
Sweets and confectioneries	Vepsäläinen and Sonestedt (2023)
Alcohol	Thelle and Grønbæk (2023)
Dietary patterns	Vepsäläinen and Lindström (2023)
Meal patterns	Svendsen and Forslund (2023)

Handling of comments from public consultation

In addition to the standard peer-review process, all background papers on nutrients, food groups, meal and dietary pattern were also submitted to public consultation as well as the background papers developed in the NNR2023 project on environmental aspects of food consumption. A consultation period of 4 weeks was practiced for the first papers. However, the period was extended to 8 weeks for papers submitted to public consultation after May 2022. Thousands of comments were received and forwarded to the authors for consideration. The NNR2023 Committee have considered all consultation comments. All consultation comments have been openly accessible through the NNR2023 website. The responsible authors have briefly formulated a response to each of the comments on nutrient, food group, meal patterns and dietary pattern background papers. All comments to the background papers on environmental aspects of food consumption have been considered by the NNR Committee and the responsible authors. The NNR Committee, in collaboration with the authors, has briefly formulated a response to each of the comments.

Throughout the project period, the public and all interested parties have also been invited to submit their comments to the NNR2023 Committee through the NNR2023 website. The NNR2023 Committee has carefully considered all comments. All comments and the response from the Committee have been openly accessible through the NNR2023 website.

After the NNR2023 project period, a separate report with all comments and responses to public consultation comments and website comments will be published.

Responsibility of experts and NNR2023 Committee

NNR2023 report

While a substantial number of scientists have contributed to the development of background papers (Appendix 1), the final text and conclusions in the present NNR2023 report are the sole responsibility of the NNR2023 Committee.

Principle and methodology papers

For guidance and transparency in the process of setting DRVs and FBDGs, several methodology papers have been developed by the NNR2023 Committee (Christensen et al. 2020; Arnesen et al. 2020a, 2020b). The final text and conclusions in these papers are the sole responsibility of the NNR2023 Committee.

Background papers

A number of background papers have been commissioned by the NNR2023 Committee, including 53 background papers on nutrient, food groups, meal patterns and dietary patterns, background papers on the local context in Nordic and Baltic countries such as burden of disease, physical activity, food and nutrient intake and body weight, and background papers on environmental aspects of food consumption. The text in all background papers is the sole responsibility of the authors. The NNR2023 Committee have had an editorial role in all background papers while the referees have peer-reviewed the manuscript.

Collaboration and harmonization of health based DRVs and FBDGs in Nordic and Baltic countries

The NNR2023 report constitutes science advice to the national authorities in Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway, and Sweden. The report offers solutions and guidance for national authorities when they develop and formulate their own food and health policies.

Universal health effects of nutrients are the main basis for setting DRVs

The amounts of dietary nutrients needed for nutrient adequacy and the upper levels of dietary intake that will not lead to adverse effects are identical, with few exceptions, among the Nordic and Baltic countries, as well as other countries across the globe (NASEM, 2018). Exceptions were considered and adjusted to the Nordic and Baltic populations when setting DRVs in the NNR2023 project.

Exceptions are reference values for energy intakes and all DRVs where energy, weight and physical activity are included when calculating the recommended intakes.

Dietary iron requirements may also vary depending on inhibitors and enhancers of iron absorption in the same meal, while zinc and iodine requirements vary depending on inhibitors such as phytate and goitrogens, respectively, in the same meal. Additionally, vitamin D requirements are dependent of sun exposure and latitude.

As a general rule, all of these factors are similar in Nordic and Baltic countries, with exception for vitamin D and specific nutrient fortification policies.

The integration of environmental sustainability in NNR2023 may open for more country-specific DRVs for alcohol and added and free sugars, both of which are unnecessary and not required for a healthy diet. Alcohol and added and free sugars, which are traditionally considered "nutrients" because they yield energy, may have substantial environmental impact when intake is high (Harwatt et al. 2023; Trolle et al. 2023).

All information for setting DRVs is summarized in the 36 nutrient background papers listed in Table 3 and in the nutrient summaries in this report.

Background papers of burden of diseases (Clarsen et al., in press), food and nutrient intake (Lemming & Pitsi, 2022), physical activity (Borodulin & Anderssen, in press), and environmental impact (Benton et al. 2022; Harwatt et al. 2023; Eneroth et al. 2023; Jackson & Holm 2023; Trolle et al. 2023) are cited when relevant.

Thus, we recommend that the authorities in the Nordic and Baltic countries adopt all DRVs set in NNR2023. Adaptations may be made in special cases, for example when formulating national recommendations for vitamin D, alcohol and added and free sugar.

FBDGs are based both on universal health effects and several country-specific contexts

FBDGs should provide country-specific guidance on food consumption. The context of the individual country is especially relevant when formulating national FBDGs. While the health effects of foods are more or less universal, the national FBDGs may also respond to the following country-specific contexts:

1. public health challenges and burden of diseases
2. food consumption pattern
3. environmental impact
4. food production and accessibility
5. sociocultural aspects

The NNR2023 report gives science advice that is based on the health effects of foods and respond to the country-specific public health challenges and burden of diseases, and food consumption pattern, as well as the country-specific environmental impact of food consumption.

The NNR2023 report does not give advice on country-specific political priorities such as food production and accessibility (e.g., agricultural methods, import and export, self-sufficiency, food security, food safety) and sociocultural aspects (e.g., animal welfare) of food consumption. Such topics, which are briefly discussed in background papers and in relevant sections of NNR2023, may be dealt with nationally.

The health effects of food groups summarized in this report build on 15 food group background papers as well as the background papers on meal patterns and dietary patterns listed in Table 4. Background papers on burden of diseases (Clarsen et al., in press), food and nutrient intake (Lemming and Pitsi

2022), physical activity (Borodulin and Anderssen, in press), and environmental impact (Benton et al. 2022; Harwatt et al. 2023; Eneroth et al. 2023; Trolle et al. 2023; Jackson and Holm 2023) are cited when relevant.

Thus, we recommend that the authorities in the Nordic and Baltic countries can use the science advice in NNR2023 as a framework for setting their country-specific FBDGs. The national authorities may consider country-specific food production and accessibility issues, affordability/economic aspects, and sociocultural aspects of food consumption when formulating their country-specific FBDGs. Translation of the science advice in NNR2023 to the public is also entrusted to the national authorities.

Integration of overweight and obesity in NNR2023

The NNR2023 report bases its conclusions on several qualified systematic reviews reporting strong or probable evidence between excessive weight gain, overweight or obesity, and the intake of foods, nutrients, and consumption patterns.

As obesity is a major cause of morbidity and mortality in the Nordic and Baltic countries, the NNR2023 report has special focus on the role of the diet for obesity, and the consequences of the present weight status on national DRVs and FBDGs. As described below, a specific review paper has been developed to describe current knowledge of the relation between nutrients, foods, and body weight (Hjelmesæth & Sjöberg, 2022).

When calculating recommended intake (RI) from the average requirement (AR), the coefficient of variation (CV) of the distribution of the requirement in the population is taken into account (see below). Typically, if normally distributed, the RI is calculated as AR + 2 standard deviations (SD) to cover the requirements of almost all individuals in the whole population (97.5%). The accurate CVs are, however, seldom known. The increase in body weight in the general population may complicate these calculations since it may affect both the AR and the CV.

One example is vitamin C. As discussed in the vitamin C background paper (Lykkesfeldt & Carr, 2023), a lighter body weight group (63 kg) reached the target for vitamin C in plasma (i.e. 50 µmol/L) at an intake of about 50 mg/day, whereas the heavier body weight group (105 kg) required about 175 mg/day to reach the same plasma concentration. Similar concerns can also be raised about for other nutrients.

In general, the basis for setting and scaling of DRVs in NNR2023 is a BMI of 23 kg/m^2, and no adjustment is done for obesity in the population. Similar to NNR2023, EFSA (2010a) and IOM/NASEM (2006) do not adjust their DRVs for body weight, except in special cases.

Thus, both ARs and CVs in the various life-stage groups may need to be re-considered due to the growing number of people with larger body weights caused by obesity or other reasons. It is important to recognize that the recommendations in NNR2023 for energy and nutrients are set for generally healthy body weights.

Maintaining a healthy body weight and body weight stability is recommended in non-pregnant adulthood and for healthy growth in childhood, due to the associated health effects and the serious health risks of underweight, overweight and obesity (Boushey et al., 2020b; Cloetens & Ellegård, 2023). For older adults, the associations between overweight and health outcomes are less clear, and the available data are inadequate to make precise recommendations for optimal BMI in this age group (Cloetens & Ellegård, 2023).

Overconsumption of food and energy is not only associated with increased risk of chronic diseases, it also has a negative environmental impact (Trolle et al., 2023). For example, as discussed in this report, high consumption of discretionary foods, such as sugar, sweets, beverages and animal fat contribute to GHG emissions, deforestation and decreased biodiversity.

When defining science advice for DRVs and framework for FBDGs, overweight, obesity and food overconsumption are important aspects discussed in relation to several nutrients and food groups. The specific role for DRVs and FBDGs are described in the nutrient and food group summaries in the present summary report.

Summary of background papers on country specific health effects in the Nordic/Baltic region

The NNR2023 Committee has developed background reviews on country-specific burden of diseases, nutrient and food intakes, and physical activity in Nordic and Baltic countries, as well as the role of diet on body weight. These papers are partly used as an essential background when formulating science advice for DRVs and FBDGs, but they are also intended to be used by the national health and food authorities when they formulate their national recommendations and guidelines.

Burden of diseases in the Nordic and Baltic countries

The Global Burden of Diseases, Injuries, and Risk Factors study (GBD) is the most comprehensive worldwide observational epidemiological study (GBD Risk Factors Collaborators, 2020; Murray, 2022). Since 1990, there have been 12 iterations of the study, each with increased scope, new data sources and methodological advancements. The most recent iteration, GBD 2021, included 286 causes of death, 369 diseases and injuries, and 87 risk factors, 15 of which were dietary factors. Age- and sex-specific estimates were generated for 990 geographical units including all Nordic and Baltic countries for every year between 1990 and 2021. GBD, with its effort to provide comparative results, offers a useful resource to model trends in diet-related burden of diseases in the Nordic and Baltic countries. It can also provide countries with insight into the potential of reducing disease burden by targeting specific dietary risks.

In the paper commissioned by the NNR Committee by Clarsen et al. (Clarsen, in press), the burden of diet-related diseases and dietary risk factors in the Nordic and Baltic countries were assessed from 1990 to 2021. In particular, a systematic analysis of the GBD 2021 for the NNR2023 project was done. The integration of the GBD 2021 study into the 6th edition of NNR may serve as a model for other countries or regions in their development of national diet recommendations and guidelines.

The paper shows that there is a substantial disease burden attributed to dietary risk factors in the region, particularly from ischemic heart disease, type 2 diabetes, stroke, and colon and rectum cancers. A diet low in whole grains was the highest-ranked dietary risk factor in eight of the nine countries (including Greenland). Across all countries, low whole grains diets were responsible for one fifth of the total burden of disease attributed to dietary factors and it was the greatest overall contributor to ischemic heart disease and colon and rectum cancers.

A diet high in processed meat was the second highest contributor to disease burden in five of eight countries and among the top-4 dietary risk factors in all countries, while a diet low in fruit was the third-highest dietary-related contributor to disease burden in the Nordic and Baltic countries. The Baltic countries have the most to gain from increasing fruit intake because the Baltic countries had higher rates of ischemic heart disease and stroke. Globally, low fruit consumption is the highest-ranked dietary risk factor for disability-adjusted life years (DALYs), and our analyses show that it is also an important factor to focus on in the Nordic and Baltic countries.

A diet high in red meat was the fourth-highest dietary risk factor for DALYs in the Nordic and Baltic countries. It was ranked second highest in Denmark and Iceland, and the third highest in Norway, Sweden and Finland.

Despite the rigorous and advanced methodology, the estimates from the GBD rely on several complex modelling assumptions which can introduce uncertainties (GBD Risk Factors Collaborators, 2020). The NNR2023 project includes a comprehensive assessment of diet exposure in Nordic and Baltic countries, includes more health outcomes, and has a broader scope when assessing the totality of evidence than the GBD project. While using somewhat different methodologies, the main conclusions in the GBD background paper are in full agreement with the conclusions in the NNR2023 report, and additionally describe the dietary-related contributors to disease burden in the Nordic and Baltic countries.

Physical activity in the Nordic and Baltic countries

The understanding of how physical activity and physical inactivity are associated with health outcomes has increased considerably over the past decades. Along with physical activity, the evidence on the associations between sedentary behaviour and poor health has increased, which has resulted in the introduction of recommendations on sedentary behaviour. The level of physical activity influences energy requirements and is therefore associated with nutrition recommendations.

The aim of the background paper developed by Borodulin and Anderssen was to 1) present terminology for physical activity and sedentary behaviour epidemiology, 2) show the relevant scientific evidence on associations of physical activity and sedentary behaviour with selected health-related outcomes and 3) introduce the global guidelines for physical activity and sedentary behaviour by the World Health Organization (WHO) (Borodulin and Anderssen In press). Health-related outcomes include cardiovascular morbidity and mortality, all-cause mortality, glucose regulation, type 2 diabetes, adiposity, overweight, obesity, cancer, musculoskeletal and bone health, brain health and quality of life. These are reflected across age groups and some population groups, such as pregnant and postpartum women. Further, physical activity levels across Nordic countries and over time were discussed. For the NNR2023 project , shared common physical activity guidelines were not developed. Instead, each country has created their own guidelines that are referenced in the article, along with the global WHO guidelines.

Role of food consumption and nutrients for body weight

Obesity is a chronic disease, which is associated with increased risk for several non-communicable diseases (NCDs), including cardiovascular diseases, type 2 diabetes, some cancers and chronic respiratory diseases, including obstructive sleep apnoea. In 2016, the age standardized prevalence of adult overweight (including obesity) in the Nordic-Baltic region varied between 55% (Denmark) and 60% (Lithuania), with an obesity prevalence between 20% (Denmark) and 26% (Lithuania). Using the WHO growth reference, the prevalence of overweight (including obesity) among school-aged children varied from 23% (Estonia) to 31% (Iceland), and among adolescents from 19% (Lithuania) to 27% (Iceland). Despite several action plans to stop the obesity epidemic, the prevalence of overweight and obesity in the WHO European Region has increased, and no member state is on course to reach the target of halting the rise in obesity by 2025 (World Health Organization 2022). The prevalence data from Iceland has recently been updated, and the prevalence of overweight (including obesity) among school-aged children and adolescents is 25% (Development Centre for Primary Healthcare in Iceland and Primary Health Care of the Capital Area 2022).

The aim of the paper by Hjelmesæth and Sjöberg (2022) was to elucidate the current knowledge for the potential role of body weight for setting and updating DRVs and FBDGs in the NNR2023 project. They observed that the overall body of evidence based on findings from SRs and MAs of observational and clinical studies indicates that changes in intakes of some specific nutrients (sugar, fibre, and fat) and/or foods (sugar sweetened beverages, fibre rich food, and vegetables) are independently associated with modest or small short-term changes (0.3–1.3 kg) in body weight in the general population (with or without obesity/overweight), while long-term studies are generally lacking.

Food consumption and nutrient intake in the Nordic and Baltic countries

Knowledge about the nutrient intakes and food consumption in the Nordic and Baltic countries is important for the use of DRVs and FBDGs, as part of the NNR2023 project.

Information about the dietary surveys as well as the daily mean intakes was retrieved from the latest national dietary surveys available at that moment in each of the five Nordic and three Baltic countries (Lemming & Pitsi, 2022). Nutrient intake (macronutrients, 20 micronutrients) and food consumption data at a broad level in the adult population were gathered for both sexes. The broad food groups were the following: beverages, cereals, potatoes, vegetables, fruits and berries, fish and seafood, meat and meat products, milk and dairy products, cheese, eggs, fats and oils, and sweets and confectioneries.

There were both similarities and differences in food consumption and nutrient intakes among different countries, which were reflected in the consumption of some foods and nutrients that were either higher or lower than current guidelines and DRVs. For example, the consumption of vegetables and fruits was too low while the consumption of red and processed meat was too high. The most notable similarities and differences among countries in terms of nutrient intake compared with recommended intake (RI) in NNR2012 were as follows:

- The percentage contribution of macronutrients to total energy was roughly similar among the populations in the Nordic countries as well as in Estonia and mostly in the range of recommendations. Since alcohol was not included in the total energy intake for Latvia and Lithuania, the reported contribution of energy from fat was higher and lower from carbohydrates compared with the other countries.
- The percentage contribution from saturated fatty acids was too high compared with the recommendation in all countries.
- Fibre intake was lower than the recommendation in all countries.

In general, mean reported intakes of most vitamins and minerals were above RI in the Nordic countries, but not to the same extent in the Baltic countries. Mean vitamin D and folate intakes were low among most population groups, while mean intake of sodium was too high. Mean iron intake was lower than RI among women in all countries. It is, however, not possible to judge the prevalence of inadequacy based on average intakes below RI. The AR is used for assessing adequacy and this requires the distribution of population nutrient intakes. For more details on use of RI and AR, see Trolle et al. (In press).

The nutrient intake and, especially, food consumption differ among the Nordic and Baltic countries because of differences in food patterns, but also due to factors related to the dietary surveying, food grouping and calculation procedures in each country. To facilitate future comparisons among countries, it would be of interest to harmonize food groupings and the age groups reported.

Science advice on a framework for integrating environmental sustainability

Scope and limitations

Sustainability is a broad and complex concept. Sustainable development has been defined as development that meets the needs of the present, without compromising the ability of future generations to meet their own needs. At the core of the concept is the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, the 17 accompanying sustainable development goals and the "Farm to Fork" strategy from the European Commission (2020). For sustainable development to be achieved, it is crucial to harmonize three core dimensions: environment, economy and the social (including health) dimension. All these elements are interconnected and crucial for the well-being of individuals and societies and may be considered by the national authorities in the eight Nordic and Baltic countries when they formulate country specific FBDGs.

In this edition of NNR, a framework for integrating environmental sustainability has been requested by the NCM. Some countries have included aspects of environmental sustainability into their FBDGs, but no country has integrated systematically the whole range of environmental aspects in their national guidelines. The EAT/Lancet report (Willett et al. 2019) is a landmark in this respect, since it represents a comprehensive assessment on both health effects and environmental impacts of diets. While the EAT/Lancet report has a predominantly global perspective, the major focus of NNR2023 is the local context in the eight Nordic and Baltic countries, and their contributions both to local and planetary boundaries.

When formulating science advice on FDBGs the following governing documents are used as a main fundament for the scope and mandate from the NCM; the Action Plan 2021-2024 Vision 2030 (Nordic Council of Ministers 2020a) and authoritative declarations from the Nordic Council of Ministers (see Box 1). The Action plan 2021-2024 from the NCM builds on the Paris Agreement and UN Agenda 2030.

Box 1: Elements from declaration from the Nordic Council of Ministers

Declaration on Nordic Carbon Neutrality by the Nordic prime ministers (25.01.19)

- *“With this declaration, we commit ourselves to working towards carbon neutrality in the five Nordic states”*
- *“We will catalyse global mitigation efforts to limit the increase in the global average temperature to 1.5°C in response to the findings of the IPCC of 1.5°C"*
- *"Catalyse the scaling up of Nordic sustainable solutions, reduce global greenhouse gas emissions, maintain or enhance carbon sinks and remove carbon dioxide from the atmosphere"*
- *"Encourage climate-conscious consumer choices by developing information on reducing individual climate impacts”*

Declaration on Biodiversity from the Nordic Council of Ministers for the Environment and Climate (MR-MK) (03.05.22)

- *We, the Nordic Ministers for Climate and the Environment from Sweden, Denmark, Norway, Finland, Iceland, the Faroe Islands, Greenland and Åland: i) Recognizing that urgent integrated action is needed for transformative change, to halt and reverse biodiversity loss through the sustainable management of land, freshwater and ocean;*
  ii) Promoting ways for Nordic consumers to make healthy and sustainable choices, with joint efforts relating to sustainable consumption reducing by at least half the waste, including food

waste, and eliminating the overconsumption of natural resources and strengthening sustainable production;
iii) Reduce our global ecological footprint to a level well within planetary boundaries;
iv) Promote urgent national action to halt biodiversity loss and strengthen policy measures to mainstream biodiversity into all sectors.

Sustainable food systems by Nordic Council of Ministers for Fisheries, Aquaculture, Agriculture, Food and Forestry (MR-FJLS) (24.06.21)

- *Achieving Agenda 2030 goals including ending hunger, achieving food security, safer food and improved nutrition and promoting sustainable agriculture within planetary boundaries are amongst the greatest challenges facing the world today.*

- *A healthy and sustainable diet should be accessible and an easy choice for everyone. Actors along the whole food chain, such as food industry, retailers and market actors, are all responsible. Nutritional guidance based on scientific evidence is essential in improving diets. The Nordic nutrition recommendations are an internationally recognized benchmark dating back over 40 years. The 2023 update of the NNR will integrate environmental sustainability into the dietary guidelines.*

Declaration on Nordic commitment for the global climate agenda

- *(30.04.20) We will work together with all countries to ensure good cooperation and dialogue in the climate negotiations leading to COP26. Climate finance to developing countries is necessary for the effective implementation of the Paris Agreement. The Nordic countries re-affirm their commitment to provide climate finance from a variety of sources. We will work together with all parties to keep up the momentum in the UN climate negotiations.*

Summary of background papers on environmental sustainability

The NNR2023 Committee commissioned five background reviews on sustainability issues related to food consumption. Four of these papers review environmental aspects of food consumption, both in relation to global and local impact of Nordic and Baltic food consumption.

These papers represent the main foundation for integrating environmental sustainability in science advice for DRVs and FBDGs. The last sustainability review deals with socioeconomic aspects of sustainability. This paper is a Nordic and Baltic summary of the SAPEA report that was commissioned by the European Commission. While the socioeconomic aspects for sustainability were not requested to be integrated by the Nordic Council of Ministers, the NNR2023 Committee have included this review as a general background that may be used by the national health and food authorities when they formulate and implement their national recommendations and guidelines.

To integrate environmental sustainability, the NNR2023 Committee has in large followed the guiding principles from the Food and Agriculture Organization of the United Nations (FAO) and WHO (FAO/WHO, 2019). Initially, the committee scrutinized recent developments of the health effects of nutrients, foods and dietary patterns. Then, the environmental impact of food consumption, and the corresponding food systems were examined, and the ranges and limits of the healthy FBDGs were considered to encompass both health and environmental goals.

Assessing the environmental sustainability of diets – a global overview of approaches and identification of 5 key considerations for comprehensive assessments

Sustainability is a complex concept that includes environmental, health, as well as economic and social dimensions. The remit of the paper by Benton et al. (2022) was to focus on the environmental dimension of sustainability. The paper focuses on global considerations and hence does not consider the local context in Nordic and Baltic countries. The review was developed as a collaboration between the NNR2023 project, Chatham House and an appointed reference group consisting of Nordic and Baltic scientists. The Nordic and Baltic scientists have given significant scientific input, while the members of the NNR Committee have ascertained that the relevance is within the scope of the NNR project.

Assessing the environmental impacts of food, food systems and diets is complex due to the multitude of processes involved, the uncertainty in assessment models, the variability in production systems and the large range of products available. No single assessment method can therefore provide a complete evidence base. However, the increasing number of LCA and food system approach studies, and the relation to integration of planetary boundaries, offers sufficiently precise estimates from which we can draw some robust conclusions, while recognising there is a need for more detailed analyses to capture the inherent nuances of more location and context specific situations.

Despite the complexity of assessing the environmental sustainability of food, diets and food systems, there are a number of key considerations that can be identified and used in the NNR2023 report, and in doing so help to increase utility of the outcomes and limit unintended adverse consequences. Benton et al. (2022) formulated 5 key considerations (the thresholds, the system, the variables, the context and the spill-over) that may be applied when integrating environmental sustainability into FBDGs in the Nordic and Baltic countries.

Overview of food consumption and environmental sustainability considerations in the Nordic and Baltic region

The paper, which was developed in collaboration with Chatham House, examines environmental impacts related to current food production and consumption using a global and Nordic perspective and discusses the implications across the 8 Nordic and Baltic countries (Harwatt et al., 2023). The aspects are discussed as an overview of each food group within the NNR2023. The content was largely drawn from scientific literature such as major reports, studies, and systematic reviews. The assessment was done partly as an expert elicitation to ensure that the rich body of existing data on the environmental impacts of foods and diets could be best interpreted within the context of the Nordic region. In the paper, data were used from different sources, all based on food availability data of FAOSTAT, and combined with a comprehensive database of environmental footprints, differentiated by country, food group, and environmental impacts. Also, global footprint data are shown.

The paper provides suggestions for overall and food group specific changes in consumption and presents opportunities for food production. Estimates from the studies show that the environmental impacts of current diets in each of the Nordic countries mostly exceed the levels that would be required to stay within the planetary boundaries related to GHG emissions, cropland use, water use, nitrogen use and phosphorus use. Estimates show that shifting to the current national Nordic and Baltic FBDGs would mostly improve the outcomes, but not enough. The estimates presented in the paper indicate that meat and dairy contribute the most to GHG emissions and crop land use. Food waste, a challenge that applies to all food groups, is not covered in this paper (see Trolle et al., 2023).

Given that biodiversity impacts are generally related to agricultural practices but not GHG emission it is important to note that foods associated with low or high GHG emission may have varying impact on biodiversity. As a result, when shifting to food production systems that may lower GHG emission potential consequences for biodiversity and other environmental impact should also be assessed in parallel.

The overarching recommendation for all countries from the background paper (Harwatt et al., 2023) is to shift to more plant-based dietary patterns. The extent to which this is necessary depends on the current consumption patterns. Priority interventions suggested in the background paper are:

- Reduce meat and dairy consumption and increase the consumption of legumes/pulses, whole grain, vegetable and fruit, vegetable oils, and nuts and seeds. The substitution process is somewhat dependent on current consumption patterns and potential to shift and should ensure nutritional adequacy and positive health impact at the dietary level.
- Explore potential shifts to sources of fish and seafood from sustainably managed stocks. Due to the potentially large-scale impacts on ecosystems, a precautionary approach to the fish group is essential – particularly in relation to an increase in consumption.
- Support a reduction in consumption of animal-source food and increase in provision of plant-based foods through feed-to-food shifts. This is relevant for cereals and pulses, as well as nuts, vegetables, and fruits. In the context where consumption of fruits and vegetables must increase, shifting production methods could help to further reduce environmental impacts (particularly water, pesticide, and fertilizer use). Fruits and vegetables that require less resources to produce could be prioritized in alignment with the requirements of a healthy diet
- The scientific literature suggests that organic cultivation methods result in greater biodiversity benefits compared to non-organic production. At the global level, it is only possible to convert agricultural production to organic methods in conjunction with substantial shifts in demand for plant-based diets.

- National strategies to facilitate changes of food consumption and production may benefit from considerations of the complexity of trade-offs and location specific impacts and contexts, including implications for trade, human health and social impacts, animal welfare, and current and emerging threats e.g., antibiotics and zoonotic-driven pandemics and potential changes in environmental conditions.
- National land use assessment could inform optimal land uses for meeting a range of environmental goals, also accounting for the environmental impacts of food imports in producer countries.
- While urgent and fundamental changes to food production and consumption are required to help meet climate change and biodiversity goals[1], tackling such issues does not remove the need for urgent reform in other sectors, including energy. Instead, transformation of food systems must be incorporated as one part of a comprehensive 'green transition' plan that includes all systems.

Integrating environmental sustainability into Food-Based Dietary Guidelines in Nordic countries

The background paper provides knowledge for science-based advice for developing Food-Based Dietary Guidelines (FBDGs) that include environmental sustainability within the Nordic and Baltic countries (Trolle et al., 2023). It gives an overview of the recent studies in the Nordics on the environmental impact, including climate and other environmental impacts of foods and dietary patterns, and on the development of FBDGs from the viewpoint of sustainability. Finally, approaches for developing national sustainable FBDGs in the Nordic and Baltic countries are suggested. The paper is a scoping review, based on literature searches regarding Nordic and Baltic studies on sustainability of diets and foods. The paper provides a concise introduction to environmental impact data, with a specific focus on Nordic data in relation to the variation in data within a food group at the global level.

According to the background paper, the Nordic studies conclude that animal-based foods are the largest contributors to dietary GHG emissions and land use in current diets. Modelling, optimization, and intervention studies confirm the potential to reduce negative environmental impacts, like GHG emissions, but also to improve positive impacts e.g., on biodiversity, by shifting towards a

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1. Harwatt, H., Wetterberg, K., Giritharan, A. and Benton, T. G. (2022), Aligning food systems with climate and biodiversity targets: Assessing the suitability of policy action over the next decade, Research Paper, London: Royal Institute of International Affairs, https://doi.org/10.55317/9781784135416

predominantly plant-based diet that is both nutritionally balanced and supported by evidence regarding the health-based recommended amount of specific food groups. A sole focus of reducing climate impact may result in nutritionally inadequate diets and may not decrease the biodiversity loss. Similarly, a healthy diet may have large environmental impacts. Thus, health and environmental impact of diets are considered simultaneously. Healthy environmentally sustainable plant-based diets can be characterized as high in a variety of vegetables, fruits and berries, cereal products as mainly whole grain products, vegetable oils, legumes (pulses), and nuts and seeds. Plant-based diets also contain animal-protein sources such as fish from sustainably managed stocks, limited to moderate amounts of low-fat dairy and eggs, and a limited amount of meat, particularly limited in ruminant and processed meats. In addition, the content of discretionary food and drinks, (e.g., sugar-sweetened beverages and alcoholic beverages) should be limited. Food group-specific considerations are essential to simultaneously reduce the environmental impacts and achieve nutritional adequacy. These considerations may include e.g., favouring more robust types of vegetables that store well and within the limited amount of beef and other ruminant meat, favouring meat products from dairy herds and grazing animals if needed to keep landscape open. However, meat from grazing animals should otherwise be limited. Further, food waste is to be decreased or avoided, as well as overconsumption, e.g., excessive consumption. Dominantly or fully plant-based diets, as vegan diet, require solutions beyond dietary guidelines in terms of food fortification and dietary supplementation to ensure nutritional adequacy.

The current FBDGs in the Nordic countries are also described in the paper. They vary in the degree of including environmental sustainability, and there is a need for further development of the country specific sustainable FBDGs. The paper suggests using standardized approaches for developing sustainable FBDGs by the national authorities. The approach should secure nutritional adequacy and health-based evidence regarding food intake and dietary patterns at the population level as boundaries for integrating the different aspects of sustainable development into the FBDGs. The scientific basis should be built by involving experts in the fields of food, nutrition, health promotion, and environmental sustainability. When relevant, insights from food system stakeholders should be included. The paper suggests different approaches for integrating health, nutritional adequacy, and environmental sustainability by national authorities. The transition to sustainable diets must be made affordable and acceptable for consumers. In the Nordic countries, cultural and sociodemographic differences in dietary composition pose challenges in defining and implementing national FBDGs. Since the transition is urgent, monitoring and evaluation should go hand in hand with public-private partnership initiatives, campaigns, and development and piloting of case-studies to facilitate the transition at consumer level and to involve all food system actors. Examples are presented in the summary of the SAPEA report (Jackson & Holm, 2023).

The background paper concludes that it is possible to develop FBDGs that support the transition to healthier and more environmentally sustainable diets in the Nordic countries. Failing to reduce environmental impacts predisposes the population to another kind of public health threat: the environmental crisis.

Moving food consumption toward sustainable diets in the Nordics: Challenges and opportunities

The overall aim of this background paper is to provide information to be used for science advice for setting sustainable Food Based Dietary Guidelines (FBGDs) in the Nordics (Meltzer et al., 2023). Important challenges and opportunities with current Nordic food systems were identified, summarized, and discussed based on literature reviews and the assessments of Nordic food systems experts. Applying FAO/WHO's guiding principles for healthy, sustainable diets (FAO/WHO, 2019), the paper evaluated how the Nordic countries are doing on environmental impact (principle #9 - #13) and sociocultural aspects (#14 - #16). In addition, the paper includes reflections at the food system level, including food security, self-sufficiency and resilience issues.

Historically, the geographical location of the five Nordic countries has determined the characteristics of food production in each country – mirrored in local food heritage. A substantial part of Nordic land is above the Arctic Circle, limiting the growth season and choice of crops. Forests dominate large parts of Nordic lowlands. Iceland and Norway have large patches of mountainous terrains unfit for crop cultivation, yet have large coastal regions suitable for extensive fishing and aquaculture. At high latitudes farming is dominated by dairy and meat production, including cattle, sheep, goats and reindeer. Together with Denmark, the southern parts of Norway, Finland and Sweden are more suitable for growing plant foods such as cereals, oilseeds, legumes and vegetables. Denmark, Finland and Sweden are net exporters of cereal grain.

Although the Nordics score high in overall global assessments like the Sustainable Development Indexes, there is a long way to go to reach net zero emissions and implement thoroughly sustainable practices within food production and consumption (Sachs et al., 2022). Furthermore, when the total global effects of the Nordic consumption are assessed, the countries are not top performers. Thus, for optimizing the total sustainability of Nordic diets, the global food system must be considered (Kinnunen et al., 2020).

According to the background paper, some challenges are unavoidable. Parts of the Nordics are best or only suited for grass production and pastures, utilization of resources resulting in significant methane emissions from ruminant meat and dairy production. In addition, fractions of the crops may be best suited for animal feed due to marginal conditions for grain production. Thus, utilisation of resources needs careful balancing between ensuring local production that can balance demand for dairy and meat on the one hand, but without resulting in a large environmental footprint domestically as well as the indirect impact from import of feed for food production. Production must also conform to net zero climate emissions and limitations on nitrogen and phosphorus spill-over. The issues connected with biodiversity, domestically and directly from import of feed, must also be adequately resolved.

A sustainable food system for the European Union. The SAPEA report – a summary with focus on the Nordic and Baltic countries

This review seeks to outline some of social and economic dimensions of sustainability, based on evidence available in the peer-reviewed literature. The review relies on a recent Evidence Review Report undertaken by an expert group of academics, convened under the auspices of SAPEA (Scientific Advice for Policy by European Academies). The SAPEA report provides an independent review of the evidence required to inform the transition to a more just and sustainable food system for the EU, including the identification of 'good practice' examples, some of which are drawn from the Nordic and Baltic countries. The SAPEA report concluded that fundamental, system-wide changes were required to promote the transition towards a fairer, more sustainable and healthier food system. Environmental, health and socio-economic issues are thoroughly interconnected and do not exist in separate silos. Meeting the growing global demand for food will require significant dietary change as well as large reductions in food waste, as technological change or yield increases are unlikely to meet demand alone. Evidence of 'what works' in policy terms requires strengthening, including further research on the public understanding of science and consumer acceptance of new technologies.

The SAPEA report identified a series of 'good practice' examples where there was strong peer-reviewed evidence of positive long-term impacts including health and sustainability benefits (Jackson & Holm, 2023). Examples included: state support for the growth of the Danish organic sector (Daugbjerg & Sønderskov, 2012); the RETHINK project in Latvia and Lithuania, an action-research programme which explored the structures and opportunities for small and medium-size agricultural holdings that are not well incorporated into the mainstream market (Šūmane et al., 2015); and the Danish Wholegrain Partnership, which achieved a significant increase in whole grain consumption through a process of multi-sector collaboration involving the Danish Veterinary and Food Administration, the food industry and health NGOs such as the Danish Cancer Society (WholEUGrain, 2021). The SAPEA report also noted a series of other initiatives.

As the foregoing discussion reveals, there are some 'win-wins' in the field of health and sustainability policy. However, difficult choices between competing policy options will occur, like those facing ordinary consumers in their everyday lives. Being clear about the way food is framed as an issue and how different framings shape policy outcomes is a useful way forward in addressing the inevitable trade-offs and compromises between competing objectives.

VEGETABLES, FRUITS, BERRIES AND POTATOES

- Increased intakes of vegetables, fruits and berries supported both by effects on health outcomes and environmental footprint.
- Higher consumption of potatoes, mainly due to environmental aspects.

RECOMMENDATIONS

Principles for setting DRVs in NNR2023

Ever since the nutrients were discovered, e.g., the vitamins between 1910-1950, societies have strived to give advice to avoid deficiency and protect health and wellbeing of people. Recommendations for nutrients were based on an estimation of the human body's requirement from studies on the nutrients' biochemical and physiological roles as reported in for example balance studies. Varying body weights and heights were typically used to estimate the distribution of the requirement in a population. In the first editions of NNR, the recommended intake (RI) of nutrients were based on various such studies and conclusions in Nordic expert committees. Among the major references for the recommendations were the "Recommended Dietary Allowances" produced by the Food and Nutrition Board of the US National Academy of Sciences (previously Institute of Medicine), UK's Committee on Medical Aspects of Food Policy (COMA), and the World Health Organization (WHO). No formal criteria or systematic methodology were available and utilized to derive the RIs.

The ideal method to set RIs was early recognized, but rarely achieved. This method included: 1) determinations of average requirement (AR) of a healthy and representative segment of each age group for the nutrient under consideration; 2) assess statistically the variability among the individuals within the group; and 3) calculate from this the amount by which the average requirement must be increased to meet the need for nearly all healthy individuals (NASEM, 2019) (see Table 5 for definition of DRVs). Similar methodologies were developed for setting the tolerable upper intake level (UL), which is the dose where risk of excess in population is close to zero (IOM, 1998b).

While this is still the basic principle, the principles and methods have developed and improved considerably in recent years. The two major organizations that have contributed to this development of methodology are the Institute of Medicine (IOM) of the US National Academies (renamed and incorporated in 2011 into the National Academies of Science, Engineering, and Medicine (NASEM)), and the European Food Safety Authority (EFSA). The recent framework for developing DRVs are most comprehensively described in the following reports from IOM/NASEM, EFSA and NNR:

- Scientific Opinion for principles for deriving and applying Dietary Reference Values, EFSA, (2010a)
- Guiding principles for Developing Dietary Reference Intakes Based on Chronic Diseases, NASEM (2017)
- The Nordic Nutrition Recommendations 2022 – principles and methodologies. Food & Nutrition Research, 2020 (Christensen et al. 2020)

Ideally, the first step is to identify the functional outcome or indicator used to set AR and UL for all life-stage groups of each micronutrient under consideration. The causality of the exposure-outcome pair should ideally be considered in a recent qSR, and the strength of evidence should be graded above a certain predefined level. Then, a dose-response curve should be established and the average requirement of a healthy and representative segment of each age group for the nutrient determinations. If data are not available for all life-stage groups, interpolation or extrapolation to the remaining life-stage groups is performed, so that all life-stage groups have a defined set of ARs and ULs (see Appendix 5). Based on the life-stage specific ARs, the corresponding RIs are then calculated. Typically, if normally distributed, the RI is calculated as AR + 2 standard deviations (SD) to cover the requirements of almost the whole population (97.5%). This ideal methodology is, however, often not possible to implement fully due to a lack of appropriate scientific data.

Table 5 Definition of different reference values (adapted from IOM (2006), EFSA (2010), NNR2012 and NASEM (2019)

Average Requirement (AR)	The average daily nutrient intake level that is estimated to meet the requirements of half of the individuals in a particular life-stage group in the general population. AR is usually used to assess adequacy of nutrient intake of groups of people, and may be used in planning for groups.
Recommended Intake (RI)	The average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (usually 97.5%) individuals in a particular life-stage group in the general population. It can be used as a guide for daily intake by individuals. Usually used to plan diets for groups and individuals.
Adequate Intake (AI)	The recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group people that are assumed to be adequate. The AI has larger uncertainty than RI. Can be used when an RI cannot be determined. The AI is expected to meet or exceed the needs of most individuals in a life-stage group.
Provisional AR	The average daily nutrient intake level that is suggested to meet the requirements of half of the individuals in a particular life-stage group. The provisional AR, which is an approximation of AR, has larger uncertainty than AR. It is calculated by multiplying AI by a factor of 0.8. Can be used when an AR cannot be determined.
Recommended intake range of macronutrients	The recommended average daily nutrient range of an energy providing macronutrients expressed as percentage of total consumed energy intake (E%). The recommended intake range is associated with reduced risk of chronic diseases while providing adequate intake of essential nutrients. The recommended intake ranges of macronutrients should not be considered as an RI that provides a defined intake level. The ranges are provided to give guidance in dietary assessment and planning by taking into account the probabilities related to the role of the total diet for risk of chronic disease.
Recommended intake of subgroup of macronutrients	The recommended energy percent (E%) of a macronutrient.
Tolerable Upper Intake Level (UL)	The highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects may increase.
Chronic Disease Risk Reduction Intake (CDRR)	The level above which intake reduction is expected to reduce chronic disease risk within a life-stage groups in the general population. The CDRR represents the level of intake for which there was sufficient strength of evidence to characterize a chronic disease risk reduction.

Similar formal methodologies have been developed to define recommended intake ranges of macronutrients and reference values for energy intakes (National Academies of Sciences, Engineering, and Medicine 2023).

There are considerable uncertainties about some of the DRVs. If AR cannot be formally defined, for example if a dose-response curve is not available or a factorial approach cannot be established, an adequate intake (AI) recommendation can be made based on observed intakes in a healthy population or other methods (Trolle, in press). In those cases, a "provisional AR" is calculated as AI x 0.8, i.e., assuming a CV of 12.5% as suggested by Allen et al. (2020). Importantly, as this is usually derived from observed intake in the general population, the provisional AR likely overestimates the true AR.

For some nutrients, AR, AI and UL are not defined at all due to lack of appropriate data.

Previous editions of NNR have not performed a formal setting of ARs, AIs, RIs, ULs for micronutrients, recommended intake ranges of macronutrients and reference values for energy intakes as described above. Values corresponding to the values set in IOM/NASEM and EFSA reports were used instead. Sometimes these values have been adjusted based on expert consensus and alternative scientific assessments or local conditions in the Nordic countries.

In each new edition of NNR, new scientific evidence published since last edition have been assessed. If significant new evidence for changing the DRVs of a nutrient was not found, the values were kept unchanged. If new significant evidence was detected, the DRVs were updated accordingly. Throughout the various updates, the visibility of the original basis for setting the DRVs and the reason for adjustments has varied. Therefore, while the DRVs in the previous editions of NNR were based on careful scrutiny of scientific evidence, the exact values may deviate from the lastest updates of IOM/NASEM and EFSA.

In NNR2023, we are more explicit in identifying the source document used for setting AR and UL (i.e., the specific IOM, NASEM or EFSA report). We have first identified the source document for AR and UL for each nutrient in the previous NNR editions. Then, we considered the most recent reports from IOM/NASEM and EFSA with an aim to harmonize the criteria for setting dietary reference values when warranted (see Allen et al., 2020; Yaktine et al., 2020). In general, we selected the most recent source document that was based on a methodology similar to that described in the NNR2023 methodology papers (Christensen et al. 2020; Arnesen et al. 2020b; Høyer et al. 2021). Harmonized criteria similar to EFSA was set for 22 nutrients, and similar to IOM/NASEM for 3 nutrients. The specific source document for each nutrient is presented in Tables 6 and 7.

Table 6 Basis for setting DRVs for vitamins in NNR2023[1]

Nutrient	Type of reference value	Source	Criteria for setting reference values
Vitamin A	AR RI	EFSA (2015)	Factorial approach, target liver concentration of 20 µg retinol/g.
Vitamin D	AR RI	NNR2023 (Brustad and Meyer 2023)	Dose-response approach, biomarker (25(OH)D).
Vitamin E	AI Provisional AR	NNR2023 (Hantikainen and Lagerros 2023), Raederstorff et al. (2015) For infants: EFSA (2015)	Relationship to PUFA intake (prevention of PUFA oxidation) For infants: estimated intake from human milk.
Vitamin K	AI Provisional AR	EFSA (2017)	Observed intakes in European countries. Biomarkers. For new-borns: prevention of vitamin K deficiency bleeding
Thiamin	AR RI	EFSA (2016)	Erythrocyte transketolase activity coefficient, urinary excretion.
Riboflavin	AR RI	EFSA (2017)	Urinary riboflavin excretion.
Niacin	AR RI	EFSA (2014)	Urinary excretion of niacin metabolites.
Pantothenic acid	AI Provisional AR	EFSA (2014)	Observed intakes in European countries. For infants: estimated intake from human milk.
Vitamin B_6	AR RI	EFSA (2016)	Biomarker (plasma pyridoxal 5-phosphate).
Biotin	AI Provisional AR	EFSA (2014)	Observed intakes in European countries. For infants: estimated intake from human milk.
Folate	AR RI	EFSA (2014)	Biomarker (serum and red blood cell folate), plasma homocysteine.
Vitamin B_{12}	AI Provisional AR	EFSA (2015)	Vitamin B_{12} biomarkers, and observed intakes in European countries.
Vitamin C	AR RI	EFSA (2013)	Biomarker (fasting plasma ascorbate concentration).
Choline	AI Provisional AR	EFSA (2016)	Observed intakes in European countries, and deficiency symptoms (organ dysfunction).

1 Scaling of all nutrients uses NNR2023 reference weights. AR: Average/provisional average requirement. RI: Recommended/provisional recommended intake.

Table 7 Basis for setting DRVs for minerals in NNR2023[1]

Nutrient	Type of reference value	Source	Criteria for setting reference values
Calcium	AR RI	EFSA (2015)	Factorial approach, calcium balance and calcium accretion in bone. For infants: estimated intake from human milk.
Phosphorus	AI Provisional AR	EFSA (2015)	Scaled to RI for calcium (molar calcium to phosphorus ratio of 1.4:1).
Potassium	AI Provisional AR	EFSA (2016)	Prevention of high blood pressure and risk of stroke.
Sodium	Chronic Disease Risk Reduction Intake	NASEM (2019)	Sodium reduction trials and one balance study. Extrapolations to children and adolescents using NNR2023 reference energy intakes.
Magnesium	AI Provisional AR	EFSA (2015)	Observed intakes in European countries. For infants 7-11 months: midpoint between extrapolated values from infants 0-6 m and the highest range of observed intakes.
Iron	AR RI	NNR2023 (Domellöf & Sjöberg, 2023)	Factorial approach, replacement of daily iron loss, and need for growth.
Zinc	AR RI	EFSA (2014)	Factorial approach, zinc balance, accounting for phytate intake (assuming a phytate intake of 600 mg/day in adults).
Copper	AR ARI	IOM (2001)	A combination of copper biomarkers (including plasma copper, serum ceruloplasmin, platelet copper concentration). For infants: estimated intake from human milk and estimated additional intake from complementary foods in infants 7-11 months.
Iodine	AI Provisional AR	EFSA (2014), NNR2023 (Gunnarsdóttir & Brantsæter, 2023)	Biomarker (urinary iodine concentration), prevention of goitre.
Selenium	AI Provisional AR	EFSA (2014), NNR2023 (Alexander & Olsen, 2023)	Biomarker (plasma selenoprotein P, target >110 µg/L). For infants: estimated intake from human milk.
Fluoride	AI Provisional AR	EFSA (2013)	Prevention of caries (for adults: extrapolated from data in children).
Manganese	AI Provisional AR	EFSA (2013)	Observed intakes in European countries, and null balance. For infants 7-11 months: a combination of extrapolation from infants 0-6 months, extrapolation from adults' AI, and observed intakes.
Molybdenum	AI Provisional AR	EFSA (2013)	Observed intakes in European countries, and null balance.

[1] Scaling of all nutrients uses NNR2023 reference weights. AI: Adequate intake. AR: Average/provisional average requirement. RI: Recommended intake.

The indicator used to set AR, AI and UL in each source document was then identified. The recent scientific evidence on the indicator is discussed in the corresponding nutrient background paper. Evidence based on new qSRs (see Table 1 and Appendix 2) were especially emphasized. If new evidence since the publication of the source document had appeared that changed the strength of evidence relative to the predefined criteria (Christensen et al. 2020), the corresponding change in AR, AI and UL were implemented. Additionally, if new SRs revealed new indicators, these were also implemented.

Next, we identify whether the AR and UL were set by dose-response or factorial approach. Again, the corresponding nutrient background papers were essential in assessing recent evidence published since the last edition of NNR. In specific cases, the NNR2023 project performed new meta-analyses (see list of *de novo* qSRs above). Otherwise, the NNR2023 project based the evaluation on dose-response curves in the source documents (see table 6 and 7).

If data were not available for all life-stage groups, interpolation or extrapolation to the remaining life-stage groups was performed in the NNR2023 project, so that all life-stage groups have a defined set of ARs and ULs. The methodology of scaling to other life stage groups was identified from the relevant source document (i.e., isometric scaling or allometric scaling, with or without a growth factor), as described in Appendix 5. When an AR could not be set, the extrapolation was performed with the AI.

An important basis for scaling is the representative healthy weights for each life-stage group. For life stage groups aged 18 years or more, healthy weights are, in agreement with the consideration in NNR2012, defined as a BMI of 23 kg/m^2 (calculated from the most recent population heights reported in national dietary surveys (Amcoff et al. 2012; Pedersen et al. 2015; Nurk et al. 2017; Valsta et al. 2018; Grīnberga et al. 2020; Abel and Totland 2020; S. Gunnarsdottir et al. 2022)). For children and adolescents aged 6-17 years, healthy weights were calculated based on height in the most recent growth curves in the Nordic and Baltic countries and corresponding healthy BMIs for age defined by WHO (World Health Organization 2007; Juliusson et al. 2013; Saari et al. 2011; Tinggaard et al. 2014; Wikland et al. 2002). For age groups 5 years and younger, healthy weights were based on the growth curves. For detailed values for weight, see Appendix 4. The new weight values are an important update from previous editions and ascertain that scaling is performed according to healthy weight curves representative for Nordic and Baltic countries. In addition, age groups have also been updated and harmonized with EFSA and IOM/NASEM.

A Physical Activity Level (PAL) of 1.6 is used when calculating AR for nutrients based on energy requirements. For the age groups 1-3 years, 4-10 years and

11-17 years, an average PAL of 1.4, 1.6 and 1.7 were used, respectively (see *Reference values for energy intake* and Cloetens and Ellegård, 2023).

The background papers on all individual nutrients (see table 6 and 7) have been essential in the assessments described above and have been used as a major source in developing the one-pagers on nutrients and the specific DRVs.

Based on the life-stage specific ARs, the NNR2023 project then calculated corresponding RIs (see Appendix 5 for details). The standard deviation used to calculate RIs is taken from the corresponding source document (Table 6 and 7). When an AR could not be set, a provisional AR was calculated from the corresponding AI.

Finally, standard rounding of all AR, AI, RI and UL values was performed according to the approach used in the source document.

The science advice for specific recommendations to authorities in the Nordic and Baltic countries are formulated in the text and tables below, and build on the detailed considerations described in the nutrient sections later in this report.

Life-stage groups in NNR2023

Different life-stage groups have been used when setting DRVs by NNR, EFSA and NASEM/IOM, making comparisons and harmonization difficult. Recently, Allen et al. (2020) suggested that life-stage groups should be harmonized according to those used by EFSA. NNR2023 has decided to change the life-stage groups used by the 5th edition of NNR (Nordic Council of Ministers, 2014) and align them with EFSA. Thus, the standard life-stage groups used in NNR2023 are the age groups ≤ 6 months, 7-11 months, 1-3 years, 4-6 years and 7-10 years for infants and children. For females and males, DRVs are individually set for the age groups 11-14 years, 15-17 years, 18-24 years, 25-50 years, 51-70 years and > 70 years. Additionally, DRVs are set for pregnant and lactating women.

DRVs in age groups are often set for a "point age" or as a median age. For example, the point age in the age group 1-3 years is 2 years, while the median in the age group 1.0-3.99 is 2.5 years. In contrast, NNR2023 uses the median as the principle for setting and scaling to different age groups of children and adolescents. In addition to age groups presented in the report, Appendix 6 contains reference weights and DRVs for children and adolescents in 1-year increments.

New DRVs for Nordic and Baltic countries

NNR2023 includes recommended intake ranges for macronutrients, upper or lower threshold levels of certain subcategories, and ARs, AIs, RIs and ULs of essential micronutrients. The macronutrient sub-categories are polyunsaturated, monounsaturated, saturated, and trans-fatty acids, dietary fibre and added and free sugars.

Reference values for energy intake

Both excessive and insufficient energy intake in relation to energy requirements can lead to negative health consequences in the long term. For adults, an individual's long-term energy intake and energy expenditure should be equal (Cloetens & Ellegård, 2023).

In Table 8, reference values are given for energy intake in MJ per day for groups of adults with three different physical activity levels (see Appendix 4 and Cloetens & Ellegård (2023) for methodology). An active lifestyle, corresponding to PAL 1.8, is considered desirable for maintaining good health. An activity level of PAL 1.6 is close to the population median and corresponds to a common lifestyle with sedentary work and some increased physical activity level during leisure time. The reference body weights used for the calculations are based on self-reported weights in Nordic populations (Appendix 4). The original weights have been adjusted so that all individuals would have a BMI of 23, as explained above. Therefore, the reference values indicate an energy intake that would maintain normal body weight in adults.

Specific recommendations for energy intake cannot be given due to the large variation among individuals with respect to metabolic rate, body composition and degree of physical activity.

Table 8 Reference values for energy intakes in groups of adults with sedentary and active lifestyles.

Age, years	Reference weight, kg[1]	BEE, MJ/d[2]	Low active PAL 1.4, MJ/d	Average PAL 1.6, MJ/d	Active PAL 1.8, MJ/d
FEMALES					
18-24 y	64.2	5.9	8.3	9.4	10.6
25-50 y	64.1	5.7	8	9.0	10.2
51-70 y	62.5	5.2	7.2	8.3	9.3
>70 y	60.6	5.1	7.1	8.2	9.2
Pregnant[3]					
≤50 y	76.4	6.4	8.9	10.2	11.5
Lactating[4]					
≤50 y	62.4	7.8	10.9	12.5	14.1
MALES					
18-24 y	75.2	7.4	10.4	11.8	13.2
25-50 y	74.8	7.1	9.9	11.3	12.7
51-70 y	73.0	6.4	9	10.3	11.6
>70 y	70.6	6.3	8.8	10.1	11.3

[1] See Appendix 4 and Cloetens & Ellegård (2023) for sources and methodology as well as reference values per year of age.
[2] For corresponding values expressed as kilocalories (kcal)/day, see Appendix 4.
[3] Weight gain of 14 kg during pregnancy, assuming a pre-pregnancy BMI of 18.5-24.9
[4] Exclusive breastfeeding 0-6 months postpartum

Tables 9 and 10 present reference values for energy intakes in groups of children. It must again be mentioned that individual energy requirements might differ from these group-based average values.

Table 9 Reference values for estimated average daily energy requirements per kg body weight for children 6-12 months, assuming partial breastfeeding.

Age, months	Average daily energy requirements, kJ/kg body weight	
	BOYS	GIRLS
6	339	342
12	337	333

Table 10 Reference values for estimated daily energy requirements (MJ/d) for children and adolescents, 1-17 years.

Age	Reference weight, kg[1]	REE, MJ/d[2]	Estimated energy requirement, MJ/d[3]
1-3 y	13.6	3.3	4.6
4-6 y	20.7	4.0	6.3
7-10 y	30.8	4.9	7.8
FEMALES			
11-14 y	46.5	5.4	9.2
15-17 y	57.8	5.9	10.1
MALES			
11-14 y	48.2	6.2	10.5
15-17 y	65.6	7.5	12.7

[1] See Appendix 4 and Cloetens & Ellegård (2023) for sources and methodology.
[2] For corresponding values expressed as kcal/day, see Appendix 4.
[3] PALs (average) for age groups: 1-3 years = 1.4; 4-10 years: 1.6; 11-17 years: 1.7

Recommended intake ranges of macronutrients

Macronutrients are nutrients required in relatively large quantities for energy and to support various bodily functions and overall health. These include proteins, fats, carbohydrates and fibre, which in general provide about 17, 37, 17 and 8 kJ/g, respectively. The energy provided vary somewhat among different types of proteins, fats, carbohydrates and fibre (Cloetens & Ellegård, 2023). Alcohol is also an energy-providing nutrient (29 kJ/g), but is not an essential nutrient. The conversion factors for joules and calories are: 1 kJ = 0.239 kcal; and 1 kcal = 4.184 kJ.

Macronutrients can to a certain degree substitute for each other to meet the body's energy needs. Thus, increasing the proportion of one macronutrient necessitates decreasing the proportion of other macronutrients. In the 3rd edition of NNR, recommendations of intake ranges for adults of fats (25-35 E%), carbohydrates (50-60 E%) and protein (10-20 E%) were included (Sandström, 1996). In the 5th edition of NNR this was updated to 25-40 E%, 45-60 E% and 10-20 E% for fats, carbohydrate and proteins, respectively. The recommendations in NNR2023 are unchanged from the 5th edition of NNR (Box #2).

Box 2: Recommended intake ranges of macronutrients for adults

Fats	**25-40 E%**
Cis-monounsaturated	10-20 E%
Cis-polyunsaturated	5-10 E%
Saturated fatty acids	<10 E%
Carbohydrates[1]	**45-60 E%**
Dietary fibre	≥25-35 g/d
Added and free sugars	<10 E%
Proteins	**10-20 E%**

[1]Including energy from dietary fibre

These ranges are defined as ranges of intakes (expressed as percentage of total energy) that are associated with low risk of chronic diseases while also providing adequate intake of essential nutrients. The ranges are also based on adequate energy intake and physical activity to maintain energy balance. If an individual consumes below or above these ranges, there is a potential for increasing the risk of a chronic disease, as well as increasing the risk of insufficient intakes of essential nutrients (EFSA, 2010; IOM, 2005; NASEM, 2023).

It is not possible to determine a definitive level of intake range for macronutrients at which chronic diseases may be prevented or may develop. Therefore, the recommended intake ranges of macronutrients should not be considered as an RI that provides a fixed intake level. The ranges are provided to give guidance in dietary assessment and planning by taking into account the role of the total diet for risk of chronic disease.

Evidence supporting these intake ranges is provided in the background reviews on protein (Geirsdóttir & Pajari, 2023), carbohydrates (Sonestedt & Øverby, 2023), dietary fibre (Carlsen & Pajari, 2023) and fatty acids (Retterstøl & Rosqvist, 2023). Besides the proportion of protein, fat and carbohydrates, the importance of the balance of their subcomponents (e.g., unsaturated fatty acids, fibre, amino acids) has gradually become more evident. For protein, an AR and RI is also established to maintain body nitrogen balance and support growth.

The recommended intake ranges for macronutrients vary among age groups (Box #3), and there are also some additional needs for pregnant and lactating women.

Age group up to 2 years of age

Exclusive breastfeeding for about 6 months is advised, with continued breastfeeding parallel to giving complementary foods from that age until 12 months of age, or longer if it suits mother and child. There is strong evidence that the risk of obesity in childhood and adolescence increases with increased protein intake higher than recommended during infancy and early childhood (Hörnell, Lagström, et al. 2013; Arnesen et al. 2022). The protein intake should increase from about 5 E% (the level in breast milk) to the intake range of 10–20 E% for older children and adults (Box #4).

Box 3: Fatty acids (expressed as triglycerides)

- n-6 fatty acids should contribute at least 4 % of the total energy intake (E%) for children 6–11 months and 3 E % for children 12–23 months of age.
- n-3 fatty acids should contribute at least 1 E% for children 6–11 months and 0.5 E% for children 12–23 months.
- During the first year, the intake of trans fatty acids should be kept as low as possible.
- From 12 months, the recommendation on saturated and trans fatty acids for older children and adults should be used.

Box 4: Recommended intake of fat, carbohydrates, and proteins

Expressed as percent of total energy intake (E%) for children 6–23 months[1]

Age	E%
6–11 months	
Protein	7–15
Fat	30–45
Carbohydrates[2]	45–60
12–23 months	
Protein	10–15
Fat	30–40[3]
Carbohydrates[2]	45–60

Avoid foods and beverages with added and free sugars for children below two years.

For young children it is advisable not to exceed a range of 10-15 E% of protein intake.

[1] Because exclusive breastfeeding is the preferable source of nutrition for infants <6 months, no recommendations for fat, protein, or carbohydrate intakes are given for this age group. For non-breastfed infants, it is recommended that the values for infant formula given in the EC legislation (REGULATION (EC) No 1243/2008 and Directive 2006/141/EC) is used.
[2] including energy from dietary fibre
3 Cis-monounsaturated and cis-polyunsaturated fatty acids should together constitute at least two thirds of the total fat intake.

Age groups 2 years and older

Fatty acids

Partly replacing saturated fatty acids with cis-polyunsaturated fatty acids and cis-monounsaturated fatty acids (oleic acid) from vegetable dietary sources (e.g., olive or rapeseed oils) is an effective way of lowering the serum LDL-cholesterol concentration. Replacement of saturated or trans-fatty acids with cis-polyunsaturated or cis-monounsaturated fatty acids also decreases the LDL/HDL-cholesterol ratio. Replacing saturated and trans-fatty acids with cis-polyunsaturated fatty acids reduces the risk of coronary heart disease, and replacement of saturated and trans-fatty acids with cis-monounsaturated fatty acids from vegetable sources (e.g., olive or rapeseed oils) has a similar effect (Box #5).

Box 5: Fatty acids (expressed as triglycerides)

- Intake of cis-monounsaturated fatty acids should be 10-20 E%.
- Intake of cis-polyunsaturated fatty acids should be 5–10 E%. N-3 fatty acids should provide at least 1 E%.
- Cis-monounsaturated and cis-polyunsaturated fatty acids should constitute at least two thirds of the total fatty acids in the diet.
- Intake of saturated fatty acids should be limited to less than 10 E%.
- Intake of trans-fatty acids should be kept as low as possible.
- The total fat recommendation is 25–40 E% and is based on the recommended ranges for different fatty acid categories.
- Linoleic (n-6) and alpha-linolenic (n-3) acids are essential fatty acids and should contribute at least 3 E%, including at least 0.5 E% as alpha-linolenic acid.
- For pregnant and lactating women, the essential fatty acids should contribute at least 5 E%, including 1 E% from n-3 fatty acids of which 200 mg/d should be docosahexaenoic acid, DHA (22:6 n-3).

Even though total fat intake varies widely, population and intervention studies indicate that the risk of atherosclerosis can remain quite low as long as the balance between unsaturated and saturated fatty acids is favourable (Retterstøl and Rosqvist, 2023). The recommended range for the total amount of fat is 25–40 E% based on the sum of the ranges of the recommendations for individual fatty acid categories.

For the intake of total fat, a suitable target for dietary planning is 32–33 E%.

At total fat intakes below 20 E%, it is difficult to ensure sufficient intake of fat-soluble vitamins and essential fatty acids. A reduction of total fat intake below 25 E% is not generally recommended because very low-fat diets tend to reduce HDL-cholesterol and increase triglyceride concentrations in serum and to impair glucose tolerance, particularly in susceptible individuals (Retterstøl and Rosqvist, 2023).

Carbohydrates and dietary fibre

Health effects of dietary carbohydrates are related to the type of carbohydrate and the food source. Carbohydrates found in whole-grain cereals, whole fruit, vegetables, pulses, nuts and seeds are recommended as the major sources of carbohydrates. Total carbohydrate intake in studies on dietary patterns associated with reduced risk of chronic diseases are in the range of 45–60 E% (including energy from dietary fibre). A reasonable range of total carbohydrate intake is dependent on several factors such as the quality of the dietary sources of carbohydrates and the amount and quality of fatty acids in the diet.

Just like the importance of the quality of fat, it is equally important to pay attention to the quality of carbohydrates and the amount of dietary fibre. The recommendations for dietary fibre and carbohydrates (with low intakes of added and free sugars) should be achieved through an ample supply of plant-based foods (Sonestedt and Øverby, 2023).

Box 6: Dietary fibre

- **Adults:** At least 3 g/MJ. Based on the reference energy intake, this corresponds to at least 25 g/d for females and 35 g/d for males.
- **Children:** An intake corresponding to 2-3 g/MJ or more is appropriate for children from 2 years of age. From school age, the intake should gradually increase to reach the recommended adult level during adolescence.

An adequate intake of dietary fibre reduces the risk of constipation and contributes to a reduced risk of colorectal cancer and several other chronic diseases such as cardiovascular disease and type 2 diabetes. Moreover, fibre-rich foods help maintain a healthy body weight. Intake of appropriate amounts of dietary fibre from a variety of foods is also important for children.

For dietary planning purposes, a suitable target is at least 3 g/MJ from natural fibre-rich foods such as vegetables, whole grains, fruits and berries, pulses, nuts and seeds (Box #6).

Box 7: Added and free sugars

- Intake of added and free sugars should be below 10 E%, and preferentially lower

Restricting the intake of added and free sugars is important to ensure adequate intakes of micronutrients and dietary fibre (nutrient density) as well as to support a healthy dietary pattern. This is especially important for children and persons with a low energy intake. Consumption of sugar-sweetened beverages should be limited due to their association with increased risk of type 2 diabetes, cardiovascular disease, and excessive weight gain. Frequent consumption of foods with added and free sugars should be avoided to reduce the risk of dental caries. The recommended upper threshold for added and free sugars is also compatible with the food-based recommendation to limit the intake of sugar-rich beverages and foods. Higher consumption of added and free sugars contributes to a negative environmental impact (Box #7).

The recommended range for the total amount of carbohydrate is 45–60 E%. For dietary planning purposes, a suitable target for the amount of dietary carbohydrate is 52–53 E%.

Proteins

In order to achieve an optimal intake in a varied diet according to Nordic dietary habits, a reasonable range for protein intake is 10–20 E% (Box #8 and Table 11). This intake of protein should adequately meet the requirements for essential amino acids.

Box 8: Protein

- AR and RI for adults are 0.66 and 0.83 g/kg, body weight, respectively (both males and females) (Table 11).
- Adults and children from 2 years of age: Protein should provide 10–20% of the total energy intake (E%).
- With decreasing energy intake (below 8 MJ/d) the protein E% should be increased accordingly.
- Dietary proteins of animal origin or a combination of plant proteins from, for example, legumes and cereal grains, give a good distribution of indispensable amino acids.

Table 11 Average requirements and recommended intakes of protein by life stage

Age group	AR g/kg	RI g/kg
≤6 mo		
7-11 mo	1.04	1.23
CHILDREN		
1-3 y	0.82	1.05
4-6 y	0.70	0.86
7-10 y	0.75	0.91
FEMALES		
11-14 y	0.72	0.88
15-17 y	0.68	0.84
18-24 y	0.66	0.83
25-50 y	0.66	0.83
51-70 y	0.66	0.83
>70 y	0.66	0.83
Pregnant	add 0.5/7.2/23 g/d[1]	add 1/9/28 g/d[1]
Lactating	add 10/15 g/d[2]	add 13/19 g/d[2]
MALES		
11-14 y	0.74	0.9
15-17 y	0.71	0.87
18-24 y	0.66	0.83
25-50 y	0.66	0.83
51-70 y	0.66	0.83
>70 y	0.66	0.83

Adapted from EFSA (2012a)
[1] Pregnancy: Additional protein requirement per trimester.
[2] Lactation: Additional protein requirement for 0-6 months and >6 months postpartum.

For planning purposes, 15 E% protein can be recommended.

The AR and RI for both sexes, which is based on nitrogen balance, is the same for older adults (>70 years of age). The available evidence in qSRs is not sufficient to increase the AR for protein intake in older adults. However, for food planning purposes a suitable target for the amount of protein for a group of older adults intake should be 18 E% which may be higher than the RI. This corresponds to about 1.2 g protein per kg body weight per day for prevention of declined physical functioning (Geirsdóttir & Pajari, 2023).

Alcohol

Based on the overall evidence, it is recommended to avoid alcohol intake. If alcohol is consumed, the intake should be very low. Alcohol is not an essential nutrient, and from a nutritional point of view, energy contribution from a high intake of alcoholic beverages negatively affects diet quality. Based on this and new systematic reviews and recommendations, and that no threshold for safe level of alcohol consumption has currently been established for human health, the NNR2023 recommends avoidance from alcohol. For children, adolescents and pregnant women abstinence from alcohol is recommended. The consumption of alcoholic beverages contributes to a negative environmental impact.

Recommended intake of micronutrients

RI (Table 12) and AI (Table 13) for vitamins, RI (Table 14) and AI (Table 15) for minerals, expressed as average daily intakes over time, are given below. The values for RIs are intended mainly for planning diets for groups of individuals of the specified age intervals and sex. The values include a safety margin accounting for variations in the requirement of the group of individuals and are set to cover the requirements of 97.5% of the group. An alternative way to plan a diet is to use the requirements in combination with the distribution of reported or usual intakes for the specific nutrients (Murphy et al. 2021).

Table 12 RI for vitamins – all life-stage groups

Age group	Vitamin A RE[2]	Vitamin D µg[3]	Thiamin mg/MJ	Riboflavin mg	Niacin NE/MJ[4]	Vitamin B_6 mg	Folate µg	Vitamin C mg
≤6 mo[1]				0.3		0.1	64	30[7]
7-11 mo	250	10	0.1	0.4[5]	1.6	0.4[5]	90	30[7]
CHILDREN								
1-3 y	300	10	0.1	0.6	1.6	0.6	120	25
4-6 y	350	10	0.1	0.7	1.6	0.7	140	35
7-10 y	450	10	0.1	1.0	1.6	1.0	200	55
FEMALES								
11-14 y	650	10	0.1	1.4	1.6	1.3	280	75
15-17 y	650	10	0.1	1.6	1.6	1.5	310	90
18-24 y	700	10	0.1	1.6	1.6	1.6	330[6]	95
25-50 y	700	10	0.1	1.6	1.6	1.6	330[6]	95
51-70 y	700	10	0.1	1.6	1.6	1.6	330	95
>70 y	650	20[8]	0.1	1.6	1.6	1.6	330	95
Pregnant	750	10	0.1	1.9	1.6	1.9	600[6]	105
Lactating	1400	10	0.1	2.0	1.6	1.7	490	155
MALES								
11-14 y	700	10	0.1	1.3	1.6	1.5	260	80
15-17 y	750	10	0.1	1.6	1.6	1.8	320	105
18-24 y	800	10	0.1	1.6	1.6	1.8	330	110
25-50 y	800	10	0.1	1.6	1.6	1.8	330	110
51-70 y	800	10	0.1	1.6	1.6	1.8	330	110
>70 y	750	20[8]	0.1	1.6	1.6	1.7	330	110

[1] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are based on estimated intake from human milk. These values represent an AI.
[2] RE = Retinol equivalents (1 RE = 1 µg retinol = 2 µg of supplemental β-carotene, 6 µg of dietary β-carotene, or 12 µg other dietary provitamin A carotenoids, e.g., α-carotene and β-cryptoxanthin).
[3] From 1-2 weeks of age, infants should receive 10 µg vitamin D_3 per day as a supplement. For people with little or no sun exposure, an intake of 20 µg/d is recommended.
[4] NE = Niacin equivalent (1 NE = 1 mg niacin = 60 mg tryptophan).
[5] Extrapolated from exclusively breast-fed infants 0-6 months. These values represent an AI.
[6] Values for pregnant women represent an AI. Most national authorities in the Nordic and Baltic countries recommend supplement of 400µg/d in addition to dietary intake for women in fertile age from planned pregnancy and throughout the first trimester.
[7] AI, set to 3 times the intake known to prevent scurvy in infants. These values represent an AI.
[8] For age group 75 years and older.

Table 13 Adequate intake[1] for vitamins – all life-stage groups

Age group	Vitamin E α-TE[4]	Vitamin K µg[5]	Pantothenic acid mg	Biotin µg	Vitamin B_{12} µg	Choline mg
≤6 mo[2]	4		2	4	0.4	120
7-11 mo	5[3]	10	3[3]	5[3]	1.5	170[3]
CHILDREN						
1-3 y	7	15	4	20	1.5	150
4-6 y	8	20	4	25	1.7	170
7-10 y	9	30	4	25	2.5	250
FEMALES						
11-14 y	10	45	5	35	3.5	350
15-17 y	11	60	5	35	4	390
18-24 y	10	65	5	40	4	400
25-50 y	10	65	5	40	4	400
51-70 y	9	60	5	40	4	400
>70 y	9	60	5	40	4	400
Pregnant	11	80	5	40	4.5	480
Lactating	12	65	7	45	5.5	520
MALES						
11-14 y	11	50	5	35	3	330
15-17 y	12	65	5	35	4	400
18-24 y	11	75	5	40	4	400
25-50 y	11	75	5	40	4	400
51-70 y	11	70	5	40	4	400
>70 y	11	70	5	40	4	400

[1] Adequate intake based on observed intakes in healthy people or approximations from experimental studies, used when an RI cannot be determined.
[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are based on estimated intake from human milk.
[3] Extrapolated from exclusively breast-fed infants 0-6 months.
[4] Assuming a PUFA intake of 5 % of energy intake. α-TE = α-tocopherol equivalents (i.e., 1 mg RRR α-tocopherol).
[5] 1 µg/kg body weight.

Table 14 RI for minerals – all life-stage groups

Age group	Calcium mg	Iron mg[2]	Zinc mg[2]	Copper µg
≤6 mo[1]	120			200
7-11 mo	310[3]	10	3.0	220[3]
CHILDREN				
1-3 y	450	7	4.5	340
4-6 y	800	7	5.8	400
7-10 y	800	9	7.7	570
FEMALES				
11-14 y	1150[4]	13[5,6]	10.8	780
15-17 y	1150[4]	15[6]	12.2	880
18-24 y	1000	15[6]	9.7	900
25-50 y	950	15[6]	9.7	900
51-70 y	950	8[7]	9.5	900
>70 y	950	7	9.3	900
Pregnant	950	26[8]	11.3	1000
Lactating	950	15	12.6	1300
MALES				
11-14 y	1150[4]	11	11.1	740
15-17 y	1150[4]	11	14.0	900
18-24 y	1000	9	12.7	900
25-50 y	950	9	12.7	900
51-70 y	950	9	12.4	900
>70 y	950	9	12.1	900

1 Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are AIs based on estimated intake from human milk.
2 Assuming a mixed animal/vegetable diet with a phytic acid intake of about 600 mg/d.
3 AI, extrapolated from exclusively breast-fed infants 0-6 months. These values represent an AI.
4 Average of females and males applied for age 11–17 y.
5 If menstruating: 15 mg.
6 If large menstruation bleedings, screening of iron status and supplementation as indicated.
7 If still menstruating, the RI for 25–50 y (15 mg/d) should be used.
8 Screening of iron status and supplementation if indicated is recommended.

Table 15 Adequate intake[1] for minerals – all life-stage groups

Age group	Phosphorus mg[3]	Potassium mg	Magnesium mg	Iodine µg	Selenium µg	Fluoride mg[6]	Manganese mg	Molybdenum µg
≤6 mo[2]		400	25	80-90[5]	10		12 µg	
7-11 mo	170	700	80[4]	80-90[5]	20[4]	0.4	0.02-0.5[7]	10
CHILDREN								
1-3 y	250	850	170	100	20	0.7	0.5	15
4-6 y	440	1150	230	100	25	1.0	1	20
7-10 y	440	1800	230	100	40	1.5	1.5	30
FEMALES								
11-14 y	640	2400	250	120	60	2.3	2	50
15-17 y	640	2850	250	120	70	2.9	3	60
18-24 y	550	3500	300	150	75	3.2	3	65
25-50 y	520	3500	300	150	75	3.2	3	65
51-70 y	520	3500	300	150	75	3.1	3	65
>70 y	520	3500	300	150	75	3.0	3	65
Pregnant	530	3500	300	200	90	3.1	3	70
Lactating	530	3500	300	200	85	3.1	3	65
MALES								
11-14 y	640	2550	300	130	65	2.4	2	45
15-17 y	640	3400	300	140	85	3.3	2.5	60
18-24 y	550	3500	350	150	90	3.8	3	65
25-50 y	520	3500	350	150	90	3.7	3	65
51-70 y	520	3500	350	150	90	3.7	3	65
>70 y	520	3500	350	150	85	3.5	3	65

[1] Adequate intake based on observed intakes in healthy people or approximations from experimental studies, used when an RI cannot be determined.
[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are AIs based on estimated intake from human milk.
[3] Assuming the RI of calcium is consumed.
[4] Extrapolated from exclusively breast-fed infants 0-6 months.
[5] The AI for iodine in infants < 1 y is presented as a range with 80 µg/d in iodine sufficient populations and 90 µg/d in populations with mild to moderate iodine deficiency. The WHO recommends 90 µg/d for all infants.
[6] Based on an adequate intake of 0.05 mg/kg bodyweight, using population reference weights. For pregnant and lactating women, this refers to pre-pregnancy weight.
[7] Range based on upwards extrapolation from intake of infants 0-6 months, the mean of observed intakes and downwards extrapolation from adult AI.

Sodium as salt

In the U.S., the AI for sodium reference level of sodium intake (adequate intake) for adults was set to 1.5 g/d due to limited evidence of health effects of sodium intake at lower levels. It was advised to reduce the intake if above 2.3 g/d (NASEM, 2019). There is strong evidence to aim for a reduction of sodium intake in the Nordic and Baltic populations (Jula, 2023). Reductions in sodium intakes that exceed the chronic disease risk reduction (CDRR) of 2.3 g/d are expected to reduce chronic disease risk within the general population.

- NNR2023 adapts the reasoning from NASEM to recommend limiting intake of sodium to 2.3 g/d in adults (Table 16), which corresponds to 5.75 g of salt/d.

Table 16 Chronic disease risk reduction intake of sodium – all life-stage groups[1].

Age group	Sodium, g
≤6 mo[2]	0.11
7-11 mo	0.37[3]
CHILDREN	
1-3 y	1.1
4-6 y	1.4
7-10 y	1.7
FEMALES	
11-14 y	2.0
15-17 y	2.3
18-24 y	2.3
25-50 y	2.3
51-70 y	2.3
>70 y	2.3
Pregnant	2.3
Lactating	2.3
MALES	
11-14 y	2.0
15-17 y	2.3
18-24 y	2.3
25-50 y	2.3
51-70 y	2.3
>70 y	2.3

[1] Values for children and adolescents 11–14 years old are extrapolated from adults based on energy intake (NASEM, 2019).
[2] Values for infants 0-6 months are derived from estimated intake from human milk.
[3] Estimated intake from breastmilk (70 mg/d) and complementary foods (300 mg/d) (NASEM, 2019)

Dietary supplements

Prolonged intakes of nutrients from supplements have generally not been associated with decreased risk of chronic diseases or other health benefits in healthy individuals eating a varied diet that covers their energy requirements. In contrast, there is a large body of evidence suggesting that elevated intakes of certain supplements, mainly vitamins with antioxidative properties, might increase the risk of certain adverse health effects, including mortality. Thus, there is no scientific justification for using supplements as a means for adjusting an unbalanced diet. Few exceptions for ensuring optimal intake are vitamin D supplementation for infants, pre-pregnant, pregnant and lactating women and elderly people, as well as folic acid supplementation for women aiming for pregnancy until the end of pregnancy week 12. Extensive dietary restrictions for health or ideological reasons, e.g., veganism, or use of certain medications often lead to the need for dietary supplements. For example, vitamin B12 supplementation is necessary when foods of animal origin are excluded from the diet, and folic acid supplementation is necessary with medication with properties of folate antagonism.

An energy intake of 6.5–8 MJ is considered a low-energy intake with an increased risk of an insufficient intake of micronutrients. A very low energy intake is defined as an energy intake below 6.5 MJ/d and is associated with a considerable risk of an insufficient intake of micronutrients. A very low energy intake may be related to either a very low physical activity level, low body weight or low small muscle mass and, therefore, to low energy expenditure. Very low energy intakes are found among persons on weight reduction diets, among persons with eating disorders, food intolerances and some other diseases or conditions. Such diets should be tailored according to individual needs under supervision from health professionals.

Reference values (AR and provisional AR) for assessing nutrient intakes in dietary surveys

Vitamins and minerals

Assessing nutrient adequacy

AR and provisional AR for vitamins and minerals are presented in Table 17-20. The values are intended for use in assessing results from dietary surveys. Before comparing intake data with these reference values, it is crucial to check whether the intake data derived from a particular survey are suitable for assessing adequacy. Assessments based on provisional ARs should take into account the higher uncertainty and the tendency to be higher than the AR values, and for some nutrients relationship to energy intake may be included in the assessment. More guidance on this topic and on how to use DRVs can be found in Trolle et al (Trolle, in press).

The AR is the value that should be used to assess the risk for inadequate intake of micronutrients in a certain group of individuals. The percentage of the individuals that has an intake below the AR is related to the proportion that have an increased risk of inadequate intake. AR values are also used as a tool when planning adequate diets for groups of people.

Table 17 Average requirements of vitamins.

Age group	Vitamin A RE[2]	Vitamin D µg	Thiamin mg/MJ	Riboflavin mg	Niacin NE/MJ[3]	Vitamin B_6 mg	Folate µg	Vitamin C mg
≤6 mo[1]				0.2		0.1	50	25[6]
7-11 mo	200	7.5	0.07	0.3[4]	1.3	0.3[4]	70[4]	25[6]
CHILDREN								
1-3 y	240	7.5	0.07	0.5	1.3	0.5	90	20
4-6 y	270	7.5	0.07	0.6	1.3	0.6	110	30
7-10 y	340	7.5	0.07	0.8	1.3	0.9	160	45
FEMALES								
11-14 y	490	7.5	0.07	1.2	1.3	1.1	220	60
15-17 y	500	7.5	0.07	1.3	1.3	1.3	240	75
18-24 y	540	7.5	0.07	1.3	1.3	1.3	250	75
25-50 y	540	7.5	0.07	1.3	1.3	1.3	250	75
51-70 y	530	7.5	0.07	1.3	1.3	1.3	250	75
>70 y	510	7.5	0.07	1.3	1.3	1.3	250	75
Pregnant	590	7.5	0.07	1.6	1.3	1.5	480[5]	75
Lactating	1060	7.5	0.07	1.6	1.3	1.4	380	75
MALES								
11-14 y	520	7.5	0.07	1.1	1.3	1.2	200	65
15-17 y	600	7.5	0.07	1.3	1.3	1.5	250	85
18-24 y	630	7.5	0.07	1.3	1.3	1.5	250	90
25-50 y	630	7.5	0.07	1.3	1.3	1.5	250	90
51-70 y	610	7.5	0.07	1.3	1.3	1.5	250	90
>70 y	590	7.5	0.07	1.3	1.3	1.5	250	90

[1] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk.
[2] RE = Retinol equivalents (1 RE = 1 µg retinol = 2 µg of supplemental β-carotene, 6 µg of dietary β-carotene, or 12 µg other dietary provitamin A carotenoids (e.g., α-carotene and β-cryptoxanthin).
[3] NE = Niacin equivalent (1 NE = 1 mg niacin = 60 mg tryptophan).
[4] Provisional AR, extrapolated from exclusively breast-fed infants 0-6 months.
[5] Provisional AR based on adequate intake (AI). Most national authorities in the Nordic and Baltic countries recommend supplement of 400µg/d in addition to dietary intake for women in fertile age from planned pregnancy and throughout the first trimester.
[6] Provisional AR based on AI set to 3 times the intake known to prevent scurvy in infants.

Table 18 Provisional average requirements of vitamins[1].

Age group	Vitamin E α-TE[4]	Vitamin K µg	Pan-tothenic acid mg	Biotin µg	Vitamin B_{12} µg	Choline mg
≤6 mo[2]	3		1.6	3	0.3	96
7-11 mo	4[3]	5	2.2[3]	4[3]	1.1	134[3]
CHILDREN						
1-3 y	6	10	3.2	16	1.2	119
4-6 y	7	15	3.2	20	1.4	139
7-10 y	7	25	3.2	20	2	199
FEMALES						
11-14 y	8	35	4	28	2.8	276
15-17 y	9	45	4	28	3.1	310
18-24 y	8	50	4	32	3.2	320
25-50 y	8	50	4	32	3.2	320
51-70 y	8	50	4	32	3.2	320
>70 y	8	50	4	32	3.2	320
Pregnant	9	60	4	32	3.6	381
Lactating	10	50	5.6	35	4.2	416
MALES						
11-14 y	9	40	4	28	2.6	259
15-17 y	10	50	4	28	3.2	318
18-24 y	9	60	4	32	3.2	320
25-50 y	9	60	4	32	3.2	320
51-70 y	9	60	4	32	3.2	320
>70 y	9	55	4	32	3.2	320

[1] Provisional average requirement (AR) calculated as 0.8 times the provisional recommended intake, assuming a CV of 12.5 %. This likely overestimates the true AR.
[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk.
[3] Extrapolated from exclusively breast-fed infants 0-6 months
[4] Assuming a PUFA intake of 5% of energy intake. α-TE = α-tocopherol equivalents (i.e., 1 mg RRR α-tocopherol).

Table 19 Average requirements of minerals.

Age group	Calcium mg	Copper µg	Iron mg[2]	Zinc mg[2]
≤6 mo[1]	96	160		
7-11 mo	250[3]	180[3]	8	2.5
CHILDREN				
1-3 y	400	260	6	3.8
4-6 y	700	300	5	4.8
7-10 y	675	440	7	6.4
FEMALES				
11-14 y	980[4]	600	10	9.0
15-17 y	980[4]	680	9	10.2
18-24 y	870	700	9	8.1
25-50 y	750	700	9	8.1
51-70 y	750	700	6	7.9
>70 y	750	700	6	7.7
Pregnant	800	800	20	9.4
Lactating	800	1000	9	10.5
MALES				
11-14 y	980[4]	570	9	9.2
15-17 y	980[4]	700	9	11.7
18-24 y	870	700	7	10.6
25-50 y	750	700	7	10.6
51-70 y	750	700	7	10.4
>70 y	750	700	7	10.1

[1] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk.
[2] Assuming a mixed animal/vegetable diet with a phytic acid intake of about 600 mg/d.
[3] Provisional AR, extrapolated from exclusively breast-fed infants 0-6 months.
[4] Average of physiological requirements for females and males 11–14 and 15–17 years of age.

Table 20 Provisional average requirements of minerals[1].

Age group	Phos-phorus mg[3]	Potas-sium mg	Magne-sium mg	Iodine µg	Sele-nium µg	Fluoride mg[4]	Manga-nese mg	Molyb-denum µg
≤6 mo[2]		320	20	64-72	10		9.6 µg	
7-11 mo	140	600	64[5]	64-72	15[5]	0.4	0.02-0.4[6]	7
CHILDREN								
1-3 y	200	700	136	80	15	0.5	0.5	10
4-6 y	350	900	184	80	20	0.8	0.7	16
7-10 y	350	1450	184	80	35	1.2	1.1	24
FEMALES								
11-14 y	510	1900	200	100	50	1.9	1.8	38
15-17 y	510	2250	200	100	55	2.3	2.2	48
18-24 y	440	2800	240	120	60	2.6	2.4	52
25-50 y	420	2800	240	120	60	2.6	2.4	52
51-70 y	420	2800	240	120	60	2.5	2.4	52
>70 y	420	2800	240	120	60	2.4	2.4	52
Preg-nant	430	2800	240	160	75	2.5	2.5	55
Lactat-ing	430	2800	240	160	70	2.5	2.3	51
MALES								
11-14 y	510	2050	240	100	50	1.9	1.6	34
15-17 y	510	2700	240	110	70	2.6	2.1	46
18-24 y	440	2800	280	120	70	3.0	2.4	52
25-50 y	420	2800	280	120	70	3.0	2.4	52
51-70 y	420	2800	280	120	70	2.9	2.4	52
>70 y	420	2800	280	120	70	2.8	2.4	52

[1] Provisional average requirement (AR) is calculated as 0.8 times the adequate intake (AI), assuming a CV of 12.5%. This likely overestimates the true AR.
[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk (except for iodine).
[3] Assuming the recommended intake (RI) of calcium is consumed.
[4] Based on an adequate intake of 0.05 mg/kg bodyweight, using population reference weights. For pregnant and lactating women, this refers to pre-pregnancy weight.
[5] Extrapolated from exclusively breast-fed infants 0-6 months.
[6] Range based on upwards extrapolation from intake of infants 0-6 months, the mean of observed intakes and downwards extrapolation from adult AI.

Tolerable upper intake level

For some nutrients, high intakes can cause adverse or even toxic symptoms. Tolerable upper intake levels (ULs) have been established for some nutrients (Table 21). For certain nutrients, especially preformed vitamin A (retinol), vitamin D, iron, and iodine, prolonged intakes above these levels can lead to an increased risk of toxic effects. For other nutrients the adverse effects might be different and milder, e.g., gastrointestinal problems or interference with the utilization of other nutrients. The ULs are not recommended levels of intake, but rather maximum levels of usual intakes judged to be unlikely to pose a risk of adverse health effects in humans. The ULs are derived for the general population, and values are given for adults. For other life stages, such as infants and children, specific data might exist for deriving specific values or such values could be extrapolated.

To establish whether a population is at risk for adverse effects, the fraction of the population exceeding the UL and the magnitude and duration of the excessive intake should be determined. There is a substantial uncertainty behind several of the ULs, and they must be used with caution on an individual basis. UL values do not necessarily apply in cases of prescribed supplementation under medical supervision.

The ULs are primarily based on the considerations in NNR2012. If EFSA has set an UL for a nutrient not covered by NNR2012, or the EFSA assessment is more recent, the EFSA values have been used. The footnotes to Table 21 indicate whether the ULs are based on NNR2012, EFSA or both.

Boron is a trace element that is naturally present in many foods and available in dietary supplements. While boron is not classified as an essential nutrient for humans, it may have adverse effects in high doses (EFSA, 2018). For boron, the most recent value from EFSA is included in Table 21 despite that this nutrient has not been assessed in any background paper in NNR2023.

Table 21 Tolerable upper intake levels of vitamins and minerals for adults.

		UL per day
Boron[1]	mg/d	10
Calcium[1,2]	mg/d	2500
Copper[2]	mg/d	5
Iodine [1,2]	μg/d	600
Iron[3]	mg/d	60
Magnesium[1,4]	mg/d	250
Molybdenum[1]	mg/d	0.6
Phosphorus[2]	mg/d	3000
Selenium[5]	μg/d	255
Zinc[1,2]	mg/d	25
Fluoride[1]	mg/d	7
Folic acid (synthetic)[1,2]	μg/d	1000
Nicotinamide[1,2]	mg/d	900
Nicotinic acid[1,2]	mg/d	10
Vitamin A[1,2,6]	μg RE/d	3000
Vitamin B6[7]	mg/d	12
Vitamin D[1,2]	μg/d	100
Vitamin E[1,2]	mg/d	300

[1] Based on EFSA (2018)
[2] Based on NNR2012
[3] Background paper on Iron (Domellöf & Sjöberg, 2023)
[4] Readily dissociable magnesium salts (e.g. chloride, sulphate, aspartate, and lactate) and compounds like magnesium oxide (MgO) in food supplements, water or added to foods; does not include magnesium naturally present in foods and beverages.
[5] EFSA (2023b)
[6] Retinol and retinyl esters
[7] EFSA (2023a)

Comparison between RI set by NNR2023 and NNR2012

Since all DRVs have been recalculated in NNR2023, we have compared the RI values with the corresponding values set by NNR2012. Some important differences are due to the most recent principles used by EFSA or NASEM, such as updated weight curves and life-stage groups in the new edition of NNR and change from RI to AI for some nutrients when a formal AR and RI cannot be defined due to insufficient evidence. The AI can be used in line with traditional RI values. However, the uncertainty in the AI values is larger than in the RI. Comparisons between the AI in NNR2023 previous RI in NNR2012 should therefore be done with care. An AI will usually be higher than an RI derived from average requirement (AR), but it does not necessarily imply evidence for an actual increase in the physiological requirement from those of the previous editions of NNR.

As shown in Table 22, for some nutrients, an RI in NNR2012 has been changed to AI in NNR2023 due to updated evidence or improved methodology. For eight nutrients (vitamin K, biotin, pantothenic acid, choline, sodium, manganese, molybdenum, and fluoride), which were not set in NNR2012, a new AI has been set in NNR2023.

For most nutrients, there are only minor changes, despite the comprehensive recalculations in NNR2023. The changes can often be attributed to updated methodology (see Table 2 and 3) and the new reference weights used in NNR2023.

For more details on the calculations and life-stage groups, please refer to the nutrient sections later in the report, the corresponding background papers, and Appendix 5.

Table 22 Comparison between RI and AI set by NNR2023 (25-50 years) and NNR2012 (31-60 years). *AI is shown in italics*

	NNR2023		NNR2012		Comments
	RI or AI		RI		
	FEMALES	MALES	FEMALES	MALES	
Vitamin A, RE	700	800	700	900	
Vitamin D, μg	10	10	10	10	
Vitamin E, α-TE	*10*	*11*	8	10	AI in NNR2023
Vitamin K, μg	*65*	*75*	ND	ND	AI in NNR2023
Thiamin, mg	0.9	1.1	1.1	1.3	
Riboflavin, mg	1.6	1.6	1.3	1.6	
Niacin, NE	14	18	14	18	
Vitamin B_6, mg	1.6	1.8	1.2	1.5	
Folate, μg	330	330	300	300	
Vitamin B_{12}, μg	*4*	*4*	2	2	AI in NNR2023
Biotin, μg	*40*	*40*	ND	ND	AI in NNR2023
Pantothenic acid, mg	*5*	*5*	ND	ND	AI in NNR2023
Choline, mg	*400*	*400*	ND	ND	AI in NNR2023
Vitamin C, mg	95	110	75	75	
Calcium, mg	950	950	800	800	
Phosphorus, mg	*520*	*520*	600	600	AI in NNR2023
Magnesium, mg	*300*	*350*	280	350	AI in NNR2023
Sodium, g	*1.5*	*1.5*	ND	ND	AI in NNR2023
Potassium, g	*3.5*	*3.5*	3.1	3.5	AI in NNR2023
Iron, mg	15	9	15	9	
Zinc, mg	9.7	12.7	7	9	
Iodine, μg	*150*	*150*	150	150	AI in NNR2023
Selenium, μg	*75*	*90*	50	60	AI in NNR2023
Copper, μg	900	900	900	900	
Manganese, mg	*3*	*3*	ND	ND	AI in NNR2023
Molybdenum, μg	*65*	*65*	ND	ND	AI in NNR2023
Fluoride, μg	*3.2*	*3.7*	ND	ND	AI in NNR2023

Comparison between AR in NNR2023 and NNR2012, and comparison with national mean intake data

We have also compared the recalculated AR values with the corresponding values set by NNR2012, and national representative intake data for the Nordic and Baltic countries (Table 23).

First, for the nine micronutrients vitamin K, biotin, pantothenic acid, choline, magnesium, potassium, manganese, molybdenum and fluoride, which did not have ARs in NNR2012, provisional ARs have been defined. Second, for the five micronutrients vitamin E, vitamin B_{12}, phosphorus, iodine and selenium, which all had ARs in NNR2012, the values have been changed to provisional ARs. The arguments for setting these provisional ARs are related to the harmonized methodologies utilized in NNR2023 and the updated scientific evidence. The arguments are clearly stated in each of the nutrient summaries in this report.

Nine of the ARs and provisional AR values, for the age group 25-50 years, in NNR2023 have increased by 20% or more compared to the corresponding AR values in NNR2012. All other values were within ± 20% of the NNR2012 AR values. The reasons for these increases have been discussed above, and in the corresponding nutrient summaries.

When comparing the ARs and the provisional AR values with national representative intake data in the Nordic countries (Lemming & Pitsi, 2022) we observed that the mean intake data for vitamin D, vitamin E, potassium and selenium were lower in one or more of the Nordic countries. In one or more of the Baltic countries, national representative intake data (Lemming & Pitsi, 2022) for vitamin D, vitamin E, riboflavin, vitamin B_6, folate, vitamin B_{12}, potassium, iodine and selenium were lower than the corresponding ARs or provisional AR values.

In the comparisons, we have only used data for adults (i.e., the age group 25-50 years in NNR2023 and the age group 31-60 years in NNR2012). National authorities in countries where representative intake data for nutrients are lower than the ARs or provisional ARs should consider further investigations of nutrient status in specific risk groups before implementation of carefully planned nutritional interventions or programs to improve the respective nutrient intake. In such considerations, care should be taken to also include the uncertainties in the assessment of nutrient intakes, including distribution of intake, and the uncertainty in the provisional AR values. Especially, an intake lower than the provisional AR on group level does not necessarily point to inadequacy. Similar assessments may also be performed for other life-stage groups.

Table 23 Comparison between AR and provisional AR set by NNR2023 (25-50 yrs) and NNR2012 (31-60 yrs), and national intake data.

	Range of mean intakes in Nordic countries		Range of mean intakes in Baltic countries		NNR2023 AR and provisional AR		NNR2012 AR		Comments
	F	M	F	M	F	M	F	M	
Vitamin A, RE	747-1110	812-1556	666-942	666-1155	540	630	500	600	
Vitamin D, µg	4.3-10.0	5.3-11.0	4.3-9.1	5.5-7.2	7.5	7.5	7.5	7.5	
Vitamin E, α-TE	8.8-11.7	9.5-13.2	7.8-12.9	9.4-14.9	*8*	*9*	5	6	Provisional AR in NNR2023
Vitamin K, µg	NA	NA	NA	NA	*50*	*60*	ND	ND	Provisional AR in NNR2023
Thiamin, mg	1.1-1.4	1.4-1.9	0.8-1.3	1.1-1.4	0.7	0.8	0.9	1.2	
Riboflavin, mg	1.4-1.6	1.7-2.1	1.0-1.2	1.2-1.4	1.3	1.3	1.1	1.4	
Niacin, NE	29-32	39-41	12.7-23.7	13.1-32.9	12	15	12	15	
Vitamin B_6, mg	1.4-1.8	1.8-2.3	1.2-1.715	1.5-1.9	1.3	1.5	1.1	1.3	
Folate, µg	222-329	247-370	164-216	198-383	250	250	200	200	
Vitamin B_{12}, µg	4.9-6.0	6.0-8.9	2.9-5.8	3.3-8.0	*3.2*	*3.2*	1.4	1.4	Provisional AR in NNR2023
Biotin, µg	NA	NA	NA	NA	*32*	*32*	ND	ND	Provisional AR in NNR2023
Pantothenic acid, mg	NA	NA	NA	NA	*4*	*4*	ND	ND	Provisional AR in NNR2023
Choline, mg	NA	NA	NA	NA	*320*	*320*	ND	ND	Provisional AR in NNR2023
Vitamin C, mg	96-115	93-113	69-132	72-116	75	90	50	60	
Calcium, mg	811-1038	945-1188	546-659	660-768	750	750	500	500	
Phosphorus, mg	1242-1384	1541-1788	867-1061	1186-1392	*420*	*420*	450	450	Provisional AR in NNR2023
Magnesium, mg	263-346	335-439	277-295	331-349	*240*	*280*	ND	ND	Provisional AR in NNR2023
Potassium, g	2.6-3.4	3.4-4.2	2.4-3.0	2.9-3.8	*2.8*	*2.8*	ND	ND	Provisional AR in NNR2023
Iron, mg	9.4-10.0	11-13	9.6-13.0	12.3-14.5	9	7	10	7	
Zinc, mg	8.8-10.5	12.4-14.1	7.2-8.3	10.1-11.4	8.1	10.6	5	6	
Iodine, µg	142-227	195-268	25-105	30-134	*120*	*120*	100	100	Provisional AR in NNR2023
Selenium, µg	42-68	50-88	20-47	31-65	*60*	*70*	30	35	Provisional AR in NNR2023
Copper, mg	1.1	1.3-1.3	1.1-1.7	1.5-2.1	0.7	0.7	0.7	0.7	
Manganese, mg	NA	NA	NA	NA	*2.4*	*2.4*	ND	ND	Provisional AR in NNR2023
Molybdenum, µg	NA	NA	NA	NA	*52*	*52*	ND	ND	Provisional AR in NNR2023
Fluoride, µg	NA	NA	NA	NA	*2.6*	*3.0*	ND	ND	Provisional AR in NNR2023

*Values are labeled in YELLOW if one or more countries have a national representative intake data lower than the corresponding AR/provisional AR / Provisional AR is shown in italics / NA: Not available /ND: Not determined /The intake data of Lemming & Pitsi (2022) is used in this table.

Major reasons for changes in DRVs from NNR2012 to NNR2023

For most nutrients, there are only minor changes, despite the comprehensive recalculations in NNR2023. The changes can be attributed to updated methodology, the new reference weights and the new age groups used in NNR2023 (see nutrient summaries, appendices and background papers). For nine nutrients, one or more DRVs changed more than 20% compared to the NNR2012 values. The main reasons are listed below.

Vitamin E. While NNR2012 defined a RI for vitamin E, NNR2023 define an AI. The AI is based on a basal vitamin E requirement (4 mg) plus a factor based on the dietary intake of 5 E% PUFA. The provisional AR is calculated from the AI.

Vitamin B_6. A new cut-off value for the indicator (plasma PLP concentration 30 nmol/l) is used to define AR, in line with EFSA. It is not based on protein intake as in NNR2012. Due to less data for males, the female AR is extrapolated to males with allometric scaling. RI is calculated from AR.

Folate: A new cut-off value for the indicator is used to define AR, in line with EFSA. RI is calculated from AR.

Vitamin B_{12}. While NNR2012 defined a RI for vitamin B_{12}, NNR2023 define an AI. A combination of new indicators is used to define an AI in line with EFSA. Cobalamin intake of 4 µg/day and greater is associated with serum concentrations of holoTC and cobalamin within the reference ranges derived from healthy subjects. These cobalamin serum concentrations together with total homocysteine and methylmalonic acid concentrations below the cut-off values for adults, are indicative of an adequate cobalamin status. Provisional AR is calculated from AI.

Vitamin C. A new cut-off value for the indicator is used to define AR in line with EFSA. A target plasma ascorbate concentration of 50 µmol/L was used in NNR2023 (32 µmol/L was used in NNR2012) to set the AR in males and extrapolated to females with isometric scaling. RI is calculated from AR.

Thiamine. NNR2023 and NNR2012 both used 0.1 mg/MJ as the basis for AR. New weight curves and age categories are used in in NNR2023. RI is calculated from AR.

Zinc. NNR2023 based the AR on a higher intake of phytate (600 mg) which resulted in a reduced absorption efficiency. The new RI is calculated from AR using updated regression analyses.

Selenium. While NNR2012 defined a RI for selenium, NNR2023 define an AI. In NNR2023, the dose-response curve of the indicator was re-evaluated (SelenoP in plasma). The intake of selenium needed to achieve a plasma concentration of about 110 µg/L is used as cut-off. An average daily intake of dietary selenium of about 1.2 µg/kg body weight would be sufficient to achieve an optimal selenium concentration and maximum expression level of SelenoP in plasma.

Calcium. The AR of calcium for adults applied in NNR2012 was derived from one Norwegian balance study in male convicts. In NNR2023, the DRVs are updated and adopted from EFSA. The updated AR for adults takes into account several balance studies, in which the mean calcium intake necessary to equal excretion was found to be 715 mg/day. Additionally, an allowance for 40 mg/day of dermal losses of calcium, which was not measured in the studies, was added to derive the revised AR of 750 in males and females aged ≥25 years.

Principles for developing a framework for setting FBDGs in NNR2023

Country-specific national FBDGs must be built on 5 pillars

The role of national FBDGs is to inform country-specific public food and nutrition, health and agricultural policies and nutrition education programs to foster healthy eating habits and lifestyles. More than 100 countries worldwide, all EU countries and all EU associated countries have developed healthy FBDGs. The national FBDGs vary across countries, because several country-specific dimensions need to be considered when formulating national FBDGs.

The scientific evidence for health effects of foods and food groups are more or less universal: similar health effects are established for the same foods or food groups independent of the country where the study population originate. There are exceptions to this rule, but these exceptions are few and will be discussed when relevant.

National FBDGs are not only informed by the universal health effect of foods. They are also informed by several country-specific factors (Food-based dietary guidelines, FAO (FAO, 2023); Sustainable healthy diets: guiding principles, WHO/FAO (2019); Food-based dietary guidelines in the WHO European Region (WHO, 2003); Preparation and use of food-based dietary guidelines (FAO/WHO, 1996)).

First, they need to respond to the public health challenges in the individual countries. While the Nordic and Baltic countries are relatively similar compared with many other countries, there are significant differences in burden of diseases in the countries that need to be addressed. This is why we have included a separate background paper on burden of diseases in the 8 Nordic and Baltic countries in the present NNR report. There may be other public health factors relevant for national FBDGs other than those described in the NNR report. Thus, national authorities should consider carefully all relevant public health factors.

Second, food consumption patterns vary considerably across and within countries and are dependent on national food culture and tradition. While nutrient adequacy can be met by a huge variety of cultural diets, it is essential to consider whether national food patterns are in accordance with national nutrient recommendations. This is why we have included a separate background paper on food and nutrient intakes in the 8 Nordic and Baltic countries in the present NNR report. We recommend that national authorities perform calculations and modelling to assess macro- and micronutrient adequacy related to the new updated DRVs. This must be performed at the national level, since food composition tables and diet intakes are different in the Nordic and Baltic countries.

Third, food availability varies considerably across countries and is dependent for example on the country's ability for food production, national agricultural policies and import restrictions. For example, Japanese FBDGs include recommendations on rice, and Greek FBDGs include recommendations on olives. Thus, the global food production and a country's food availability need to be taken into account when developing country-specific FBDGs. While food availability is briefly discussed and considered in general terms in the NNR report, these factors are dependent on national policies and priorities, and are not taken into consideration in the NNR framework for developing FBDGs. National authorities may or may not align their country-specific food availability when they formulate national FBDGs.

Fourth, there are sociocultural or socioeconomic aspects that need to be considered and prioritised. A general overview of socio-economical aspects relevant for the Nordic and Baltic countries is described in Jackson and Holm (2023). These are also country-specific issues that depend on national policies that need to be considered by the national authorities.

Fifth, the project description of the present NNR project includes milestones not only for the development of a framework for setting FBDGs, but also a framework for integrating environmental sustainability into the FBDGs. That is why we have included several background papers on environmental sustainability in the present report and include specifically environmental issues when we give science advice in the NNR framework for formulation of country-specific healthy and environment-friendly FBDGs. Sustainable healthy diets should promote all dimensions of indivuduals' health and well-being, have low environmental pressure and impact, be accessible, affordable, safe and equitable, and culturally acceptable, as described by FAO and WHO (2019).

Thus, the major contribution of the present NNR for the national authorities in the 8 Nordic and Baltic countries, is to give science advice on health and environmental effects of food. It is important to realize that certain country-specific aspects other than those assessed in the NNR report may need to be considered by the national authorities when formulating their national FBDGs.

Assessing health effects of foods and food groups in NNR2023

During the last decades, nutritional sciences have revealed that foods contribute to overall health beyond simply providing the appropriate amounts of essential nutrients. The health effects of foods extend the effect on known essential nutrients, especially when it comes to chronic diseases. These health effects of foods are the major foundation for FBDGs. There has been a considerable development in new methodologies to assess health effects of foods. To improve quality and reduce bias, health effects of foods are ideally considered through qSRs. Recent developments and harmonization of common principles and methodologies for synthesizing totality of evidence in qSR enable the NNR project to use qSRs developed from other national or international health authorities that used similar methodologies. The list of qSRs that are the main foundation of the FBDGs in NNR is presented in Table 1 and 2 and Appendix 2.

First, it is essential to evaluate the causality of each individual food/food group and various relevant health outcome pairs. This exercise may result in the identification of indicators that may be used to formulate FBDGs. If strength of evidence is graded above a certain predefined level, this indicator may be used for FBDG setting (Arnesen et al., 2020a, b; Christensen et al., 2020).

Then, a dose-response curve should be considered in a meta-analysis or qSR. If a dose-response curve can be established, a quantitative FBDG may be formulated. If no adequate dose-response curve can be established, in general, a qualitative FBDG may still be formulated (Arnesen et al., 2020a; Christensen et al., 2020).

Some food groups may have a quantitative FBDG, even without an established dose-response relationship with a health outcome (e.g., dairy). In such cases, the quantitative FBDG is based on the significance of the food group for nutritional adequacy and the intake of specific nutrients.

In general, all quantitative FBDGs are formulated as guidelines for individuals. FBDGs are formulated more generally than the DRVs for nutrients, although the causal associations of foods and health outcomes can be stronger than for nutrients and health outcomes. As with DRVs, there are seldom precise calculations behind the quantitative FBDGs. The precise FBDGs are based on best scientific knowledge and most often decided as consensus among expert groups. FBDGs are typically formulated for adults, not for all life-stage groups. Thus, when using the FBDGs for health guidance, care should be taken when considering the total amount of foods and energy consumed. For example, the general FBDGs should be scaled down for children, and other relevant populations such as elderly with low energy intake.

There is considerable uncertainty about health effects for some foods/food groups. If FBDGs cannot be formally defined, it does not necessarily mean that there are not any health effects of the foods/food groups. It simply means that the present scientific evidence is not strong enough to formulate a FBDG.

Assessing environmental effects of foods and food groups in NNR2023

In accordance with the scope and mandate from NCM we have assessed environmental effects of foods and food groups.

The primary assessment is based on the four environment background papers (summarized in the section "Summary of background papers on environmental sustainability"). The sixth assessment reports from the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2022a, b) and the Global Assessment Report on Biodiversity and Ecosystem Services from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem

Services (IPBES) (IPBES, 2019) are pillars in the evaluation of environmental impact of food consumption in NNR2023. The most recent synthesis report from IPCC (IPCC, 2023) concludes with "high confidence" that human activities have unequivocally caused global warming, with global surface temperature reaching 1.15 °C above pre-industrial levels. Global GHG emissions continue to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use changes, lifestyles and patterns of consumption and production across regions, and between and within countries. Global GHG emissions in 2030 implied by nationally determined contributions announced by October 2021 make it likely that global warming will exceed 1.5 °C within a few years and make it much harder to limit warming below 2 °C. Without strengthening of policies, global warming of 3.2 °C [2.2-3.5] °C is projected by 2100 (*medium confidence).*

The IPCC report also concludes with "very high confidence" that climate change is a threat to human well-being and planetary health and that there is a rapidly closing window of opportunity to secure a liveable and sustainable future for all. Rapid and far-reaching transitions across all sectors and systems are therefore necessary. These system transitions involve a significant upscaling of a wide portfolio of mitigation and adaptation options across systems and regions.

IPCC estimates that the share of food systems in global anthropogenic GHG emissions is 23–42% (IPCC, 2022b). While there are many options that may provide adaptation and mitigation benefits that could be up-scaled in the near-term across most regions, the demand-side measures, such as shifting to sustainable healthy diets and reducing food loss/waste, are essential parts of these adaptions and mitigations. The report concludes with high confidence that a diet featuring plant-based foods, such as one based on whole grains legumes, fruits and vegetables, nuts and seeds, and animal-sourced food produced in resilient, sustainable, and low-GHG emission systems, present major opportunities for adaptation and mitigation while generating significant co-benefits in terms of human health.

The background papers on environmental sustainability contribute with science-based inputs on environmental (including climate) effects of foods and diets from a global and regional, as well as national perspectives. The background papers also provide status on the current FBDGs in the Nordic countries and suggestions for the approach to be used by the national authorities when developing or updating FBDGs that integrate environmental sustainability. The NNR2023 project initially considered optimization models for integration of environmental sustainability. While these are useful tools, we conclude that they should not be used in the present NNR. Openness and transparency are essential; however, in modelling it is less transparent how different assumptions used in models influence the outcomes.

We base our science advice on expert judgement of literature reviews of scientific evidence, and systematic reviews of available science. We did not use optimization as an overarching principle for developing science advice for FBDGs in NNR. However, several different studies, also using optimization methodologies and referred to in the background papers, informed the science advice.

The four steps for developing healthy and environment-friendly FBDGs

Weighing of health versus environment when formulating FBDGs is essential and dependent on many factors and priorities. No formal mathematical weighing of health versus environment is performed in the science advice for developing FBDGs in the NNR report. We describe the considerations transparently and conclude by formulating quantitative or qualitative science advice for each individual food group.

Diet is a complex system of interacting components that cumulatively affect health. Foods are not consumed in isolation and decreasing the intake of one food group usually entails increasing the intake of another food group to make up for the reduction in energy and nutrients. Therefore, there is a strong inter-connectivity between the science advice of different food groups (partially visible with cross-references). Food group-specific advice should always be interpreted in relation to the whole diet.

The FBDGs have an emphasis on plant-based sources of nutrients, based on health outcomes alone or in combination with the effort to reduce environmental impact of diets. Many new products have emerged on the market with the aim of replacing meat or dairy products in a meal. Such products may be part of a healthy diet, but the nutrient content of these products may vary considerably (Trolle et al., 2023). The NNR2023 project has not evaluated the nutritional content of these products separately.

When developing a framework for integrating environmental sustainability into healthy FBDGs, we used the following strategy and principles:

1. First, we considered health effects of food groups. Health effects were given priority. The background papers of respective food groups were the main background for assessment. We focused primarily on evidence from qSRs on chronic disease outcomes. If there is strong evidence that a causal effect is established, we defined the range that is associated with low risk of diseases. The range spans a value larger than 0 up to the maximal intake. Alternatively, we set an upper level (in the case of adverse effect of high intakes) or a lower level (in the case of no relevant upper level).
2. Second, we considered whether the food group contributes significant amounts of essential nutrients in the general population in Nordic and Baltic countries. If significant contribution, the range spans a value larger than 0 up to the maximal intake. If no significant contribution, the range spans a value from 0 up to the maximal intake.
3. Third, we considered public health challenges related to health effects of the food group. Health effects related to prevalent chronic diseases were given priority.
4. Fourth, we considered the environmental impact of consumption of the food groups. We gave priority to changes in dietary patterns that reduce the environmental impact of the food group. We first considered whether narrowing the health defined ranges of intakes can contribute to reducing the environmental impact without compromising the beneficial health effects.

Science advice for a healthy and environment-friendly diet in Nordic and Baltic Countries

Based on the scientific evidence documented in the NNR2023 report and the NNR2023 background papers regarding associations between food and food patterns and risk of chronic disease, health effects of nutrients, the current food intake and burden of diseases, and the environmental footprint of current food consumption, several general guidelines for a healthy and environment-friendly diet can be defined for the Nordic and Baltic Countries.

Among the food groups, there are, in general, few conflicts between a healthy diet and an environment-friendly diet. While specific conflicts may occur among individual foods, the general guidelines concerning consumption of the food groups cereals, vegetables, fruits, berries, nuts and seeds, red meat, eggs, fats and oils, sweets and alcohol are supported both by their effects on health outcomes and their environmental footprint. The recommendations to increase consumption of potatoes and legumes, and to reduce white meat, are mainly based on their environmental footprints. For fish, the health-based advice for increased consumption should be primarily from sustainably managed stocks. For milk and dairy, a moderate intake is suggested which may be in conflict with the environmental impact. The suggested general guidelines and their consequences for health outcomes and environmental footprint are summarized below. For more details, see Table 24, the food groups sections in this report, and the four environmental sustainability background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

1. **Cereals:** Increased intake of whole grains supported both by effects on health outcomes and environmental footprint.
2. **Vegetables, fruits and berries:** Increased intake supported both by effects on health outcomes and environmental footprint.
3. **Potatoes:** Higher consumption is recommended, mainly due to environmental aspects.
4. **Pulses:** Higher consumption is recommended, mainly due to environmental aspects and nutrient contribution.
5. **Nuts:** Increased intake supported both by effects on health outcomes and environmental footprint.
6. **Fish:** Increased intake from sustainably managed stocks supported both by effects on health outcomes and environmental footprint.
7. **Red meat:** Reduced intake supported both by effects on health outcomes and environmental footprint.
8. **White meat (poultry):** Preferentially lower intake due to environmental impact.
9. **Milk and dairy:** Moderate intake of low-fat milk recommended mainly due to nutrient adequacies, high intakes not compatible with low environmental impact.
10. **Eggs:** Low intake may be included in the diet due to nutrient adequacy, high intakes may not be compatible with beneficial health effects and low environmental impact.

11. **Fats and oils:** Moderate intake recommended mainly due to nutrient adequacies and low environmental impact.
12. **Sweets:** Reduced intake supported both by effects on health outcomes and environmental footprint.
13. **Alcohol:** Reduced intake supported both by effects on health outcomes and environmental footprint.

It is important to note that the healthy and environmental-friendly FBDGs suggested in this report are only based on human food consumption. Several agriculture production methods, processing procedures, transport, packing and waste, as well as many other aspects of the food system may greatly influence the environmental footprint related to human food consumption. National authorities may also consider the potential for reduced country-specific environmental footprints by taking into account the complete food system. Additionally, other dimensions of sustainability may also be considered. The five sustainability background papers included in the extended NNR2023 report may serve as a scientific foundation for such national considerations.

Overall, we recommend a predominantly plant-based diet rich in vegetables, fruits, berries, pulses, potatoes and whole grains, ample amounts of fish and nuts, moderate intake of low-fat dairy products, limited intake of red meat and poultry, and minimal intake of processed meat, alcohol, and processed foods containing high amounts of added fats, salt and sugar.

Thus, at the population level, and for most individuals, the NNR2023 report recommends an increased intake of vegetables, fruits, berries, pulses, potatoes, whole grains, nuts and seeds, and fish, and reduced intake of red and processed meat, and foods containing high amounts of added fats, salt and sugar, and alcohol.

Refined cereals should be replaced by whole grain products, butter and butter-based spreads should be replaced by vegetable oils and vegetable oil-based fat spreads, while high fat dairy should be replaced by low-fat dairy. Red meat and processed meat consumption should be reduced in favour of plant foods, such as legumes, and fish from sustainably managed stocks.

Diets dominated by naturally fibre-rich plant foods (e.g., vegetables, pulses, fruits and berries, nuts and seeds, and whole grains) will generally be lower in energy and higher in micronutrients compared to diets dominated by animal food. The energy density is generally higher in food products high in fat and sugar (e.g., desserts, sweets, cakes and biscuits, savoury snacks, some breakfast cereals, and ice-cream).

A reduction in consumption of SSB will contribute to increased micronutrient density and reduced intake of added and free sugars. Fatty fish, nuts and seeds, vegetable oils and vegetable oil-based fat spreads high in unsaturated fat should largely replace butter, high-fat meat, and meat products. A switch from high-fat to low-fat dairy will also improve the dietary fat quality while sustaining micronutrient density.

Processed food products provide a high proportion of the total fat, sugar, and salt intake. A reduced intake can be achieved by choosing varieties containing lower amounts, or by choosing more whole foods instead of processed foods.

Figure 1 Dietary changes that promote a healthy and environment-friendly diet in Nordic and Baltic populations

Increase	Exchange	Limit
Vegetables	Refined cereals → whole grain products	Processed meat Red meat
Fruits and berries	Butter and butter-based spreads → vegetable oils, vegetable oil-based spreads	Sugar-sweetened beverages
Pulses	High-fat dairy → low-fat dairy	Processed foods with high amounts of added fats, salt and sugar
Potatoes	Processed foods with high amounts of added fats, salt and sugar → whole foods and varieties containing low amounts	Alcohol
Whole grains		
Nuts		
Fish		

A short summary of individual considerations and the main science advice from the NNR Committee is summarized in Table 24. The specific conclusions and advice, which are also summarized in the corresponding summaries in this report, build on the corresponding NNR2023 food group background papers as well as the NNR2023 background papers on food and diet intake, burden of diseases and environmental sustainability.

The main principle, when developing the NNR2023 recommendations, is that the effects on health are initially and primarily assessed. Then, the effect of food consumption on environmental impact is assessed and integrated. No recommendation has been adjusted by environmental impact in such a way that it is in conflict with the health-based recommendations.

All quantitative recommendations are based on health effects. The direction for further changes in food consumption due to environmental impact is clearly stated. It is up to the national authorities in the eight countries to define further quantitative recommendations which are in accordance with described directions for change due to environmental impact.

As guided by the NNR2023 Steering Committee and the NNR2023 project description, no exact quantitative recommendation is set based on environmental impact, rather a framework for integrating environmental impact of food consumption has been described.

We expect all countries to follow this NNR2023 framework and define ambitious quantitative environment-based recommendations to achieve more environment-friendly recommendations, such as the most recent Danish FBDGs (Ministry of Food, 2021). Even more ambitious initiatives would be in line with the NNR2023 framework, international obligations and relevant declarations from Nordic Council of Ministers.

Adults in the general population are the target for the food based dietary guidelines in Table 24 unless otherwise stated.

Table 24 Science advice for food groups for adults

Food group	Health effects of foods on chronic diseases not attributed to specific nutrients	Health effects of foods based on nutritional adequacy and effects of specific nutrients	Environmental impacts of foods consumed	Advice to authorities in Nordic and Baltic countries
Beverages	A moderate intake of coffee may reduce the risk of some cancers. High intake of unfiltered coffee may increase LDL-cholesterol levels. High SSB consumption probably increases risk of obesity, CVD, type 2 diabetes and dental caries.	Negative health effects of caffeine more than 400 mg/d. SSB consumption displaces nutrient-dense foods and may contribute to excess energy and added sugars intake.	The high coffee and SSB consumption can contribute to a higher total environmental footprint in the Nordic and Baltic diet and consumption should therefore be limited. High-quality tap water should be the preferred choice before SSB, LNCSB and bottled water.	Moderate consumption of filtered coffee (about 1-4 cups/day) and tea may be part of a healthy diet. The total consumption of caffeine from all sources should be limited to 400 mg caffeine/day. For children, a safe level of caffeine intake is 3 mg per kg body weight per day. Consumption of unfiltered coffee and SSB should be limited. High-quality tap water should be the preferred choice of beverage.
Cereals	Intake of at least 90 grams/day (dry weight) of whole grains (including whole grains in products), reduces the risk of CVD, CRC, T2D and all-cause mortality, with likely further benefits of higher intakes.	Contribute with energy, protein, dietary fibre and many essential nutrients, such as thiamin, folate, vitamin E, iron, and zinc.	Due to the low climate impact of cereals and cereal-based foods, rice being an exception, they are key foods in the transition to an environment-friendly diet.	It is recommended to have an intake of at least 90 grams/day of whole grains (including whole grains in products), with likely further benefits of higher intakes. Whole-grain cereals other than rice should preferentially be used.
Vegetables, fruits, berries	High consumption (500-800 grams/day) reduces the risk of several cancers, CVD, all-cause mortality.	Contribute with many essential nutrients, such as dietary fibre, vitamin C, vitamin E, vitamin K, folate, and potassium. Cruciferous vegetables provide calcium, and leafy green vegetables provides, iron, zinc, calcium, magnesium, carotenoids.	Vegetables fruits and berries have in general low climate and environmental impact/footprints per weight unit. Environmental impacts are mainly related to pesticide use and impacts on biodiversity, locally and globally. Fruits and vegetables that store well will reduce waste and thereby reduce negative impacts.	It is recommended to consume a variety of vegetables, fruits, and berries, 500-800 grams, or more, per day in total. A variety of different types of both vegetables and fruits (including berries) should be consumed, with emphasis on dietary fibre contribution (potatoes and pulses are not included). Limit intake of products prepared with added/free sugars. Please refer to separate recommendation on fruit juice.
Potatoes	Not sufficient evidence to inform a quantitative FBDG	Common staple food, contribute with fibre and some essential nutrients. Negative health effects of potato products with added salt and fat.	The environmental impacts are among the lowest among food products, supporting potatoes as part of a plant-based healthy diet.	Potatoes can be part of a healthy and environment-friendly diet. Potatoes should be included as a significant part in the regular dietary pattern in the Nordic and Baltic countries. Intake of boiled or baked potatoes and potatoes prepared with low content of fat and salt should be preferred. Intake of deep-fried potatoes should be limited.

Fruit juices	Not sufficient evidence to inform a quantitative FBDG.	Contributes with energy and many essential nutrients. May contribute with fibre.	Climate and environmental impact of fruit juice depend on the fruits and berries they contain, and climate impact is generally low.	Low to moderate intake of fruit juice may be part of a healthy diet. Intake of fruit juice should be limited for children.
Pulses	Intake of pulses may protect against cancer and all-cause mortality. Not sufficient evidence to inform a quantitative FBDG.	Contribute with protein, fibre and many essential nutrients such as folate, potassium, magnesium, iron, zinc, and thiamine, as well as bioactive compounds such as phytochemicals.	Pulses have low climate impact while environmental impacts vary depending on production method and production site.	Pulses should be included as a significant part in the regular dietary pattern in the Nordic and Baltic countries. Pulses are important providers of nutrients such as dietary fibre, protein, iron and zinc.
Nuts and seeds	Reduced risk of CVD from intake of 20-30 grams nuts/day.	High nutrient density. Contribute with unsaturated fatty acids, protein, fibre and micronutrients.	Nuts and seeds have a low GHG emissions. However, when increased consumption is achieved, more detailed recommendations are warranted to avoid the potential water stress and biodiversity loss associated with nut and seed consumption.	It is recommended to consume 20-30 grams nuts per day. It is also recommended to include seeds in the diet due to the nutrient content; however, evidence for a certain quantity is not available. Nuts and seeds are important in plant-based diets as they have low GHG emissions and high nutrient density.
Fish and seafood	Intake of 300-450 grams fish/week (of which at least 200 grams fatty fish/week) reduces risk of CVD, Alzheimer's disease, cognitive decline, and all-cause mortality.	Contribute to n-3 fatty acids and essential nutrients such as protein, vitamin D, vitamin B_{12} and iodine.	Fish and seafood from sustainably managed farms and wild stocks should be prioritized and consumption of species with high environmental impact should be limited.	It is recommended to consume 300–450 grams fish/week (ready-to-eat or cooked weight), of which at least 200 grams/week should be fatty fish. It is recommended to consume fish from sustainably managed fish stocks.
Red meat	Intake above 350 grams/week increases the risk of CRC. Intake of processed meat increases risk of CRC.	Contributes with many essential nutrients, such as protein, iron and vitamin B_{12} but also a source of saturated fatty acids, and processed meat is a source of sodium.	High environmental impact. The high consumption of red meat is the most important contributor to GHG emissions from the diet in the Nordic and Baltic countries. Negative environmental impact is related to methane emissions from ruminants, and feed which contribute through fertilizer, pesticide, water and land use and thereby reduced biodiversity. Positive environmental impact may be related to grazing and biodiversity. GHG emission from pigs is lower than ruminants but there are environmental issues related to the feed production and manure management.	For health reasons, it is recommended that consumption of red meat from cattle, sheep, goats and pigs (including red meat in products and processed foods) should be low and not exceed 350 grams/week ready-to-eat (cooked) weight. Processed red meat should be as low as possible. For environmental reasons the consumption of red meat should be considerably lower than 350 grams/week (ready-to-eat weight). The choice of meat should comply with the recommendations for fatty acids. The reduction of red meat consumption should not result in an increase in white meat consumption. To minimize environmental impact, meat consumption should be replaced by increased consumption of plant foods, such as legumes and fish from sustainably managed stocks.
White meat (poultry)	Not sufficient evidence to inform a quantitative FBDG. Intake of processed meat increases risk of CRC.	Contributes with many essential nutrients, such as protein, iron and vitamin B_{12}.	In general, lower environmental impact across many environmental metrics compared to red meat. Negative environmental impact is related to feed production and manure management. Due to negative environmental impacts, it is not desirable to increase white meat consumption from current levels.	It is recommended that consumption of processed white meat should be as low as possible. To minimize environmental impact, consumption of white meat should not be increased from current levels, and may be lower. Instead, meat consumption should be replaced by increased consumption of plant foods, such as legumes and fish from sustainably managed stocks.

Milk and dairy	Moderate consumption may reduce risk of CRC. High consumption of high-fat milk may increase risk of CVD.	Contributes with many essential nutrients, such as protein, calcium, iodine, riboflavin and vitamin B_{12}.	In general, dairy, especially concentrated products such as hard cheese, is associated with high environmental impact. The high consumption of milk and dairy is an important contributor to GHG emissions from the diet in the Nordic and Baltic countries. Negative environmental impact is related to methane emissions from the enteric fermentation of ruminants. Feed contributes through fertilizer, pesticide, water and land use, and thereby reduced biodiversity. Positive environmental impact is related to grazing and biodiversity.	Intake of between 350 ml to 500 ml low fat milk and dairy products per day is sufficient to meet dietary requirements of calcium, iodine and vitamin B_{12} if combined with adequate intake of legumes, dark green vegetables and fish (varies among different species). The range depends on national fortifications programs and diets across the Nordic and Baltic countries. If consumption of milk and dairy is lower than 350 gram/day, products may be replaced with fortified plant-based alternatives or other foods.
Eggs	Not sufficient evidence to inform a quantitative FBDG.	Contributes with all essential nutrients except vitamin C.	Egg consumption is associated with lower GHG emissions than meat, but feed production demands land and may contribute negatively to biodiversity.	A moderate intake of egg may be part of a healthy and environment-friendly diet.
Fats and oils	Not sufficient evidence to inform a quantitative FBDG.	Vegetable oils contribute with essential fatty acids and some fat-soluble vitamins.	A shift from animal to plant-based fats it is recommended to contribute to lower GHG emissions and it is recommended to avoid oils that contribute to deforestation.	It is recommended to consume at a minimum of 25 g/day vegetable oil (or similar amounts of fatty acids from whole foods) considering a sufficient intake of ALA (minimum of 1.3 g/day per 10 MJ/day) and limiting the consumption of butter and tropical oils.
Sweets	High intake of sweets, including other sugary foods, as well as SSB increases risk of chronic metabolic diseases, reduces diet quality and increases risk of caries.	Sweets, cakes and biscuits contribute to high energy intake of sugar and fat.	Even though the GHG emission from sugar production is low, the high consumption of the food group contributes to the relatively high GHG emissions in the Nordic countries. Sweets also contribute to decreased biodiversity by land use change and intensive large-scale cropping systems with low diversity.	Limiting the consumption of sweets and other sugary foods is recommended.
Alcohol	Intake increases risk of several cancers and total mortality.	High intake reduces diet quality.	The consumption of alcoholic beverages contributes to negative environmental impact.	No safe lower limit for alcohol consumption has been established. For children, adolescents and pregnant women abstinence from alcohol is advised.
Dietary patterns	Healthy dietary patterns are associated with beneficial health outcomes, such as reduced risk of CVD, T2D, obesity, cancer, bone health, and premature death.	Healthy dietary patterns are often micronutrient dense, including high intake of unsaturated fats and fibre, and low intake of saturated fats, added/free sugars and sodium.	Transitioning towards a healthy dietary pattern, i.e., a more plant-based dietary pattern, will reduce several negative environmental effects of the diet. However, the environmental impact of dietary patterns depends on the specific foods included. Limiting food waste and overconsumption is important for limiting the environmental impact.	A dietary pattern, characterized by high intakes of vegetables, fruits, whole grains, fish, low-fat dairy, and legumes and low in red and processed meats, sugar-sweetened beverages, sugary foods, and refined grains, would benefit health and will lower the climate impacts. Food group-specific considerations are essential to simultaneously reduce the environmental impacts and achieve nutritional adequacy of dietary patterns.

Abbreviations: CVD, cardiovascular disease; CRC, colorectal cancer; GHG, greenhouse gas; LNCSB, low- and no-calorie sweetened beverages; SSB, sugar-sweetened beverages; T2D, type 2 diabetes.

Processing of foods

Many of the FBDGs summarized in Table 24 are related to food processing. In general, food processing is the transformation of agricultural and fish products into human foods. Some kind of food processing is needed to make most foods edible and accessible, while extensive food processing may have a role in overeating and overnutrition. Food processing takes place at home in the kitchen and by the food industry.

Many terms have been used to describe the degree and type of processing of foods such as whole foods, minimally processed foods, unrefined foods, unprocessed foods, processed foods, refined foods, highly processed foods and ultra-processed foods.

In general, a processed food is any food that has been altered in some way during preparation. Historically, the main food processing techniques have been heating, drying, fermenting, smoking, milling, canning or salting. Some foods need processing to make them safe, such as milk, which needs to be pasteurised to inactivate harmful bacteria. Salt, sugar and fat are often added to processed foods to make their flavour more appealing and savoury, to extend their shelf life, and to improve the food's structure.

Consumption of processed foods, especially highly processed foods, may contribute to intakes higher than the recommended amounts of sugar, salt, total and saturated fat and energy and lower amounts of fibre and micronutrients.

The NNR2023 report includes a number of recommendations related to food processing (see respective nutrient and food group summaries for more details), such as:

- Breastfeeding should be preferred compared to infant formulas
- Consumption of SSB and energy drinks should be limited
- Whole grain cereal products should preferentially be used instead of refined cereal products
- Fruit and vegetable products with added sugar should be limited
- Intake of deep-fried potatoes and potato products with added fat and salt should be limited
- High intake of fruit juices should be avoided
- Intake of processed red and white meat (poultry) should be limited
- Milk and dairy products with high amounts of saturated fat should be limited

- Some vegetable oils should be preferred over butter and butter-mixes, hard margarine and tropical oils.
- Sweets, confectioneries and other sugary foods should be limited
- Advice on selecting more whole foods instead of processed foods for environmental reasons
- A dietary pattern with limited amounts of added total fat, saturated fat, salt and sugar is recommended
- In addition to these FBDGs, several DRVs also have high relevance for food processing, including limitation of trans fatty acids, saturated fatty acids, salt and added sugar.

The background paper by Juul and Bere (2023) concludes that there are increased risks for several health outcomes with high intake of so-called ultra-processed foods. Despite the observed association between ultra-processed foods as a category and health outcomes, the NNR2023 Committee decided not to formulate any specific recommendations on ultra-processed foods. NNR2023 includes a number of recommendations related to specific types of processed foods (see above). The NNR Committee's view is that the current categorization of foods as ultra-processed foods does not add to the already existing food classifications and recommendations in NNR2023. These FBDGs and DRVs greatly overlap with many aspects of ultra-processed foods. In addition, the Nova classification of ultra-processed foods also includes many food products which are not associated with any apparent adverse health effect. The decisions not to give specific guideline on ultra-processed foods is in line with the FBDGs in USA (Dietary Guidelines Advisory Committee, 2020; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020), Canada (Health Canada, 2019) and most European countries (FAO, 2023). Some countries, like Brazil (Ministry of Health of Brazil, 2015), Israel (Israeli Ministry of Health, 2019) and Malaysia (NCCFN, 2021), as well as the American Heart Association (Lichtenstein et al., 2021), have decided to include ultra-processed foods in their FBDGs.

NUTS, FATS AND OILS

- Increased intake of nuts supported both by effects on health outcomes and environmental footprint.
- Moderate intake of fats and oils mainly due to nutrient adequacies and low environmental impact.

NUTRIENTS

NUTRIENTS

Summaries for deriving DRVs for nutrients

The sections below summarize the evidence for setting DRVs for all the nutrients considered in NNR2023. The text on dietary intakes is mainly based on the background paper by Lemming and Pitsi (2022). The text in the sections on main functions, indicator for recommended intake, main data gaps, and deficiencies and risk groups are based on the corresponding nutrient background papers. All nutrient backgrounds papers are clearly cited to credit all authors. As described in this report, qualified systematic reviews are the main fundament for assessment of evidence. All qualified systematic reviews included in each of the nutrient summaries are listed in Table 1 and Appendix 2.

While the recommendations are mainly based on the corresponding nutrient background papers (Table 6 and 7) as well as qualified systematic reviews (Table 1), the NNR2023 Committee has the sole responsibility for the text in the nutrient sections, the principles, methodology, calculations and the final setting of all DRVs. All final DRVs were set unanimously by the NNR2023 Committee.

For each nutrient, the setting of DRVs is summarized in a graphical abstract. All DRVs in the graphical abstracts refer to the age group 25-50 years. For information about scaling to other life-stage groups, please refer to table 12–15 and 17–20 and appendix 5.

Nutrient intakes should not be interpreted as absolute; rather, they are estimates with uncertainty, and depend on factors such as food consumption, survey methods, reporting errors, countries' food databases, calculation procedures, and similar. The range of estimated average intakes, excluding intake from dietary supplements, in the Nordic and Baltic countries is given in the text. Sources for nutrient intakes are mainly based on Nordic and Baltic food databases (Lemming & Pitsi, 2022).

OVERVIEW OF NUTRIENTS

Fluid and water balance
Energy
Fat and fatty acids
Carbohydrate
Dietary fibre
Protein
Vitamin A
Vitamin D
Vitamin E
Vitamin K
Thiamin (vitamin B1)
Riboflavin (vitamin B2)
Niacin (vitamin B3)
Pantothenic acid (vitamin B5)
Vitamin B6
Biotin (vitamin B7)
Folate (vitamin B9)
Vitamin B12
Choline
Vitamin C
Calcium
Phosphorus
Magnesium
Sodium
Potassium
Iron
Zinc
Iodine
Selenium
Copper
Chromium
Manganese
Molybdenum
Fluoride
Antioxidants and phytochemicals

Fluid and water balance

DIETARY INTAKE

- H_2O in beverages and foods

BIOMARKER

Indicator of recommended intake

- No single qualified indicator can be identified
- Plasma osmolality range of 285–295 mOsm/kg is considered normal

Indicator of adverse effect

- Plasma osmolality below 285 mOsm/kg is considered too low and indicates too high fluid intake

HEALTH EFFECT

Beneficial effects

- Essential nutrient
- Required for optimal fluid balance, which is a prerequisite for cellular homeostasis and blood pressure regulation and other physical functions, and transfer of for example nutrients

Adverse effects of high intake

- Water retention in the body can cause hypervolemia, incl. high blood pressure and impairment of the heart and respiratory system

	Females	Males
AI (L/d)	2.0	2.5

For more information about the health effects of dietary intake of fluids and water balance, please refer to the background paper by Per Ole Iversen and Mikael Fogelholm (2023).

Dietary intake. The main dietary sources are drinking water, beverages, and solid foods. Drinking water and beverages often provide between 700 to 1400 mL/day of water. Estimated intake from solid foods is on average 600—800 mL per day, with water content in food items varying from about 5% in nuts to 90% or more in many fruits and vegetables (Guelinckx et al., 2016).

Main functions. Water is an essential nutrient needed to maintain normal physiological functions (e.g., blood pressure, pH, internal body temperature) and health (Iversen & Fogelholm, 2023). It is needed to transport essential substances (e.g., oxygen, carbon dioxide, water, and glucose) to and from cells, regulate body temperature, provide structure to cells and tissues, and to help preserve cardiovascular function.

Indicator for recommended intake. Plasma osmolality in the range of 285 to 295 mOsm/kg (Iversen & Fogelholm, 2023).

Main data gaps. Limited data on drinking water intake in the Nordic or Baltic countries.

Deficiency and risk groups: Sick and frail older adults as well as those performing physical work/exercise, particularly at high ambient temperatures, may be at risk of becoming dehydrated. Overhydration, i.e., too much water for optimal body functions, may be seen as oedema or hyponatremia in certain conditions.

Recommendations. An AI is set to 2.0 L/day for females and 2.5 L/day for males 14 years or older, based on EFSA recommendations (EFSA, 2010b). The AI is set on the basis of total water intake including water from beverages and from food moisture under moderate ambient temperatures and physical activity levels (PAL 1.6). The AI is set to 0.8–1.0, 1.1–1.2, and 1.3, and 1.6 L per day for children aged 0.5–1, 1–2, 2–3, and 4–8 years, respectively. AI for 9–13-year-olds is set to 2.1 L for boys and 1.9 L for girls.

Energy

DIETARY INTAKE	BIOMARKER	HEALTH EFFECT
	Indicator for energy requirement • Weight stability and balance at healthy body weight and healthy growth	**Beneficial effects** • Energy is necessary for health, to cover energy expenditure in individuals with body weight, body composition and physical activity compatible with good health
• Foods including energy-giving nutrients, i.e., foods containing carbohydrates, lipids, proteins and alcohol		
	Indicator of adverse effect • Unstable weight. Overweight and obesity. Underweight. Insufficient and unhealthy growth at young age or in pregnancy	**Adverse effects of low/high intake** • Increased mortality rate and risk of chronic diseases with too low or high intake. Continuous too high intake leads to positive energy balance and surplus of adipose tissue

	Females	Males
Reference values for PAL 1.6 (MJ/d)	9	11.3

For more information about the health effects of dietary intake of foods including energy-giving nutrients, please refer to the background paper by Lieselotte Cloetens and Lars Ellegård (Cloetens & Ellegård, 2023).

Dietary intake. The average energy intake ranges from 6.5 to 11.2 MJ/d (Lemming & Pitsi, 2022).

Main functions. Energy is needed by all cells in the body. It is stored as chemical energy and metabolised to adenosine triphosphate (ATP) units of energy that are used for cellular functions in the body. This average energy intake should give energy balance for adults of healthy body weight and composition, and a positive energy balance or building of energy containing tissue in growing infants, children and adolescents as well as pregnant and lactating women (Cloetens & Ellegård, 2023). Energy in foods is largely in the form of carbohydrates and proteins (both approximately 16.7 kJ/g [4 kcal/g]), fats (37.7 kJ/g [9 kcal/g]), and dietary fibre (8 kJ/g [2 kcal/g]). The recommended intake of energy-yielding nutrients is expressed in intervals of E% with the sum of 100%. Alcohol also yields energy of 29 kJ/g (7 kcal/g), but is not included in the recommendation. The available energy from dietary fibre depends on the type and nature of the fibre.

The energy requirement of the body is determined by: The basal energy expenditure (BEE), proximately measured as resting energy expenditure (REE), which accounts for the major part of the energy requirement (up to 70-80% in adults) and is mainly based on 1) body fat free mass (FFM); 2) energy expenditure from physical activity level (PAL), which varies between 20-40%; and 3) diet induced thermogenesis (DIT), which is approximately 10% of the energy requirement (Cloetens & Ellegård, 2023; NASEM, 2023).

Additional energy intake and a positive energy balance is needed for tissue building i.e., in growth and tissue building for infants, children, adolescents and pregnant women, and for milk production in lactating women (Cloetens & Ellegård, 2023; NASEM, 2023). There is convincing evidence for a causal association between high BMI and risk for cardiovascular disease and type 2 diabetes (Cloetens & Ellegård, 2023; NASEM, 2023; WCRF/AICR, 2018b, f), as well as for an increased risk of cancer in oesophagus (adenocarcinoma), pancreas, liver, colon, breast (at postmenopausal age), endometrium and kidney. There is also probable evidence for an association between fatness in adulthood and lower risk for premenopausal breast cancer and between fatness in young adulthood and breast cancer in general (WCRF/AICR, 2018f).

Indicator for energy requirement. Weight stability and balance at healthy body weight and healthy growth (NASEM, 2023). Energy requirement covers energy expenditure in individuals with body weight, body composition and physical activity compatible with good health. In childhood, pregnancy and lactation, the energy requirement includes energy for growth and milk production.

Deficiency and risk groups. Frail older adults are at risk of low energy intake.

Main data gaps. Studies to evaluate body weight stability over time and methods to measure energy intake correctly, besides the doubly labelled water (DLW) method, are needed. Studies on energy requirements of different age groups are needed.

Dietary reference values. Reference energy requirements for adult females and males are estimated from updated weight and height data using the Henry equation (Henry, 2005) and a PAL value of 1.6 (Appendix 4). Reference heights and weights for children 0-5 years old and height data for those 6–17 years old are from five Nordic and Baltic countries (Juliusson et al., 2013; National Institute for Health Development, 2021; Pitsi, 2017; Salm et al., 2013; Saari et al., 2011; Tinggaard et al., 2014; Wikland et al., 2002). For 6–17-year olds, reference weights were calculated from the 50th percentile of BMI according to WHO growth reference curves for school-aged children and adolescents (de Onis et al., 2007). The reference body heights for adults are from seven recent Nordic and Baltic national dietary surveys (Abel & Totland, 2020; Amcoff et al., 2012; Grīnberga et al., 2020; Gunnarsdottir et al., 2022; Nurk et al., 2017; Pedersen et al., 2015; Valsta et al., 2018), and reference weights for adults are calculated to BMI = 23 kg/m^2.

The total energy requirement is 11.3 MJ/day for males and 9 MJ/day for females (PAL 1.6).

Fat and fatty acids

DIETARY INTAKE

- The quality of dietary fat (esp. the proportion of saturated to unsaturated fatty acids)
- Two fatty acids are essential, linoleic acid (n-6) and alpha-linolenic acid (n-3)

BIOMARKER

Indicator of recommended intake

- No qualified indicator can be identified

Indicator of adverse effect

- No qualified indicator can be identified

HEALTH EFFECT

Beneficial effects

- Partial replacement of saturated fat (SFA) with n-6 polyunsaturated fat (PUFA) improves plasma lipid profile, decreases the risk of cardiovascular disease (CVD) and improves glucose metabolism
- Long-chain n-3 PUFA (EPA and DHA) decrease the plasma concentration of triglycerides and when eaten as seafood it is associated with lower risk of CVD
- Biomarker concentrations of PUFA, both n-3 and n-6, is associated with reduced risk of type 2 diabetes

Adverse effects of high intake

- High intakes of PUFA may result in increased lipid peroxidation, impaired immune function, and increased bleeding tendency

Total fat	25-40 E%
Saturated fat	<10 E%
Monounsaturated fat	10-20 E%
Polyunsaturated fat	5-10 E%
of which n6/n3/ALA at least	3/1/0.5 E%
Trans fat	As low as possible

For more information about the health effects, please refer to the background paper by Kjetil Retterstøl and Fredrik Rosqvist (Retterstøl & Rosqvist, 2023).

Dietary sources and intake. The main sources of fat are oils and dietary fats, nuts, seeds, but also dairy and meat products, snacks, and confectionary. In the Nordic countries and Estonia, the average intake of fat varies between 34 and 39 E%. In Latvia and Lithuania, the intake is above 40 E%, because of different calculation procedures. The average intake of saturated fat in all countries is above the recommendation (Lemming & Pitsi, 2022).

Main functions. Fat is needed as a source of energy and essential fatty acids, and for the absorption of fat-soluble vitamins. A diet lower in total fat is associated with reductions in body weight compared to a diet higher in total fat in adults (Hooper et al., 2020b). Partial replacement of saturated fat (SFA) with n-6 polyunsaturated fat (PUFA), mainly linoleic acid, or whole grains/high-fibre carbohydrate-containing foods, improves blood lipid profiles, decreases the risk of coronary heart disease, and improves glucose-insulin homeostasis (Hooper et al., 2020a; Reynolds et al., 2022; Schwab et al., 2014; Snetselaar et al., 2020a; Wolfram et al., 2015). Intake of long-chain n-3 PUFA (EPA and DHA) decreases concentrations of triglycerides and is associated with lower risk of cardiovascular disease (Snetselaar et al., 2020a). Higher biomarker concentrations of PUFA intake, both n-3 and n-6 PUFA, are associated with lower risk of type 2 diabetes (Retterstøl & Rosqvist, 2023).

Interaction with other nutrients. Diets with total fat intake lower than recommended may compromise the intake and absorption of fat-soluble vitamins.

Indicator for recommended intake. There is no specific biological marker for recommended fat intake.

Main data gaps. There is a lack of studies on the associations between ruminant trans fatty acids and odd-chain fatty acids and risk of type 2 diabetes and cardiovascular disease. The potential impact of different types of dietary fats on musculoskeletal and mental health also warrants more investigation. A *de novo* NNR2023 qSR found that the evidence was limited and inconclusive regarding health effects of types of fatty acids and adverse cognitive outcomes, due to a lack of data (Nwaru et al., 2022). Another *de novo* NNR2023 qSR also found limited evidence for effects of supplementation of long-chain n-3 fatty acids during pregnancy, lactation or infancy on risk of asthma/wheeze, eczema/atopic dermatitis or allergy (Bärebring et al., 2022). More conclusive evidence for potential food source-specific effects of SFA is needed for FBDG.

Deficiency and risk groups. Diagnosed deficiency of the essential fatty acids linoleic acid (LA) and alpha-linolenic acid (ALA) in adults is rare. Reported cases have been associated with chronic gastrointestinal diseases or prolonged parenteral or enteral nutrition either without fat or very low in fat. Clinical symptoms of deficiency (skin changes, neurological symptoms and growth retardation) have been found in healthy new-born babies fed for 2 to 3 months with a diet low (<1 E%) in LA.

Recommendations. An extensive discussion on the recommendations for fats and fatty acids is described in the NNR2023 background review (Retterstøl & Rosqvist, 2023; Rosqvist & Niinistö, 2023). The recommendations from NNR2012 are kept unchanged. Recommendations for fat are set based on health effects, the need for essential fatty acids and the requirement of fat-soluble vitamins. Minimum requirements of PUFA for adults are not known and the estimates are based on threshold intake data from children. There is not enough available scientific evidence for setting a recommendation for the ratio of n-6 to n-3 PUFA.

Intake of SFA should be less than 10 E% in the general population. The intake of trans fats should be as low as possible and will be ensured by complying with total SFA intake below 10 E%. MUFA should contribute between 10–20 E% in the diet. The intake of n-6 and n-3 PUFA in total should give 5–10 E%, of which n-3 fatty acids should account for at least 1 E%. MUFA and PUFA should make up at least two thirds of the total fatty acids. The recommendation for essential fatty acids is 3 E%, of which at least 0.5 E% should be ALA.

Carbohydrate

DIETARY INTAKE	BIOMARKER	HEALTH EFFECT
	Indicator of recommended intake • No qualified indicator can be identified	**Beneficial effects** • Total carbohydrates: Diets with proportions of carbohydrates within 45-60 E% tend to be associated with reduced all-cause mortality among adults, particularly when the diets examined are of higher quality
• The quality of dietary carbohydrate is affected by the proportion of added or free sugar and the content of dietary fibre within the carbohydrate source		
	Indicator of adverse effect • No qualified indicator can be identified	**Adverse effects of high intake** • Added/free sugars: risk of developing chronic metabolic diseases and dental caries risk; should be as low as possible in the context of a nutritionally adequate diet • Increasing intake of added and free sugars leaves less room for healthy foods and micronutrients, which is especially important for those with low energy intake, such as children

Total carbohydrates	45-60 E% (including dietary fibre)
Added/free sugar	<10 E% (preferably lower)

For more information about the health effects, please refer to the background paper by Emily Sonestedt and Nina Øverby (Sonestedt & Øverby, 2023).

Dietary sources and intake. The main sources of carbohydrates are cereal products, vegetables, fruits, and berries, but also dairy products, snacks, and confectionery. Added and free sugars are mostly found in granulated sugar, honey, sweets, confectionary, sugar sweetened beverages, but also in juices, and all other sweetened food products (e.g., milk products, breakfast cereals, some types of baby foods etc.).

In the Nordic countries and Estonia, the average intake of carbohydrates varies between 42 and 48 E%. In Latvia and Lithuania, the intake is below 42 E%, because of different calculation procedures (Lemming & Pitsi, 2022).

Main functions. Dietary carbohydrates is a major source of energy. No beneficial health effects of carbohydrate intakes outside the current recommended range of 45-60 E% have been demonstrated. Intake of carbohydrates within this range tends to be associated with reduced all-cause mortality among adults, particularly when the diets examined were of higher quality (Sonestedt and Øverby 2023).

No consistent benefits on clinical outcomes have been demonstrated when changing the glycaemic index of a diet, and findings from prospective studies of diets characterized by glycaemic index or load are inconsistent. Strong evidence for an association between glycaemic load and endometrial cancer and type 2 diabetes were observed in two qualified systematic reviews (SACN, 2015; WCRF/AICR, 2018i).

Based on the risk of developing chronic metabolic diseases and dental caries, the EFSA Panel concluded that the intake of added and free sugars should be as low as possible within the context of a nutritionally adequate diet (EFSA, 2022). In a WHO guideline from 2015, it was recommended to limit free sugars intake to less than 10 E%. In addition, a conditional recommendation was set to limit the intake of free sugars to less than 5 E% (WHO, 2015). This was mainly based on effects on body weight in adults, and the latter with dental caries. EFSA (2022) found moderate evidence, based on RCTs, for a causal relationship between higher ad libitum intake of added and free sugars and risk of obesity and dyslipidaemia. The effect on body weight seems to be mediated mainly by changes in energy intake (EFSA, 2022; Hjelmesæth & Sjöberg, 2022; SACN, 2015; WHO, 2015).

Interaction with other nutrients Diets high in added and free sugars may compromise the intake of dietary fibre, vitamins, and minerals.

Indicator for recommended intake There is no specific biological marker for recommended total carbohydrate intake or added or free sugar intake.

Main data gaps. There is a lack of studies on carbohydrates and health effects in pregnancy. There is also a lack of a standardized definition for dietary sugars (free and added sugars) and a lack of long-term studies measuring the impact of reducing intake of free and added sugars (especially below 10 E%) on chronic metabolic diseases and surrogate outcomes. Because of the difficulties in measuring carbohydrate quality in observational studies, there is a need for further development and use of objective biomarkers.

Deficiency and risk groups. No risk group is identified regarding total available carbohydrate intake. The combinations of foods needed to achieve recommended intakes of key nutrients for ages 6 to 24 months leave virtually no remaining dietary energy for added and free sugars, apart from the very small amounts (less than 3 grams per day) already inherent in the foods used in modelling (Dietary Guidelines Advisory Committee, 2020).

Recommendations. An extensive discussion on the recommendations for carbohydrates is described in the carbohydrates review (Sonestedt & Øverby, 2023). Recommendations for adults and children above 2 years:
Carbohydrates should provide 45-60 E% (including energy from dietary fibre).
Intake of added and free sugars should be below 10 E%, and preferentially lower.

Foods and beverages with added and free sugars should be avoided in children below 2 years.

Dietary fibre

DIETARY INTAKE

- Main natural dietary fibres are cellulose, hemicellulose lignin, pectins and β-glucans. Others include oliogosaccharides and resistant starch

BIOMARKER

Indicator of recommended intake
- No qualified indicator can be identified

Indicator of adverse effect
- No qualified biomarker of adverse effects can be identified

HEALTH EFFECT

Beneficial effects
- Increased intake associated with lower all-cause mortality, lower risk of coronary heart disease, colorectal cancer, stroke and type 2 diabetes.
- May increase nutrient uptake and satiety

Adverse effects of high intake
- Can reduce digestibility of fats and proteins

RI (g/MJ/d)	Females	Males
	at least 3	at least 3

For more information about the health effects, please refer to the background paper by Harald Carlsen and Anne-Maria Pajari (Carlsen & Pajari, 2023).

Dietary sources and intake. The main sources of fibre are whole grain foods, fruits and berries, vegetables, nuts/seeds, and pulses. Of these, pulses is the food group containing the highest amount of dietary fibre. Additionally, several processed foods contain additives with fibre properties, including galactomannan from guar gum, alginates from seaweed, and methylcellulose (Gill et al., 2021). The average dietary fibre intake ranges from 16 to 26 g/d (Lemming & Pitsi, 2022).

Main functions. Dietary fibre contributes to swelling and delayed gastric emptying, leading to increased satiety and nutrient uptake in the small intestine. Dietary fibre, through the effect on swelling, viscosity and bulking caused by mixtures, can optimize nutrient uptake, but also decrease gastrointestinal transit time. Viscosity, caused primarily by soluble fibres such as β-glucans from oats and barley, can also lead to a less penetrable barrier close to the epithelial cells and delay uptake of nutrients. This process leads to a reduced postprandial rise in glucose and lipids. Reduced uptake of bile acids molecules by β-glucans is now accepted as the main mechanism for the blood cholesterol lowering effects of fibre (Carlsen & Pajari, 2023). A considerable body of evidence over many years consistently reports on beneficial health effects of a higher intake of dietary fibre. The strongest evidence is related to all-cause mortality followed by coronary heart disease and colorectal cancer (Reynolds et al., 2019). Evidence for a protective effect against stroke and type 2 diabetes is judged to be weaker, but still significant. Effects on body weight is judged as significant, but modest. A *de novo* qSR for NNR2023 found no clear evidence relating high intakes of dietary fibre to growth or bowel function in young children living in affluent countries, mainly due to a limited number of studies (Dierkes et al., 2023).

An adequate intake of dietary fibre reduces the risk of constipation and contributes to a lower risk of colorectal cancer and several other chronic diseases such as cardiovascular disease and type-2 diabetes. Moreover, fibre-rich foods help maintain a healthy body weight. Intake of appropriate amounts of dietary fibre from a variety of foods is also important for children (Carlsen & Pajari, 2023).

Interaction with other nutrients. May increase nutrient uptake, and may reduce fat and protein digestibility. Phytate content related to dietary fibre content (depending on the source) can decrease availability of iron and zinc, see the respective summaries in the report.

Indicator for recommended intake. No biomarker for intake.

Main data gaps. There is a lack of studies investigating health effects of high fibre intake in small children.

Deficiency and risk groups. People with very low carbohydrate intake.

Dietary reference values. An extensive discussion on the recommendations for dietary fibre is covered in the NNR2023 background review (Carlsen & Pajari, 2023). Recommended intake for adults: at least 3 g/MJ. Based on the reference energy intake, this corresponds to at least 25 g/d for females and 35 g/d for males. Whole grain cereals, whole fruits, berries, vegetables, legumes/pulses, and nuts should be the major sources.

Protein

DIETARY INTAKE	BIOMARKER	HEALTH EFFECT
• Protein intake • Protein quality (protein digestibility and availability of indispensable amino acids)	**Indicator of recommended intake** • Physiological requirements are based on nitrogen-balance studies as no good biomarker for protein status exists	**Beneficial effects** • Limited/suggestive and difficult to separate from effect of other nutrients in protein-rich foods
	Indicator of adverse effect high intakes • Indicator is lacking	**Adverse effects of high intakes** • Some biomarkers of kidney function are affected

	Females	Males
AR (g/kg/d)	0.66	0.66
RI (g/kg/d)	0.83	0.83
RI (E%)	10-20	10-20

For more information about the health effects, please refer to the background paper by Ólöf Guðný Geirsdóttir and Anne-Maria Pajari (Geirsdóttir & Pajari, 2023).

Dietary sources and intake. The main sources of animal protein are meat, fish, milk, and eggs, and the main sources of plant protein are cereals, legumes, nuts, and seeds. Fungi (in the form of mycoprotein) are also a source of non-animal protein. In the Nordic countries and Estonia, the average intake of protein varies between 15 and 19 E%. In Latvia and Lithuania, the intake is also between the range, despite of different calculation procedures (Lemming & Pitsi, 2022).

Main functions. Protein is an essential nutrient needed in the human body for growth and maintenance. Proteins provide essential amino acids, nitrogen, and energy. Severe protein deficiency results in oedema, muscle weakness, and changes to the hair and skin. Protein deficiency is often concomitant to deficiency of energy and other nutrients; however, protein-energy malnutrition is uncommon in the Nordic and Baltic countries.

The health effects of protein intake are difficult to separate from effects of other nutrients or ingredients in protein-rich foods. The results are inconclusive or seem neutral for the association between total protein intake and obesity, cardiovascular disease, glycaemic control, bone health, kidney function, oesophageal cancer and prostate cancer in adults (Geirsdóttir & Pajari, 2023). A *de novo* SR for NNR2023 concluded that a high-protein diet in infancy was suggested as a risk factor for childhood overweight and obesity (Arnesen et al., 2022). There was probable evidence for a causal relationship between total and animal protein intake and higher BMI in children up to 18 years of age. Evidence for substituting animal protein with plant protein to reduce the risk of cardiovascular disease mortality and type 2 diabetes incidence is *limited but suggestive*, as evaluated in another de novo SR (Lamberg-Allardt et al., 2023b). Results from studies on protein sources and mortality are mixed.

Interaction with other nutrients and food components. Unprocessed plant protein sources often contain phytates, tannins, and protease inhibitors which interfere with the digestion of plant proteins, making them less well-digestible than animal-source proteins (Sarwar Gilani et al., 2012). In practice, the differences in quality between proteins might be less critical in diets containing a variety of protein sources (Lemming & Pitsi, 2022).

Indicator for recommended intake. While some biomarkers are used in the clinical setting, there is no specific biological marker to evaluate optimal protein status. On a long-term basis, intake and losses of nitrogen should be equal in weight-stable, healthy adults. Nitrogen-balance studies have been used to establish DRVs.

Main data gaps. The underlying assumptions to the nitrogen-to-protein conversion factor of 6.25 traditionally applied for measuring protein content in foods may lead to errors in the estimation. Evidence for associations between protein intakes and health outcomes are limited or suggestive. Studies are needed on both subjects.

Deficiency and risk groups. Proteins are required during active growth in late pregnancy, lactation and childhood. Older adults are at higher risk of inadequate protein intakes (Geirsdóttir & Pajari, 2023). Individuals with chronic kidney disease are sensitive to high protein intakes (IOM, 2005; WHO/FAO/UNU, 2007).

Dietary reference values. Based on the available evidence of nitrogen balance and isotope tracer studies, AR and RI were set to 0.66 g/kg and 0.83 g/kg body weight per day for adults, respectively (EFSA, 2012a). This protein intake should also adequately meet the requirements for essential amino acids. The recommended intake range is 10–20 E%. For planning purposes, 15 E% can be recommended. With energy intake below approximately 8 MJ (e.g., at low body weight, low physical activity levels or during intentional weight loss), the protein E% should increase accordingly to ensure that the AR and RI is met. The AR and RI based on nitrogen balance is the same for older adults. However, recent studies have found that intakes above the RI may be optimal to prevent decline of physical functioning (Geirsdóttir & Pajari, 2023). Therefore, the recommended range for older adults is 1.2–1.5 g/kg body weight, approximately 15–20 E%. For older adults, 18 E% is recommended for planning and assessment (Geirsdóttir & Pajari, 2023). For young children below 2 years of age, it is advisable not to exceed a range of 10–15 E% protein.

Dietary proteins of animal origin or a combination of plant proteins from, for example, legumes and cereal grains, give a good distribution of essential amino acids. Replacing a part of animal proteins in the current Nordic diet with plant proteins would provide enough protein and essential amino acids at recommended protein intake levels (Geirsdóttir & Pajari, 2023).

Vitamin A

DIETARY INTAKE

- All-*trans*-retinol (retinol)
- Molecules with the biological activity of retinol (retinal, retinoic acid, retinyl esters)
- Pro-vitamin A carotenoids (precursors of retinol)

BIOMARKER

Indicator of recommended intake

- The required intake to maintain liver retinol concentrations of 20 µg (0.07 µmol) retinol/g liver

Indicator of adverse effect

- Hypervitaminosis A (>1 µmol retinol/g liver)

HEALTH EFFECT

Beneficial effects

- Involved as retinal in nighttime vision as part of the photo pigment rhodopsin in the eye
- Involved in the systemic maintenance of the growth and integrity of cells in body tissues through the action of retinoic acid

Adverse effects of high intake

- Nausea, vomiting, skin disorders, liver damage
- Teratogenicity

	Females	Males
AR (RE/d)	540	630
RI (RE/d)	700	800

For more information about the health effects, please refer to the background paper by Thomas Olsen and Ulf H. Lerner (Olsen & Lerner, 2023)

Dietary sources and intake. Vitamin A is an essential fat-soluble vitamin that refers to several precursor and bioactive molecules. Precursors include all-*trans* retinol and pro-vitamin A carotenoids such as β-carotene. Vitamin A can be obtained from both animal and plant sources in the diet. In animal tissues, vitamin A exists predominantly as retinyl palmitate (a retinyl ester) whereas in plants only in the form of precursor compounds such as β-carotene (Olsen & Lerner, 2023). We convert all sources of vitamin A into a single unit with the term 'retinol equivalents' (RE). 1 RE is equal to: 1 µg of dietary or supplemental preformed vitamin A (retinol), 2 μg of supplemental β-carotene, 6 μg of dietary β-carotene, 12 μg of other dietary provitamin A carotenoids (e.g., α-carotene and β-cryptoxanthin) (Olsen & Lerner, 2023). Foods rich in retinol include offal, meat, dairy products and eggs. Foods rich in β-carotene include vegetables and fruits, such as carrots, dark green leafy vegetables, red peppers, and melons (EFSA, 2015a). The average vitamin A intake ranges from 600 to 1500 RE/d (Lemming & Pitsi, 2022).

Main functions. Vitamin A acts through nuclear receptors in target cells. Activation of nuclear receptors requires that vitamin A is converted to all-*trans*-retinoic acid (ATRA). Vitamin A is involved in the visual cycle in the retina as part of the photopigment rhodopsin in the eye, where 11-cis retinal is the major bioactive component crucial for rhodopsin formation, and in the systemic maintenance of growth and integrity of cells in body tissues (EFSA, 2015a; Olsen & Lerner, 2023).

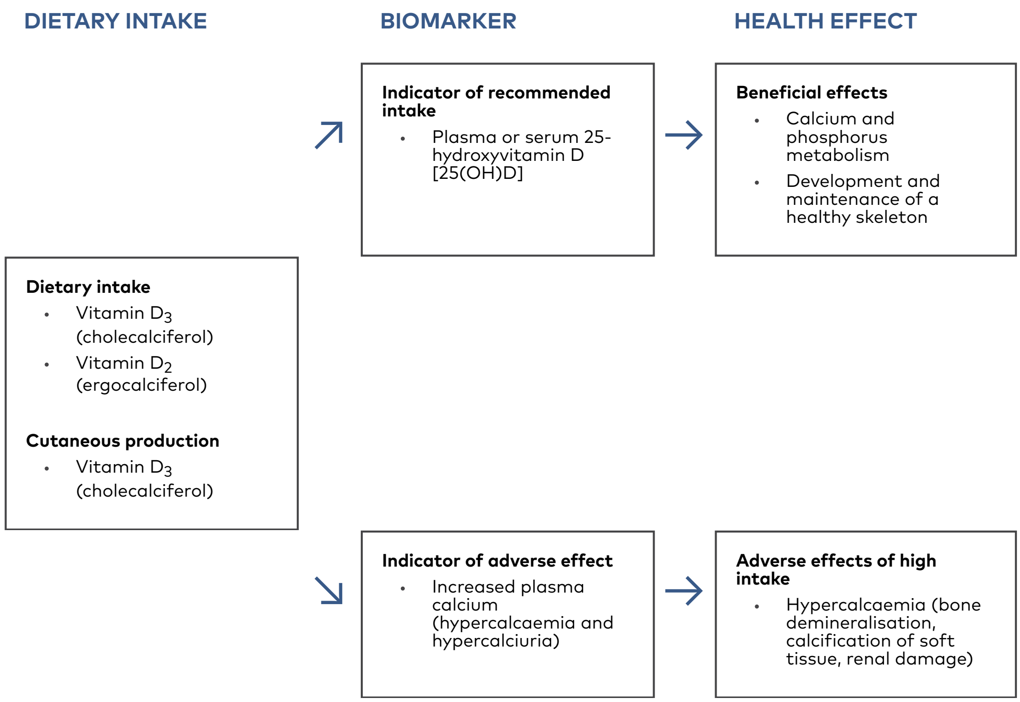
Indicator for recommended intake. The required intake to maintain liver retinol concentrations of 20 μg (0.07 μmol) retinol/g liver (EFSA, 2015a; Olsen & Lerner, 2023).

Main data gaps. There is a lack of simple screening tests to measure sub-clinical deficiency as plasma retinol is kept under tight homeostatic control. There is uncertainty in the variation of average requirements across populations. Little data are available on excessive intakes among children and adolescents. There is lack of consensus regarding the role that vitamin A may have on the skeleton. Harmonization in estimating the conversion rates of β-carotene to retinol is missing (Olsen & Lerner, 2023).

Deficiency and risk groups. Definitions of deficiency vary. Vitamin A deficiency is defined as liver stores of <0.07 or <0.10 μmol retinol/g liver depending on the publication, or alternatively serum/plasma retinol of <0.7 μmol/L. Clinical vitamin A deficiency is characterized by several ocular features (xerophthalmia) and a generalized impaired resistance to infection and increased infectious disease mortality (Olsen & Lerner, 2023).

Dietary reference values. Requirements and reference values for vitamin A are based on the required intake to maintain liver retinol concentrations of 20 μg retinol/g liver. The recommendations in NNR2012 were based on the factorial methods of IOM 2001 (IOM, 2001). EFSA also used the factorial method, but with more recent data on body/liver stores of vitamin A (EFSA, 2015a; Olsen & Lerner, 2023), and NNR2023 have updated this with Nordic body weights for setting recommendations. The following factors are multiplied to arrive at average requirements in adults that are in turn multiplied by a coefficient of variation (15 %) to yield final recommendations: target liver concentration (20 µg retinol/g), body/liver retinol stores ratio of 1.25, liver/body weight ratio of 2.4%, fractional catabolic rate of 0.7%, 1/efficiency of body storage, and reference body weight (see Appdenix 5). The RIs were set to 700 RE/day (females) and 800 RE/day (males). AR: 540 RE/day (females) and 630 RE/day (males).   The UL of vitamin A is 3,000 RE/day.

Vitamin D



	Females	Males
AR (µg/day)	7.5	7.5
RI (µg/day)	10	10

For more information about the health effects, please refer to the background paper by Magritt Brustad and Haakon Meyer (Brustad & Meyer, 2023).

Dietary intake. Vitamin D_3 (cholecalciferol) is a steroid-like molecule synthesised from 7-dehydro-cholesterol in the skin by ultraviolet B (UVB) light from the sun (wavelength 290-315 nm). The Nordic and Baltic countries are situated at latitudes (54–71°N) where the sun radiation is insufficient for part of the year for vitamin D_3 production in skin to occur. Food sources of vitamin D_3 are fish, especially fatty fish like salmon, trout, mackerel, and herring, and egg yolk. Some products (including milk products, butter and margarine) are fortified to variying degrees in most of the Nordic countries (Brustad & Meyer, 2023). The average vitamin D intake (not including dietary supplements) ranged from 4.3 to 13 µg /d, partly reflecting differences in fortification practices between the countries (Lemming & Pitsi, 2022).

Main functions. Vitamin D is an essential nutrient and a pro-hormone. It is first hydroxylated to 25-hydroxyvitamin D [25(OH)D] in the liver. Thereafter it is further hydroxylated to the active form of vitamin D, 1,25-dihydroxyvitamin D (calcitriol), predominantly in the kidneys but also in other tissues. The active form of vitamin D exerts its mechanism of action through the vitamin D receptor on cellular functions such as proliferation, differentiation, and immunity. Its roles in calcium and phosphorus metabolism, and in the development and maintenance of a healthy skeleton, are well documented.

Indicator for recommended intake. Circulating 25(OH)D is considered as the most reliable biomarker for vitamin D status in humans as it captures both dietary intake and cutaneous vitamin D-production. Based on available evidence there is a growing agreement that circulating 25(OH)D above 50 nmol/l corresponds to sufficient concentrations, and that less than 25–30 nmol/l indicates deficiency (Brustad & Meyer, 2023). Factors like UV exposure, skin pigmentation and clothing habits are some of the determinants of 25(OH)D concentration. Over the years, different approaches have been used to analyse the dose-response relationship between vitamin D intake and 25(OH)D concentration. The different approaches are described in the Appendix 7.

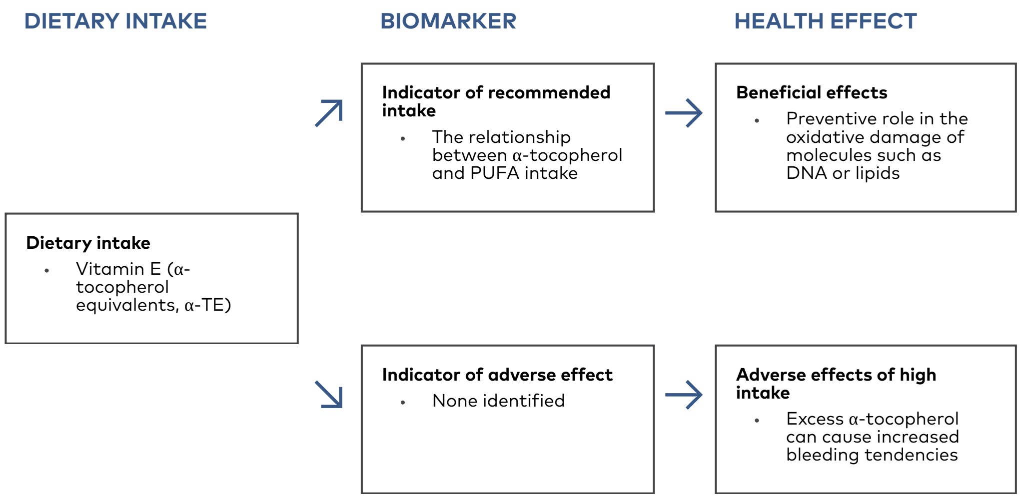
Main data gaps. Despite the growing number of RCTs, the interpretation of some RCTs regarding the health effects of vitamin D is complicated by the fact that they often involve other co-treatments such as calcium, besides, few studies are conducted on participants with deficient 25(OH)D concentrations, and there is a lack of well-designed RCTs on some suggested vitamin D related health outcomes. More knowledge on vitamin D status being a *result of,* more than a *cause of,* diseases and ill health, could have methodological implications for future study designs (Brustad & Meyer, 2023).

Deficiency and risk groups. Vitamin D deficiency leads to impaired mineralisation of bone due to an inefficient absorption of dietary calcium and phosphorus, and is associated with an increase in serum parathyroid hormone (PTH) concentration. Clinical symptoms of vitamin D deficiency manifest as rickets in children, and osteomalacia in adults. Skin pigmentation attenuates vitamin D production (Brustad & Meyer, 2023). Frail older adults, people with low sun exposure (e.g., due to institutionalisation) and people with dark skin pigmentation are at risk of vitamin D deficiency. People with restriction of fish products in their diets, such as vegans, are at risk of becoming vitamin D deficient unless consuming supplements or fortified foods.

Dietary reference values. There is convincing evidence for recommendations to be set to prevent the population from being vitamin D deficient defined as circulating 25(OH)D <30 nmol/l. There is an increasing body of evidence showing that there is no additional health benefit from increasing the 25(OH)D concentration above the suggested sufficient concentration at 50 nmol/l. Based on the totality of present available scientific evidence on vitamin D and health, the overall picture is in line with what was described in NNR2012. The body of evidence has increased due to the large research activity within this field. Thus, there is stronger certainty now to conclude that increasing the recommendations will not reduce disease risks in the population (Brustad & Meyer, 2023).

RI for adult females and males: 10 µg/day (≥75 years: 20 µg/day). AR is unchanged from NNR2012 (7.5 µg/day). The RI considers some contribution of vitamin D from outdoor activities during the summer season (late spring to early autumn), and this is compatible with normal, everyday life and is also in line with recommendations on physical activity. For people with little or no sun exposure, an intake of 20 µg/d is recommended. The UL of vitamin D is 100 µg/day (Lamberg-Allardt et al. 2023a).

Vitamin E



	Females	Males
Provisional AR **(α-TE/d)**	8	9
AI (α-TE/d)	10	11

For more information about the health effects, please refer to the background paper by Essi Marjatta Hantikainen and Ylva Trolle Lagerros (Hantikainen & Lagerros, 2023).

Dietary sources and intake. Vitamin E is used as a generic term for molecules that possess the biological effects of α-tocopherol, of which four tocopherols (α-, β-, γ-, and δ) and four tocotrienols (α-, β-, γ-, and γ) occur naturally. In NNR2023, vitamin E activity is confined to α-tocopherol, since α-tocopherol is the only form that is recognized to meet human requirements. The naturally occurring α-tocopherol in foods is the stereoisomer RRR-α-tocopherol (Hantikainen & Lagerros, 2023). Food sources of vitamin E are vegetable oils, vegetable oil-based spreads, nuts, seeds, and egg yolk. The average vitamin E intake ranges from 7.8 to 14.9 mg /d (Lemming & Pitsi, 2022).

Main functions. Vitamin E is a fat-soluble antioxidant that also exhibits non-antioxidant activities, such as modulation of gene expression, inhibition of cell proliferation and regulation of bone mass. The main biochemical function of α-tocopherol is antioxidant activity. α-tocopherol is present in cell membranes. It has a significant preventive role in the oxidative damage of molecules such as DNA or lipids by neutralizing free radicals and breaking the chain reaction in the oxidation of PUFA. Increased dietary intake of PUFA decreases vitamin E concentrations in plasma and tissues (Hantikainen & Lagerros, 2023).

Indicator for recommended intake. EFSA found that there was insufficient data on markers of a-tocopherol intake/status/function to derive the requirement, and instead set AIs based on observed dietary intakes in healthy populations with no apparent α-tocopherol deficiency (EFSA, 2015g). The IOM based the adult requirements for vitamin E on prevention of hydrogen peroxide–induced haemolysis (Hantikainen & Lagerros, 2023; Raederstorff et al., 2015).

Main data gaps. Some of the evidence related to chronic diseases relies on findings from observational studies only, rather than RCTs. The effect of vitamin E can therefore not be fully separated from other nutritional factors. In addition, several studies suggest that besides α-tocopherol, other tocopherols and tocotrienols might have important functions and beneficial effects on various chronic disease outcomes.

Deficiency and risk groups. Vitamin E deficiency due to low dietary intake has not been described in healthy adults. However, deficiency can be caused by prolonged fat malabsorption due to genetic defects in lipoprotein transport or in the hepatic α-tocopherol transfer protein, or fat malabsorption syndromes, such as cholestatic liver disease or cystic fibrosis. Vitamin E deficiency is more frequently found in children, likely due to limited stores and rapid growth. Specifically, premature and very low birth weight infants are at risk and symptoms such as haemolytic anaemia, thrombocytosis, and oedema have been reported.

Dietary reference values. To estimate the AI for vitamin E the NNR Committee considered a basal vitamin E requirement (4 mg) plus a factor based on the dietary intake of PUFA. The recommended intake of PUFA is 5–10 E%. For calculating the AI, the lower value of this range is used (i.e., 5 E%). The estimated optimal vitamin E:PUFA ratio, which ranges from 0.4 to 0.6 mg RRR-α-tocopherol/g of PUFA in the diet, suggests that a ratio of 0.5 mg α-TE/g of PUFA can reasonably be used (Hantikainen & Lagerros, 2023; Raederstorff et al., 2015). The AI is set to 10 α-TE/day in females and 11 α-TE/day in males. The provisional AR is set to 8 α-TE/day (females) and 9 α-TE/day (males). The UL of vitamin E is 300 mg/d.

Vitamin K

DIETARY INTAKE

BIOMARKER

HEALTH EFFECT

Indicator of recommended intake
- No qualified indicator can be identified

Beneficial effects
- Enzyme cofactor of gamma-glutamyl carboxylase that catalyses carboxylation of glutamic acid residues in vitamin K-dependent proteins
- Hepatic vitamin K-dependent proteins are involved in coagulation

Dietary intake
- Phylloquinone (K_1)
- Menaquinones (K_2)

Gut microbial production
- Menaquinones (K_2)

Indicator of adverse effect
- No qualified indicator can be identified

Adverse effects of high intake
- No qualified adverse effect can be identified

	Females	Males
Provisional AR (µg/d)	50	60
AI (µg/d)	65	75

For more information about the health effects, please refer to the background paper by Arja Lyytinen and Allan Linneberg (Lyytinen & Linneberg, 2023).

Dietary sources and intake. Vitamin K is the collective term for fat soluble compounds with the common 2-methyl-1,4-naphtoquinone ring structure. It occurs in foods as phylloquinone (vitamin K_1; 2-methyl-3-phytyl-1,4-naphtoquinone) and menaquinones (vitamin K_2; multi-isoprenylquinones). Phylloquinone is plant-based, and sources are leafy green vegetables, and certain vegetable oils (soybean, canola/ rapeseed, olive oils) and fat spreads made from the oils. Menaquinones-5 through -13 have bacterial origin, and main sources are fermented foods, meat and dairy products. Sources of menaquinone-4 are meat and dairy products. Menaquinones are also produced by gut microbiota. Phylloquinone is regarded as the predominant form of vitamin K in Western diets (Lyytinen & Linneberg, 2023). For most of the Nordic and Baltic countries no intake data are available (Lemming & Pitsi, 2022).

Main functions. Vitamin K functions as an enzymatic cofactor in the gamma-carboxylation of vitamin K dependent proteins. Hepatic vitamin K dependent proteins are involved in coagulation. Extrahepatic vitamin K dependent proteins have a role e.g., in bone health and vascular calcification. The amount of vitamin K needed for optimal functioning of the different vitamin K dependent proteins is not known (Lyytinen & Linneberg, 2023).

Indicator for recommended intake. There are several biomarkers that reflect vitamin K intake; however, none are considered sufficient to be used alone, and no qualified indicator can be identified (Lyytinen & Linneberg, 2023).

Main data gaps. Data on vitamin K intake from nationally representative samples in Nordic and Baltic countries are missing. It is not known to which extent gut bacterial production plays a role in human physiology and health. In food composition databases, vitamin K content data mostly include only phylloquinone, not menaquinones. The relative bioavailability of different forms of vitamin K is poorly known. More research is also needed on dose-response, optimal level of gamma-carboxylation, relationships with health outcomes and what biomarker to choose (Lyytinen & Linneberg, 2023).

Deficiency and risk groups. Bleeding and haemorrhage are the classic signs of vitamin K deficiency affecting coagulation. Vitamin K deficiency in adults is rare and usually limited to people with malabsorption disorders or those taking drugs, e.g., vitamin K antagonists, which interfere with vitamin K metabolism. Breast-fed new-borns can develop vitamin K deficiency (Lyytinen & Linneberg, 2023).

Dietary reference values. For prevention of vitamin K deficiency bleeding, all new-born infants should receive vitamin K prophylaxis. In NNR2012, a provisional recommended intake of 1 μg phylloquinone/kg body weight per day was given for both children and adults. This level is maintained in NNR2023, since the limitations to set a DRV have not been resolved, and the data used to derive this are limited. A similar recommendation on adequate intake of phylloquinone has been set by EFSA (2017b). There is limited data available on the need for vitamin K during pregnancy and lactation and health outcomes during pregnancy, and the same AI as for adult women applies to pregnant and lactating women (EFSA, 2017b; Lyytinen & Linneberg, 2023). AI based on reference weights: 65 μg/day (females), 75 mg/day (males). Provisional AR, based on AI: 50 μg/day (females), 60 μg/day (males). Not sufficient data to derive UL.

Thiamin (vitamin B_1)

DIETARY INTAKE

- Free thiamin
- Thiamin diphosphate (ThDP)
- Thiamin monophosphate (ThMP)
- Thiamin triphosphate (ThTP)
- 2-(1-hydroxyethyl-thiamin) (HET)

BIOMARKER

Indicator of recommended intake

- Transketolase activity in erythrocytes
- Concentration of total thiamin in whole blood, serum and erythrocytes

Indicator of adverse effect

- No qualified biomarker of adverse effects can be identified

HEALTH EFFECT

Beneficial effects

- Coenzyme for enzymes involved in oxidative decarboxylation or transketolation

Adverse effects of high intake

- No qualified adverse effect can be identified

	Females	Males
AR (mg/d)	0.65	0.75
RI (mg/d)	0.9	1.1

For more information about the health effects, please refer to the background paper by Hanna Sara Strandler and Tor A. Strand (Strandler & Strand, 2023).

Dietary sources and intake. Thiamin (thiamine or vitamin B_1) is a water-soluble compound present in foods mainly as free thiamin and thiamin diphosphate (ThDP) (EFSA, 2016; IOM, 1998b; Strandler & Strand, 2023). Thiamin monophosphate (ThMP), thiamin triphosphate (ThTP) and 2-(1-hydroxyethyl-thiamin) (HET) are also present. Main sources in Nordic and Baltic diets are cereal products, meat and dairy products. The average thiamin intake ranges from 0.8 to 1.9 mg /d (Lemming & Pitsi, 2022).

Main functions. Free thiamin functions as the precursor for ThDP, which acts as a coenzyme for enzymes involved in carbohydrate and branched chain amino acid metabolism, and in energy-yielding reactions (EFSA, 2016; IOM, 1998b; Strandler & Strand, 2023).

Indicator for recommended intake. The enzymatic activity of transketolase in the erythrocytes and blood, serum and erythrocyte concentration of total thiamin can be used as biomarkers of thiamin intake (EFSA, 2016; IOM, 1998b; Strandler & Strand, 2023).

Main data gaps. Established cut-offs are lacking for the biomarkers (EFSA, 2016).

Deficiency and risk groups. Thiamin deficiency, which is uncommon, leads to beriberi with mostly neurological and cardiovascular manifestations. Wernicke-Korsakoff syndrome is a condition of severe brain function impairment caused by thiamin deficiency related to chronic alcohol abuse. People at risk of refeeding syndrome usually need additional thiamin administration for prevention of neurological, cardiac and pulmonary disturbances that can be fatal (Strandler & Strand, 2023).

Dietary reference values. Based on data from depletion–repletion studies in adults on the amount of dietary thiamin intake associated with erythrocyte transketolase activity coefficient <1.15 or with the restoration of normal activity, without a sharp increase in urinary thiamin excretion, AR is set to 0.072 mg/MJ for all life-stages. Assuming a BMI of 23 kg/m^2 and PAL 1.6, this corresponds to AR of 0.6–0.7 mg/day in adult females and 0.7–0.8 mg/day in males. RI: 0.1 mg/MJ (corresponding to 0.9 mg/day (females), 1.1 mg/day (males)). Not sufficient data to derive UL (EFSA, 2016; Strandler & Strand, 2023).

Riboflavin (vitamin B_2)

DIETARY INTAKE

- Riboflavin-5′-phosphate (flavin mononucleotide, FMN)
- Riboflavin-5′-adenosyl diphosphate (flavin adenine dinucleotide, FAD)
- Free riboflavin

BIOMARKER

Indicator of recommended intake

- Inflection point in mean urinary riboflavin excretion curve in relation to riboflavin intake
- Erythrocyte glutathione reductase activation coefficient (< 1.3 reflects adequate status, supporting evidence)

Indicator of adverse effect

- No qualified biomarker of adverse effects can be identified

HEALTH EFFECT

Beneficial effects

- Enzyme cofactor and proton carriers

Adverse effects of high intake

- No qualified adverse effect can be identified

	Females	Males
AR (mg/d)	1.3	1.3
RI (mg/d)	1.6	1.6

For more information about the health effects, please refer to the background paper by Vegard Lysne and Hanna Sara Strandler (Lysne & Strandler, 2023).

Dietary sources and intake. Riboflavin (vitamin B2) is a water-soluble compound present in foods as riboflavin-5′-phosphate (flavin mononucleotide, FMN), riboflavin-5′-adenosyl diphosphate (flavin adenine dinucleotide, FAD) and free riboflavin (EFSA, 2017a; IOM, 1998b; Lysne & Strandler, 2023). Main sources in Nordic and Baltic diets are dairy and meat products. Non-animal sources include legumes, almonds, green vegetables and mushrooms, whilst grain products are relatively poor sources unless they are enriched or fortified. The average riboflavin intake ranges from 1 to 2.1 mg/d (Lemming & Pitsi, 2022).

Main functions. FAD and FMN act as cofactors of several flavoprotein enzymes, e.g., glutathione reductase and pyridoxamine phosphate oxidase, and as proton carriers in redox reactions involved in energy metabolism. Flavoproteins are involved in e.g., tricarboxylic acid cycle, fatty acid β-oxidation, amino acid catabolism, electron transport chain, DNA repair/gene expression and cell signalling (EFSA, 2017a; IOM, 1998b; Lysne & Strandler, 2023).

Indicator for recommended intake. The inflection point in mean urinary riboflavin excretion curve in relation to riboflavin intake reflects body saturation and is used as indicator for setting AR (EFSA, 2017a; IOM, 1998b; Lysne & Strandler, 2023).

Main data gaps. Physical activity modifies riboflavin status, but there is a lack of data on a quantitative relationship between riboflavin status biomarkers and energy expenditure. The role of MTHFR C677T polymorphism, which modifies the riboflavin requirement, needs to be determined (Lysne & Strandler, 2023).

Deficiency and risk groups. Clinical signs of deficiency are unspecified and include stomatitis, seborrheic dermatitis, glossitis, cheilosis, sore throat, hyperaemia and oedema of pharyngeal and oral mucous membranes, and normochromic normocytic anaemia. Risk groups for riboflavin deficiency include older adults, haemodialysis patients, people with alcohol use disorder, users of diuretics and people with severe malabsorption (EFSA, 2017a; IOM, 1998b; Lysne & Strandler, 2023). People with prolonged restriction of animal products in their diets, such as vegans, are at risk of riboflavin inadequacy unless consuming supplements or fortified foods.

Dietary reference values. The weighted mean of riboflavin intake associated with the inflection point in the mean urinary excretion curve in relation to riboflavin intake was used to identify AR. Assuming that the frequency distribution is normally distributed, AR in adults is set to 1.3 mg/d (females and males). RI: 1.6 mg/day (females and males). Not sufficient data to derive UL (Lysne & Strandler, 2023).

Niacin (vitamin B_3)

DIETARY INTAKE

- Nicotinic acid (pyridine-3-carboxylic acid)
- Nicotinamide (pyridine-3-carboxamide)
- Tryptophan (60 mg equals 1 mg niacin equivalents, NE)

BIOMARKER

Indicator of recommended intake

- Urinary excretion of niacin metabolites, i.e., N-methyl-nicotinamide and N-methyl-2-pyridone-carboxamide

Indicator of adverse effect

- No qualified biomarker of adverse effects can be identified

HEALTH EFFECTS

Beneficial effects

- Oxidation-reduction reactions in energy metabolism and synthesis/degradation systems

Adverse effects of high intake

- Flushing, pruritus, rash, gastrointestinal symptoms, new-onset diabetes

	Females	Males
AR (NE/d)	12	15
RI (NE/d)	14	18

For more information about the health effects, please refer to the background paper by Riitta Freese and Vegard Lysne (Freese & Lysne, 2023).

Dietary sources and intake. Niacin (vitamin B_3) is the common term for nicotinic acid (pyridine-3-carboxylic acid), nicotinamide (pyridine-3-carboxamide) and derivatives that exhibit the biological activity of nicotinamide (EFSA, 2014g; Freese & Lysne, 2023; IOM, 1998b). The main sources in Nordic and Baltic countries are meat, eggs, fish, dairy, legumes (including peanuts), and cereals. Protein-rich foods contribute to the niacin intake through endogenous conversion from tryptophan, and 60 mg tryptophan is equivalent to 1 mg NE (Freese & Lysne, 2023). The average niacin intake ranges from 12.7 to 41 NE/d (Lemming & Pitsi, 2022).

Main functions. Oxidation-reduction reactions in energy metabolism and various synthesis/degradation systems, DNA repair, transcriptional regulation, circadian rhythms, mitochondrial homeostasis and calcium signalling (EFSA, 2014g; Freese & Lysne, 2023; IOM, 1998b).

Indicator for recommended intake. The relationship between intake and urinary excretion of nicotinamide metabolites (EFSA, 2014g; Freese & Lysne, 2023; IOM, 1998b).

Main data gaps. Dose-response of niacin intake and health outcomes.

Deficiency and risk groups. The classical niacin deficiency disease is pellagra characterized with diarrhoea, photosensitive dermatitis, dementia, and, if not treated, death. Pellagra is mainly observed in populations consuming predominantly a maize-based diet or a diet with other cereals with low protein content and low bioavailability of niacin (Freese & Lysne, 2023).

Dietary reference values. Based on urinary excretion of niacin metabolites the AR is set to 1.3 NE/MJ for females and males. Assuming a BMI of 23 kg/m^2 and PAL 1.6, this corresponds to AR of 12 NE/day (in females) and 15 NE/day (in males). RI is set to 1.6 NE/MJ (corresponding to 14 NE/day (females) and 18 NE/day (males)). The UL for nicotinamide and nicotinic acid is 900 and 10 mg/day, respectively.

Pantothenic acid (vitamin B_5)

DIETARY INTAKE

- Pantothenic acid (dihydroxy-b,b-dimethylbutyryl-b-alanine)

BIOMARKER

Indicator of recommended intake
- No qualified indicator can be identified

Indicator of adverse effect
- No qualified indicator can be identified

HEALTH EFFECT

Beneficial effects
- Component of coenzyme A (CoA) and acyl carrier protein (ACP)
- Sufficiency corrects deficiency symptoms: burning feet syndrome, neurodegenerative diseases

Adverse effects of high intake
- Water retention and occasional diarrhoea

	Females	Males
Provisional AR (mg/d)	4	4
AI (mg/d)	5	5

For more information about the health effects, please refer to the background paper by Riitta Freese, Tonje Aarsland and Maja Bjørkevoll (Freese et al., 2023)

Dietary intake. Pantothenic acid, *dihydroxy-b,b-dimethylbutyryl-b-alanine*, is a water-soluble vitamin that belongs to the group of B vitamins (vitamin B_5). Pantothenic acid is widely distributed in foods of both animal and vegetable origin, rich sources include organ meats, eggs, seafood, cheese, mushrooms, legumes, whole grains, vegetables and nuts. Pantothenic acid is not part of food composition tables in most Nordic and Baltic countries and information on intake is limited. In Latvia, the average intake of pantothenic acid was estimated to be 3.2-6.3 mg/d in adult men and women (EFSA, 2014c).

Main functions. As a component of coenzyme A (CoA) and acyl-carrier protein (ACP), pantothenic acid plays a central role in metabolism as a carrier of acyl groups. ACP is needed in fatty acid synthesis.

Indicator for recommended intake. No qualified indicator can be identified. Urinary pantothenic acid excretion reflects recent pantothenic acid intake and is considered the most reliable indicator of vitamin status (EFSA, 2014c; Freese et al., 2023).

Main data gaps. The concentration of pantothenic acid in foods should be analysed and incorporated into the Nordic and Baltic food composition tables to estimate dietary intakes and requirements.

Deficiency and risk groups. Deficiency is only likely to occur in conjunction with multiple nutrient deficiencies.

Dietary reference values. Population-level data on pantothenic acid biomarkers are lacking, and no cut-off values for pantothenic acid adequacy or insufficiency can be established. Based on dietary intake data with no sign of deficiency in the EU, AI has been set by EFSA (EFSA, 2014c), and was used as AI for NNR2023, and as the basis for provisional ARs. AI is set to 5 mg/day (females and males). Provisional AR is set to 4 mg/day (females and males). Not sufficient data to derive UL.

Vitamin B_6

DIETARY INTAKE

- Pyridoxal 5´-phosphate
- Pyridoxine 5´-phosphate
- Pyridoxamine 5´-phosphate

BIOMARKER

Indicator of recommended intake

- Plasma pyridoxal 5´-phosphate concentration

Indicator of adverse effect

- No qualified biomarker of adverse effects can be identified

HEALTH EFFECT

Beneficial effects

- Amino acid metabolism, one-carbon reactions, glycogenolysis, gluconeogenesis, haem synthesis, niacin formation, lipid metabolism, neurotransmitter synthesis and hormone action

Adverse effects of high intake

- Neurological symptoms, neurotoxicity

	Females	Males
AR (mg/d)	1.3	1.5
RI (mg/d)	1.6	1.8

For more information about the health effects, please refer to the background paper by Anne-Lise Bjørke Monsen and Per Magne Ueland (Bjørke-Monsen & Ueland, 2023b).

Dietary sources and intake. Pyridoxal 5´-phosphate (PLP) is the main form of vitamin B_6 in animal tissue. Major sources of vitamin B_6 in the Nordic and Baltic diets are fish, meat, potatoes, bread, cereals, milk, and dairy products. The bioavailability of vitamin B_6 in animal foods is considered to be approximately 50%, whereas the bioavailability in plant-based foods varies from 0 to 80% (Bjørke-Monsen & Ueland, 2023b). The average vitamin B_6 intake ranges from 1.2 to 2.3 mg/d (Lemming & Pitsi, 2022).

Main functions. PLP functions as a coenzyme for more than 160 different enzymatic reactions in the metabolism of amino acids, one-carbon reactions, glycogenolysis and gluconeogenesis, haem synthesis, niacin formation, and also in lipid metabolism, neurotransmitter synthesis and hormone action (Bjørke-Monsen & Ueland, 2023b; EFSA, 2016a; IOM, 1998b).

Indicator for recommended intake. Plasma PLP concentration reflects the tissue stores of vitamin B_6 (biomarker of status) and has a defined cut-off value for an adequate vitamin B_6 status (Bjørke-Monsen & Ueland, 2023b; EFSA, 2016a; IOM, 1998b).

Main data gaps. There are limitations in biomarkers of vitamin B_6 intake and status, and information on the variability in the requirement is absent (EFSA, 2016a).

Deficiency and risk groups. Prolonged vitamin B_6 deficiency, which is uncommon, is reported to cause peripheral neuropathy that leads to weakness, decreased reflexes, sensory loss, and ataxia, particularly in the lower limbs. Seizures, migraine, cognitive decline, and depression have also been linked to vitamin B_6 deficiency (Bjørke-Monsen & Ueland, 2023b). Mean plasma values below 30 nmol/l are associated with perturbations of amino acid, lipid, and organic acid profiles in plasma (EFSA, 2016a).

Dietary reference values. Plasma PLP concentration is considered as the biomarker of status; it has a defined cut-off value for an adequate vitamin B_6 status (30 nmol/l). AR is set to 1.3 mg/day in females based on balance studies, this was extrapolated to 1.5 mg/day in males (see Appendix 5). RI is set to 1.6 mg/day in females and 1.8 mg/day in males. UL is defined as 12.5 mg/d for both males and females (EFSA, 2023a).

Biotin (vitamin B_7)

DIETARY INTAKE

- Free biotin
- Protein-bound biotin

BIOMARKER

Indicator of recommended intake

- No qualified indicators of deficiency and sufficiency

Indicator of adverse effect

- No qualified indicator can be identified

HEALTH EFFECT

Beneficial effects

- Co-factor for several carboxylases
- Sufficiency corrects deficiency symptoms: hair loss, conjunctivitis, scaly dermatitis, ataxia, hypotonia, seizures, and developmental delays in infants and children

Adverse effects of high intake

- No qualified adverse effect can be identified

	Females	Males
Provisional AR (µg/d)	32	32
AI (µg/d)	40	40

For more information about the health effects, please refer to the background paper by Beate Stokke Solvik and Tor A. Strand (Solvik & Strand, 2023).

Dietary intake. Biotin, also referred to as vitamin B_7, is a water-soluble vitamin. Most foods, such as milk, liver, grain, egg yolk, and some vegetables, contain low concentrations of biotin. Protein-bound biotin needs to be released by biotinidase before absorption. The dietary intake of biotin is not estimated in any of the Nordic national surveys. In Latvia, the average intake of biotin in adults was between 34 and 45 µg/day (EFSA, 2014a).

Main functions. Biotin functions as a cofactor for several carboxylases that are involved in fatty acid synthesis, gluconeogenesis, and catabolism of branched-chained amino acids. Biotin may also have a role in cellular processes, including gene regulation.

Indicator for recommended intake. No qualified indicator can be identified (Eeuwijk et al., 2012; Solvik & Strand, 2023). Biomarkers sensitive to biotin depletion, including urinary biotin excretion and biomarkers of biotin function, have been identified. Dose-response relationships between biotin intakes and these biomarkers have not been established.

Main data gaps. The concentration of biotin in foods should be analysed and incorporated into the Nordic and Baltic food composition tables to estimate dietary intakes and requirements for different age groups.

Deficiency and risk groups. A deficiency is unlikely in the general population. Biotin deficiency has been demonstrated in cases of inherited biotinidase deficiency. Symptoms of biotin deficiency include hair loss, conjunctivitis, scaly dermatitis, ataxia, hypotonia, seizures, and developmental delays in infants and children

Dietary reference values. Population-level data on biotin biomarkers are lacking, and no cut-off values for biotin adequacy or insufficiency can be established. In NNR2023, an AI is set to 40 μg/day (females and males), derived from AI set by EFSA (2014a) which is based on observed dietary intake data with no sign of deficiency in the EU. Provisional AR is set to 32 μg/day (females and males). Not sufficient data to derive UL.

Folate (vitamin B_9)

DIETARY INTAKE

- Polyglutamyl and its derivatives

BIOMARKER

Indicator of recommended intake

- Serum or plasma folate and folate in red blood cells
- Serum folate > 10 nmol/L in adults and red cell folate > 906 nmol/L in women of fertile age reflects adequate status

Indicator of adverse effect

- No cutoff for serum folate has been established

HEALTH EFFECT

Beneficial effects

- For adults, adequate intake protects against folate-deficiency anaemia.
- For pregnant women adequate status lowers the risk of neural tube defects in the offspring

Adverse effects of high intake

- No adverse effects from dietary folate identified. Possible B_{12} deficiency from synthetic folate at high intakes

	Females	Males
AR (μg/d)	250	250
RI (μg/d)	330	330

For more information about the health effects, please refer to the background paper by Anne-Lise Bjørke Monsen and Per Magne Ueland (Bjørke-Monsen & Ueland, 2023a).

Dietary sources and intake. Folate is present in most foods, with main sources in Nordic and Baltic diets being green vegetables and whole grain products. Highest folate concentrations are found in liver and legumes. Dietary folate is sensitive to light and oxidation and is partly degraded by cooking. Synthetic folic acid is mainly found in supplements. Mean daily intakes of folate in the Nordic and Baltic countries vary from 164 μg in women in Estonia to 370 μg in men in Denmark. The average folate intake ranges from 164 to 383 μg/d (Lemming & Pitsi, 2022).

Main functions. Folate is an essential micronutrient for normal development and metabolic function as a cofactor for enzymes in one-carbon metabolism, thus important for the biosynthesis of nucleotides (RNA and DNA) (Bjørke-Monsen & Ueland, 2023a). Folates are also necessary for the conversion of homocysteine to methionine (Bjørke-Monsen & Ueland, 2023a; EFSA, 2014f). Supplemental folic acid (in addition to dietary folate intake) before pregnancy prevents neural tube defects (spina bifida and anencephaly) in infants (Bjørke-Monsen & Ueland, 2023a).

Indicator for recommended intake. Serum or plasma folate and folate in red blood cells are the primary biomarkers of dietary intake.

Main data gaps. Lack of biomarker cut-offs for adverse health effects.

Deficiency and risk groups. Deficiency is manifested mainly as megaloblastic anaemia. People with low folate intake, malabsorption or increased folate requirements have a risk of developing folate deficiency. Individuals who are homozygous for the C677C→T-polymorphism (TT genotype) in the methylene tetrahydrofolate reductase (MTHFR) gene have increased requirements (Bjørke-Monsen & Ueland, 2023a). Alcohol use disorder is associated with severe folate deficiency linked to poor dietary intake, intestinal malabsorption, impaired hepatic uptake with reduced storage of folates, and increased renal excretion. Children and pregnant and lactating females also have an increased demand for folate and may be at risk of inadequate intake.

Dietary reference values. The AR for adults was derived from the level of intake required to maintain serum and red blood cell folate concentrations of ≥10 and 340 nmol/L, respectively. AR is set to 250 µg/day in females and males. RI is set to 330 µg/day (females and males). No AR is set for pregnant females due to insufficient evidence. Instead, an AI is set to 600 µg/day for pregnant females, and a provisional AR is set to 480 µg/day, derived from the AI set by EFSA (EFSA, 2014f), which is based on a controlled metabolic study in pregnant females (Caudill et al., 1997). In most Nordic and Baltic countries, females of reproductive age are recommended to take a supplement of 400 µg/day from planned pregnancy and throughout the first trimester of pregnancy. The UL of folic acid (synthetic) is 1000 µg/d.

Vitamin B_{12}

DIETARY INTAKE

- Methylcobalamin
- 5′-deoxyadenosyl-cobalamin

BIOMARKER

Indicator of recommended intake

- Serum or plasma cobalamin
- Bioavailable fraction in the circulation: serum holotranscobalamin (holoTC)
- Functional biomarkers: plasma total homocysteine (tHcy) and serum methylmalonic acid (MMA)

Indicator of adverse effect

- No qualified biomarker of adverse effects can be identified

HEALTH EFFECT

Beneficial effects

- Enzyme cofactor
- Sufficiency prevents megaloblastic anaemia and neurological dysfunction

Adverse effects of high intake

- No qualified adverse effect can be identified

	Females	Males
Provisional AR (µg/d)	3.2	3.2
AI (µg/d)	4.0	4.0

For more information about the health effects, please refer to the background paper by Anne-Lise Bjørke Monsen and Vegard Lysne (Bjørke-Monsen & Lysne, 2023).

Dietary sources and intake. Vitamin B_{12} is a water-soluble vitamin that is naturally present in animal-based foods. Main sources in Nordic and Baltic diets are meat, liver, dairy products, fish, and shellfish. The average vitamin B12 intake ranges from 2.9 to 8.9 µg/d (Lemming & Pitsi, 2022).

Main functions. Vitamin B_{12} (cobalamin) is a cofactor for two enzymes in the human metabolism (2-5). Methylcobalamin is a cofactor for methionine synthase, the enzyme that catalyses the conversion of homocysteine to methionine. Adenosylcobalamin is a cofactor for methylmalonyl-CoA mutase in the isomerization of methylmalonyl-CoA to succinyl-CoA. An adequate supply of vitamin B_{12} is essential for normal development, neurological function, and blood formation.

Indicator for recommended intake. Biomarkers of vitamin B_{12} status include serum and plasma B_{12} and holoTC (bioavailable fraction in the circulation), and the functional biomarkers total homocysteine (tHcy) and methylmalonic acid (MMA). All four B_{12} biomarkers have limitations as standalone markers, and a combination of biomarkers is the most suitable approach to derive DRVs for vitamin B_{12} (Allen et al., 2018; Bjørke-Monsen & Lysne, 2023; EFSA, 2015c; IOM, 1998b). Because vitamin B_{12} is essential for folate metabolism, it is also important to consider folate status.

Main data gaps. Data are needed to improve the definition of deficiency. In addition, there are insufficient data to derive an AR for infants and children. A *de novo* NNR2023 systematic review concluded that there is not enough evidence to conclude if the habitual vitamin B_{12} intake, or an intake in line with the previous NNR (NNR2012), is sufficient to maintain adequate status for populations susceptible to vitamin B12 deficiency (i.e., children pregnant and lactating women, young adults, older adults, and vegetarians or vegans) (Bärebring et al., 2023).

Deficiency and risk groups. The main clinical symptoms of vitamin B_{12} deficiency is macrocytic, megaloblastic anaemia or neurologic dysfunction. Deficiency also causes increased plasma tHcy.

People with prolonged restriction of animal products in their diets, such as vegetarians and vegans, are at risk of becoming vitamin B_{12} deficient unless consuming supplements or fortified foods. Frequent causes of a decline in cobalamin status in older adults are malabsorption of cobalamin bound to food as a consequence of atrophic gastritis. The neonatal period is particularly sensitive to cobalamin insufficiency and deficiency.

Dietary reference values. In NNR2023, an AI is set to 4.0 μg/day (females and males), derived from the AI set by EFSA (2015c), which is based on both different biomarkers of cobalamin status and observed intakes. Provisional AR is set to 3.2 μg/day (females and males). Not sufficient data to derive UL.

Choline

DIETARY INTAKE

- Free choline
- Esterified choline

BIOMARKER

Indicator of recommended intake
- No indicator identified

Indicator of adverse effect
- No indicator identified

HEALTH EFFECT

Beneficial effects
- Cell membranes
- Lipoprotein metabolism
- Precursor acetylcholine

Adverse effects of high intake
- Hypotension, GI symptoms, fishy body odour

	Females	Males
Provisional AR (mg/d)	320	320
AI (mg/d)	400	400

For more information about the health effects, please refer to the background paper by Rima Obeid and Therese Karlsson (Obeid & Karlsson, 2023).

Dietary sources and intake. Choline is found in foods as free choline or esterified forms (phosphatidylcholine, phosphocholine, glycerophosphocholine and sphingomyelin). It is ubiquitous in foods, but high in liver, eggs and wheat germ. Main sources are meat, dairy, eggs and grains. Dietary intake data from Nordic and Baltic populations are scarce. Average choline intake was 317–468 mg/day (males) and 317–404 mg/day (females) in adults aged 18 to ≥75 y, and 171–180 mg/day (1-3 y), 256–285 mg/day (3-10 y), and 292–373 mg/day (10-18 y) in children (Lemming & Pitsi, 2022).

Main functions. Choline has roles in one-carbon metabolism, as a component of cell membranes (phospholipids such as phosphatidylcholine, the main storage form of choline), in lipoprotein metabolism (VLDL assembly and secretion from the liver), and as a precursor for the neurotransmitter acetylcholine (Obeid & Karlsson, 2023).

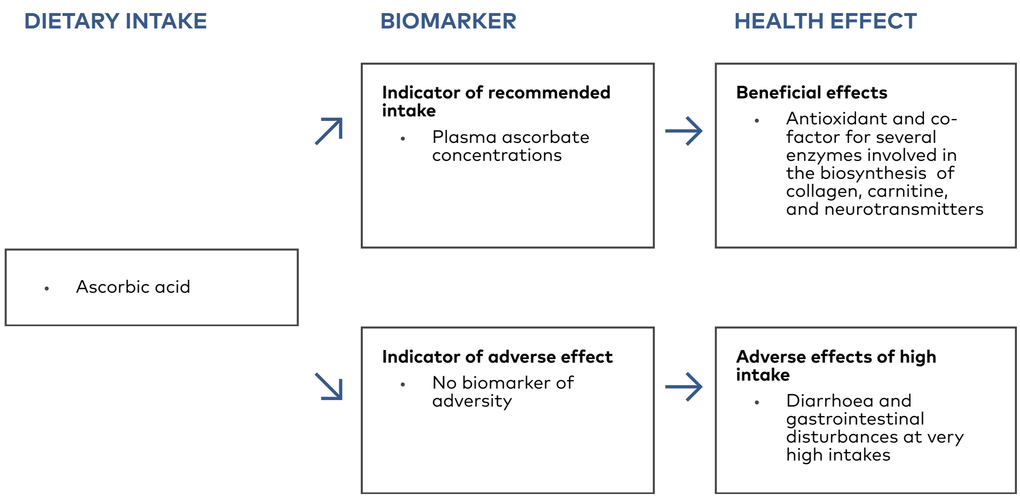
Indicator for recommended intake. No indicator was identified for setting AR and RI. For AI, the selected indicator was liver damage and average intake across European populations (EFSA, 2016c). For UL, selected indicators included hypotension, GI symptoms and fishy body odour.

Main data gaps. Dietary intake data for Nordic and Baltic populations, including assessment of choline content of foods in this region, and databases. Surrogate markers or a combination of markers that reflect long-term average choline intake from the diet. Impact of genetic variation in choline metabolism.

Deficiency and risk groups. A choline-free diet results in liver damage (corrected by 500 mg choline/d). No specific risk groups established, although pregnant and lactating women and children are likely more vulnerable.

Dietary reference values. AI is set to 400 mg/day (females and males), based on EFSA (EFSA, 2016c). Provisional AR is set to 320 mg/day (females and males). Values are based on AI from observed dietary intake values set by EFSA (EFSA, 2013c). Not sufficient data to derive UL.

Vitamin C



	Females	Males
AR (mg/d)	75	90
RI (mg/d)	95	110

For more information about the health effects, please refer to the background paper by Jens Lykkesfeldt and Anitra Carr (Lykkesfeldt & Carr, 2023).

Dietary sources and intake. The major sources of vitamin C (ascorbic acid) in the diet are fresh fruit and vegetables. Potatoes have a relatively low content of vitamin C but because of a relatively high intake in the Nordic and Baltic countries they can be an important source. The average vitamin C intake ranges from 69 to 132 mg/d (Lemming & Pitsi, 2022).

Main functions. Vitamin C is a low-molecular weight electron donor that has the capacity to reduce any biologically relevant oxidant species as well as regenerate other antioxidants, such as vitamin E, from their oxidized forms. It is a cofactor for several enzymes involved in the biosynthesis of collagen, carnitine, and neurotransmitters.

Indicator for recommended intake. Plasma ascorbate concentration is a marker of vitamin C status (EFSA, 2013b; Lykkesfeldt & Carr, 2023). A target plasma ascorbate concentration of 50 µmol/L is used to set the AR. People who smoke need to increase their daily vitamin C intake by 40 mg/d to compensate for the increased metabolic turnover induced by smoking.

Main data gaps. Lack of dose-response data from controlled studies for solid clinical endpoints which could be used to set target plasma concentrations of ascorbate.

Deficiency and risk groups. Deficiency is defined as plasma vitamin C <11 µmol/L (Lykkesfeldt & Carr, 2023). Prolonged deficiency causes scurvy. Low intake of fruits and vegetables (including fruit juices) is a risk factor. Smokers may have increased requirement for vitamin C and are at risk of inadequate intake (Lykkesfeldt & Carr, 2023).

Dietary reference values. For infants (<12 months of age), an AI is set to three times higher than the intake known to prevent scurvy in infants, i.e., 30 mg/d (Lykkesfeldt & Carr, 2023). Using a target plasma ascorbate concentration of 50 µmol/L, the AR is set to 90 mg/day in males, extrapolated to females with isometric scaling to 75 mg/day (females). RI is set at 95 mg/day (females) and 110 mg/day (males) (EFSA, 2013b). People who smoke need to increase their daily vitamin C intake from foods by approximately 40 mg/d.

Calcium

DIETARY INTAKE

- Organic and inorganic calcium compounds

BIOMARKER

Indicator of recommended intake

- No indicator of nutrient status due to tight homeostatic control

Indicator of adverse effect

- No qualified biomarker of adverse effects can be identified

HEALTH EFFECT

Beneficial effects

- Important secondary messenger
- Integral component of bones and teeth
- Sufficiency prevents rickets, osteomalacia and fractures

Adverse effects of high intake

- No qualified adverse effect can be identified
- May have adverse effects on mineral metabolism in combination with high vitamin D intake

	Females	Males
AR (mg/d)	750	750
RI (mg/d)	950	950

For more information about the health effects, please refer to the background paper by Kirsti Uusi-Rasi and Jóhanna E. Torfadóttir (Uusi-Rasi & Torfadóttir, 2023).

Dietary sources and intake. Calcium (Ca) is present in foods as calcium salts which are water-soluble, with a few exceptions. Most foods contain calcium but usually not in high concentrations. There are large differences in the bioavailability of calcium from foods and it is generally low from vegetables. Most of the dietary calcium intake is provided by milk and dairy products in the Nordic and Baltic countries. Other good food sources include cruciferous vegetables (e.g. kale, broccoli), and calcium-fortified foods. The average calcium intake ranges from 550 to 1200 mg/d (Lemming & Pitsi, 2022).

Main functions. Most (99%) of total body calcium is found in bones and teeth as calcium hydroxyapatite ($Ca_{10}[PO_4]_6[OH]_2$), where it has a structural role. In soft tissues and body fluids calcium (< 1%) serves as an essential regulator of several body functions, such as muscle contraction, the functioning of the nervous system, and blood clotting.

Interaction with other nutrients. Calcium intake can reduce the absorption of other divalent cations such as iron, zinc and copper. Calcium is regulated by the intake of vitamin D.

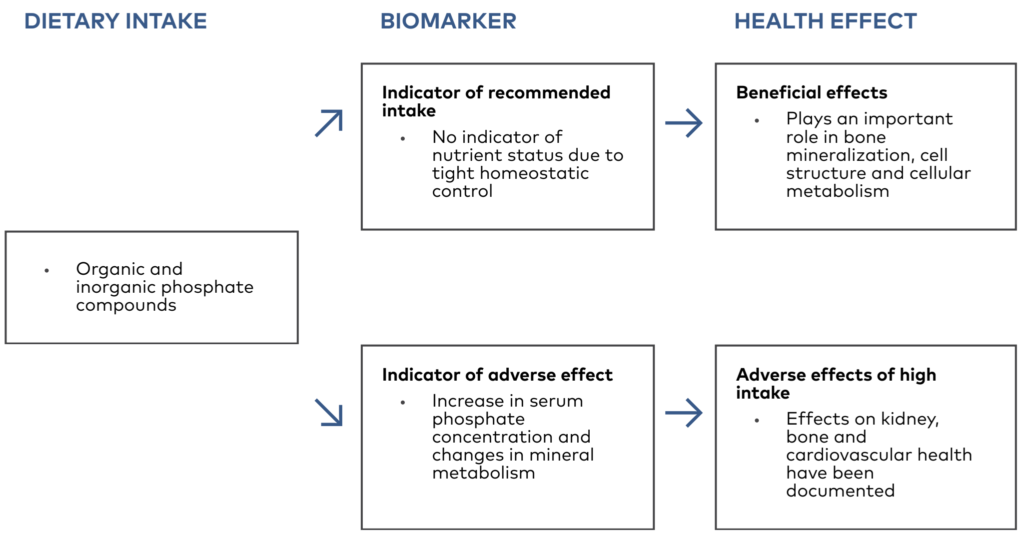
Indicator for recommended intake. Urinary and faecal calcium excretion combined with estimated losses in skin, and sweat reflect body saturation and may be used as an indicator for setting AR. Balance studies have provided an estimation of AR (Uusi-Rasi & Torfadóttir, 2023).

Main data gaps. There lacks data on the efficacy of calcium with or without vitamin D on extra skeletal health outcomes. In terms of a whole diet, more prospective research is needed to clarify the impact of plant-based diets on bone health (Newberry et al., 2014; Uusi-Rasi et al., 2013; Uusi-Rasi & Torfadóttir, 2023).

Deficiency and risk groups. Clinical signs of deficiency include osteopenia, osteoporosis, and fractures. Groups with no or low intake of dairy products, such as vegans, are at risk of deficiency if not consuming fortified foods or supplements. Risk groups for calcium deficiency include children, adolescents and young adults accumulating calcium in bones, postmenopausal women, and people of all ages following a diet, e.g., vegan, with no rich calcium and/or vitamin D sources (Lemming & Pitsi, 2022; Uusi-Rasi et al., 2013; Uusi-Rasi & Torfadóttir, 2023).

Dietary reference values. The AR and RI are based on data from balance studies and on epidemiological and clinical studies on the role of calcium in maintaining a healthy skeleton. For children and adolescents, the AR is derived using factorial approach based on estimates of calcium retention in the skeleton during growth in addition to the requirement for losses, adjusted for the percentage of absorption (EFSA, 2015e; Nordic Council of Ministers, 2014) (see Appendix 5). For children aged 11–14 and 15–17 years, the AR was first calculated separately for each sex and age group, and then averaged for a combined AR and RI for both females and males 11–17 years of age. The recommended intake for adolescents is partly extended to young adults (18-24 years), acknowledging that some bone mass is still accreted (EFSA, 2015e). The foetal need for calcium is met by maternal physiological changes. AR at age ≥25 years is set to 750 mg/day (females and males). RI is set to 950 mg/day (females and males). The values are based on EFSA (EFSA, 2015e). The UL for calcium for adults is based on evidence from intervention studies in which calcium intakes of 2500 mg/d were tolerated without adverse effects (EFSA, 2012b). UL for calcium is 2,500 mg/d.

Phosphorus



	Females	Males
Provisional AR (mg/d)	420	420
AI (mg/d)	520	520

For more information about the health effects, please refer to the background paper by Suvi T. Itkonen and Christel Lamberg-Allardt (Itkonen & Lamberg-Allardt, 2023).

Dietary sources and intake. Phosphorus occurs widely in foodstuffs, but the highest content is found in protein-rich foods, including meat, fish, eggs, dairy, legumes, whole-grain cereals, nuts and seeds. Various phosphate compounds are also used as food additives. The average phosphorus intake ranges from 870 to 1800 mg/d (Lemming & Pitsi, 2022).

Main functions. Phosphorus-containing compounds are involved in e.g., ATP synthesis, signal transduction, cell structure, cellular metabolism, regulation of subcellular processes, acid-base homeostasis and in bone mineralization (Itkonen & Lamberg-Allardt, 2023). About 85% of the body's phosphorus is in bones and teeth, and phosphorus homeostasis is closely linked to that of calcium because of the actions of calcium-regulating hormones, such as parathyroid hormone (PTH) and 1,25-dihydroxy-vitamin D (1,25(OH)2D), at the level of the bone, the gut and the kidneys.

Indicator for recommended intake. Due to tight homeostatic control, no reliable indicator for recommended intake is available. Serum inorganic phosphate reflects short term intake after meal. Surrogate markers such as FGF23 or PTH are also influenced by other nutrients.

Main data gaps. Effects of phosphorus on health may depend on the source from which it is ingested, but methods by which phosphorus bioavailability can be taken into account are lacking. Data on bioavailability and total phosphate content (including additives) in foods is missing and there is a need to conduct studies on phosphorus intake and health outcomes.

Deficiency and risk groups. Phosphorus deficiency is related to metabolic disorders. Although vitamin D deficiency or resistance decreases phosphorus absorption, hypophosphatemia due to low intestinal absorption is rare and only becomes apparent when phosphorus deprivation has continued for a long time, such as in the case of diarrhoea (Itkonen & Lamberg-Allardt, 2023).

Dietary reference values. An AI is set to 520 mg/day (females and males), based on the RI for calcium, as calcium and phosphorus metabolism is closely linked, considering a whole-body molar ratio of calcium to phosphorus of 1.4:1. Provisional AR is set to 420 mg/day (females and males). Values are based on AIs set by EFSA, scaled to the RI for calcium in NNR2023 (EFSA, 2015f). UL for phosphorus is 3,000 mg/d (NNR2012).

Magnesium

DIETARY INTAKE

- Magnesium

BIOMARKER

Indicator of recommended intake

- No adequate functional biomarker of magnesium status has been identified
- Plasma/serum magnesium can be used to identify severe deficiency

Indicator of adverse effect

- No adequate functional biomarker of adverse effect of high magnesium intake has been established

HEALTH EFFECT

Beneficial effects

- Energy metabolism, neurological and muscular function
- Function of cells and membranes

Adverse effects of high intake

- Diarrhoea

	Females	Males
Provisional AR (mg/d)	240	280
AI (mg/d)	300	350

For more information about the health effects, please refer to the background paper by Christine Henriksen and Jan Olav Aaseth (Henriksen & Aaseth, 2023).

Dietary sources and intake. Milk, whole grain cereals, starchy roots, vegetables and legumes are dietary sources of magnesium in Nordic and Baltic populations. Magnesium concentrations are especially high in cocoa, nuts and seeds. The average magnesium intake ranges from 260 to 440 mg/d (Lemming & Pitsi, 2022).

Main functions. Magnesium is a cofactor of many enzymes and thus necessary in a large number of biochemical and physiological processes such as energy metabolism, glucose transport, electrical potential in nerves and cell membranes and transmission of neuromuscular impulses (Henriksen & Aaseth, 2023).

Interaction with other nutrients. A diet high in phytic acid and phosphate reduces absorption, but the clinical relevance is uncertain (Henriksen & Aaseth, 2023). Plasma magnesium concentrations are regulated by kidney excretion, which is increased by hypernatraemia, metabolic acidosis, unregulated diabetes, and alcohol consumption (Henriksen & Aaseth, 2023).

Indicator for recommended intake. No adequate functional biomarker of magnesium status has been identified (EFSA, 2015d). Plasma or serum concentrations can be used to identify severe deficiency. The available evidence suggests a causal relationship between magnesium intake and lower risk for CVD, hypertension, metabolic syndrome and improvement of glucose tolerance, but limitations of the studies makes it impossible to identify an optimal magnesium intake (Henriksen & Aaseth, 2023).

Main data gaps. The lack of an appropriate biomarker.

Deficiency and risk groups. Magnesium depletion is uncommon and usually secondary to a disease or to the use of a therapeutic agent.

Dietary reference values. In NNR2012, magnesium recommendations were based on balance studies. However, in the most recent review of the evidence of magnesium and health it was concluded that the lack of a functional biomarker of magnesium status makes it impossible to define an average requirement (EFSA, 2015d). EFSA (2015d) set an AI based on the average magnesium intakes of the EU population and NNR2023 adopts these values to set AI and AR. AI is set to 300 mg/day (females) and 350 mg/day (males). Provisional AR is set to 240 mg/day (females) and 280 mg/day (males). UL is set to 250 mg/day based on the health outcome mild diarrhoea, and it applies only to magnesium in dietary supplements (SCF, 2006).

Sodium

DIETARY INTAKE

- Intake of sodium (NaCl; dietary salt)

BIOMARKER

Indicator of recommended intake
- No qualified biomarker for sodium status is identified
- Interactions with potassium intake

Indicator of adverse effect of high intakes
- Blood pressure is used as a biomarker

HEALTH EFFECT

Beneficial effects
- Functions in cells, membranes, muscles and nerves

Adverse effects of high intake
- High blood pressure (blood pressure is a risk factor for stroke and cardiovascular events)
- Sodium intake is associated with mortality

	Females	Males
AI (g/d)	1.5	1.5
Chronic disease risk reduction (g/d)	2.3	2.3

For more information about the health effects, please refer to the background paper by Antti Jula (Jula, 2023).

Dietary intake. The main sources of sodium chloride (NaCl) are bread and other bakery products, meat and fish products and ready meals such as pizza, pie and soups, and table salt. Sodium is usually found in very low concentrations in unprocessed foods. One gram of NaCl (salt) corresponds to about 0.4 g sodium, and 1 g sodium is equivalent to 2.54 g salt. Estimates of sodium intakes have been made with different methodologies, and ranges from about 1.8 g/d to 4.4 g/d (Lemming & Pitsi, 2022).

Main functions. The volume of the extracellular fluid and the equilibrium between intracellular and extracellular osmolality is controlled by systems transporting sodium into the cell and by the energy-dependent sodium pump (Na^+/K^+-ATPase) that pumps sodium out of the cell in exchange for potassium.

Interaction with other nutrients. Renal sodium excretion is closely related to potassium intake, whereas sodium intake normally does not influence potassium excretion (Toft et al., 2023).

Indicator for recommended intake. There is no sensitive and specific biomarker for estimating sodium status. The impact of sodium on blood pressure is an important indicator of the health impact of sodium as elevated blood pressure is a leading global and Nordic risk factor for premature death and disability (Clarsen, in press).

Main data gaps. A limitation of the current evidence is the lack of a robust biomarker and the limited evidence of health effects of intakes below 1.5 g sodium per day. The currently often used proxy indicator spot urine as a measure of sodium intake instead of the gold standard method, 24-h urinary sodium, is also a limitation (Jula, 2023). Identifying sodium sensitivity among individuals and groups, i.e., the extent that blood pressure responds to changes in sodium intake, is challenging (NASEM, 2019).

Deficiency and risk groups. Sodium deficiency due to low dietary intake is rare. Risk of elevated blood pressure due to high sodium intake increases with ageing. Acute toxicity with fatal outcomes has been reported with single doses ranging from about 7 g, but smaller amounts may be detrimental for subjects with heart failure, renal failure or decompensated liver cirrhosis (Jula, 2023).

Dietary reference values. Sodium balance can be maintained at intakes of about 10 mmol (230 mg) per day in adults, corresponding to about 0.6 g of salt (Jula, 2023). An intake of 25 mmol (575 mg) per day, corresponding to about 1.5 g salt, is set as the estimated lower intake level and accounts for variations in physical activity and climate (SCF, 1993).

Sodium restriction down to a sodium intake level of less than 2 g/d decreases blood pressure linearly by a dose-response manner. Prospective cohort studies indicate that higher sodium intake is associated with an increased risk of stroke and cardiovascular events and mortality among the general adult population. Interventional studies confirm the efficiency and safety of reducing sodium intake to a level of less than 2 g/d (Jula, 2023).

The EFSA Panel considered 2.0 g sodium/day to be a safe and adequate intake for the general EU population of adults (EFSA, 2019b). Also in 2019, the U.S. National Academies of Sciences, Engineering, and Medicine (NASEM) set the reference intake for adults to 1.5 g/d due to limited evidence on health effects of sodium intakes lower than that (NASEM, 2019).

Based on an overall evaluation of the available data in the recent reviews (EFSA, 2019b; NASEM, 2019), the AI in NNR2023 is set to 1.5 g sodium per day (females and males), which corresponds to 3.75 g salt per day.

Reductions in sodium intakes that exceed the chronic disease risk reduction (CDRR) of 2.3 g/d are expected to reduce chronic disease risk within the general population. NNR2023 thus adapts the reasoning from NASEM to recommend limiting intake to 2.3 g/d (about 5.75 g salt).

Potassium

DIETARY INTAKE

- Potassium (K) intake

BIOMARKER

Indicator of recommended intake

- No qualified indicator can be identified
- Interactions with sodium intake

indicator of adverse effect

- No qualified biomarker of adverse effects can be identified

HEALTH EFFECT

Beneficial effects

- Functions in cells, membranes, muscles and nerves
- Fluid balance and acid-base balance
- Lower blood pressure in individuals with hypertension
- Decreased risk of stroke

Adverse effects of high intake

- None identified in healthy individuals

	Females	Males
Provisional AR (mg/d)	**2800**	**2800**
AI (mg/d)	**3500**	**3500**

For more information about the health effects, please refer to the background paper by Ulla Toft, Nanna Louise Riis and Antti Jula (Toft et al., 2023).

Dietary sources and intake. Potassium is widely available in different types of foods and about 90% of the ingested potassium is absorbed. The most important dietary sources are potatoes, fruits, vegetables, cereal and cereal products, milk and dairy products, and meat and meat products. The average potassium intake ranges from 2400 to 4200 mg/d (Lemming & Pitsi, 2022).

Main functions. Potassium is essential for normal cell and membrane function, for maintenance of fluid balance, acid-base balance, and for normal excitation in nerves and muscles. Results from observational studies have shown that a potassium intake above 3500 mg/day is associated with a reduced risk of stroke. Intervention studies provide evidence that potassium intakes at this level have a beneficial effect on blood pressure, particularly in individuals with high blood pressure or high sodium intakes (>4000 mg/day) (Toft et al., 2023). Increased potassium intake from dietary supplements reduces blood pressure in adults with prehypertension or hypertension, but not in adults with normal blood pressure (NASEM, 2019). Elevated blood pressure is very common in the adult population in Nordic and Baltic countries and a leading risk factor for premature death and disability (Clarsen, in press).

Interaction with other nutrients. The metabolism of potassium is strongly related to that of sodium due to the Na^+/K^+-ATPase pump that maintains the extracellular/intracellular concentration. Potassium is also interrelated with calcium and with magnesium.

Indicator for recommended intake. The plasma concentration of potassium is strictly regulated within narrow limits by homeostasis and can thus not be used to assess status. No sensitive or specific biomarker to determine potassium status is currently proposed (NASEM, 2019).

Main data gaps. The lack of biomarkers for potassium status and the uncertainties of the data relating potassium intake to chronic outcomes are the main data gaps. The estimation of potassium requirements during lactation is uncertain.

Deficiency and risk groups. Potassium deficiency due to low dietary intake is rare. High intakes are regulated via renal excretion or cellular uptake and release. There is no evidence of adverse effects of high dietary potassium intake in healthy individuals. People with kidney dysfunction may have a risk of hyperkalemia, which may be lethal if untreated.

Dietary reference values. The links between potassium intakes and chronic disease were recently evaluated, but data were insufficient to set a reference value based on chronic disease outcomes according to set criteria (NASEM, 2019; Newberry et al., 2018). Instead, NASEM set an AI based on the highest median intake in U.S. dietary surveys (2600 mg/day for women and 3400 mg/day for men). EFSA set a health-based AI, as the evidence was not strong enough to set an AR (EFSA, 2016b). The EFSA AI is based on the associations between potassium and normal blood pressure and the risk of stroke. The NNR2023 Committee finds the link between potassium intakes and normal blood pressure well-established and supports the EFSA AI of 3500 mg/day for both men and women, including pregnant women. EFSA set an AI of 4000 mg/d for lactating women by adding the requirements for production of breastmilk corresponding to about 400 mg/day (EFSA, 2016b). The NNR Committee notes that the evidence for such a high requirement during lactation is limited and recommends 3500 mg of potassium also during lactation. AI is set to 3500 mg/day (females and males). Provisional AR is set to 2800 mg/day (females and males). Not sufficient data to derive UL.

Iron

DIETARY INTAKE

- Haem iron, from animal tissues (Fe^{2+})
- Non-haem iron (Fe^{3+})

BIOMARKER

Indicator of recommended intake
- No qualified biomarker
- Factorial method used to derive DRV

Non-haem iron interacts with
- Vitamin C
- The meat factor
- Phytate
- Polyphenols
- Calcium

Indicator of adverse effect
- Plasma ferritin

HEALTH EFFECT

Beneficial effects
- Is the main transporter of oxygen and electrons
- Found in haemoglobin and myoglobin
- Iron is important in many enzymes

Adverse effects of high intake
- Mucosal erosion in the stomach and intestine, leading to nausea, abdominal pain, vomiting and diarrhoea
- Even higher doses may lead to systemic iron overload and can result in gastrointestinal bleeding, shock, metabolic acidosis and acute liver failure

	Females	Males
AR (mg/d)	9	7
RI (mg/d)	15	9

Magnus Domellöf and Agneta Sjöberg have co-authored this summary. For more detailed information on the background, evidence and calculations behind these recommendations, please see the NNR2023 paper on iron (Domellöf & Sjöberg, 2023).

Dietary sources and intake. Meat, poultry, and fish as well as bread and cereals are the main iron sources in a mixed Nordic diet. Legumes, legume-based meat substitutes, wholegrain cereals and dark green vegetables are also important iron sources. Dietary iron consists of haem (from animal tissues) and non-haem iron. Mean average dietary intake in the Nordic and Baltic countries ranges between 9.4 mg and 14.5 mg in adults (Lemming & Pitsi, 2022).

Main functions. Iron is essential for oxygen transport (e.g. haemoglobin, myoglobin) and for many enzymes involved in energy metabolism and other functions in different tissues, including the brain (Domellöf & Sjöberg, 2023).

Iron absorption and homeostasis . Iron absorption from foods is generally lower than that of most other nutrients, typically around 10–15% from a mixed diet. Haem iron is generally more efficiently absorbed than non-haem iron and generally not affected by other food components. Absorption of non-haem iron is enhanced by ascorbic acid and muscle tissue (meat/poultry/fish) and inhibited by phytate, polyphenols and calcium. Iron absorption is homeostatically regulated, i.e., upregulated when iron stores are low and downregulated when iron stores are high. Iron is recycled in the body and humans have no pathway for excretion of surplus iron.

Main data gaps. Health effects of different iron intakes in different risk groups. How to minimize the risk of iron deficiency in populations shifting to vegetarian diets.

Indicators for recommended intake. Serum ferritin and other iron status biomarkers can be used in combination with haemoglobin to assess iron status in individuals and populations.

Deficiency and risk groups. Iron deficiency is one of the most common micronutrient deficiencies globally and is the most common cause of nutritional anaemia. Large population groups in the Nordic and Baltic countries are at risk of iron deficiency, including infants, young children, menstruating females, pregnant women as well as vegetarians.

Dietary reference values. DRVs were set based on factorial calculations (Domellöf and Sjöberg 2023) considering the following factors: 1) iron losses, 2) iron absorption and 3) iron requirements for growth (in children and pregnant women). Basal iron losses were assumed to be 12–22 μg/kg/day in the different population groups. Average menstrual blood losses were assumed to be 0.45 mg/day. Dietary iron bioavailability of 10% was assumed for children up to 11 years, and 15% for other population groups. Iron requirements for growth in children in the different age intervals were based on average weight gain and a total body iron content of 38–48 mg/kg. Additional iron requirements for pregnancy was assumed to be 1.91 mg/day. RI is based on the 97.5th percentile of variation of the main contributing factor. A CV of 15% was used in the absence of variability data. For menstruating females, the RI is based on the 95th percentile of menstrual loss. UL is 60 mg/d.

Zinc

DIETARY INTAKE	BIOMARKER	HEALTH EFFECT
	Indicator of recommended intake • No qualified biomarker • Factorial method used to derive DRV	**Beneficial effects** • Zinc is an essential element • Has structural and catalytic roles in each of the seven classes of enzymes and is involved in the synthesis, metabolism, and turnover of proteins, carbohydrates, lipids, nucleic acids, and some vitamins
• Divalent cation Zn^{2+} • Phytate and calcium negatively impacts the amount of absorbable zinc • Zinc intake can reduce absorption of copper, iron, and calcium		
	Indicator of adverse effect • No qualified biomarker of adverse effects can be identified	**Adverse effects of high intake** • May induce vomiting but is considered non-toxic

	Females	Males
AR (mg/d)	8	11
RI (mg/d)	10	13

For more information about the health effects, please refer to the background paper by Tor A. Strand and Maria Mathisen (Strand & Mathisen, 2023).

Dietary sources and intake. Meat, milk and dairy products, legumes, eggs, liver grains, and grain-based products are rich dietary sources of zinc. The average zinc intake ranges from 7.2 to 14.1 mg/d (Lemming & Pitsi, 2022).

Main functions. Zinc is a widespread element which exists as a stable divalent cation (Zn^{2+}). It has a wide range of vital physiological functions and is present in every cell of the human body.   Zinc has a structural and catalytic role in each of the seven classes of enzymes and is involved in the synthesis, metabolism, and turnover of proteins, carbohydrates, lipids, nucleic acids, and some vitamins. An essential structural role of zinc is zinc motifs (zinc fingers) for transcription factors, and account for a significant part of the zinc requirement. Zinc acts as a cofactor for key enzymes for reducing oxidative stress. Strong homeostatic mechanisms keep the zinc content of tissues and fluids constant over a wide range of intakes through changes in excretion and absorption (Strand & Mathisen, 2023).

Interaction with other nutrients. The luminal content of phytate and calcium negatively impacts the amount of zinc available for absorption. Zinc intake can also reduce the absorption of other divalent cations such as copper, iron, and calcium.

A more plant-based diet with a higher content of chelating substances such as phytic acid and tannins increase zinc requirements. In 2014, EFSA updated their population reference intake (PRI) for zinc adjusted for the intake of phytic acid (EFSA, 2014h). The scenario with the lowest phytate intake (300 mg per day) gave a population reference intake close to the RIs in NNR 2012. In EFSA, the ARs for adults were estimated as the zinc requirement at levels of phytate intake of 300, 600, 900 and 1 200 mg/day. Data on population intake of phytate is scarce, but according to the EFSA opinion this ranged between 300 to 1400 mg/day, depending on diet composition (EFSA, 2014h). The phytate content of foods can be modified through preparation methods, e.g., soaking, fermenting and sprouting of pulses and grains.

Main data gaps. The consequences of mild or moderate zinc deficiency and the identification of reliable biomarkers for zinc status are important knowledge gaps. Furthermore, it is expected that the intake of animal-source foods will decrease, and how this will influence zinc status and the risk for zinc deficiency is important to study.

Deficiency and risk groups. Zinc deficiency is rare in the Nordic and Baltic countries. Although it may induce vomiting, zinc is not considered to be toxic even in relatively high doses. Excess zinc in the diet is not absorbed and stored in the body for later use. People with restriction of animal products in their diets, such as vegans, are at risk of becoming zinc inadequacy unless consuming supplements or fortified foods.

Dietary reference values. Recommendations for children and adolescents are set based on factorial methods that considered daily losses through the kidneys, skin, semen, or menses, and the gastrointestinal tract (faeces) (EFSA, 2014h). For adults, the AR is based on the physiological requirement related to body weight. The dietary requirement is also dependent on the fraction of zinc absorbed from the diet, which is dependent on zinc content and on diet composition, including intake of phytate. In NNR2023, AR and RI for adults are based on a phytate intake of 600 mg/day, reflecting a semi-refined diet. The DRVs set by EFSA for a diet with a lower or higher phytate content (300, 900 or 1200 mg per day) can be used. For children, there is an extra need for zinc for growth. The extra need during pregnancy is smaller than for lactating women. With a phytate intake of 600 mg, the AR is set to 8 μg/day in females and 11 mg/day in males. Based on a CV of 10%, the RI is set to 10 and 13 mg/day in females and males, respectively. UL of zinc is 25 mg/d.

Iodine

DIETARY INTAKE

- Inorganic iodide absorbed from the diet

BIOMARKER

Indicator of recommended intake

- Median urinary iodine concentration in groups. Thyroid volume

Indicator of adverse effect

- Changes in markers of thyroid function (TSH, Tg, thyroid hormones, thyroid volume)

HEALTH EFFECT

Beneficial effects

- Essential component of the thyroid hormones T4 and T3

Adverse effects of high intake

- Thyroid dysfunction and disease

	Females	Males
Provisional AR (µg/d)	120	120
AI (µg/d)	150	150

For more information about the health effects, please refer to the background paper by Ingibjörg Gunnarsdóttir and Anne Lise Brantsæter (Gunnarsdóttir & Brantsæter, 2023).

Dietary sources and intake. Lean fish is a rich source of iodine. The main sources of iodine in the Nordic and Baltic countries include dairy products, excluding cheese (differences may occur between countries), saltwater fish, eggs, iodized table salt and products containing iodized salt, such as bread (Gunnarsdóttir & Brantsæter, 2023). The average iodine intake ranges from 30 to 270 µg/d (Lemming & Pitsi, 2022).

Main functions. Iodine is an essential component of the thyroid hormones thyroxine (T4, a pro-hormone) and triiodothyronine (T3, the active hormone), which are involved in metabolic regulation throughout life. During the foetal stage, infancy and childhood, these hormones are crucial for growth and numerous processes of neural and cognitive development, e.g., myelinization, neural migration and differentiation, and gene expression.

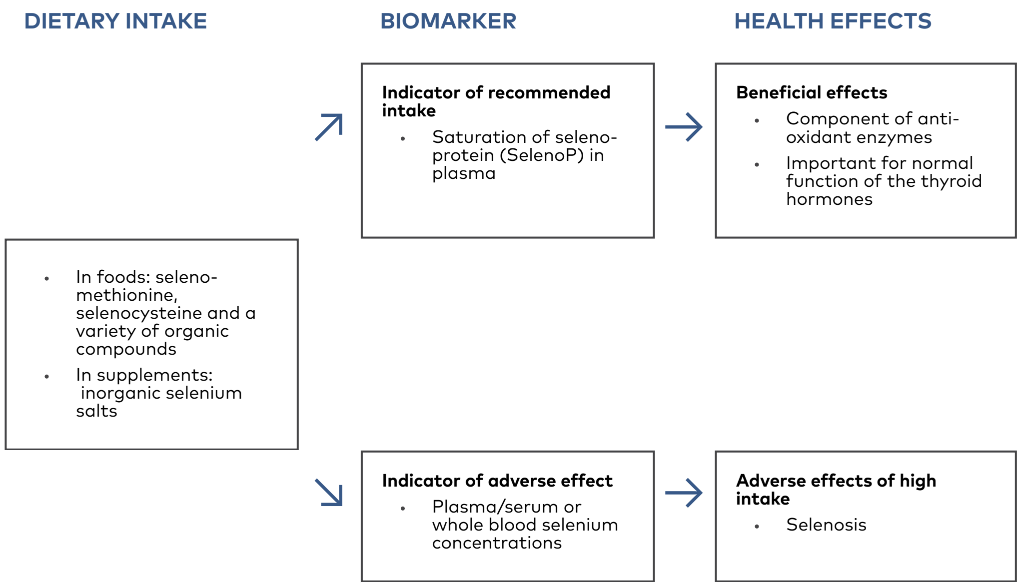
Indicator for recommended intake. There is no good indicator for adequate iodine intake at the individual level. Median urinary iodine concentration (UIC) is a valid marker of iodine intake at the group level (Gunnarsdóttir & Brantsæter, 2023).

Main data gaps. There is a need to re-evaluate the risk of iodine intakes above the current UL of 200 μg/day for 1 to 2-year-old children versus the benefit of implementing universal salt iodization to increase iodine intake in women of childbearing age. More nationally representative data on iodine status in infants, toddlers and breastfeeding women are warranted.

Deficiency or risk groups. Risk groups for iodine deficiency in the Nordic and Baltic countries include people with low or no intake of milk/milk products and fish (depends on the iodine content in fish) in countries with no fortification of e.g., bread and/or very low levels of iodine in salt. Children at particular risk of iodine deficiency include breastfed and weaning infants in countries with no or voluntary salt iodization or fed by mothers on a restrictive diet. Seaweed consumers may have a risk of excess intake. People with restriction of animal products in their diets, such as vegetarians and vegans, are at risk of becoming iodine deficient unless consuming supplements or fortified foods. . Both deficiency and excessive intake may cause thyroid dysfunction and disease, in addition to decreased fertility, adverse pregnancy and birth outcomes, and impaired neurocognitive development in children. Thyroid enlargement is the most recognizable consequence (Gunnardsottir & Brantsæter 2023).

Dietary reference values. Based on a recent balance study in infants and subsequent review-paper of iodine nutrition in lactating women and infants, the AI for infants has been adjusted to 80–90 μg/day for infants through 11 months (Gunnarsdóttir & Brantsæter, 2023). For adults, an AI is set from the AI set by EFSA (2014b), which is based on urinary iodine excretion to minimise thyroid volume enlargement. AI for adults is set to 150 μg/day (females and males). Based on the AI (EFSA, 2014b), provisional AR for adults is set to 120 μg/day (females and males). UL of iodine is 600 μg/day.

Selenium



	Females	Males
Provisional AR (µg/d)	60	70
AI (µg/d)	75	90

For more information about the health effects, please refer to the background paper by Jan Alexander and Ann-Karin Olsen (Alexander & Olsen, 2023).

Dietary sources and intake. Selenium concentrations in foods are highly dependent on soil content and availability. The Nordic and Baltic countries have low soil selenium content followed by low concentrations in locally grown foods. Finland has amended this by adding selenium to fertilizers while the other Nordic countries add selenium to animal feed. The main food sources are cereals (if imported from countries with higher soil selenium), fish, meat, dairy and eggs. The average selenium intake ranged from 20 to 88 µg/d (Lemming & Pitsi, 2022).

Main functions. The physiological functions of selenium are mediated by its presence in selenoproteins (Alexander & Olsen, 2023). Five of these are the antioxidant enzyme group of glutathione peroxidases, of which one is also a structural protein in sperm. The three iodothyronine deiodinases converting T4 to T3, the active thyroid hormone, are also selenium dependent. Three selenium containing thioredoxin reductases play key roles in cellular redox regulation. The function of several selenoproteins have not yet been fully characterized. Selenoprotein P (SelenoP) in plasma has a dual role; it transports selenium to peripheral tissue, has antioxidative properties and appears to play a role in protecting circulating lipoproteins against oxidation to more toxic species.

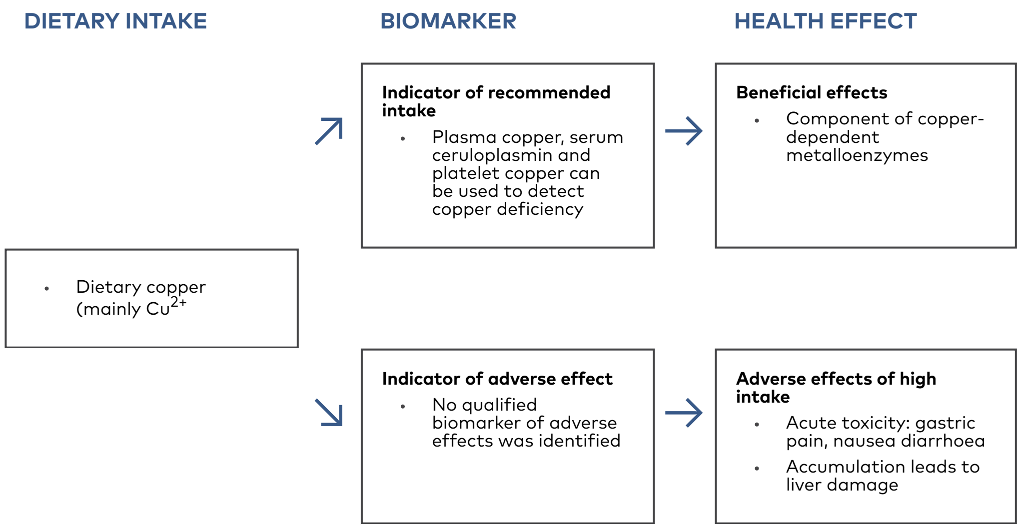
Indicator for recommended intake. Saturation of SelenoP in plasma. This is obtained at plasma selenium concentrations of approximately 110 µg/L (Hurst et al., 2013). The selenium intake needed to achieve a plasma concentration of about 110 µg/L is dependent on the selenium compound given, e.g., Se-methionine has higher bioavailability than most other forms of selenium. Based on a Chinese study (Xia et al., 2010), an average daily intake of dietary selenium of about 1.2 µg/kg body weight would be sufficient to achieve an optimal selenium concentration and maximized expression of SelenoP in plasma (Alexander & Olsen, 2023).

Main data gaps. More studies are needed on the relationship between selenium status and health outcomes, in populations low in selenium. Health outcomes include developmental effects in humans, e.g., neurodevelopment, immune function, cardiovascular diseases, cancer, immune function, ageing etc.

Deficiency and risk groups. Persons with a high intake of locally grown plant foods in soils low in selenium, like vegans and vegetarians, might have very low selenium intakes, especially if the foods are grown organically (Kristensen et al., 2015). People with restriction of animal products in their diets, such as vegans, are at risk of becoming selenium inadequacy unless consuming supplements or fortified foods.

Dietary reference values. SelenoP in plasma represents a saturable pool of selenium and is maximised at a selenium concentration in plasma of about 110 µg/L or an intake of about 1.2 µg/kg bw. At intakes above 330 to 450 µg/day selenium may cause toxic effects affecting liver, peripheral nerves, skin, nails and hair. AI is set to 75 µg/day (females) and 90 µg/day (males). Provisional AR is set to 60 µg/day (females) and 70 µg/day (males). NNR2023 adopt EFSA's new UL of 255 µg/day (EFSA, 2023b).

Copper



	Females	Males
AR (µg/d)	700	700
RI (µg/d)	900	900

For more information about the health effects, please refer to the background paper by Christine Henriksen and Erik Kristoffer Arnesen (Henriksen & Arnesen, 2023).

Dietary intake. Copper is found in a variety of foods. The average copper intake ranges from 1100 to 2100 µg/d (Lemming & Pitsi, 2022)

Main functions. Copper functions as a structural component in many proteins involved in energy and iron metabolism, production of neurotransmitters, formation of connective tissue, and endogenous antioxidant defence. Copper imbalances and copper deficiency have been linked to the pathogenesis of several chronic inflammatory diseases, but study design precludes conclusions about causality in these associations (Henriksen & Arnesen, 2023). Intake of high doses of copper leads to acute toxicity, which includes symptoms of gastric pain, nausea, vomiting, and diarrhoea. High chronic intakes of copper, for example in drinking water, can lead to gastro-intestinal disorders in children (Henriksen & Arnesen, 2023).

Interactions with other nutrients. Copper absorption is inhibited by the presence of other minerals, like zinc and iron, and compounds like phytates and oxalates that bind to Cu^{2+} in the gastrointestinal tract (Henriksen & Arnesen, 2023).

Indicator for recommended intake. Diets low in copper reduce the activity of several copper-dependent metalloenzymes. Plasma copper, serum ceruloplasmin and platelet copper has been used to indicate adequate copper status (IOM, 2001).

Main data gaps. A single sensitive and reliable biomarker of copper status is currently lacking (EFSA, 2015b). The role of copper imbalances in inflammatory and chronic disease needs further investigation.

Deficiency and risk groups. There are no risk groups for copper deficiency, but infants are sensitive to high intakes.

Recommendations. An intake of approximately 700–800 µg/d will maintain adequate copper status (IOM, 2001) and no new balance studies have been published since NNR2012 (Henriksen & Arnesen, 2023). Few data are available on copper absorption and needs during pregnancy. Based on the accumulation of copper in the foetus and maternal tissue, an additional 100 µg per day was recommended. The calculation of the copper content of human breast milk is the basis of a recommendation on additional copper during lactation. Based on a combination of copper status indicators, AR is set to 700 µg/day (females and males). RI is set to 900 µg/day (females and males). The values are adopted from the IOM (IOM, 2001). UL is set to 5 mg for adults, corresponding to the ADI of 70 µg/kg, based on probability for retention in liver (EFSA, 2023).

Chromium

DIETARY INTAKE	BIOMARKER	HEALTH EFFECT
	Indicator of recommended intake • No qualified indicator can be identified	**Beneficial effects** • Enhances insulin sensitivity, possibly through an influence on the glucose transporter 4 (GLUT-4) receptors. Inhibits hepatic enzyme 3-hydroxy-3-methyl-glutaryl-CoA reductase and affects cholesterol metabolism
• Trivalent chromium (CrIII)		
	Indicator of adverse effect • No qualified indicator can be identified	**Adverse effects of high intake** • No qualified adverse effect can be identified

No recommendation given due to lack of evidence

For more information about the health effects, please refer to the background paper by Christine Henriksen and Susanne Bügel (Henriksen & Bügel, 2023).

Dietary sources and intake. Trivalent chromium (CrIII) is the principal form of chromium which is ubiquitous in nature and exists in the air, water, soil, and biological materials. CrIII is found in foods and dietary supplements. EFSA has estimated the intake to be between 57 and 84 µg/day. No intake data on chromium is available from Nordic and Baltic dietary surveys (Lemming & Pitsi, 2022).

Interaction with other nutrients. Simultaneous ascorbate administration increases chromium uptake in humans and animals, and chromium absorption is also higher in zinc- and iron-deficient animals.

Main functions. About 0.5% of the dietary intake of chromium is absorbed by the body via passive diffusion, and the remainder is excreted in the faeces. The exact biological function of chromium has not yet been determined (Henriksen & Bügel, 2023). CrIII is considered to enhance insulin sensitivity, possibly through an influence on the glucose transporter 4 receptors. Chromium inhibits the cholesterol biosynthesis enzyme HMG-CoA reductase and thereby affects cholesterol metabolism.

Data gaps. Biomarkers for evaluating chromium status should be explored in balance studies, where a given amount of chromium is given. Furthermore, long-term effects of increased chromium intake in physiological dosages need to be assessed by clinical trials.

Indicator for recommended intake. There are no reliable biomarkers for chromium status.

Deficiency and risk groups. The essentiality of chromium is disputed, as no deficiencies have been documented in healthy humans. Toxicity of chromium is generally low and only achieved at very high doses.

Dietary reference values. There is no evidence of beneficial effects associated with increased chromium intake in healthy subjects (Henriksen & Bügel, 2023). This is also in line with EFSA's review of the topic (EFSA, 2014e). Not sufficient data to derive UL.

Manganese

DIETARY INTAKE

- Dietary manganese
- Occupational exposure

BIOMARKER

Indicator of recommended intake

- None identified

Indicator of adverse effect

- None identified

HEALTH EFFECTS

Beneficial effects

- A manganese-free diet results in fleeting dermatitis, miliaria crystallina, and lower plasma cholesterol

Adverse effects of high intake

- High intake linked to neurological outcomes, bone health, metabolic syndrome, type 2 diabetes (evidence uncertain and inconclusive)

	Females	Males
Provisional AR (mg/d)	2.4	2.4
AI (mg/d)	3	3

For more information about the health effects, please refer to the background paper by Maria Kippler and Agneta Oskarsson (Kippler & Oskarsson, 2023).

Dietary sources and intake. Manganese is ubiquitous (including occupational exposure), but main dietary sources are cereal-based products, nuts, chocolate, shellfish, pulses, fruits, and beverages (coffee, tea, alcoholic beverages, drinking water). Intake in Nordic populations is typically around 4 mg/d, but ranges from 3 to 7 mg/d. With an average milk intake of 0.8 L/day, the mean intake of exclusively breast fed infants up to 6 months of age would range between 2.4 and 24 µg/day (Kippler & Oskarsson, 2023).

Main functions. Manganese is an essential trace element for mammals. It is found in all tissues and is involved in synthesis and activation of enzymes and is a cofactor for metalloenzymes. Additionally, it is required for normal metabolism of proteins, amino acids, lipids, and carbohydrates. Manganese is important for maintenance of mitochondria by scavenging free radicals. It is further involved in reproduction, bone formation, immune function, regulation of blood glucose and cellular energy, digestion, and in blood clotting.

Indicator for recommended intake. No indicator was identified for setting any DRV. Under experimental conditions (depletion-repletion studies), a manganese-free diet results in fleeting dermatitis, miliaria crystallina, and lower plasma cholesterol, which normalizes during repletion.

Main data gaps. Biomarkers of intake and status are lacking. There is limited information concerning the relationship between manganese intake or status and health-related endpoints or disease prevention, especially high exposure levels and neurodevelopment in infants, children, and adolescents. There are no studies from the Nordic or Baltic countries (Kippler & Oskarsson, 2023).

Deficiency and risk groups. Deficiency is not characterized in the general population. No specific risk groups are established.

Dietary reference values. IOM (IOM, 2001) and EFSA (EFSA, 2013d) provided age and sex-specific AI values from approximately 0.003 mg/d before 6 months age to approximately 2–3 mg/d in adulthood. AI is set to 3 mg/day (adult females and males). A provisional AR is set to 2.4 mg/day (adult females and males). The values are based on AI from observed dietary intake values from EFSA (EFSA, 2013d). Not sufficient data to derive UL.

Molybdenum

DIETARY INTAKE

- Food and water molybdenum
- Occupational exposure

BIOMARKER

Indicator of recommended intake

- No qualified indicator can be identified

Indicator of adverse effect

- No qualified indicator can be identified

HEALTH EFFECTS

Beneficial effects

- Sufficiency corrects deficiency symptoms, including irritability, tachycardia, tachypnea, night blindness, low plasma methionine, low serum uric acid, and reduced urinary concentrations of sulphate, thiosulphate and uric acid

Adverse effects of high intake

- Increased plasma uric acid, gout-like symptoms, decline in GFR

	Females	Males
Provisional AR (µg/d)	52	52
AI (µg/d)	65	65

For more information about the health effects, please refer to the background paper by Agneta Oskarsson and Maria Kippler (Oskarsson & Kippler, 2023).

Dietary sources and intake. Molybdenum is ubiquitous in food and water as soluble molybdates. The main dietary sources of molybdenum are cereal products, vegetables and dairy products (Oskarsson & Kippler, 2023). There are few published studies on the dietary intake in the Nordic countries. Dietary intake is approximately 30 µg/day in children, and 60–172 µg/day in adults. Plasma molybdenum reflects longer-term intake and 24-h urinary excretion is related to recent intake. No intake data on molybdenum are available from Nordic and Baltic dietary surveys (Lemming & Pitsi, 2022).

Main functions. Molybdenum is a cofactor for enzymes involved in oxidation of purines to uric acid, metabolism of aromatic aldehydes and heterocyclic compounds and in the catabolism of sulphur amino acids.

Indicator for recommended intake. No indicator was identified for setting AR and RI.

Main data gaps. Indicators for AR and UL based on health outcomes in humans.

Deficiency and risk groups. Although considered an essential element, there are no reports on clinical signs of dietary molybdenum deficiency in healthy humans (Oskarsson & Kippler, 2023). Total parenteral nutrition with no molybdenum results in signs of clinical deficiency, including irritability, tachycardia, tachypnea, night blindness, low plasma methionine, low serum uric acid, and reduced urinary concentrations of sulphate, thiosulphate and uric acid (normalized after 30 days of treatment with 300 µg/day of ammonium molybdate) (Oskarsson & Kippler, 2023).

Dietary reference values. IOM set an AR (34 µg/d) and RI (45 µg/d) for adults, and RI and AI for certain other life-stage groups (IOM, 2001). EFSA set only an AI for adults (15–65 µg/d) due to limited evidence (EFSA, 2013a). For NNR2023, AI is set to 65 µg/day (females and males), based the AI from the lower end of the range of observed intakes from mixed diets in European countries, as given by EFSA (EFSA, 2013a). A provisional AR is set to 52 µg/day (females and males).

Based on EFSA (2018), UL is set at 0.6 mg/d.

Fluoride

DIETARY INTAKE	BIOMARKER	HEALTH EFFECT
	Indicator of recommended intake • No qualified indicator can be identified	**Beneficial effects** • There are no known functions or deficiencies of fluoride, and fluoride is thus not considered essential for humans • Reduction in risk of dental caries
• Fluoride in drinking water (main source), foods, and toothpaste		
	Indicator of adverse effect • No qualified indicator can be identified	**Adverse effects of high intake** • Dental fluorosis or "mottled teeth" • Skeletal mineralization • High intake causes acute symptoms such as nausea, stomach pain, and vomiting • Very high intake is lethal

	Females	Males
Provisional AR (mg/d)	2.6	3.0
AI (mg/d)	3.2	3.7

For more information about the health effects, please refer to the background paper by Mariann Kjellevold and Maria Kippler (Kjellevold & Kippler, 2023).

Dietary sources and intake. Drinking water is the dominant source of fluoride. Fluoride levels in foods are low, with a few exceptions, like seafood and tea. There is a lack of fluoride in food composition tables. Toothpaste contributes to fluoride intake in small children. No intake data on fluoride is available from Nordic and Baltic dietary surveys (Lemming & Pitsi, 2022).

Main functions. There are no known functions or deficiencies of fluoride, and fluoride is thus not considered essential for humans (Kjellevold & Kippler, 2023). However, fluoride can bind to calcium in the skeleton and tooth tissues, creating complexes that replace the hydroxyl ions in hydroxyapatite crystals thereby making the crystals less acid-soluble, which prevents dental caries.

Indicator for recommended intake. No indicator was identified for setting AR and RI. For setting AI, the selected indicator was reduction in risk of dental caries (observational studies). An intake of 2.2 g/kg bodyweight is lethal in adults. In children, 15 mg/ kg bodyweight is lethal, and 5 mg/kg bodyweight causes acute symptoms such as nausea, stomach pain, and vomiting. Chronic high intakes of fluoride via drinking water can affect skeletal mineralization. The most common side effect of high fluoride intake is dental fluorosis, or "mottled teeth".

Main data gaps. The main challenges for setting recommended intake in the Nordic and Baltic countries are lack of food composition data reporting fluoride content in food and lack of data on fluoride status in the population.

Deficiency and risk groups. There are no known deficiencies from low/zero fluoride exposure (Kjellevold & Kippler, 2023).

Dietary reference values. IOM set an AI for adults to 3 mg/d and 4 mg/d for females and males, respectively; for infants and children (> 6 months), 0.05 mg/kg/d (IOM, 1997). EFSA set an AI to 0.05 mg/kg/d for both children and adults (EFSA, 2013c). Using reference weights for NNR2023, the AI is set to 3.2 mg/day (females) and 3.7 mg/day for males). Provisional AR is set to 2.6 mg/day (females) and 3 mg/day (males). Values are based on AI from observed dietary intake values set by EFSA (EFSA, 2013c).

Based on EFSA (2018), UL is set at 7 mg/d.

Antioxidants and phytochemicals

DIETARY INTAKE

- Dietary antioxidants and phytochemicals, as measured for example by the dietary total antioxidant capacity (dTAC)
- Main dietary sources are fruits and vegetables

BIOMARKER

Indicator of recommended intake

- None identified

Indicator of adverse effect

- None identified

HEALTH EFFECT

Beneficial effects

- Dietary antioxidants and phytochemicals may reduce oxidative stress

Adverse effects of high intake

- High-dose β-carotene supplements increase the risk of lung cancer among people exposed to tobacco

No recommendation given due to lack of evidence

For more information about the health effects, please refer to the background paper by Mari Myhrstad and Alicja Wolk (Myhrstad & Wolk, 2023).

Dietary sources and intake. Fruits and vegetables are the main contributors to dietary total antioxidant capacity (dTAC). Only a few studies have assessed dTAC in Nordic and Baltic countries. Estimated median dTAC (assessed by oxygen radical absorbance capacity [ORAC] assay) from foods in Swedish males and females were median 14,025 and 12,353 μmol Trolox equivalents/day, respectively. For Swedish girls and boys aged 8 y, estimated median dTAC was 10,397 and 9611 μmol Trolox equivalents/day, respectively (Myhrstad & Wolk, 2023). Plasma TAC is considered a valid and reproducible biomarker of dietary intake. Fruits and vegetables contain not only antioxidants and phytochemicals, but are commonly high in water, low in energy, contain numerous nutrients, vitamin C, vitamin E, vitamin K, folate, potassium and are good source of fibre. See other summaries in this report for further discussions related to antioxidants and phytochemicals specific to specific foods (vegetables, fruits and berries) or nutrients with antioxidant capacity (vitamin C, vitamin E, β -carotene, and selenium).

Main functions. In plants, phytochemicals protect against pathogens and UV radiation, and provide colour and flavour. In humans, phytochemicals may affect biological functions via regulation of redox reactions, including antioxidative (scavenge free radicals, induce endogenous antioxidants), anti-apoptotic, anti-carcinogenic, anti-inflammatory, and anti-atherosclerotic properties, and modification of endothelial function and angiogenesis (Myhrstad & Wolk, 2023).

Indicator for recommended intake. No indicator was identified for setting any DRV. The WCRF considered high-dose β-carotene supplements to convincingly increase the risk of lung cancer among people exposed to tobacco/smoke (WCRF/AICR, 2018d).

Main data gaps. More research is needed on the role of phytochemical and antioxidant rich fruits and vegetables in oxidative stress related diseases, such as cancers.

Deficiency and risk groups. Risk groups may be individuals with very low intake of fruits and vegetables.

Dietary reference values. Reference values for specific antioxidants or phytochemicals beyond the ordinary dietary recommendations for vitamin C, vitamin E, β-carotene, and selenium cannot be given. High intakes of supplements with antioxidant properties, such as beta-carotene, increase the risk of all-cause mortality, and is therefore not recommended (O'Connor et al., 2022; WCRF/AICR, 2018d).

FISH

Increased intake of fish from sustainably managed stocks supported both by effects on health outcomes and environmental footprint.

FOOD GROUPS, MEAL AND DIETARY PATTERNS

FOOD GROUPS, MEAL AND DIETARY PATTERNS

Summaries for deriving FBDGs for food groups, meal and dietary patterns

The sections below summarize the evidence for setting science advice for FBDGs for all the food groups, meal and dietary patterns. The text in the sections on dietary intakes is mainly based on the background paper by Lemming and Pitsi (2022). The text in the sections on health effects are based on qualified systematic reviews (see Table 2), emphasizing conclusions with strong evidence (convincing and probable evidence), and the corresponding background papers (see Table 4). The text in the sections on environmental effects is mainly based on four background papers discussing the environmental impacts of human food consumption (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). While the science advice is partly based on the corresponding background papers, the NNR2023 Committee has the sole responsibility for the text in all sections, including the science advice for all FBDGs. All final science advice for FBDGs were set unanimously by the NNR2023 Committee.

Food intakes should not be interpreted as absolute, since they are uncertain and depend on, food consumption, but also survey methods, reporting errors, countries' food databases, calculation procedures etc. The range of average intakes in the Nordic and Baltic countries is given.

OVERVIEW OF FOOD GROUPS, MEAL AND DIETARY PATTERNS

Breastfeeding

DIETARY INTAKE

HEALTH AND ENVIRONMENTAL EFFECTS

Breastmilk

Beneficial health effects
Breastfeeding protects against infections, overweight and obesity, and has positive association with cognition/performance in intelligence tests. Breastmilk can fulfil nutrient requirements of the infant the first 6 months, except for vitamin D.

Environmental impacts
Breastmilk has lower environmental impact compared to infant formula.

Science advice: It is recommended to protect early initiation of exclusive breastfeeding continued for about 6 months and continued breastfeeding combined with complementary feeding for the first 12 months, or for a longer time if it suits both mother and child and is balanced with complementary feeding. If breastfeeding and exclusive breastfeeding is not possible, infant formula is recommended before 4 month, and infant formula together with complementary foods after 4 months.

For more information about the health effects, please refer to the background paper by Agneta Hörnell and Hanna Lagström (Hörnell & Lagström, 2023). For more information about the environmental impacts, please refer to the following background papers (Harwatt et al., 2023; Trolle et al., 2023).

Food and nutrient intake. The Nordic and Baltic countries have relatively high breastfeeding (BF) rates (Hörnell & Lagström, 2023). Almost all mothers BF their infants (Hörnell & Lagström, 2023). Exclusive BF (EBF) rates at 4 months of age is 40-50 % and decline rapidly thereafter. BF is commonly continued together with the addition of solids and other fluids than breastmilk, i.e., complementary foods. About 60–80 % of infants are still breastfed at 6 months, and 30–60 % at 12 months. BF rates seem similar in the Baltic countries with 50–70 % of infants breastfed at 6 months.

Health effects. Several recent qSRs have been published on BF and several health outcomes both for the mother and the child, as discussed by Hörnell and Lagström (2023). Overall, these qSRs found strong evidence for a lower risk of breast cancer for the mother (WCRF/AICR, 2018c), lower risk of diarrhoea, overall infections, acute otitis media, and respiratory infections for the child (Victora et al., 2016), lower risk of overweight and obesity for the child (Dewey et al., 2020a; WCRF/AICR, 2018b) and childhood asthma (Güngör et al., 2019b). However, these studies did not compare EBF for 4 months vs 6 months, and the relationship between these outcomes and the duration of exclusive breastfeeding is limited or insufficient.

As discussed in Hörnell and Lagström (2023), some studies also suggest that BF has positive effects on cognition and performance in intelligence tests, decreased mortality and malnutrition. Breastmilk contains water, protein, lipids, carbohydrates, vitamins, minerals as well as non-nutritive bioactive factors, such as hormones, growth factors, antibodies, human milk oligosaccharides and bacteria with metabolites. Breastmilk gives the newborn essential nutrients in an efficiently absorbed combination. Breastfeeding protects against too high protein intake too early in childhood and is most often sufficient as the only form of nutrition for the first 6 months, except for vitamin D which needs to be given as supplement (Hörnell & Lagström, 2023).

Too long EBF, i.e., longer than 6 months, increases the risk of food allergies, leads to insufficient nutrient intake and may lead to difficulties in learning to eat a variable diet (Hörnell & Lagström, 2023). In addition, too long EBF, i.e., more than 6 months, may increase the risk of iron deficiency.

Environmental impacts. Recent papers demonstrate lower climate and other environmental impacts of BF compared to formula feeding in many countries. The environmental impact of 4 months exclusive feeding with infant formula was 35–72% higher than that of 4 months exclusive breastfeeding, depending on the impact category, i.e., global warming potential, terrestrial acidification, marine and freshwater eutrophication, or land use (Harwatt et al., 2023). The FAO/WHO guidelines for sustainable diets recommend early initiation of BF, EBF until six months of age, and continued BF, combined with appropriate complementary feeding, as long as it suits mother and child (FAO/WHO, 2019).

Main data gaps. More knowledge about varying duration of EBF and partial BF is needed, as is knowledge about complementary feeding and foods for young children. Further, evidence for associations between infant nutrition and health effects, such as risk of food allergies and asthma, and the optimal duration of EBF, is needed.

Risk groups. Limited possibilities for maternity leave may influence breastfeeding. Social inequalities in breastfeeding are observed in all Nordic countries. For some ethnic minority groups exclusive breastfeeding is much shorter than recommended.

Science advice:

- **Based on health outcomes:** From a health perspective, it is important to protect, support and promote breastfeeding. For most full-term, normal weight infants, breast milk is sufficient as the only form of nutrition for the first 6 months, except for vitamin D which needs to be given as supplement. International authorities recommend EBF for the first 6 months of life, or for the first 4–6 months (EFSA, 2019a; ESPHGAN Committee on Nutrition, 2009; NASEM, 2020; SACN, 2018; USDA/USDHHS, 2020; Victora et al., 2016; WCRF/AICR, 2018c). For nutritional reasons, most infants need complementary feeding from about 6 months of age.
- **Based on environmental impacts**: BF in accordance with the recommendations has been shown to decrease the environmental impact from the consumption of other foods. Breastmilk has low environmental impact as compared to formula and industrially made foods for infants.
- **Overall science advice**: It is recommended to protect early initiation of EBF continued for about 6 months and continued BF combined with complementary feeding for the first 12 months, or for a longer time if it suits both mother and child and is balanced with complementary feeding. If EBF and BF is not possible, infant formula is recommended before 4 month, and infant formula together with complementary foods after 4 months.

Complementary feeding

DIETARY INTAKE		HEALTH AND ENVIRONMENTAL EFFECTS
	↗	**Beneficial health effects** Giving various complementary foods of the correct consistence for age, from about 6 months of age (not before 4 months), stimulate the child's development and learning to eat a variable diet. Complementary foods including a variation of food groups, including common food antigens decrease the risk for allergies. Iron rich foods given early (about 6 months) prevent iron deficiency, e.g., meat, egg, whole grain or fortified cereals, beans, lentils, nuts and seeds.
Breastfeeding in combination with solid and liquid foods	→	**Adverse health effect** Complementary feeding before 4 months may cause harmful effects. Too much complementary feeding up to 12 months may have negative effects on breastfeeding duration, and therefore halt the positive effects of breastfeeding. Adding cow's milk before 12 months of age and gluten before 4 months of age to the infant's diet, has been associated with Type 1 diabetes, and cow's milk especially with the risk of iron depletion.
	↘	**Environmental impacts** Industrially made products for young children based on cereals/vegetables/fruits/meat/fish associate with their origin and procedures for production.

Science advice: It is advised to start with solid complementary foods from about 6 months of age, and not before 4 months of age. Various complementary foods should be given, and some iron-containing foods should be ensured.

For more information about the health effects, please refer to the background paper by Agneta Hörnell and Hanna Lagström (Hörnell & Lagström, 2023). For more information about the environmental impacts, please refer to the following background papers (Harwatt et al., 2023; Trolle et al., 2023).

Food and nutrient intake. At 4 month of age, approximately 40–50 % of infants in the Nordic and Baltic countries are still exclusively breastfed. A further 15–30 % are still breastfed together with complementary foods (semi-solids and/or infant formula), while about 15–30 % are not being breastfed. At 12 months of age, about 30–60 % of infants are still breastfed together with complementary foods (Hörnell & Lagström, 2023).

Health effects. Several qSRs are available on the role and timing of complementary feeding and asthma, allergy and atopic dermatitis/eczema (de Silva et al., 2020; Obbagy et al., 2019b), coeliac disease (EFSA, 2019), micronutrient status (Obbagy et al., 2019a), childhood growth and development (EFSA, 2019a; English et al., 2019a, b, c; Padhani et al., 2023), bone health (Obbagy et al., 2019c) and food acceptability (Spill et al., 2019). Two qSRs concluded that there was at least moderate evidence for a lower risk of egg and peanut allergy when small amounts of cooked (not raw) eggs and peanuts are introduced from 4 to 6 months of age in high-risk children (de Silva et al., 2020; Obbagy et al., 2019b). On the other hand, there was also moderate evidence for no associations between the age at introduction of complementary foods and risk of food allergy, atopic dermatitis/eczema, or asthma (Obbagy et al., 2019b), and probably no effect of introducing gluten-containing complementary foods at 4 vs 6 months of age on risk of coeliac disease.

Other qSRs found moderate evidence for no effect on growth, size, body composition or risk of overweight and obesity of introducing complementary foods at 4-5 months compared to with 6 months of age, nor of meat intake or complementary foods with different types of fats, in healthy, full-term infants (EFSA, 2019a; English et al., 2019b, c). There is also moderate evidence suggesting that complementary feeding at 4 months compared with 6 months of age is not associated with iron status (Obbagy, 2019). There is strong evidence that complementary foods and beverages high in iron, such as meat or iron-fortified cereals, help maintaining iron status or prevent iron deficiency among infants with insufficient iron stores or breastfed infants who are not otherwise receiving adequate iron (EFSA, 2019a; Obbagy et al., 2019a). Repeated tasting of vegetables or fruits is also associated with increased acceptability of the exposed food in infants and toddlers (age 4–24 months) (Spill et al., 2019). A *de novo* qSR on protein intake in children found probable evidence for a cause-and-effect association between higher total protein intake during the first 18 months of age and higher BMI later in childhood (Arnesen et al., 2022).

As discussed in Hörnell and Lagström (2023), no conclusive evidence can be drawn regarding complementary foods for the first 6 months of life for other health outcomes. Giving various complementary foods of the appropriate texture for age, from 6 months of age, stimulates the child's development and learning to eat a variable diet (EFSA, 2019a; Hörnell & Lagström, 2023). For nutritional reasons, the majority of infants need complementary feeding from around 6 months of age (EFSA, 2019a; Hörnell & Lagström, 2023). Iron rich foods given early, e.g., meat, eggs, whole grains or fortified cereals, beans, lentils, and nuts, prevent iron deficiency (Hörnell & Lagström, 2023). Too early and too much complementary feeding reduces the positive health effects of breastfeeding for mother and child, such as protection of the child against infections, overweight and obesity. Adding cow's milk before 12 months of age and gluten before 4 months of age to the infant's diet has been associated with Type 1 diabetes, and cow's milk especially with the risk of iron depletion (Hörnell & Lagström, 2023; SACN, 2018).

Environmental impacts. The climate impact of infant formulas is twice as high as that of breastmilk (Harwatt et al., 2023). The environmental impact of complementary foods for young children depends on their ingredients and procedures for production.

Main data gaps. More knowledge about complementary feeding is needed as well as about foods for young children. Further evidence for associations between infant nutrition and health effects is also needed. Studies and innovation to explore the possibilities and challenges with a vegan or mainly plant-based diet is necessary. More knowledge about the risk of food allergies and asthma in relation to timing of complementary feeding is needed.

Risk groups. The market of special foods for the youngest citizens is large and evolving and needs to be regularly explored by experts. Complementary feeding before 4 months may cause harmful effects. Too much complementary feeding up to 12 months may have negative effects on breastfeeding duration. Cow's milk before 12 months of age has been associated with type 1 diabetes and with the risk of iron depletion. Gluten before 4 months of age has been associated with type 1 diabetes.

Science advice:

- **Based on health outcomes**: It is advised to start with various solid foods of appropriate texture from about 6 months of age, and not before 4 months of age. Various complementary foods including potentially allergenic foods should be given and iron containing foods ensured.
- **Based on environmental impacts:** The climate impact of infant formulas is substantially higher than breastmilk, and this difference might be larger if the mother has a more environmentally conscious diet.
- **Overall science advice:**It is recommended to start with solid complementary foods from about 6 months of age, and not before 4 months of age. Various complementary foods should be given and some iron containing foods should be ensured.

Beverages

DIETARY INTAKE

Coffee, tea, sugar-sweetened beverages (SSB), low- and no-caloric sweetened beverages (LNCSB)

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects
Is a source of water. Long-term moderate coffee and tea consumption have been observed to have health favorable and no negative health effects.

Adverse health effects
Unfiltered coffee increases cholesterol levels. SSBs are associated with obesity in children and adults, type 2 diabetes and CVD in adults, and caries, especially in children.

Environmental impacts
The high coffee and SSB consumption can contribute to a higher total environmental footprint in the Nordic and Baltic diet. Land use for growing coffee, tea and sugar may have contributed to decreasing biodiversity through monoculturalism.

Science advice: Moderate consumption of filtered coffee (about 1-4 cups/day) and tea may be part of a healthy diet. The total consumption of caffeine from all sources should be limited to 400 mg caffeine/day. For children, a safe level of caffeine intake is 3 mg per kg body weight per day. Consumption of unfiltered coffee and SSB should be limited. High-quality tap water should be the preferred choice of beverage.

For more information about the health effects, please refer to the background paper by Emily Sonestedt and Marko Lukic (Sonestedt & Lukic, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary intake. The average intake of coffee is about 250–700 ml/day, the intake of tea is about 40–240 ml/day and the intake of soft drinks is about 40–280 ml/day (Lemming & Pitsi, 2022). The added sugars in sugar-sweetened beverages (SSB) account for 1–7 E% in the Nordic and Baltic countries. Among the groups with very high intake of added sugars (i.e., the 95th percentile), the added sugar in SSB contribute with up to 24 E% (EFSA, 2022).

Health effects. Seven qSRs are available on the role of SSB, LNCSB, tea, and coffee and health outcomes (EFSA, 2022; Mayer-Davis et al., 2020a; Rios-Leyvraz & Montez, 2022; Rousham et al., 2022; SACN, 2015; Sonestedt et al., 2012; WCRF/AICR, 2018g). For cancer outcomes, there is strong evidence from observational studies that consuming coffee probably decreases the risk of liver cancer and endometrial cancer (WCRF/AICR, 2018g). SSB consumption is associated with obesity and dental caries, especially in children, and has also been associated with increased risk of type 2 diabetes, hypertension, and cardiovascular disease and cardiovascular mortality, possibly mediated by energy intake (EFSA, 2022; Mayer-Davis et al., 2020a; SACN, 2015; Sonestedt et al., 2012).

As discussed in Sonestedt and Lukic (Sonestedt & Lukic, 2023), moderate consumption of coffee (about 1-4 cups/day) may also reduce the risk of cardiovascular diseases and type 2 diabetes. Negative health effects of high intake of coffee, tea, and SSB may be mediated through their ingredients, such as caffeine, added and free sugars or other sweeteners. Unfiltered (such as boiled or French press) coffee increases LDL-cholesterol concentrations in plasma (Sonestedt & Lukic, 2023). High caffeine intake in pregnancy is associated with higher risk of pregnancy loss, pre-term birth, and low birth weight. Replacing SSB with LNCSB may result in a small weight reduction, likely through reduced total energy intake (Hjelmesæth & Sjöberg, 2022; Rios-Leyvraz & Montez, 2022; Sonestedt & Lukic, 2023).

Health effects of artificial sweeteners are not considered in NNR2023, as this is assessed by national food safety authorities.

Environmental impacts. The high consumption of coffee contributes to the total environmental impacts in the Nordic and Baltic diet and consumption should therefore be limited. For environmental reasons tap water should be the preferred choice before SSB, LNCSB and bottled water. Land for growing coffee, tea, and sugar may contribute to decreasing biodiversity and land use in species rich areas (Ahlgren et al., 2022; Trolle et al., 2023).

Main data gaps. Further research on the health effects and safe intake levels are needed. Further research is needed on the effect of intake of coffee and other drinks in various risk groups.

Risk groups. Children and pregnant women are more sensitive to high caffeine intakes. High consumption of caffeinated "energy drinks" may cause multiple adverse health consequences for children and adolescents due to the caffeine and sugar content.

Science advice:

- **Based on health outcomes:** A moderate intake of coffee probably reduces the risk of some cancers and may be part of a healthy diet. Consumption from 0 to a maximum of 400 mg/d of caffeine is considered a safe level for adults. The caffeine concentration in tea is generally lower than in coffee but varies from highest content in black tea to the lowest in herbal tea, with green tea in between. Many energy drinks contain high amounts of caffeine. Some SSB and LNCSB may also contribute significantly to the total caffeine intake. Consumption of energy drinks, boiled/unfiltered coffee, and SSB should be limited. EFSA considers that single doses of caffeine up to 200 mg and total intake up to 400 mg per day from all sources do not raise safety concerns for the general healthy adult population. For children, the current recommendation for a safe level of caffeine intake is 3 mg per kg body weight per day. For pregnant and lactating women, the recommendation for total caffeine intake is set to maximum 200 mg per day. SSB consumption should be reduced due to the evidence for causal effects on obesity and dental caries, especially in children, CVD and type 2 diabetes.
- **Based on environmental impacts:** The high coffee consumption can contribute to a higher total environmental impacts in the Nordic and Baltic diet and consumption should therefore be limited. High-quality tap water should be the preferred choice before SSB, LNCSB and bottled water.
- **Overall science advice:** Moderate consumption of filtered coffee (about 1–4 cups/day) and tea may be part of a healthy diet. The total consumption of caffeine from all sources should be limited to 400 mg caffeine/day. For children, a safe level of caffeine intake is 3 mg per kg body weight per day. Consumption of unfiltered coffee and SSB should be limited. High-quality tap water should be the preferred choice of beverage.

Cereals

DIETARY INTAKE

Cereals most consumed in the Nordics

- Wheat
- Oats
- Rice
- Rye
- Barley

HEALTH AND ENVIRONMENTAL EFFECTS

↗ **Beneficial health effects**
A high intake of whole grains lowers the risks of cardiovascular disease, colorectal cancer, type 2 diabetes, and all-cause mortality.

→ **Adverse health effects**
No adverse effects found from high intakes of whole grains. Few or no studies on refined grains (flour) specifically.

↘ **Environmental impacts**
Cereals have low GHG emissions. However, global cereal production vastly surpasses the amount needed to feed humans and thus a large percent of the surplus is used animal feed, biofuel production. Also, the Nordic countries use most of their cereal production for animal feed. Furthermore, the production is dominated by monocultures, contributing to reduction in biodiversity.

Science advice: It is recommended to have an intake of at least 90 g/day of whole grains (including whole grains in products), with likely further benefits of higher intakes. Whole grain cereals other than rice should preferentially be used.

For more information about the health effects, please refer to the background paper by Guri Skeie and Lars T. Fadnes (Skeie & Fadnes, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

The definition of cereals (grains) comprises commonly eaten seeds from species from the grass family, i.e., wheat, rye, oat, barley, maize, rice, millet, sorghum/durra, teff and wild rice (Christensen & Biltoft-Jensen, 2022). In addition, the global consensus definition includes 'pseudo-cereals' (amaranth, buckwheat and quinoa) (van der Kamp et al., 2021). Whole grains are defined as intact grains or processed grains (e.g., ground, cracked or flaked) where the three fractions endosperm, germ and bran are present in the same relative proportion as in the intact grains (van der Kamp et al., 2021). A consensus statement suggests that whole grain should be the main ingredient in whole grain food products, i.e., whole grain should constitute more than 50 % of the dry matter (WholEUGrain, 2021). The term "cereals" also encompasses refined grains, where the refining process involves removing the bran and germ, which are nutrient rich components, leaving the starchy endosperm, containing varying amounts of protein (e.g., gluten). Many whole grain breads also contain refined grains for taste and baking properties.

Dietary sources and intake. Cereals are important sources of energy, carbohydrate and protein, and a source of thiamine, folate, vitamin E, iron, and zinc. If cereals have been grown in selenium-rich soils (i.e., U.S. and Canada), they are also an important source of this element. The average intakes of cereal products range from approximately 110 g/day in Finnish females to 270 g/day in Norwegian males (Lemming & Pitsi, 2022).

Health effects. Seven qSRs are available on the role of cereals (grains) and health outcomes (Fogelholm et al., 2012; Hauner et al., 2012; Reynolds et al., 2019; SACN, 2015; WCRF/AICR, 2018b, j; Åkesson et al., 2013). There is a convincing dose-response association between whole grain consumption and lower risk of all-cause mortality, coronary heart disease, colorectal cancer and type 2 diabetes incidence (Reynolds et al., 2019; Skeie & Fadnes, 2023; WCRF/AICR, 2018j). Higher intake of whole grains is also associated with lower body weight, total cholesterol and systolic blood pressure (Reynolds et al., 2019).

Dose-response curves show that risk reduction for all-cause mortality is observed for intakes up to 50-60 g/day of whole grains. Higher intakes (i.e. 90 g/day) confer even greater risk reduction for coronary heart disease, type 2 diabetes and colorectal and breast cancer (Reynolds et al., 2019).

According to the discussion in Skeie and Fadnes (2023), there is less evidence for refined grains, but available evidence does not indicate similar beneficial associations compared with whole grains.

As described in the collaboration between the Global Burden of Disease project and the NNR2023 project, a diet low in whole grains is the highest-ranked dietary risk factor in the Nordic and Baltic countries. Across all countries, low whole grains diets are responsible for one fifth of the total burden of disease attributed to dietary factors and it is the greatest overall contributor to ischemic heart disease and colon and rectum cancer (Clarsen, in press).

Environmental impacts. Most modern grain varieties have relatively high yields, and except for large methane emissions from traditional rice paddies and nitrous oxide from excess nitrogen fertilizer, GHG emissions from grain production are low (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). Fertilizer utilization is variable but can be high. Thus, grain-based foods can be produced with a relatively modest environmental impacts. However, the production is dominated by intensive, large-scale cropping systems with low diversity, contributing to reduced biodiversity and where long-term sustainability is difficult to ensure. Global cereal production vastly surpasses the amount needed to feed humans (Bahadur KC et al., 2018). The surplus is used for animal feed and biofuel production. The large demand generated by such uses may contribute to adverse environmental effects of grain production.

Main data gaps. There is more information available for the health effects of whole grain than for that of refined grains. Papers analysing how substitution of refined grains with whole grains influences health outcomes are sparse. There are few studies on specific cereals. There is a lack of data on differences in environmental impacts among domestically, regionally and internationally sourced cereals, especially when considering the potential changes in environmental conditions and increasing occurrence of environmental shocks.

Risk groups. People with coeliac disease and other gluten-related disorders are at risk of low cereal intakes, but can instead consume other cereals such as millet, rice, maize, quinoa, buckwheat, amaranth, teff and sorghum products to cover energy, fibre, and nutrient needs. Gluten-free oats are also an option.

Science advice:

- **Based on health outcomes:** It is recommended to consume at least 90 g/day (dry weight) of whole grains (including whole grains in products), with likely further benefits of higher intakes. Such further intakes have no adverse effects and may contribute to a healthy, plant-based diet. At high energy requirements refined grains also have a role. This justifies allowing some refined cereals in the diet.
- **Based on environmental impacts:** Due to the low climate impact of cereals and cereal-based foods, rice being an exception, they are key foods in the transition to a lower climate impact diet.
- **Overall science advice:** It is recommended to have an intake of at least 90 g/day of whole grains (including whole grains in products), with likely further benefits of higher intakes. Whole grain cereals other than rice should preferentially be used.

Vegetables, fruits, and berries

DIETARY INTAKE

Culinary defined into
- Vegetables, excl. potatoes and pulses
- Fruits excl. fruit juice
- Berries

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects
- Contributes to adequate supply of some nutrients in different types of diets, e.g., dietary fibre, vitamin C, E and K, folate and potassium. Some vegetables provides minerals such as iron, e.g., dark green leafy vegetables, which also provides β-carotene, as do other vegetables, such as carrots.
- Increasing intakes positive effect on lowering cancer in the gastric system and lung, cardiovascular disease and all-cause mortality.

Adverse health effects
Available evidence does not indicate any significant adverse health effects.

Environmental impacts
Vegetables fruits and berries have in general low climate and environmental impact/footprints per weight unit. Environmental impacts are mainly related to pesticide use and impacts on biodiversity, locally and globally. Fruits and vegetables that store well will reduce waste and thereby reduce negative impacts.

Science advice: **It is recommended to consume a variety of vegetables, fruits, and berries, 500-800 grams, or more, per day in total. A variety of different types of both vegetables and fruits (including berries) should be consumed, with emphasis on dietary fibre contribution (potatoes and pulses are not included). Limit intake of products prepared with added/free sugars. For recommendation on fruit juice consumption, please refer to separate summary on fruit juice.**

For more information about the health effects, please refer to the background paper by Magdalena Rosell and Lars. T Fadnes (Rosell & Fadnes, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023)

Products within this food group are culinary defined as vegetables, fruits and berries. Potatoes and pulses are not included as vegetables in the NNR2023 report. Green beans and peas may be included in the vegetable food group. Fruit juices derived from fruits and berries also constitute a separate food group.

Vegetables include cruciferous vegetables, leafy green vegetables, yellow/orange/red vegetables, allium vegetables, and non-starchy root vegetables, such as carrots, beets, parsnips, turnips, and swedes. Fruit subgroups are citrus fruits (e.g., oranges, lemon, lime, grapefruit), stone fruits (e.g., cherries, plums) and pome fruit (e.g., apples, pears). Vegetables, fruits and berries are commonly high in water, low in energy, contain numerous nutrients, and good sources of dietary fibre, vitamin C, vitamin E, vitamin K, folate, and potassium. They also contain other bioactive compounds, or phytochemicals, and the synergistic effects of these are still not fully understood. Cruciferous vegetables (Brassica), including broccoli, Brussels sprouts, cabbage, cauliflower, kale, and turnips, are sources of calcium. Additionally, leafy green vegetables such as spinach, Swiss chard, and lettuce offer iron, zinc, calcium, magnesium, and carotenoids, with dark green vegetables particularly rich in carotenoids. Berries are small, juicy and pulpy fruits (Rosell & Fadnes, 2023).

Dietary sources and intake. The average intake of vegetables, fruits, and berries ranges between 200 and 400 g/d. The average intake of vegetables ranges approximately between 120 and 200 g/d, while fruits and berries approximately between 100 and 230 g/d. The intake of fruits and berries is higher in females than in males in all countries (Lemming & Pitsi, 2022).

Health effects. Three qSRs are available on the role of vegetables and fruits and health outcomes (Fogelholm et al., 2012; Stanaway et al., 2022; WCRF/AICR, 2018j). The qSR from WCRF/AICR found strong (probable) evidence for lower risk of aerodigestive cancers with higher intake of non-starchy vegetables and fruit. Numerous qSRs on dietary patterns in which fruits and vegetables are a major component are also available, demonstrating beneficial health effects, including lower risk of cardiovascular disease (2020 Dietary Guidelines Advisory Committee, 2020), breast and colorectal cancer (Boushey et al., 2020c) and favourable body weight outcomes (Boushey et al., 2020a).

In addition, as discussed by Rosell and Fadnes (Rosell & Fadnes, 2023), several recent high-quality systematic reviews support the role of consuming vegetables, fruits, and berries for preventing chronic diseases, including several other types of cancer (WCRF/AICR, 2018j), cardiovascular disease, and all-cause mortality (Rosell & Fadnes, 2023). The largest reductions in risk are generally seen at the lower intake ranges, but for cardiovascular disease, reductions have been observed up to 800 g of fruits and vegetables per day. Recent meta-analyses also show inverse associations with all-cause mortality, levelling off at 5-6 servings of fruits and vegetables per day, or 2-3 servings of fruits per day and 3-4 servings of vegetables per day (Rosell & Fadnes, 2023). Also relevant for intake of vegetables and fruits is the evidence that consumption of foods containing dietary fibre probably lowers all-cause mortality, coronary heart disease and colorectal cancer (Reynolds et al., 2019; WCRF/AICR, 2018j). Regarding risk of type 2 diabetes, the results are mixed, associations are weaker and further studies are needed to reach conclusive results. The beneficial effects may be attributed to several mechanisms and constituents, such as dietary fibre, antioxidant nutrients and a range of other bioactive components (Rosell & Fadnes, 2023).

As described in the collaboration between the Global Burden of Disease project and the NNR2023 project, a diet low in fruit is the third-highest dietary-related contributor to disease burden in the Nordic and Baltic countries. The Baltic countries have the most to gain from increasing fruit intake because the Baltic countries have higher rates of ischemic heart disease and stroke, which are both linked to low fruit consumption (Clarsen, in press).

Environmental impacts. Vegetables, fruits and berries have in general low environmental impacts per weight unit, although impacts vary between products (Harwatt et al., 2023). Estimates of the impacts of the whole diets also show low impacts from the food group "vegetables, fruits and berries" in the current diets as well as in modelled plant-based diets (Harwatt et al., 2023; Trolle et al., 2023).

The supply of vegetables, fruits and berries in the Nordic and Baltic countries is based on a combination of locally grown products and imported products from different regions of the world. The impacts of individual types of vege tables, fruits, and berries vary mainly due to different horticultural production practices, but also mode of transportation, transportation length and processing have climate impacts. Products locally grown in Nordic countries seem to be among the products with the lower impact, due to less waste during transport and storing. This is the case for salad vegetables and for berries. The more robust types of fruits and vegetables, like apples, pears and citrus fruits, root vegetables, onions and leeks, and brassica can be most easily stored, with relatively small energy use and little waste. These also seem to be the types with the lower impact when imported. Apples, pears, cherries, currants and plums may provide additional benefits, such as carbon sequestration and storage through photosynthesis during tree growth.

Climate and environmental impact of greenhouse grown vegetables depends on the heating source. Greenhouse production in general might lower the land use and the pesticide use.

In general, more plant protection products (e.g. pesticides) are used in the production of fruits and vegetables than in other types of agricultural production (in terms of per hectare and kg of harvested product) and tends to be higher in intensive fruit and berry production (e.g., large scale cropping systems with low diversity) compared to vegetables (Harwatt et al., 2023). In organic production of vegetables, fruits and berries within the Nordic and Baltic countries, less chemicals are used. However, organic production often requires higher land use and has similar GHG emissions compared with conventional production (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Overall water stress is not a major issue in the Nordic and Baltic countries but can, however, appear locally. Many fruits, vegetables and berries are imported, some from water-scarce regions and regions likely to become water-stressed (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023)..

Main data gaps. Possible health effects of different subgroups of fruit and vegetables need further investigation, including the role of phytochemicals. Nutrient and phytochemical bioavailability and interactions, including effects of different preparation methods, might also be an area for further research. There is a lack of data on the production systems and their environmental impacts for imported fruits and vegetables.

Risk groups. People with specific allergies within the food group

Science advice:

- **Based on health outcomes:** It is recommended to consume 500–800 grams, or more, per day of vegetables, fruits and berries in total. A variety of different types of both vegetables and fruits (including berries) should be consumed, with emphasis on dietary fibre contribution (potatoes and pulses are not included). Limit intake of products prepared with high content of added free sugar. A low to moderate amount of fruit juice may be a part of the fruit recommendations (see summary for fruit juice).
- **Based on environmental impacts**: Vegetables fruits and berries have in general low climate and environmental impact/impacts per weight unit. Environmental impacts are mainly related to pesticide use and impacts on biodiversity, locally and globally. Fruits and vegetables that store well will reduce waste and thereby reduce negative impacts.

- **Overall science advice:** It is recommended to consume a variety of vegetables, fruits, and berries, 500-800 grams, or more, per day in total. A variety of different types of both vegetables and fruits (incl. berries) should be consumed, with emphasis on dietary fibre contribution (potatoes and pulses are not included). Limit intake of products prepared with added/free sugars. For recommendation on fruit juice consumption, please refer to separate summary on fruit juice.

Potatoes

DIETARY INTAKE		HEALTH AND ENVIRONMENTAL EFFECTS
	↗	**Beneficial health effects** Contributes to adequate supply of some nutrients, e.g., vitamin C, vitamin B_6, niacin, folate, potassium, calcium, phosphorus and they also contain dietary fibre, protein of high quality and phytochemicals such as phenolics and carotenoids.
Potatoes (*Solanum tuberosum*)	→	**Adverse health effects** Intake of deep-fried (French fried) but not boiled potatoes is associated to increased risk of hypertension.
	↘	**Environmental impacts** Like vegetables, in particular root vegetables, potatoes are among the food products with the lowest climate and environmental impacts. Environmental impacts are mainly related to pesticide uses and impacts on biodiversity, locally and globally.

Science advice: **Potatoes can be part of a healthy and environment-friendly diet. It is recommended that potatoes are included as a significant part of the regular dietary pattern in the Nordic and Baltic countries. Intake of boiled or baked potatoes and potatoes prepared with low content of fat and salt should be preferred. Intake of deep-fried potatoes should be limited.**

For more information about the health effects, please refer to the background paper by Magdalena Rosell and Christine Delisle (Rosell & Deslisle, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Potatoes (*Solanum tuberosum*) is a commonly consumed staple food. Potatoes are not included in the vegetable food group, due to their high content of starch.

Dietary sources and intake. Potatoes contribute to the supply of e.g., vitamin C, vitamin B_6, niacin, folate, potassium and phosphorus. They also contain dietary fibre, protein of high quality and phytochemicals such as phenolics and carotenoids. However, potatoes are often consumed in processed forms with added fat and salt, such as French fried and mashed potatoes. The average intake of potatoes ranges from approximately 50 to 130 g/d (Lemming & Pitsi, 2022).

Health effects. Two qSRs are available on the role of potatoes and health outcomes (SACN, 2015; Åkesson et al., 2013), in which no conclusions could be drawn on risk of CVD and T2D due to limited evidence. A qSR on dietary patterns indicated that French fried (deep-fried) potatoes and total potatoes as part of a dietary pattern high in red and processed meats and added sugars, were associated with an increased risk of colorectal cancer in adults; the evidence was graded as moderate (Boushey et al., 2020c).

As discussed in Rosell and Deslisle (2023), recent studies have reported no association between total intake of potatoes and cardiovascular disease and all-cause mortality. For cancer and type 2 diabetes, the evidence is inconclusive (Rosell & Deslisle, 2023).

Some studies have indicated that isoenergetic portions of potatoes, particularly boiled potatoes, generates a higher satiation compared with other starchy carbohydrates when consumed in isolation. An association between the intake of French fried (deep-fried) potatoes and an increased risk of hypertension has been reported in a dose-response analysis, while this was not seen for boiled/baked/mashed potatoes. The quality of evidence was considered moderate (Rosell & Deslisle, 2023).

Environmental impacts. Like vegetables and in particular root vegetables, potatoes are among the food products with the lowest climate and environmental impacts. Potatoes can be easily stored, with relatively small inputs and little waste (Harwatt et al., 2023). The difference in GHG emissions between organic and conventional production is relatively small (Harwatt et al., 2023). Organic production can result in significantly lower yields, leading to an increase in land usage. In conventional production fungicides are applied to control potato blight and increase the yield. In the diet, potatoes often replace grains with potentially larger environmental impacts (e.g., rice) and potatoes can be grown widely in the Nordic and Baltic regions (Meltzer et al., 2023; Trolle et al., 2023).

Main data gaps. There is a need for further research regarding the intake of potatoes, including different cooking methods, and health.

Risk groups. No risk groups identified.

Science advice:

- **Based on health outcomes:** Potatoes comprise a common staple food in the Nordic and Baltic countries, they provide vitamins, minerals, dietary fibre, protein, and phytochemicals, and may be part of a healthy diet. Intake of boiled or baked potatoes and potatoes prepared with low amounts of fat and salt should be preferred. Intake of deep-fried potatoes should be limited.
- **Based on environmental impacts:** The environmental impacts are among the lowest among food products, supporting potatoes as part of a plant based healthy diet.
- **Overall science advice:** Potatoes can be part of a healthy and environment-friendly diet. It is recommended that potatoes are included as a significant part of the regular dietary pattern in the Nordic and Baltic countries. Intake of boiled or baked potatoes and potatoes prepared with low amounts of fat and salt should be preferred. Intake of deep-fried potatoes should be limited.

Fruit juices

DIETARY INTAKE

- 100 % pure juice made from whole or flesh of fruits and berries, not added sugar, sweeteners, preservatives, flavouring or colouring
- Nutrients can be added up to the level of the original fruit

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects
In general, fruit juice has a similar nutritional value as whole fruit – except dietary fibre and vitamin C. Low to moderate consumption of fruit juice is not associated with an apparent risk of chronic diseases.

Adverse health effects
A possible effect of acids in fruit juices on tooth erosion. Fruit juice may contribute to excess energy intake, a particular concern for people with obesity and small children.

Environmental impacts
Climate and environmental impact of fruit juice depend on the fruits and berries they contain, and climate impact is generally low.

Science advice: Low to moderate intake of fruit juice may be part of a healthy diet. Intake of fruit juice should be limited for children.

For more information about the health effects, please refer to the background paper by Magdalena Rosell and Christine Delisle (Rosell & Delisle, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Fruit juice is 100 % pure juice made from whole or flesh of fruits and berries. It is not permitted to add sugar, sweeteners, preservatives, flavouring or colouring to fruit juice (Rosell & Delisle, 2023).

Dietary sources and intake. The nutrient content of fruit juice might be similar to the nutrient content of the fruits (or berries), although some juices contain no or a lower amount of dietary fibre. The average intake of juices ranges from approximately 35 to 115 g/d (Lemming & Pitsi, 2022).

Health effects. Two qSRs are available on the role of fruit juice and health outcomes (Mayer-Davis et al., 2020a; WCRF/AICR, 2018b). It has been suggested that large quantities of fruit juice may promote weight gain; however, none of these qSRs could demonstrate evidence for this association. A separate qSR found some evidence that a higher consumption of SSB and acidic foods and beverages, such as fruit juice, may result in more dental caries in children's teeth and increase tooth wear, but the effects of fruit juice per se could not be determined (SACN, 2015).

As discussed in Rosell and Deslisle (2023), fruit juices are sugary drinks and could have similar effects as SSB has on weight gain. Therefore, it is recommended that high intake of fruit juice should be avoided.

Suggested beneficial effects on cardiovascular disease as well as adverse effects on weight gain and tooth erosion remain to be further investigated. Avoiding drinking fruit juice between meals may be relevant to prevent possible tooth erosion (Rosell & Delisle, 2023).

Environmental impacts Considerations regarding the climate and the environmental impact of fruit juice are similar to the original fruits and berries (Harwatt et al., 2023). The impact from fruit juice production varies, depending on technology, waste handling, site specific conditions and yield of the original fruit. However, the impacts are still lower compared to animal-based products. As for fruit and berries, environmental concerns are mainly related to pesticide uses and impacts on biodiversity, locally and globally. In landscapes, flowering crops such as fruits and berries support pollinators and add diversity to the landscape. Fruit and berries not meeting food grade quality can be made into fruit juice, thereby keeping that part of the harvest in food production (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Main data gaps. More data on health outcomes are warranted.

Risk groups. No risk groups identified.

Science advice:

- **Based on health outcomes:** A low to moderate intake of fruit juice, may contribute to some nutrients and be part of a healthy diet for adults. High intake of fruit juice should be avoided. Intake of fruit juice should be limited for children.
- **Based on environmental impacts:** Climate and environmental impact of fruit juice depend on the fruits and berries they contain, and climate impact is generally low.
- **Overall science advice:** Low to moderate intake of fruit juice may be part of a healthy diet. Intake of fruit juice should be limited for children.

Pulses/legumes

DIETARY INTAKE

Pulses include the dried form of peas, beans and lentils, but exclude green beans and peas.

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects
Contributes to appropriate supply of some nutrients in different types of diets, e.g., protein, dietary fibre, starch, vitamins and minerals, such as thiamine, potassium, magnesium, iron and zinc. Increased intake of legumes is associated with decreased risk of mortality and gastric, colorectal, breast, and lung cancer. Protective effects on established risk factors for CVD and T2D.

Adverse health effects
No established adverse effects.

Environmental impacts
Pulses have low climate impacts while environmental impacts vary depending on production method and production site.

Science advice: It is recommended that pulses are included as a significant part of the regular dietary pattern in the Nordic and Baltic countries. Pulses are important providers of nutrients such as protein iron and zinc.

For more information about the health effects, please refer to the background paper by Liv Elin Torheim and Lars T. Fadnes (Torheim & Fadnes, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). A culinary definition of legumes includes peas, lentils and beans (excludes coffee and cacao beans). Peanuts are botanically legumes but are included in the nuts and seeds food group. The terms legumes and pulses are often used interchangeably. Legumes is a collective term for plants under the *Fabaceae* botanical family and include various types of beans, lentils, peas, and soybeans (Torheim & Fadnes, 2023).

Pulses is often used as the term for the ripened (or dried) form of peas and beans, including lentils, but excluding green beans and green peas.

Dietary sources and intake. The average intake of pulses (legumes) ranges from 1 to 18 g/d (Lemming & Pitsi, 2022). Among the food groups, pulses contain the most dietary fibre. Pulses are also good sources of protein and essential amino acids, complex carbohydrates, and are low in total fat and saturated fatty acids. The content of micronutrients differs between varieties, but several pulses are rich in folate, potassium, magnesium, iron, zinc, and thiamine, as well as bioactive compounds such as phytochemicals (Torheim & Fadnes, 2023).

Health effects. Four qSRs are relevant for the role of pulses and health outcomes, including one *de novo* qSR (Thórisdottír et al., 2023). The *de novo* qSR by Thórisdóttir et al. had mixed findings on legume consumption and risk of cardiovascular disease and type 2 diabetes, with observational studies suggesting no association in healthy adult populations with generally low legume consumption. However, protective effects on blood lipids and glycaemic markers seen in RCTs support recommending legume consumption as part of diverse and healthy dietary patterns (Thórisdottír et al., 2023).

Also, of relevance for pulses, consumption of foods containing dietary fibre probably protects against colorectal cancer according to the qSR from WCRF/AICR (WCRF/AICR, 2018j). There is also strong evidence from the qSR by Reynolds et al. (2019) that dietary fibre reduce risk of all-cause mortality, coronary heart disease, and colorectal cancer. The qSR from SACN found moderate evidence for an effect of legume fibre on increased faecal weight (SACN, 2015).

Further, the *de novo* qSR by Lamberg-Allardt et al. (Lamberg-Allardt et al., 2023b) found that replacement of animal proteins (most often dairy protein) with plant protein (e.g., soy protein) was shown in RCTs to modestly lower total and LDL cholesterol, while there were no effects on HDL cholesterol or triglycerides. There was *limited/suggestive* evidence for favourable associations between higher intake of plant protein as a replacement for animal protein and CVD mortality and type 2 diabetes, based on a limited number of prospective cohort studies.

As discussed in Torheim and Fadnes 2023, increasing consumption of legumes/pulses is associated with a lower risk of mortality from gastric, colorectal, breast, endometrial, and lung cancers (Torheim & Fadnes, 2023). A high consumption of legumes is also associated with reduced mortality (Torheim & Fadnes, 2023). Based on meta-analyses and data from the Global Burden of Disease study, one modelling study showed sustained change in the consumption of legumes from none to 100 grams per day was associated with an increase in life expectancy of approximately 1 year for male and female adults in the age range 30 to 50 years (Nordic Council of Ministers, 2020b; Torheim & Fadnes, 2023).

Some early studies suggested hormonal effects of soy products. However, an extensive review of potential endocrine disruption, does not support such concerns (Torheim & Fadnes, 2023)(Nordic Council of Ministers, 2020b)

Pulses also contain anti-nutritional compounds such as amylase inhibitors, phytate and tannins, which are considerably lowered or eliminated during preparation such as soaking and boiling. Correct preparation methods are important, due to the content of lectins in raw form of most dry beans.

Environmental impacts Pulses and legumes (both domestically produced and imported) have among the lowest relative climate impacts, for example in comparison to all types of meat (Meltzer et al., 2023; Trolle et al., 2023). However, only 7 % of global soy production is used to produce products directly for human consumption, with most soy (77 %) being used as farmed animal feed – largely for chickens and pigs. Growing practices greatly influence the environmental impacts of pulses and legume production, in terms of both scale and type. As legumes and pulses fix nitrogen in the soil, they do not require nitrogen fertilizers. Despite this, high amounts of nitrogen fertilizer are sometimes used to increase yields e.g., cultivating soya beans in intensive large-scale cropping systems. These production systems require the use of chemical plant protection products (e.g., pesticides).

Monocultures with fertilizer and pesticide application can adversely impact the landscape and surrounding biodiversity (Harwatt et al., 2023). Organic production minimizes the use of chemical plant protection and fertilizers.

Main data gaps. More prospective studies on different health outcomes are warranted at a wide range of intakes. There is insufficient data available on environmental impacts beyond climate impact for both domestically produced and imported products. There is a need for data on environmental impact of processed products made from pulses and legumes.

Risk groups. People with specific allergies for foods within the food group.

Science advice:

- **Based on health outcomes:** Pulses are important providers of nutrients such as dietary fibre, protein, iron and zinc in plant based diets, especially with limited amounts of meat. Higher intake of pulses may also protect against cancer and lower mortality. Overall, the current health evidence and supply of nutrients supports an increased legume consumption. Adequate soaking and rinsing of legumes are needed for beneficial effects.

- **Based on environmental impacts:** Pulses have low climate impacts while environmental impacts vary depending on production method and production site.
- **Overall science advice:** It is recommended that pulses are included as a significant part of the regular dietary pattern in the Nordic and Baltic countries. Pulses are important providers of nutrients such as dietary fibre, protein, iron and zinc.

Nuts and seeds

DIETARY INTAKE		HEALTH AND ENVIRONMENTAL EFFECTS
	↗	**Beneficial health effects** • Reduced risk of cardiovascular disease
Nuts and seeds, including tree nuts and peanuts	→	**Adverse health effects** Anaphylaxis reactions if allergy
	↘	**Environmental impacts** Nuts and seeds have lower green-house gas emissions, land and energy use, and potential for acidification and eutrophication compared to animal-based products.

Science advice: **It is recommended to consume 20-30 grams nuts per day. It is also recommended to include seeds in the diet due to the nutrient content; however, evidence for a certain quantity is not available. Nuts and seeds are important in plant-based diets as they have low GHG emissions and a high nutrient density.**

For more information about the health effects, please refer to the background paper by Lars T. Fadnes and Rajiv Balakrishna (Fadnes & Balakrishna, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

A culinary definition of nuts, includes tree nuts, peanuts, and seeds. Peanuts, almonds, walnuts, hazelnuts, cashew, Brazil nuts, macadamias, pistachio, sesame, and sunflower seeds, are some of the frequently consumed nuts and seeds (Fadnes & Balakrishna, 2023).

Dietary sources and intake. The average intake of nuts and seeds ranges from 3 to 9 g/d (Lemming & Pitsi, 2022). Nuts and seeds are nutrient-dense and contain mostly mono- and polyunsaturated fatty acids, protein, fibre, micronutrients such as magnesium, selenium, zinc, vitamin E and a range of other metabolites such as phenolic compounds (Fadnes & Balakrishna, 2023).

Health effects. One *de novo* qSR is available on the role of nuts and seeds and health outcomes demonstrating an inverse dose-response relationship with a risk of cardiovascular disease, in particular coronary heart disease, in prospective cohort studies (Arnesen et al., 2023). A modest effect on blood lipids as seen in randomized controlled trials suggests a plausible, partial mechanism for the association. Thus, the causality was judged as probable. There was no evidence for stronger associations for nut intakes beyond 20-30 grams per day (Arnesen et al., 2023; Fadnes & Balakrishna, 2023). There was also suggestive evidence for a modestly protective effect of nut consumption on stroke, while the evidence was insufficient regarding risk of type 2 diabetes. In the *de novo* qSR it was not possible to separate nuts from seeds in the cohort studies, and all RCTs were on nuts, not seeds.

As discussed in Fadnes and Balakrishna 2023 (Fadnes and Balakrishna 2023), there is also suggestive evidence for associations between nut consumption and lower all-cause mortality, cancer, respiratory disease and infectious disease mortality, less cognitive decline and lower risk of depression. Despite having a high energy density, nut consumption does not seem to increase the risk of weight gain (Fadnes & Balakrishna, 2023; Fogelholm et al., 2012; Hjelmesæth & Sjöberg, 2022).

Environmental impacts. Nuts and seeds have lower green-house gas emissions, land use, and potential for eutrophication compared to most animal products (Harwatt et al., 2023). However, nuts and seeds production contributes to overall high land use compared to other plant-based foods due to a relatively low yield of the edible nuts (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). The environmental impacts vary widely among nuts and seeds. Impacts of nuts and seeds production on biodiversity may be positive (flowering crops such as flax and sunflower in crop rotations benefit pollinators) or negative (in intensive, large-scale cropping systems with low diversity). For some nuts, the use of plant protection products (e.g., pesticides) can be high. Current nut production contributes to and is affected by water stress in many regions (Harwatt et al., 2023). Groundnuts generally have less water impacts per kg and per g of protein than tree nuts such as almonds.

Main data gaps. There is a lack of data on the effects of individual types of nuts and seeds, and on seeds separately on health outcomes. There is a need for data on the environmental aspects other than climate impact such as biodiversity and ecotoxicity aspects for nuts and seeds in general and for the variation within product groups.

Risk groups. People with allergies and related adverse reactions to nuts (1-2% of adult populations). For some people such allergies could cause severe anaphylaxis reactions that can be life-threatening if not handled promptly and properly. Regular consumption of Brazil nuts may cause too high intakes of selenium.

Science advice:

- **Based on health outcomes:** It is recommended to consume 20-30 grams nuts per day. It is also recommended to include seeds in the diet due to the nutrient content; however, evidence for a quantitative recommendation is not available.
- **Based on environmental impacts:** Nuts and seeds have low GHG emissions. However, when increased consumption is achieved, more detailed recommendations are warranted to avoid the potential water stress and biodiversity loss associated with nut and seed consumption.
- **Overall science advice:** It is recommended to consume 20-30 grams nuts per day. It is also recommended to include seeds in the diet due to the nutrient content; however, evidence for a certain quantity is not available. Nuts and seeds are important in plant-based diets as they have low GHG emissions and a high nutrient density.

Fish and seafood

DIETARY INTAKE		HEALTH AND ENVIRONMENTAL EFFECTS
	↗	**Beneficial health effects** Positive effects on overall cardiovascular health, all-cause mortality and protection from cognitive decline in adults. Provides nutrients such as n-3 fatty acids, iodine and other micronutrients and protein of high quality.
Fish, lean and fat species, and crustaceans	→	**Adverse health effects** Fish from polluted areas or high in environmental contaminants can influence pregnant women negatively.
	↘	**Environmental impacts** Greenhouse gas (GHG) emissions per kg edible seafood varies; emissions associated with commonly consumed species such as wild cod and pollock are considerably lower than any meat alternative. GHG emissions of seafood are highest for shrimp, flounder and lobster and four-fold as high as emissions from wild cod and haddock, but farmed bivalves and small pelagic fish have the lowest impact. GHG emissions by farmed salmon varies. Wild salmon generally has lower impact. If allowed to be uncontrolled, capture fisheries involve environmental risks such as overfishing, and aquaculture may involve risks on, e.g., land use.

Science advice: It is recommended to consume 300-450 g fish/week (ready-to-eat weight), of which at least 200 g/week should be fatty fish. It is recommended to consume fish from sustainably managed fish stocks.

For more information about the health effects, please refer to the background paper by Stine Ulven and Johanna E. Torfadóttir (Ulven & Torfadóttir, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intake. Fish is an important source of nutrients such as n-3 fatty acids, vitamin B_{12} and D, iodine, selenium and protein of high quality. The average intake of fish and other seafood ranges from approximately 150 to 500 g/week (Lemming & Pitsi, 2022).

Health effects. Four qSRs are available on the role of fish and seafood and health outcomes (Norwegian Scientific Committee for Food and Environment (VKM), 2022; Snetselaar et al., 2020b, c; WCRF/AICR, 2018e). The report from the Norwegian Scientific Committee for Food and Environment (VKM) demonstrated strong evidence for lower risk of cardiovascular diseases such as coronary heart disease, myocardial infarction and stroke, as well as all-cause mortality (VKM, 2022). In addition, a probable protective association with cognitive decline in adults (e.g., Alzheimer's dementia) and a reduced risk of pre-term birth and low birth weight was found (VKM, 2022). Fish may include contaminants such as dioxins and PCBs that may have harmful effects at high doses (VKM, 2022). Based on a risk-benefit assessment, VKM concludes that the benefits from increasing fish intake to the recommended two to three dinner courses per week (corresponding to 300-450 grams, including at least 200 grams fatty fish in adults) outweigh potential risks for all age groups. Requirements for n-3 fatty acids can be reached by consuming fatty fish and fish oil (VKM, 2022). The reports from the U.S. Dietary Guidelines Advisory Committee demonstrated moderate evidence for a favourable association between intake of seafood during pregnancy and cognitive development in the child (Snetselaar et al., 2020b), while the evidence for a similar relationship with intake during childhood and adolescents was insufficient (Snetselaar et al., 2020c), due to limited available research. The WCRF/AICR (2018e) found only limited evidence for an association between fish and seafoods and certain cancers.

As discussed in the background review by Ulven and Torfadóttir 2023 (Ulven and Torfadóttir 2023), health effects of fish have mainly been associated with their lipid contents, n-3 fatty acids, but fish proteins may also be important. Low intake of n-3 fatty acids is considered a dietary risk, especially in the Baltic countries (Clarsen, in press).

Environmental impacts. Greenhouse gas (GHG) emissions per kg edible seafood varies (IPCC, 2022a). Seafood can have less, but also bigger, footprint on water, land and carbon, than poultry (Gephart et al., 2021). In terms of GHG, the main impact from capture fisheries is fossil fuel use for fishing vessels while the main impact of aquaculture comes from feed production. Overfishing puts strain on fish stocks locally and globally.

A major impact of wild capture fisheries conducted with any kind of net is by-catch. Type and size of by-catch can have large implications for biodiversity (Gephart et al., 2021). Another environmental stressor associated with capture of wild fish is bottom trawling; when used across large areas, bottom trawling can negatively impact biodiversity. Farmed fish and seafood now contribute to 53 % of the total global production, which is expected to increase due to limited growth potential in the capture sector. Aquaculture puts pressure on the environment, due to land use, freshwater use, spread of disease, eutrophication and chemical pollution (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). To efficiently use fish without necessary waste, the inclusion of processed fish products is justified from an environmental perspective.

Main data gaps. More data is needed about health-promoting constituents and health effects of fish. A comprehensive assessment of sustainable fish and seafood yields in the Nordic and Baltic countries is needed. For reliable assessment of biodiversity impact more data on by-catch and on physical damage to ecosystems via trawling methods are required.

Risk groups. People with allergies to fish and other seafood. Pregnant and lactating women are advised to avoid certain fish that may be polluted by environmental toxins. Large fresh-water fish from certain areas may contain methyl mercury, and fish from the Baltic Sea or fjords may contain pollutants. Lean fish generally contain lower levels of persistent organic pollutants (POPs). Low- or non-consumers have an increased risk of iodine, vitamin B_{12} and vitamin D inadequacy.

Science advice:

- **Based on health outcomes:** It is recommended to consume 300-450 g fish/week (cooked or ready-to-eat weight). At least 200 g/week should be fatty fish, due to the content of long-chain n-3 fatty acids. Limit intake of fish from polluted areas or high in environmental contaminants, especially during pregnancy and lactation.
- **Based on environmental impacts:** Fish and seafood from sustainably managed farms and wild stocks should be prioritized and consumption of species with high environmental impact should be limited.
- **Overall science advice:** It is recommended to consume 300-450 g fish/week (cooked or ready-to-eat weight), of which at least 200 g/week should be fatty fish. It is recommended to consume fish from sustainably managed fish stocks.

Red meat

DIETARY INTAKE		HEALTH AND ENVIRONMENTAL EFFECTS
	↗	**Beneficial health effects** Provider of high-quality protein, iron, zinc, thiamin, riboflavin, vitamin B_6 and B_{12}
Ruminants • Cattle • Sheep • Goats • Game: Moose, deer, reindeer **Non-ruminant** • Pigs	→	**Adverse health effects** • Major source of saturated fatty acids • Increased risk of colorectal cancer, may increase risk of CVD
	↘	**Environmental impacts** • Ruminants are main contributors to methane emissions from agriculture • Pigs' GHG footprint is lower than for ruminant meat, but their demand on cereals for feed is high

Science advice: **For health reasons, it is recommended that consumption of red meat from cattle, sheep, goats and pigs (including red meat in products and processed foods) should be low and not exceed 350 gram/week ready-to-eat (cooked) weight. Processed red meat should be as low as possible. For environmental reasons, the consumption of red meat should be considerably lower than 350 grams/week (ready-to-eat (cooked) weight). The choice of meat should comply with the recommendations for fatty acids. The reduction of red meat consumption should not result in an increase in white meat consumption. To minimize environmental impact, meat consumption should be replaced by increased consumption of plant foods, such as legumes, and fish from sustainably managed stocks.**

For more information about the health effects, please refer to the background paper by Jelena Meinilä and Jyrki K. Virtanen (Meinilä & Virtanen, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intake. Red meat (i.e., ruminant and pork meat) provides high-quality protein, monounsaturated fatty acids, iron (with high bioavailability), zinc, and vitamins B_1 (thiamine), B_2 (riboflavin), B_6 and B_{12} in a regular diet, but it is also a source of saturated fatty acids and ruminant trans-fatty acids. Processed red meat is a source of sodium. The reporting of red meat and meat products differs among the Nordic and Baltic countries. Therefore, the intake estimates of red meat and products are rough and ranges from 50 to 150 g/d (Lemming & Pitsi, 2022).

Health effects. Three qSRs are available on the role of meat and meat products and health outcomes (Fogelholm et al., 2012; Lescinsky et al., 2022; WCRF/AICR, 2018e).

The WCRF/AICR demonstrated strong evidence for a significant, largely linear relationship between red meat and risk of colon cancer. For colorectal cancer, stratified analyses by geographic location showed especially a significant increased risk in studies with European populations. The report also concluded that intake of processed meat is a convincing cause of colorectal cancer. Processed red meat includes red meat preserved by smoking, curing, or salting, or by the addition of preservatives (WCRF/AICR, 2018e). A separate dose-response meta-analysis of 15 studies showed a linear dose-response relationship between red and processed meat and risk of colorectal cancer (12 % increased risk per 100 grams increase in red and processed meat consumed per day). The relative risk of colon cancer is increased by 10% per 50 grams intake of unprocessed red meat per day (WCRF/AICR, 2018e). The International Agency for Research on Cancer (2018) classifies processed meat as carcinogenic for humans, and red meat as probably carcinogenic, based on observational, animal and mechanistic data.

Using a more conservate interpretation of the total body of evidence, the "Burden of Proof" study, conducted for the Global Burden of Disease (GBD) project, concluded that there is a weak association between unprocessed red meat consumption and colorectal cancer, breast cancer, ischemic heart disease and type 2 diabetes (Lescinsky et al., 2022). Despite their conservative methodology, the collaboration between GBD and the NNR2023 project observed that a diet high in red meat is the fourth-highest dietary risk factor for Disability Adjusted Life Years (DALYs) in the Nordic and Baltic countries. It is ranked second highest in Denmark and Iceland, and the third highest in Norway, Sweden and Finland (Clarsen, in press). In addition, a diet high in processed meat is the second highest contributor to disease burden in five of eight countries and among the top-4 dietary risk factors in all countries (Clarsen, in press).

Also of relevance to red and processed meat is that numerous qSRs on dietary patterns have found that adhering to diets characterized by lower amounts of red and processed meats are compatible with beneficial health effects, including strong and consistent evidence for lower risk of all-cause mortality (Boushey et al., 2020), cardiovascular disease (2020 Dietary Guidelines Advisory Committee, 2020), and moderate evidence for lower risk of type 2 diabetes (Boushey et al., 2020f) and favourable body weight-related outcomes (Boushey et al., 2020a).

As discussed by Meinilä and Virtanen (2023), red meat can be a good source of nutrients, in particular protein, iron, zinc and vitamin B_{12}. However, regular high intake of red meat and processed red meat, may increase the risk of colorectal cancer, cardiovascular diseases and type 2 diabetes due to several mechanisms (IARC, 2018; Meinilä & Virtanen, 2023; WCRF/AICR, 2018e). The risk increase appears to be linear with most outcomes (Meinilä & Virtanen, 2023; WCRF/AICR, 2018e).

Based on all available evidence, considering both beneficial effect of nutrients and the dose-response curves demonstrating adverse effects for several chronic diseases, NNR2023 recommends that the intake of red meat should be limited to maximum 350 grams/week (cooked or ready-to-eat weight). The Committee notes that a clear-cut level of intake that minimizes risk is difficult to set, as the associations are often linear.

Environmental impacts. High production and consumption of ruminant meat is a major contributor to GHG emissions, especially methane (Harwatt et al., 2023; Poore & Nemecek, 2018), in total being approximately 4- and 7-fold higher on protein basis compared with pork and poultry, respectively (FAO, 2013). Meat from dairy cows has lower GHG emissions than meat from suckler cows. Nordic/European beef production has lower GHG emissions per kg meat produced compared to other regions of the world (FAO, 2013; Poore & Nemecek, 2018; Trolle et al., 2023). However, the high consumption of red meat is the most important contributor to GHG emissions from the diet in the Nordic and Baltic countries. Feed ingredients contribute to environmental impacts through fertilizer, pesticide, water and land use. Their ability to utilize grass make ruminants important for resource utilization (including outfields). If well managed and avoiding overgrazing, grazing ruminants contribute to biodiversity and keeping cultural landscapes open in some settings in the Nordics (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). If we are to consume milk and dairy, a certain amount of beef from milk producing cattle needs to be consumed in order for the food system to be resource efficient. The largest proportions of overall environmental impacts from pig meat production tend to come from feed production and manure management (Harwatt et al., 2023). Feeds for pigs compete for land with food for direct human consumption. However, pigs can also make use of residual products which can contribute to an efficient food system. Free-living game contributes to food consumption based on local natural resources and has a lower climate impact per kilogram of meat than farmed or fenced game. The amount of animal waste should be minimized to reduce its environmental impact. To efficiently use meat and meat products without unnecessary waste, the inclusion of some processed meat products is justified from an environmental perspective.

Main data gaps. We lack studies on the health effects of different types of red meat, especially game meat. Little is known about the nutritional impact of how they are reared, e.g., fatty acid profile of meat from feedlot cows versus grassland herds. Data are still lacking on the health effects of substances formed when meat is processed. There is a lack of comparative environmental data and on studies covering environmental impacts other than climate impact, such as biodiversity aspects.

Risk groups. High consumers of red meat, especially processed red meat, have an increased risk of several chronic diseases, including colorectal cancer, type 2 diabetes and cardiovascular disease. Small amounts of red meat, especially beef, supply iron, zinc and other nutrients with high bioavailability and are important contributors of iron, especially for children and women of fertile age who are at increased risk of developing iron deficiency. Low- or non-consumers have an increased risk of vitamin B_{12} inadequacy.

Science advice:

- **Based on health outcomes:** Red meat is nutrient dense and a provider of iron and zinc in the diet. Based on meta-analyses of RCTs and observational studies on red meat and health outcomes, it is recommended to consume a limited amount of red meat in the diet, with a maximum intake of 350 grams of red meat (including red meat in products and processed foods) per week. The choice of meat should comply with the recommendations for fatty acids.
- **Based on environmental impacts:** High environmental impact. The high consumption of red meat is the most important contributor to GHG emissions from the diet in the Nordic and Baltic countries. Negative environmental impact is related to methane emissions from ruminants, and feed which contribute through fertilizer, pesticide, water and land use. Positive environmental impact may be related to grazing and biodiversity. GHG emission from pigs is lower than ruminants but there are environmental issues related to feedproduction.

- **Overall science advice:** For health reasons, it is recommended that consumption of red meat from cattle, sheep, goats and pigs (including red meat in products and processed foods) should be low and not exceed 350 gram/week ready-to-eat (cooked) weight. Processed red meat should be as low as possible. For environmental reasons the consumption of red meat should be considerably lower than 350 grams/week. The choice of meat should comply with the recommendations for fatty acids. The reduction of red meat consumption should not result in an increase in white meat consumption. To minimize environmental impact, meat consumption should be replaced by increased consumption of plant foods, such as legumes and fish from sustainably managed stocks.

White meat

DIETARY INTAKE

Poultry meat

- Chicken
- Hen
- Turkey
- Duck

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects
Provider of high-quality protein, selenium and thiamin, riboflavin, niacin, vitamin B_6 and B_{12}. The fatty acid profile is better than for red meats.

Adverse health effects
The currently available evidence does not indicate a role, beneficial or detrimental, of white meat consumption for CVD and T2D.

Environmental impacts
Poultry meat tends to have the lowest environmental impacts across a range of metrics compared to red meat, the largest negative impact often being from feed production and manure management.

Science advice: **It is recommended that consumption of processed white meat should be as low as possible. To minimize environmental impact, consumption of white meat should not be increased from current levels and may be lower. Instead, total meat consumption should be replaced by increased consumption of plant foods, such as legumes, and fish from sustainably managed stocks.**

For more information about the health effects, please refer to the background paper by Jelena Meinilä and Jykri K. Virtanen (Meinilä & Virtanen, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intake. White meat provides high-quality protein, iron and many B vitamins in addition to having a more beneficial fatty acid profile than red meats. The dietary intake of white meat has increased the last decades and is the main driver of increased total meat intake. The average intake of white meat (poultry) ranges from approximately 20 to 50 g/d (Lemming & Pitsi, 2022).

Health effects. A *de novo* qSR developed within the NNR2023 project concluded that there is no currently available evidence for beneficial or detrimental effects of white meat consumption for cardiovascular diseases and type 2 diabetes (Ramel et al., in press). The WCRF/AICR (2018e) also concluded that intake of processed meat is a convincing cause of colorectal cancer. Processed white meat includes white meat preserved by smoking, curing, or salting, or by the addition of preservatives (WCRF/AICR, 2018). The International Agency for Research on Cancer (2018) classifies processed meat as carcinogenic for humans, based on observational, animal and mechanistic data.

For more detailed background information on health effects of white meat consumption, please refer to the background paper by Meinliä and Virtanen (2023).

Environmental impacts. Across a range of metrics, including GHG, poultry tend to have the lowest climate impact within the meat food group, however, in general, the environmental impact is higher than plant-foods. Feed production (mostly cereals and soy) and manure management, has an environmental impact which cannot be neglected (Harwatt et al., 2023; Vinnari & M., 2022). Food-feed competition is an issue as feed crops are generally produced on land that is also suitable for production of food for human consumption. However, poultry may make use of cereals not meeting food grade quality, thereby keeping those cereals in the food system. If we are to consume eggs, a certain amount of poultry meat from laying hens needs to be consumed in order for the food system to be efficient. To efficiently use poultry without unnecessary waste, the inclusion of some processed poultry products in the diet is justified from an environmental perspective. The amount of animal waste in the poultry industry should be minimized to reduce the environmental impact.

For environmental reasons, reduction in red meat consumption, as suggested above, should not be countered with an increase in white meat consumption, but rather increased intake of plant-based foods and fish from sustainably managed stocks (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Main data gaps. Few long-term intervention studies on risk factors and disease endpoints. Little data on potentially differential effects of processed vs. unprocessed white meat, different subgroups of white meat, and preparation methods. It is also difficult to determine effects of white meat per se, rather than as substitutes for red meat or fish. There are few studies covering environmental aspects other than climate impact, such as biodiversity aspects.

Risk groups. Low- or no-consumers have an increased risk of vitamin B_{12} inadequacy.

Science advice:

- **Based on health outcomes:** White meat is nutrient-dense and a provider of protein and other nutrients in the diet, with a relatively low content of saturated fatty acids. Intake of processed white meat should be limited due to increased risk of colorectal cancer and to comply with the recommended intake of sodium. Otherwise, based on meta-analyses of RCTs and observational studies, white meat is considered relatively neutral when it comes to health outcomes, and it is therefore not possible to set a recommended intake range for unprocessed white meat.
- **Based on environmental impacts**: In general, lower environmental impact across many environmental metrics compared to red meat. Negative environmental impact is related to feed production and manure management. Due to negative environmental impacts, it is not desirable to increase white meat consumption from current levels.
- **Overall science advice**: It is recommended that consumption of processed white meat should be as low as possible. To minimize environmental impact, consumption of white meat should not be increased from current levels and may be lower. Instead, meat consumption should be replaced by increased consumption of plant foods, such as legumes and fish from sustainably managed stocks.

Milk and dairy products

DIETARY INTAKE

- Milk, yoghurt, cheese

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects
Milk and dairy products are major sources of protein, calcium, iodine, vitamin B12 and other micronutrients. Evidence suggests inverse associations between fermented and low-fat dairy and cardiometabolic risk factors such as total and LDL cholesterol. The World Cancer Research Fund concluded that there is evidence for a protective association with colorectal cancer.

Adverse health effects
High intake of full-fat milk may contribute to increased risk of cardiovascular disease.

Environmental impacts
In general, dairy, especially concentrated products such as hard cheese, is associated with high environmental impact. The high consumption of milk and dairy is an important contributor to GHG emissions from the diet in the Nordic and Baltic countries. Negative environmental impact is related to methane emissions from the enteric fermentation of ruminants., Feed contributes through fertilizer, pesticide, water and land use. Positive environmental impact is related to grazing and biodiversity.

Science advice: **Intake of between 350 ml to 500 ml low fat milk and dairy products per day is sufficient to meet dietary requirements of calcium, iodine and vitamin B12 if combined with adequate intake of legumes, dark green vegetables and fish (varies among different species). The range depends on national fortifications programs and diets across the Nordic and Baltic countries. If consumption of milk and dairy is lower than 350 gram/day, products may be replaced with fortified plant-based alternatives or other foods.**

For more information about the health effects, please refer to the background paper by Kirsten Holven and Emily Sonestedt (Holven & Sonestedt, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intake: Milk and dairy products are a source of high-quality protein calcium, riboflavin, vitamin B_{12}, vitamin D (if fortified), and other nutrients. Milk and yoghurt products are rich in iodine. The average intake of milk and dairy products ranges from approximately 120 to 500 g/d (Lemming & Pitsi, 2022).

Health effects: Several qSRs are available on the role of milk and dairy products and health outcomes (Lamberg-Allardt et al., 2023b; WCRF/AICR, 2018e; Åkesson et al., 2013). A *de novo* qSR for NNR2012 found moderate evidence for no association between dairy consumption and risk of cardiovascular disease (Åkesson et al., 2013). The WCRF/AICR concluded that there is strong evidence for a probable protective association with colorectal cancer, e.g., a 13 % decreased risk per 400 g/d intake of total dairy in adults (WCRF/AICR, 2018e). The associations may be attributed mainly to calcium, e.g., through binding secondary bile acids in the intestine that promote colon cancer progression, although other nutrients or bioactive components may contribute (Holven & Sonestedt, 2023; WCRF/AICR, 2018e).

qSRs of dietary patterns have found strong evidence for an association between dietary patterns that include a higher intake of low-fat dairy and lower risk of CVD and colorectal cancer (2020 Dietary Guidelines Advisory Committee, 2020; Boushey et al., 2020c), while a lower intake of full-fat dairy is a component of dietary patterns associated with lower risk of all-cause mortality and risk of type 2 diabetes (Boushey et al., 2020f, g). A moderate consumption of dairy products, particularly low and fat-free, is also part of dietary patterns associated with lower risks of obesity and other body weight-related outcomes (Boushey et al., 2020a). Regular consumption of predominately low-fat dairy products within an overall healthy dietary pattern is thus compatible with favourable health outcomes.

The *de novo* qSR by Lamberg-Allardt et al. (2023b) demonstrated that replacement of animal proteins (most often dairy protein) with plant protein (e.g., soy protein) was shown to lower total and LDL cholesterol in RCTs while there were no effects on HDL cholesterol or triglycerides.

As discussed in the background review by Holven and Sonestedt, higher intake of dairy products may also be associated with modestly lower blood pressure. On the other hand, the associations between dairy products as a group and cardiovascular disease or risk factors are not clear. The associations may however be different between subgroups of dairy products, as favourable associations with low-fat and fermented dairy products (such as yoghurt and cheese) have been reported (Holven & Sonestedt, 2023). Dairy protein has been used as a reference for high quality protein because of its content and composition of essential amino acids (Holven & Sonestedt, 2023).

Intake of between 350 ml to 500 ml milk and dairy product per day is sufficient to meet dietary requirements of calcium, iodine and vitamin B_{12} if combined with adequate intake of legumes, dark green vegetables and fish (varies among different species) (Lassen et al., 2020; Meltzer et al., 2016).

Lower amounts of cheese can substitute milk and milk products (depending on product and nutrient content). Since calcium and iodine content of cheese varies in national food tables and between products, national authorities may define a national conversion factor. Typically, about 10-20 grams cheese corresponds to 100 g milk. If the intake of dark green vegetables and legumes is lower than recommended, the intake of milk and dairy products in the higher range is needed to meet requirements for calcium. If intake of white fish is lower than recommended, the intake of milk and dairy products in the higher range is needed to meet requirements for iodine. Various fortification policies will also affect the role of dairy products for nutrients such as calcium, iodine and vitamin B_{12}. For nutritional reasons, milk and dairy products with high content of calcium and iodine should preferentially be used.

Environmental impacts: As for all foods derived from ruminants, the GHG emissions of dairy products, particularly hard cheese and butter, are relatively high. The risk of eutrophication from animal husbandry is significant, especially in the case of concentrated and intensive animal husbandry in sensitive areas. The environmental impact from dairy production in the Nordic countries varies. Feed ingredients contribute to the environmental impacts through fertilizer, pesticide, water and land use (Meltzer et al., 2023).

Main data gaps: Different dairy products may possess different effects dependent on fermentation, matrix and composition, therefore more studies on the effect of the different dairy products are needed (Holven & Sonestedt, 2023). Moreover, little focus has been on systematically comparing the effect of low- versus full-fat dairy because most studies compare different dairy products to other foods. Studies using objective biomarkers of dairy consumption are lacking. Because of an increasing focus on plant-based diets, more studies focusing on alternatives to dairy to meet dietary requirements for calcium, iodine and other nutrients are needed (Holven & Sonestedt, 2023). There is also a lack of studies covering environmental impacts other than climate impact, such as biodiversity aspects.

Risk groups: People with milk protein allergy. Low- or no-consumers have an increased risk of vitamin B_{12}, iodine and calcium inadequacy if fortified plant-based alternatives or other foods are not consumed.

Science advice:

- **Based on health outcomes:** It is recommended to consume 350-500 grams milk and dairy products/day with reference to fulfilling recommended intakes for calcium, iodine and vitamin B_{12} in combination with a varied diet. Milk and dairy products are also major dietary sources of saturated fatty acids. Therefore, replacing full-fat dairy products with low-fat products is considered more beneficial for health. Since calcium and iodine content of cheese varies in national food tables and between products, national authorities may define a national conversion factor. Typically, about 10-20 grams cheese corresponds to 100 g milk.
- **Based on environmental impacts**: In general, dairy, especially concentrated products such as hard cheese, is associated with high environmental impact. The high consumption of milk and dairy is an important contributor to GHG emissions from the diet in the Nordic and Baltic countries. Negative environmental impact is related to methane emissions from the enteric fermentation of ruminants. Feed contributes through fertilizer, pesticide, water and land use. Positive environmental impact may be related to grazing and biodiversity.
- **Overall science advice:** Intake of between 350 ml to 500 ml low fat milk and dairy products per day is sufficient to meet dietary requirements of calcium, iodine and vitamin B12 if combined with adequate intake of legumes, dark green vegetables and fish (varies among different species). The range depends on national fortifications programs and diets across the Nordic and Baltic countries. If consumption of milk and dairy is lower than 350 gram/day, products may be replaced with fortified plant-based alternatives or other foods.

Eggs

DIETARY INTAKE		HEALTH AND ENVIRONMENTAL EFFECTS
	↗	**Beneficial health effects** Eggs are a source of high-quality protein, all essential vitamins except vitamin C, all minerals and several bioactive compounds such as carotenoids.
Chicken eggs	→	**Adverse health effects** Eggs may increase plasma cholesterol and LDL/HDL ratio but observational studies indicate no adverse effects on CVD, T2D or cancer of intake up to one egg per day.
	↘	**Environmental impacts** Egg consumption is associated with lower GHG emissions than meat, but feed production demands land and may contribute negatively to biodiversity.

Science advice: A moderate intake of egg may be part of a healthy and environment-friendly diet.

For more information about the health effects, please refer to the background paper by Jyrki K. Virtanen and Susanna C. Larsson (Virtanen & Larsson, 2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intake. Eggs is a source of high-quality protein. It also contains all essential vitamins except vitamin C, all minerals and several bioactive compounds such as carotenoids. The average intake of eggs ranges from 10 to 40 g/d (Lemming & Pitsi, 2022).

Health effects. No qSRs are available on the role of eggs and health outcomes (Høyer et al., 2021).

As discussed in the background review by Virtanen and Larsson randomized controlled trials show that higher egg intake may increase serum total cholesterol concentration and the ratio of low-density lipoprotein (LDL) to high-density lipoprotein (HDL) cholesterol, but there is substantial heterogeneity in the response. Observational studies indicate no adverse effects of up to one egg per day on the risk of cardiovascular disease. Observational studies indicate no association between egg consumption and mortality or type 2 diabetes, stroke and cancer, but the evidence is limited (Virtanen & Larsson, 2023). Consumption of up to 1 egg per day can be part of a healthy diet (Virtanen & Larsson, 2023).

Environmental impacts. (Harwatt et al., 2023; Meltzer et al., 2023) Environmental issues related to egg consumption are land use, nutrient pollution of surrounding ecosystems from manure and urea, ecotoxicity, and resource use on farm including water and energy (Harwatt et al., 2023). Egg production produces GHG emissions per kilogram which are lower than those of most other land animal sourced foods but considerably higher than those for root vegetables and legumes (Meltzer et al., 2023). Feed for laying-hens may contribute to biodiversity loss when grown intensively in large fields in simplified crop rotations with low diversity, for example soy or cereals. Food-feed competition is an issue as feed crops are generally produced on land that is also suitable for production of food for human consumption. On the other hand, laying hens can make use of cereals not meeting food grade quality thereby keeping such cereals in the food system. In intensive and efficient egg production, male chickens and most of the laying hens post-production are considered waste. A more resource efficient system would make use of all by-products that are the result of egg production.

Main data gaps. There are limited data on health effects of >1 egg per day (Virtanen & Larsson, 2023). There is a lack of studies covering environmental aspects other than climate impact such as biodiversity aspects.

Risk groups. People with allergies to egg. There are no population groups especially vulnerable to positive or negative health effects of egg consumption of up to one egg per day. People with familial hypercholesterolemia should limit their consumption of cholesterol-rich foods such as eggs, in line with clinical guidelines.

Science advice:

- **Based on health outcomes:** Eggs are nutrient dense and can be part of a healthy diet at current level of consumption in Nordic and Baltic countries, although evidence on health outcomes from intakes of more than one egg per day is limited.
- **Based on environmental impacts**: Egg consumption is associated with lower GHG emissions than most other animal sourced foods, but as feed production demands land and may contribute negatively to biodiversity.
- **Overall science advice:** A moderate intake of egg may be part of a healthy and environment-friendly diet.

Fats and oils

DIETARY INTAKE

- Vegetable oils
- Margarine
- Butter
- Butter mixes
- Shortenings

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects

- Vegetable oils rich in unsaturated fats contribute essential n-6 LA and bioactive components and have cardioprotective effect when used instead of butter.
- Rapeseed, linseed, soyabean, hempseed, wheat germ, and walnut oils contribute essential n-3 ALA
- Providers of vitamin E and vitamin A

Adverse health effects

- Butter, spreads, and tropical oils rich in saturated fats → increased LDL cholesterol

Environmental impacts

- Environmental impact (GHGE, reduced biodiversity) is highest for animal-based fats, namely butter.
- Palm oil is a major driver of deforestation.

Science advice: It is recommended to consume a minimum of 25 g/day vegetable oil (or similar amounts fatty acids from whole foods) to obtain a sufficient intake of ALA (minimum of 1.3 g/day per 10 MJ/day), and limit the consumption of butter and tropical oils in favour of fats and oils high in unsaturated fatty acids.

For more information about the health effects, please refer to the background paper by Fredrik Rosqvist and Sari Niinistö (2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intake. Fats and oils contribute with essential fatty acids, fat-soluble vitamins, and bioactive components in a regular diet. The average intake of fats and oils ranges from 10 to 50 g/d (Lemming & Pitsi, 2022).

Health effects. No qSRs are available on the role of fats and oils as a food group and health outcomes (Høyer et al., 2021; Rosqvist & Niinistö, 2023).

As discussed in the background review by Rosqvist and Niinistö, the degree of saturation is the primary mediator in terms of the health effects of dietary fats and oils together with different contents of bioactive components and degree of processing (Rosqvist & Niinistö, 2023). Replacing animal-based saturated fats (mainly butter) with plant-based fats (unsaturated oils) may reduce the risk of cardiovascular diseases and mortality. Regarding specific oils, the evidence mostly concerns olive oil, which has been favourably associated with cardiovascular disease, type 2 diabetes, certain types of cancer as well as all-cause mortality. Rapeseed oil is also associated with lower LDL-cholesterol compared with sources of saturated fatty acids and other types of oil in RCTs, while palm oil and coconut oil increase LDL-cholesterol compared with oils rich in MUFA and PUFA (Rosqvist & Niinistö). The average daily intake of 25 g/10MJ of rapeseed oil and some other oils would secure the recommended intake of essential fatty acids (Retterstøl & Rosqvist, 2023; Rosqvist & Niinistö, 2023). Rapeseed oil is a preferable source of added fat due to its nutritional profile.

For cardioprotective effects, vegetable oils rich in unsaturated fatty acids and margarines produced therefrom should be preferred over butter and butter-mixes, hard margarines, and tropical oils (palm, palm kernel, shea, and coconut oil) (Rosqvist & Niinistö, 2023).

Environmental impacts. The high production and consumption of animal-based fats contribute to GHGE, reduced biodiversity, and loss of nature (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). Palm oil is a major driver of deforestation and has the highest carbon and biodiversity impacts of all vegetable oils, followed by soybean oil (Bajzelj et al., 2021). Among the main fat sources, sunflower and rapeseed oil have the lowest GHGE. Land and water use are highest for olive oil and sunflower oil (Harwatt et al., 2023). When oil crops are grown in intensive large-scale cropping systems with low diversity, they have a negative impact on biodiversity. Rapeseed and sunflower can contribute with variety to cereal dominated crop rotations and thereby reduce the need for chemical plant protection, making them beneficial in Nordic agricultural landscapes. In addition, flowering crops support pollinators (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Main data gaps. Studies on health effect of margarines and butter mixes, commonly used products in the Nordic countries, are scarce (Rosqvist & Niinistö, 2023). In addition, further studies of different consumption levels of vegetable oils, rapeseed oil in particular, in relation to disease outcomes, mortality, blood lipids, overweight, and obesity in different age groups are needed. There is a lack of studies covering environmental aspects other than climate, for example biodiversity aspects for different types of products within this food group.

Risk groups. From the perspective of weight management, it is advisable to use fats and oils in moderate amounts.

Science advice:

- **Based on health outcomes:** To secure the intake of essential fatty acids, it is recommended to consume vegetable oils rich in unsaturated fatty acids a minimum of 25 g/day paying attention to a sufficient intake of ALA (minimum of 1.3 g/day per 10 MJ/day). For cardioprotective effects, vegetable oils rich in unsaturated fatty acids and margarines produced therefrom should be preferred over butter and butter-mixes, hard margarines, and tropical oils (palm and coconut oil).
- **Based on environmental impacts:** A shift from animal to plant-based fats its recommended to contribute to lower GHG emissions and it is recommended to avoid oils that contribute to deforestation.
- **Overall science advice:** It is recommended to consume a minimum of 25 g/day vegetable oil (or similar amounts of fatty acids from whole foods) to obtain a sufficient intake of ALA (minimum of 1.3 g/day per 10 MJ/day) and limit the consumption of butter and tropical oils.

Sweets

DIETARY INTAKE

HEALTH AND ENVIRONMENTAL EFFECTS

Sweets, e.g., chocolate and other sugary foods such as cakes, biscuits, other confectioneries, and sugar-sweetened beverages (SSB)

↗ **Beneficial health effects**
Sweets are high in energy and added sugar, and low in essential nutrients and fibre, and do not have beneficial effects on health.

→ **Adverse health effects**
Sweets mainly provide energy, and a diet rich in sweets may increase the risk of poor dietary quality low in nutrient density, which may lead to low nutrient intake, or a risk of too high energy intake. Sugary foods are often also rich in fats. They increase the risk of caries. SSBs are associated with obesity and T2D.

↘ **Environmental impacts**
Sweets contribute to GHG emissions and to decrease biodiversity through its sugar content and further by the fat constituents of these products (tropical oils/butter) and, e.g., cocoa. Even though the GHG emission from sugar production is low, the high consumption of the food group contributes to its large GHG emissions in the Nordic countries.

Science advice: Limited consumption of sweets and other sugary foods is recommended.

For more information about the health effects, please refer to the background paper by Henna Vepsäläinen and Emily Sonestedt (2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intake. Sweets, chocolate and other sugary foods contains high amount of energy and added sugar, and low amount of essential nutrients and fibre. The average intake of sweets and confectioneries ranges from approximately 40 to 90 g/d (Lemming & Pitsi, 2022).

Health effects. Four qSR is available on the role of foods high in added/free sugar and health outcomes (EFSA, 2022; Mayer-Davis et al., 2020b; Rousham et al., 2022; WHO, 2015). The EFSA report found a positive and causal relationship with risk of chronic metabolic diseases such as obesity and dyslipidemia (EFSA, 2022). A qSR from WHO (2015) found a moderate level of evidence for an effect of change in free sugars intake on change in body weight in adults and BMI in children. The report from the U.S. Dietary

Guidelines Advisory Commitee (Mayer-Davis et al., 2020b), found limited evidence regarding associations between added sugars and cardiovascular disease.

Sweets contribute mainly to energy intake by their sugar and fat content. A high intake of sweets may increase the risk of poor dietary quality and low nutrient density (EFSA, 2022; Vepsäläinen & Sonestedt, 2023). Consumption of sugars is associated with increased risk of dental caries (Vepsäläinen & Sonestedt, 2023). It has been estimated that overconsumption of energy-dense foods contributes to half of the adult population and one in seven children being overweight or having obesity (Meltzer et al., 2023). For health effects on SSB, please refer to the summary on beverages in this report and the background review on beverages by Sonestedt and Lukic (2023).

Environmental impacts. Because of the high consumption of discretionary foods (e.g., sugar, sweets, and beverages) in the Nordic countries, they have a large contribution to GHG emissions (Trolle et al., 2023), even though the emissions from sugar production is low (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). This group of foods also includes ingredients such as fats and oils (see summary on *Fats and oils*) and cocoa, which have an impact on biodiversity (Harwatt et al., 2023).

Main data gaps. There is a lack of research on the role of sweets and confectionaries and risk of chronic diseases. There is a lack of comprehensive environmental impact assessment data on sweets and confectioneries.

Risk groups. Children and adolescents are risk groups for high intake of sweets, cakes and biscuits, as well as sugar-sweetened beverages (Hauner et al., 2012; SACN, 2015; WHO, 2015). People with relatively low energy requirements are at risk of low nutrient intake if their diet is rich of sweets and confectioneries.

Science advice:

- **Based on health outcomes:** It is recommended to limit the intake of sweets, including other sugary foods such as cakes, biscuits, and other confectioneries, as well as SSB. This advice is based on the risk of chronic metabolic diseases such as obesity and dyslipidemia, and the lower quality of the diet (high in energy and low in nutrient density) and risk of caries.
- **Based on environmental impacts:** Even though the GHG emissions from sugar production are low, the high consumption of the food group contributes to the relatively high GHG emissions in the Nordic countries. Sweets also contribute to decreased biodiversity by land use change and intensive large-scale cropping systems with low diversity.
- **Overall science advice:** Limiting the consumption of sweets and other sugary foods is recommended.

Alcohol

DIETARY INTAKE	BIOMARKER	HEALTH EFFECTS
	Indicator of recommended intake No qualified indicator can be identified.	**Beneficial effects** No beneficial health effects.
Ethanol in beer, wine and spirits	**Indicator of adverse effect** Carbohydrate-deficient transferrin (CDT) concentration in blood, biomarker of chronic alcohol abuse.	**Adverse effects of high intake** Increased mortality rate and risk of chronic diseases (cancer, liver disease) with high intake.
		Adverse effects of high intake Alcoholic beverages have a climate impact associated with the energy and fuel use in manufacturing and transportation and post-use, as well as water use, generation and management of organic and inorganic waste streams, GHG emissions, chemical use, land use and the impact on ecosystems.

Science advice: No safe lower limit for alcohol consumption has been established. For children, adolescents and pregnant women abstinence from alcohol is advised.

For more information about the health effects, please refer to the background paper by Dag S. Thelle and Morten Grønbæk (Thelle & Grønbæk, 2023).

Dietary intake. Alcohol (ethanol) is generally consumed as beer (about 2.5–6 vol% alcohol), wine (about 12 vol%), or spirits (about 40 vol%). In the Nordic countries and Estonia, the average intake of alcohol varies between 0.7 and 5.3 E%. There are no data on alcohol E% in Latvia or Lithuania (Lemming & Pitsi, 2022).

Main health effects. Alcohol is a toxic substance that affects all organs of the body. The energy from oxidation of alcohol in the body corresponds to 29 kJ (7 kcal) per gram, with a reduced energy efficiency at high alcohol consumption

(Thelle & Grønbæk, 2023). Alcohol is efficiently absorbed through passive diffusion, mainly in the small intestine, and is distributed throughout the total water compartment of the body.

As reviewed in the background paper by Thelle and Grønbæk (2023), both acute and chronic alcohol-induced damage contributes significantly to morbidity and mortality (CCSA, 2023; GBD Alcohol Collaborators, 2018; Mayer-Davis et al., 2020c). Alcohol consumption has been associated with cancer, with convincing evidence for breast cancer and cancer sites in the gastrointestinal tract (WCRF/AICR, 2018h). The older population, e.g., above 50 years of age, has a higher cancer risk associated with alcohol (GBD Alcohol Collaborators, 2018). Chronic high consumption of alcohol may lead to liver cirrhosis and is associated with increased mortality and lower quality of life (CCSA, 2023; GBD Alcohol Collaborators, 2018; Mayer-Davis et al., 2020c; WHO, 2018).

Indicator for recommended intake. Carbohydrate-deficient transferrin (CDT) concentration in blood is a biomarker for chronic alcohol abuse. Blood Alcohol Level (BAL) can be measured and should be zero or close to zero for no alcohol effect in the body (CCSA, 2023; GBD Alcohol Collaborators, 2018; Mayer-Davis et al., 2020c). There is strong evidence linking alcohol consumption to cancer, particularly breast cancer and various cancer locations within the gastrointestinal tract (CCSA, 2023; GBD Alcohol Collaborators, 2018; WCRF/AICR, 2018h; WHO, 2018).

Environmental impacts. Consumption of alcoholic beverages contributes to negative environmental impact just as non-alcoholic beverages (see review and summary on *Beverages* (Sonestedt & Lukic, 2023)). Alcoholic beverages have a climate impact associated with the energy and fuel used in manufacturing, transportation and post-use. Alcoholic beverages generated 3 % of the dietary climate impact in a Swedish study (Hallström et al., 2018; Trolle et al., 2023). The crops used for alcohol production, barley and wheat, may be associated with low biodiversity if produced in large-scale cropping systems with low diversity.

Main data gaps. Studies on methods on how to investigate the amount and pattern of alcohol intake are scarce. There is a lack of data for the evaluation of the quantitative environmental impact of alcoholic beverages.

Risk groups. Excessive alcohol intake increases the risk of low intake and bioavailability of nutrients. Risk groups especially vulnerable for adverse effects of alcohol intake are children, adolescents, pregnant women, and older adults. Occasional intoxication with alcohol, binge drinking, may have detrimental effects, such as violence and traffic accidents. High intake may cause liver disease.

Recommendations

- **Based on health outcomes:** Alcohol is not an essential nutrient, and from a nutritional point of view, energy contribution from high intake of alcoholic beverages affects diet quality negatively. Based on this and new systematic reviews, and since no threshold for safe level of alcohol consumption has currently been established for human health, the NNR2023 recommends avoiding alcohol intake. If alcohol is consumed, the intake should be very low. For children, adolescents and pregnant women abstinence from alcohol is advised.
- **Based on environmental impacts**: The consumption of alcoholic beverages contributes to negative environmental impact.
- **Overall recommendation:** No safe lower limit for alcohol consumption has been established. For children, adolescents and pregnant women abstinence from alcohol is advised.

Dietary patterns

DIETARY INTAKE

- Dietary patterns attempts to describe the totality of the diet over a given time period
- A dietary pattern can be defined as the quantities, proportions, variety, or combination of foods and drinks typically consumed

HEALTH AND ENVIRONMENTAL EFFECTS

↗ **Beneficial health effects**
Healthy dietary patterns are associated with beneficial health outcomes, such as reduced risk of CVD, T2D, obesity, cancer, bone health, and premature death. Such dietary patterns are micronutrient dense, including high intake of unsaturated fats and fiber, and low intake of saturated fats, added sugar and sodium.

→ **Adverse health effects**
None identified.

↘ **Environmental impacts**
Transitioning towards a healthy dietary pattern, i.e., a more plant-based dietary pattern, will reduce several negative environmental effects of the diet. However, the environmental impact of dietary patterns depends on the specific foods included. Reduction of food waste and overconsumption is important to reduce environmental impacts.

Science advice: A dietary pattern characterized by high intakes of vegetables, fruits, whole grains, fish, low-fat dairy, and legumes and low in red and processed meats, sugar-sweetened beverages, sugary foods, and refined grains, would benefit health and lower the climate impacts. Food group-specific considerations are essential to simultaneously reduce the environmental impacts and achieve nutritional adequacy of dietary patterns.

For more information about the health effects, please refer to the background paper by Henna Vepsäläinen and Jaana Lindström (2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Food and nutrient intake. Dietary patterns attempt to describe the totality of the diet over a given time. A dietary pattern can be defined as the quantities, proportions, variety, or combination of foods and drinks typically consumed. The dietary pattern approach aims to place the emphasis on the total diet as a long-term health determinant, instead of focusing on separate foods and nutrients, which may interact or confound each other.

Health effects. Several qSRs on the role of dietary patterns and health effects are available (2020 Dietary Guidelines Advisory Committee, 2020; Boushey et al., 2020a, b, c, d, e, f, g) . The conclusions from these qSRs are described in detail in Vepsäläinen and Lindström (2023).

A healthy diet can be characterized as follows: high in vegetables, fruits, whole grains, fish, low-fat dairy, and legumes and low in red and processed meats, sugar-sweetened beverages, high sugar foods, and refined grains. Such dietary patterns are often micronutrient dense, including high intake of unsaturated fats and fibre, and low intake of saturated fats, added sugar and sodium. Healthy dietary patterns are associated with beneficial health outcomes, such as reduced risk of cardiovascular disease, type 2 diabetes, obesity, cancer, bone health, and premature death (Vepsäläinen & Linström, 2023).

Environmental impacts. The current average Nordic diets greatly exceed the planetary boundaries related to GHG emissions cropland use, biodiversity, nitrogen use, and phosphorus use (Harwatt et al., 2023; Trolle et al., 2023). The water footprint is mainly located outside the Nordic regions (Trolle et al., 2023). In Nordic dietary patterns, the majority of the GHGE are from ruminant meat and dairy with some country- and gender-specific differences (Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023). Transitioning from the current Nordic diets to the previous national FBDGs (which are based on NNR2012) would reduce GHG emissions. Larger changes, within the framework of the recommendations in NNR2023, are needed to stay within the limits of planetary boundary for GHG emissions. The environmental impact of dietary patterns depends on the specific foods included, thus also including type of production and site-specific impacts. The foodstuffs comprising the diet should contribute positively and/or have the least negative impact on the environment. In order for dietary patterns to be resource efficient it is fundamental to reduce overconsumption and prevent food waste including using several parts of the animal/plant and encouraging combined systems, e.g., meat and dairy production.

Main data gaps. There is a lack of a comprehensive, structured information on pre-defined and explicit dietary patterns over time in the Nordic and Baltic countries. There is a need for more studies on health effects of different dietary patterns in certain subgroups, such as children, adolescents, and the frail older adults. There is a lack of precision and nuance in present modelling of environmental impact of diets. This is due to a lack of studies providing modelling data on environmental aspects other than climate impact such as biodiversity aspects. Data on region of origin and local conditions constitute fundamental input data for modelling but these are usually lacking for imported products. There is also a need for data on variation within product groups. Moreover, the production of supplements and fortification have environmental impact, though there is a lack of data on this.

Risk groups. People with relatively low energy requirement and those with low appetite (e.g., frail older adults) are at risk of low nutrient intake even when eating a healthy and sustainable diet.

Science advice:

- **Based on health outcomes**: To decrease the risk of diet-related chronic diseases and premature death, consume a dietary pattern characterized by high intakes of vegetables, fruits, whole grains, fish, low-fat dairy, and legumes and low in red and processed meats, sugar-sweetened beverages, sugary foods, and refined grains.
- **Based on environmental impacts**: Transitioning towards a healthy dietary pattern, i.e., a more plant-based dietary pattern, will reduce several negative environmental effects of the diet. However, the environmental impact of dietary patterns depends on the specific foods included. Reduction of food waste and overconsumption is important to reduce environmental impacts.
- **Overall science advice**: A dietary pattern, characterized by high intakes of vegetables, fruits, whole grains, fish, low-fat dairy, and legumes and low in red and processed meats, sugar-sweetened beverages, sugary foods, and refined grains, would benefit health and will lower the climate impacts. Food group-specific considerations are essential to simultaneously reduce the environmental impacts and achieve nutritional adequacy of dietary patterns.

Meal patterns

DIETARY INTAKE

- Eating frequency, occasions snacking, timing and regularity
- Intermittent fasting

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects
None (isocaloric conditions)

Adverse health effects
None (isocaloric conditions)

Environmental impacts
Potential environmental effects of meal patterns were not considered in NNR2023

Science advice: There is not enough evidence to set dietary guidelines on meal patterns based on health effects, based on studies of isocaloric intake. Meal patterns may vary within the context of an energy balanced and nutritionally adequate diet.

For more information about the health effects, please refer to the background paper by Mette Svendsen and Heléne Bertéus Forslund (2023). For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Food and nutrient intake. Studies considered investigated eating frequency, occasions of eating, snacking, timing and regularity of food consumption under isocaloric conditions.

Health effects. Three qSRs are available on the role of eating frequency and health outcomes (Heymsfield et al., 2020a, b, c). Due to a limited amount of data, no conclusions could be drawn regarding the risk of overweight and obesity, cardiovascular disease, or type 2 diabetes.

As discussed by Svendsen and Forslund, the evidence is also limited regarding health effects of breakfast skipping, meal timing and intermittent fasting. In the context of weight reduction, the effects of intermittent fasting are generally equal to those of continuous energy restriction Svendesen & Forslund, 2023.

Given the overall low to critically low quality of the reviews, the evidence is too limited and inconclusive to set recommendations for meal patterns (Svendsen & Forslund, 2023).

Environmental impacts. NNR2023 did not evaluate the potential environmental impact of different meal patterns.

Main data gaps. There is a lack of good quality long term studies on health effects of meal patterns.

Risk groups. No risk groups for adverse effects were identified in Svendsen & Forslund (2023) but some population groups are more vulnerable to inadequate energy and/or nutrient intake and more dependent on meal regularity. For example, frail older adults and young and growing children, may have to eat more frequently than the general population as they may otherwise be unable to eat adequately sized portions of food to cover energy and nutrient needs.

Science advice: There is not enough evidence to set dietary guidelines on meal patterns based on health effects, based on studies of isocaloric intake. Meal patterns may vary within the context of an energy balanced and nutritionally adequate diet.

Ultra-processed foods (UPFs)

DIETARY INTAKE

UPFs are industrial food and drink formulations made of food-derived substances and additives, often containing little or no whole foods. Many are characterized by a high content of sugars, fats and/or salt.

HEALTH AND ENVIRONMENTAL EFFECTS

Beneficial health effects

- If fortified, may support adequate nutrient intake in highly refined products
- Some UPFs are considered healthy from a nutritional point of view

Adverse health effects

- May contain high amounts of sugars, fats or salt
- May encourage over-eating
- Total intake is associated with increased risk of obesity, CVD, T2D, cancer, depression, and all-cause mortality

Environmental impacts

Environmental impact of UPFs as such has not been evaluated in NNR2023.

Science advice: **Despite the observed association between ultra-processed food and health outcomes, the NNR2023 Committee decided not to formulate any specific recommendations on ultra-processed foods. NNR2023 includes several recommendations related to specific processing of foods. The NNR committee's view is that the categorization of foods as ultra-processed foods does not add to the already existing food classifications and recommendations in NNR2023. For more details, please see the section on food processing.**

For more information about the health effects, please refer to the background paper by Filippa Juul and Elling Bere (Juul & Bere, 2023) For more information about the environmental impacts, please refer to the following background papers (Benton et al., 2022; Harwatt et al., 2023; Meltzer et al., 2023; Trolle et al., 2023).

Dietary sources and intakes. According to the NOVA classification, ultra-processed foods are defined as ready-to-eat/heat formulations whose manufacture involves several stages and various processing techniques and ingredients, mostly of exclusive industrial use. Examples of ultra-processed foods include SSBs and other soft drinks, sweet and savoury, packaged snacks, ice cream, potato chips, pizza, commercial breads, cakes and biscuits, confectioneries, sweetened breakfast cereals, margarine, hamburgers, hot dogs and many ready-to-eat products. Most ultra-processed foods are energy dense products, high in added or free sugars, salt and total fat/saturated fat, and low in fibre and micronutrients. In the NOVA framework many foods such as infant formulas, industry produced baby foods, industry- or bakery produced whole grain breads, yoghurt, fish-, fruits and vegetable products, and many other products are also classified as ultra-processed foods depending on their formulation and processing. Several studies suggest that the intake is increasing and might be around 50 percent or more in the Nordic and Baltic countries (Juul & Bere, 2023).

Health impacts. No qualified SRs are available on the health effect of UPF.

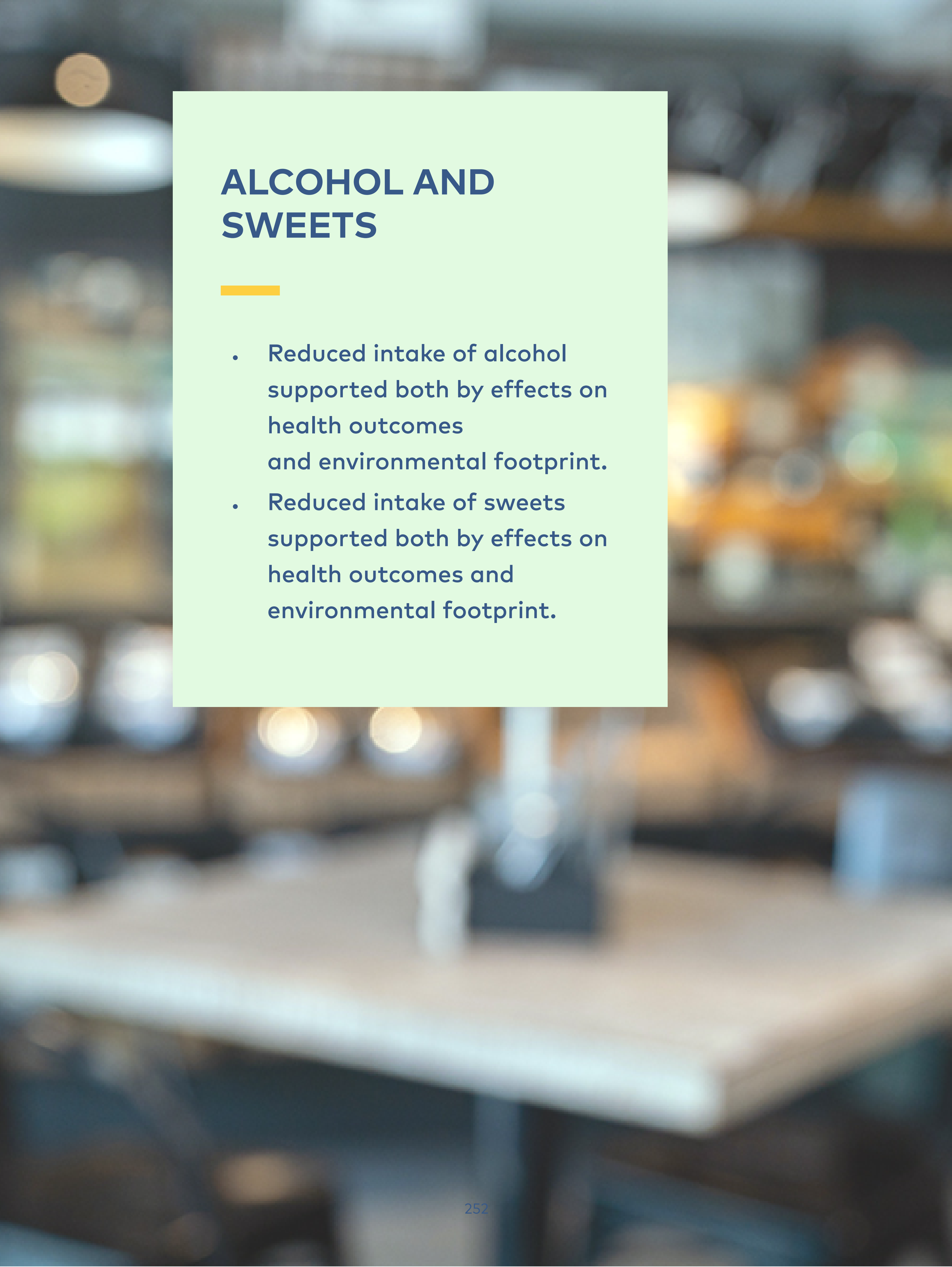
As discussed in the background paper by Juul and Bere (Juul & Bere, 2023), there is strong evidence for an association between ultra-processed foods as a group and weight gain and obesity. Evidence from a limited number of studies (primarily observational) suggest that diets high in ultra-processed foods are associated with an increased risk of hypertension, cancer, type 2 diabetes, depression and premature death. Diets high in ultra-processed foods tend to be nutritiously unbalanced and are less likely to adhere to the overall NNR2023 recommendations than minimally processed foods.

Environmental impact. Environmental impact of ultra-processed foods as such has not been evaluated in NNR2023. Ultra-processed foods is a heterogenous group of foods with varied environmental impact associated mainly with the production of the raw material, but also with energy use during food processing, packaging and transports, as for all foods. In general, processing of foods may have a positive environmental impact by reducing waste and utilization of by-products. For information on the environmental impacts, please see other summaries for example for beverages, sweets and confectioneries, fats and oils.

Main data gaps. More data are needed on the mechanisms for the observed health effects of ultra-processed foods, and the various types and degrees of processing. More data are also needed to define whether the NOVA classification of ultra-processed foods add value compared to the conventional food categorizations used in the NNR2023 FBDGs.

Risk groups. Intake of ultra-processed foods is linked to social inequalities and deprived groups.

Science advice. Despite the observed association between ultra-processed food and health outcomes, the NNR2023 Committee decided not to formulate any specific recommendations on ultra-processed foods. NNR2023 includes several recommendations related to specific processing of foods. The NNR committee's view is that the current categorization of foods as ultra-processed foods does not add to the already existing food classifications and recommendations in NNR2023. For more details, please see the section on food processing.



ALCOHOL AND SWEETS

- Reduced intake of alcohol supported both by effects on health outcomes
and environmental footprint.
- Reduced intake of sweets supported both by effects on health outcomes and environmental footprint.

ACKNOWLEDGEMENTS

Two hundred and thirty one experts have been recruited to the NNR2023 project and been directly involved in the development of NNR2023 (see appendix 1). In addition, a large number of scientists have also contributed with important input through 59 public consultations. Their names and input as well as the responses from the NNR2023 Committee will be published in a separate report. Finally, consultations with scientific committees among health authorities in many countries in Europe, America, Asia and Oceania have also contributed significantly to the report. Thus, while the NNR2023 Committee is solely responsible for the text in the final NNR2023 report, we greatly appreciate and acknowledge the essential input from many hundred scientists and international external experts.

OVERVIEW OF NNR2023 TABLES

INTRODUCTION

RECOMMENDATIONS

CEREALS AND PULSES

- Increased intake of whole grains supported both by effects on health outcomes and environmental footprints.
- Higher consumption of pulses supported both by effects on health outcomes and environmental footprints.

BACKGROUND PAPERS FOR THE NNR2023 REPORT

The NNR2023 report is based on background papers published in the Food and Nutrition Journal. While the text in the NNR2023 report is the sole responsibility of the NNR2023 Committee, the text in all background papers is the sole responsibility of the authors. The NNR2023 Committee has an editorial role in background papers commissioned by the NNR project. All background papers have been peer-reviewed and submitted to public consultation. All papers are Open Access and can be downloaded from the website of the journals.

Link to the collection of all background papers:

https://pub.norden.org/nord2023-003/background-papers

PUBLIC CONSULTATION COMMENTS

In addition to the standard peer-review process, all background papers on nutrients, food groups, meal and dietary patterns as well as the background papers developed in the NNR2023 project on environmental aspects of food consumption were also submitted to public consultation. A consultation period of 4 weeks was initially practiced. However, the period was extended to 8 weeks for papers submitted to public consultation after May 2022. Thousands of comments were received and forwarded to the authors for consideration. All consultation comments have in the project period been openly accessible through the NNR2023 website.

The manuscript authors have briefly formulated a response to each of the comments. All comments to the background papers have also been considered by the NNR Committee.

The NNR2023 draft report was also submitted for public consultation. All of these comments have been answered by the NNR2023 Committee.

Throughout the project period, the public and all interested parties have also been invited to submit their comments to the NNR2023 Committee through the NNR2023 website. The NNR2023 Committee has carefully considered all comments.

Find links to public consultation reports here:

https://pub.norden.org/nord2023-003/public-consultation-comments

MEAT, MILK AND DAIRY

- Reduced intake of red meat supported both by effects on health outcomes and environmental footprint.
- Preferentially lower intake of white meat (poultry) due to environmental impact.
- Moderate intake of low-fat milk mainly due to nutrient adequacies; high intakes not compatible with low environmental impact.

ABOUT THE NNR2023 PROJECT

The NNR collaboration

The Nordic Nutrition Recommendations (NNR) is an international collaboration among health and food authorities in Denmark, Finland, Iceland, Norway, and Sweden that was initiated more than 40 years ago. A major outcome of the collaboration has been a regular update of dietary reference values (DRVs). In the last edition, general advice on food-based dietary guidelines (FBDGs) was also included (Nordic Council of Ministers 2014). Each updated edition serves as science advice to the national authorities who establish country specific recommendations. Thus, NNR has constituted the scientific basis for national DRVs and FBDGs. In addition, NNR has served as a key scientific foundation for national food and health policies, food labelling, taxes and regulations, education, food and nutrition surveillance and research. The Baltic countries have used previous editions of NNR as a scientific background for their national DRVs, FBDGs and health policies. For the first time, representatives from the Baltic health authorities have participated as observers in the NNR2023 Committee.

The pre-project

Since the first publication in 1980, NNR has been updated every 8-10 years. The leadership and organisation for updating the NNR has rotated among the health and food authorities in the Nordic countries. At a meeting in Reykjavik in September 2016, the Working Group on Food, Diet and Toxicology (NKMT) under the auspices of the Nordic Committee of Senior Officials for Food Issues (ÄK-FJLS Livsmedel) decided to update the fifth edition of NNR and invited the Norwegian Directorate of Health to take on the task of administratively organise a sixth edition of the NNR. The health and food authorities in the Nordic countries established the following working group to assist in the development of a project plan for the new edition:

Denmark: Ellen Trolle, Technical University Denmark, Kgs. Lyngby, Rikke Andersen, Technical University Denmark, Kgs. Lyngby, and Lisa von Huth Smith, Danish Health Authority, Copenhagen

Finland: Sirpa Kurppa, Natural Resources Institute Finland, Helsinki, Heli Kuusipalo, Finish Institute for Health and Welfare, Helsinki, Ursula Schwab, University of Eastern Finland, Kuopio Campus, and Katja Borodulin, Age Institute, Helsinki

Iceland: Inga Þórsdóttir, University of Iceland, Reykjavík, Þórhallur Ingi Halldórsson, University of Iceland, Reykjavík, Gígja Gunnarsdóttir, Directorate of Health, Reykjavik, and Sigríður Lára Guðmundsdóttir, University of Iceland, Reykjavík

Norway: Rune Blomhoff (head of pre-project), University of Oslo, Oslo, Helle Margrete Meltzer, Norwegian Institute of Public Health, Oslo, and Sigmund Anderssen, Norwegian School of Sport Sciences, Oslo

Sweden: Hanna Eneroth, The Swedish Food Agency, Uppsala, Eva Warensjö Lemming, The Swedish Food Agency, Uppsala, and Marita Friberg, Public Health Agency, Stockholm

Based on funding from the Nordic Council of Ministers, the pre-project working group and the health and food authorities in the Nordic countries developed a project plan. In February 2018, the Norwegian Directorate of Health submitted the project plan to the Nordic Council of Ministers. Based on feedback from the Nordic Council of Ministers, an updated description of the project (NNR2023) was accepted and funded by the Nordic Council of Ministers for Fisheries, Aquaculture, Agriculture, Food and Forestry (MR-FJLS).

The major milestones in the accepted project description were:

1. Update dietary reference values for energy, macro- and micronutrients
2. Develop an evidence-based platform for national food-based dietary guidelines
3. Develop an evidence-based platform for integration of environmental sustainability into food-based dietary guidelines

The inclusion of milestones 2 and 3 represents a substantial extension from previous editions of NNR which focused on updating dietary reference values for energy, macro- and micronutrients (milestone 1).

Funding of the NNR project

The NNR project is funded by the Nordic Council of Ministers (NCM) and the food and health authorities in Denmark, Finland, Iceland, Sweden, and Norway. The following organs within the NCM, each with their respective mandates, have funded the project:

- Ministers for Co-operation (MR-SAM)
- Nordic Council of Ministers for Fisheries, Aquaculture, Agriculture, Food and Forestry (MR-FJLS)
- Nordic working group for Healthy, Safe and Sustainable Diet (HSSD)

In kind contributions were substantial from the authors of this report and their affiliations.

NNR project period and project plan

The original project period was from January 2019 to December 2022. Due to delays during the COVID-19 pandemic, the delay in publication of the IPCC synthesis report from UN (IPCC 2023), and the extensive work related to preparing the background papers, the Nordic Council of Ministers decided to extend the project period to June 2023 based on an application from the NNR Committee. Some previous documents and background papers refer to the present NNR project as the NNR2022 project due to its originally planned delivery date. In this report we have corrected this and refer to the present NNR project as the NNR2023 project.

Based on the project description, the NNR Committee developed a project plan for project organization. The project plan also included general principles and methodologies for the project (Christensen et al. 2020). During the project period, the project plan and process has been developed further in collaboration with the Nordic Council of Ministers. The text in this report reflects the final description of the project by the NNR2023 Committee. During the project period, the Nordic Committee of Senior Officials for Fisheries, Aquaculture, Agriculture, Food and Forestry (EK-FJLS Executive and

and EK-FJLS Foods) and the Healthy, Safe and Sustainable Diet (HSSD) working group were informed about project status and guided the development of the project.

Estonia, Latvia and Lithuania are associated members of Nordic Council of Ministers, and they have previously used NNR editions as the main source for their national DRVs and FBDGs. Thus, it was decided that these countries should be invited to participate in the project. Specifically, the health authorities in Estonia, Latvia and Lithuania were invited to participate in the NNR Committee with one observer each.

Organization of the NNR2023 project

The NNR2023 project is commissioned by the Nordic Council of Ministers. The Norwegian Directorate of Health, Oslo, Norway administered the NNR2023 project. Members of the Steering Committee and the NNR2023 Committee were recruited by the Nordic health and food authorities.

NNR2023 Steering Committee

The responsibilities of the Steering Committee were to approve the budget, set the criteria for conflict of interest, and evaluate the declarations of conflict of interest for the NNR2023 Committee. The Steering Committee regularly approved the progress and status reports from the NNR2023 Committee.

- Head of Steering Committee: Henriette Øien, The Norwegian Directorate of Health, Oslo, Norway
- Satu Männistö, Finnish Institute for Health and Welfare, Helsinki, Finland
- Hólmfrídur Þorgeirsdóttir, Directorate of Health, Reykjavík, Iceland
- Ulla-Kaisa Koivisto Hursti, Swedish Food Agency, Uppsala, Sweden
- Anne Pøhl Enevoldsen/Else Molander, Danish Veterinary and Food Administration, Glostrup, Denmark

NNR2023 Committee

The NNR2023 Committee has been responsible for organizing and implementing the NNR2023 project and publishing the final NNR2023 report. The NNR2023 Committee has also been responsible for appointing the Scientific Advisory Group, the NNR Systematic Review Centre, background paper authors, referees, and for approving any conflict-of-interest forms for involved experts. The project organization is described in detail in Christensen et al. (Christensen et al. 2020).

Head of Committee:

Rune Blomhoff, University of Oslo and Oslo University Hospital, Oslo, Norway

NNR Committee members:

- Ellen Trolle, Technical University of Denmark, Kgs. Lyngby, Denmark
- Rikke Andersen, Technical University of Denmark, Kgs. Lyngby, Denmark
- Maijaliisa Erkkola, University of Helsinki, Helsinki, Finland
- Ursula Schwab, University of Eastern Finland, Kuopio Campus, Finland
- Þórhallur Ingi Halldórsson, University of Iceland, Reykjavík, Iceland
- Inga Þórsdóttir, University of Iceland and landspitali, Reykjavík, Iceland
- Helle Margrete Meltzer, Norwegian Institute of Public Health, Oslo, Norway
- Jacob Juel Christensen, University of Oslo, Oslo, Norway
- Eva Warensjö Lemming, The Swedish Food Agency and Uppsala University, Uppsala, Sweden
- Hanna Eneroth, The Swedish Food Agency, Uppsala, Sweden

Observers:

- Tagli Pitsi, National Institute for Health Development, Tallinn, Estonia
- Inese Siksna, Institute of Food Safety, Animal Health and Environment, Riga, Latvia/Lāsma Pikele, The Ministry of Health of the Republic of Latvia, Riga, Latvia
- Almantas Kranauskas, Ministry of Health, Vilnius, Lithuania (until Dec. 2021), Ieva Gudanaviciene, Ministry of Health, Vilnius, Lithuania (from Dec. 2021)
- Bjørg Mikkelsen, Food Department at Faroese Food and Veterinary Authority, Faroe Islands

Project administration:

- Scientific project secretary: Ane Sørlie Kværner (11.02.19-01.07.19), Anne Høyer-Lund (01.11.19-30.06.23), Norwegian Directorate of Health, Oslo, Norway
- Scientific advisor: Erik Kristoffer Arnesen (01.02.23-30.06.23), University of Oslo and the Norwegian Directorate of Health, Oslo, Norway

NNR2023 Scientific Advisory Group

The NNR2023 Committee recruited a Scientific Advisory Group after consultation with the Steering Committee. The group consisted of international leading scientists with experience in developing DRVs and FBDGs for national authorities or health organizations. The group has advised on principles and methodologies, they have given advice on general scientific issues related to the project, and peer-reviewed several background papers and the final NNR2023 report. The Scientific Advisory Group consisted of the following scientists:

- Amanda MacFarlane, Agriculture, Food, and Nutrition Evidence Center, Texas A&M University System, Fort Worth TX, US
- Joseph Lau, Center for Evidence Synthesis in Health, Brown University School of Public Health, US
- Susan Fairweather-Tait, Norwich Medical School, University of East Anglia, Norwich Research Park, Norwich, UK
- Joao Breda, Head WHO European Office for Prevention and Control of Noncommunicable Diseases & a.i. Programme Manager Nutrition, Physical Activity and Obesity, Division of Noncommunicable Diseases and Promoting Health through the Life-course, Copenhagen, Denmark
- Dominique Turck, Division of Gastroenterology, Hepatology and Nutrition, Department of Pediatrics, Lille University Jeanne de Flandre Children's Hospital and Faculty of Medicine, Lille, France | Univ. Lille, Inserm, CHU Lille, U1286 - INFINITE - Institute for Translational Research in Inflammation, Lille, France
- Giota Mitrou, World Cancer Research Fund International, London, UK.
- Wulf Becker, Uppsala University, Department of Public Health and Caring Sciences, Clinical Nutrition and Metabolism, Uppsala University, Uppsala, Sweden

NNR2023 Systematic Review Centre

As the NNR2023 project aimed to develop de novo qualified systematic reviews (SRs), an independent Systematic Review Centre (SR Centre) was funded by the project. The following team members were recruited by the NNR2023 Committee based on competence and previous experience in developing SRs:

- Agneta Åkesson, Karolinska Institutet, Sweden (SR Centre leader)
- Christel Lamberg-Allardt, University of Helsinki, Finland.
- Erik Kristoffer Arnesen, University of Oslo, Norway
- Linnea Bärebring, University of Gothenburg, Sweden
- Bright I. Nwaru, University of Tampere/University of Gothenburg, Finland/Sweden
- Jutta Dierkes, University of Bergen, Norway
- Birna Þórisdóttir, University of Iceland, Reykjavik, Iceland
- Alfons Ramel, University of Iceland, Reykjavik, Iceland
- Fredrik Söderlund, Karolinska Institutet, Sweden

Recruitment of other experts

Several hundred experts and scientists have contributed to the NNR2023 project. Two hundred and thirty one scientists have been recruited as authors, peer-reviewers and members of reference groups for the development of background papers. All scientists are acknowledged in each of the papers and in Appendix 1. The experts were appointed by the NNR2023 Committee based on a public call and after careful evaluation of their competence, experience and conflict of interest related to the tasks. To supplement the call, some experts were also recruited after invitation from the NNR2023 Committee. A fair distribution of experts among the Nordic countries was sought when appointing experts. In addition, a large number of scientists have also contributed with important input through 59 public consultations. Their names and input as well as the responses from the NNR2023 Committee will be published in a separate report.

Handling of conflict of interest and bias of experts involved

Almost all scientists may have some sort of direct or indirect conflict of interest. Conflict of interest may arise due to the role of the institution where the scientist is employed, external funding to the institution or the scientist, or to personal economic interests, voluntary activities and memberships, or other personal biases. All scientists must compete for internal and external resources for scientific activities. The external sources that fund most research span from national research funds that distribute resources from governmental budgets to patient or interest organizations (e.g., cancer, heart or diabetes funds) and commercial entities (e.g., pharmaceutical industry and food producers). Furthermore, governmental funds, including those resources distributed through the European Union and national research councils, often demand collaboration with commercial companies. While industry-sponsored research is a large part of modern medical and nutrition science, it is essential that all such ties are declared and openly available. Scientists with strong ties to industry or ideological organizations have been excluded from serving as experts.

The NNR2023 project is organised with several "checks and balances" (Christensen et al. 2020) to reduce the risk of such influence of biases and to minimize the influence of innate bias of the scientists involved. Some important features of this system with "checks and balances" were that:

- the project was split into discrete parts done by separate experts to reduce experts influencing multiple parts of the process
- the project involved many experts from several nutrition and non-nutrition sub-disciplines
- background papers were peer-review by independent scientists
- background papers and the final NNR2023 report were submitted to public consultation
- several papers were also developed based on workshops and consultations with reference groups
- the international Scientific Advisory Group peer-reviewed and advised on principles and methodologies and the final NNR2023 report

The central goal of the conflict-of-interest policies is to protect the integrity of professional judgement and to preserve public trust. The disclosure of individual and institutional conflict of interest, including financial relationships, is a critical step in the process of identifying and responding to conflict of interest. All NNR2023 experts, including all committee members, background paper authors and peer reviewers, have declared their conflict of interest according to standard procedures used when health authorities in the Nordic countries recruit scientists for outsourced expert tasks. The NNR2023 Committee handled all matters regarding conflict of interest of the experts. In cases of any uncertainty, the NNR2023 Committee sought advice from the Steering Committee. The NNR2023 Steering Committee handled all matters concerning potential conflict of interest for the NNR2023 Committee members.

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APPENDIX

Appendix 1. Experts involved in the NNR project

Name, affiliation, country	Role	
Agneta Hörnell, UmU, SE	Author "Infant feeding"	
Agneta Oskarsson, SLU, SE	Author "Manganese", "Molybdenum"	
Agneta Sjöberg, UoG, SE	Author "Iron", "Human body weight, nutrients and foods: a scoping review"	
Agneta Åkesson, KI, SE	Author 9 *de novo* systematic reviews	
Alfons Ramel, UoI, IS	Author 9 *de novo* systematic reviews	
Alicja Wolk, KI, SE	Author "Phytochemicals and antioxidants"	Referee "Meat and meat products"
Allan Linneberg, GUH, DK	Author "Vitamin K"	
Almantas Kranauskas, MH, LT	NNR2023 Observer	
Amanda MacFarlane, HC, CA	Referee NNR2023 report and methodology background papers	
Amanda Wood, SRC, SE	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region", Resource group "Moving food production and consumption toward sustainable diets in the Nordics: Challenges and opportunities"	
Amund Måge, HI, NO	Author "Moving food production and consumption toward sustainable diets in the Nordics: Challenges and opportunities"	
Ane Sørlie Kværner, UoO, NO	Scientific secretary	
Anete Dudele, UoI, IS	Author systematic reviews in the NNR-EFSA collaborating project	
Anette Hjartåker, UoO, NO	Referee "Chromium", "Molybdenum"	

Anitra Carr, OU, NZ	Author "Vitamin C"	
Anna Bergström, KI, SE	Referee "Phytochemicals and antioxidants", "Breastfeeding"	
Anna Karin Lindroos, SFA, SE	Referee "Sweets and confectionaries", "Meals patterns"	
Anne Høyer-Lund, NDH, NO	Scientific secretary	
Anne Juul Skjetne, UoO, NO	Pre-project coordinator	
Anne Lise Brantsæter, NIPH, NO	Author "Iodine"	
Anne Pøhl Enevoldsen, FVST, DK	NNR2023 Steering group member	
Anne Scott, FVST, DK	NNR2023 Steering group member	
Anne-Lise Bjørke Monsen, UoB, NO	Author "Vitamin B6", "Folate", "Vitamin B12"	
Anne-Marja Pajari, UoH, FI	Author "Dietary fibre", "Protein"	Reference group member "Assessing the environmental sustainability of diets – an overview of approaches and identification of 5 key considerations for comprehensive assessments"
Ann-Karin Olsen, NIPH, NO	Author "Selenium"	
Ann-Kristin Skrindo Knutsen, NIPH, NO	Author "The burden of diet related diseases and dietary risk factors in the Nordic and Baltic countries: a systematic analysis of the global burden of diseases, injuries and risk factors study 2021"	
Anthea Van Parys, UoB, NO	Referee "Choline"	
Antti Jula, Fimnet, FI	Author "Sodium", "Potassium"	
Arja Lyytinen, UEF, FI	Author "Vitamin K"	
Asim Duttaroy, UoO, NO	Referee "Vitamin E"	
Audun Korsæth, NIBIO, NO	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Beate Stokke Solvik, UoB, NO	Author "Biotin"	
Benjamin Clarsen, NIPH, NO	Author "The burden of diet related diseases and dietary risk factors in the Nordic and Baltic countries: a systematic analysis of the global burden of diseases, injuries and risk factors study 2021"	
Birna Thorisdottir, UoI, IS	Author 9 *de novo* systematic reviews	
Bjørg Mikkelsen, FFVA, Faroe Islands	NNR2023 Observer	
Bob van Oort, CICERO, NO	Author and workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	Referee "Integrating sustainability into Food Based Dietary Guidelines in the Nordic countries", "Moving food production and consumption toward sustainable diets in the Nordics: Challenges and opportunities", reference group member "Assessing the environmental sustainability of diets – an overview of approaches and identification of 5 key considerations for comprehensive assessments"
Bright Nwaru, UoG, SE	Author 9 *de novo* systematic reviews	

Bruna Miguel, CH, UK	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Bryndís Eva Birgisdóttir, UoI, IS	Co author and workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region", Author systematic reviews in the NNR-EFSA collaborating project	Referee "Carbohydrates", "Dietary fibre"
Caroline Filskov Petersen, UoC, DK	Author systematic reviews in the NNR-EFSA collaborating project	
Christel Lamberg-Allardt, UH, FI	Author "Phosphorus", 9 *de novo* systematic reviews	Referee "Vitamin D"
Christine Delisle, KI, SE	Author "Fruit juice", "Potatoes"	
Christine Henriksen, UoO, NO	Author "Magnesium", "Copper", "Chromium"	
Corné van Dooren, WWF, NL	Author "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Cornelia Witthöft, LU, SE	Referee "Folate", "Vegetables, fruits and berries", "Potatoes", "Fruit juice", "Pulses"	Author systematic reviews in the NNR-EFSA collaborating project
Dag S Thelle, UoO, NO	Author "Alcohol"	
Dagfinn Aune, ICL, UK	Statistical consultant	
David Smith, UoO, UK	Referee "Thiamin", "Folate", "Vitamin B12"	
Davy Vanham, JRC, IT	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Dena Alavi, UoO, NO	Referee "Alcohol", "Biotin", "Pantothenic acid"	
Dominique Turck, LU, FR	Referee NNR2023 report and methodology background papers	
Ebba Nexø, AaU, DK	Referee "Vitamin B12"	
Eirin Bar, NTNU, NO	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Elin Röös, SLU, SE	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region", Resource group "Moving food production and consumption toward sustainable diets in the Nordics: Challenges and opportunities"	
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Ellen Trolle, DTU, DK	NNR2023 Committee member	
Elling Bere, UoA, NO	Author "Ultraprocessed foods"	
Emilie Helte, KI, SE	Referee "Calcium", "Magnesium", "Fluoride"	

Emily Sonestedt, LU, SE	Author "Carbohydrates", "Beverages", "Milk and diary", "Sweets and confectionaries"	
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Eva Warensjö Lemming, SFA, SE	NNR2023 Committee member	
Filippa Juul, KI, SE	Author "Ultraprocessed foods"	
Folasade Adebayo, UoH, FI	Author systematic reviews in the NNR-EFSA collaborating project	
Fredrik Jernerén, UU, SE	Referee "Thiamin", "Riboflavin", "Niacin", "Vitamin B6"	
Fredrik Rosqvist, UoU, SE	Author "Fat and fatty acids", "Fats and oils"	Referee "Eggs"
Fredrik Söderlund, KI, SE	Author 9 *de novo* systematic reviews	
Frode A Norheim, UoO, NO	Referee "Copper"	
GBD collaboration group (TBA)	Author "The burden of diet related diseases and dietary risk factors in the Nordic and Baltic countries: a systematic analysis of the global burden of diseases, injuries and risk factors study 2021"	
Gigja Gunnarsdottir, DH, IS	Pre-project participant	
Giota Mitrou, WCRF, UK	Referee NNR2023 report and methodology background papers	
Gry Hay, NDH, NO	Referee "Iron", "Breastfeeding"	
Gun Brit Knutssön, KI, SE	Research librarian	
Guri Skeie, UiT, NO	Author "Cereals"	
Hanna Eneroth, SFA, SE	NNR2023 Committee member	
Hanna Karlsson, SLU, SE	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Hanna Lagström, TUH, FI	Author "Infant feeding"	
Hanna Sara Strandler, SLV, SE	Author "Thiamin", "Riboflavin"	Referee "Niacin"
Hanna Tuomisto, LUKE, FI	Author and workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
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Harald Carlsen, NMBU, NO	Author "Dietary fibre"	Referee "Vitamin A", "phytochemicals and antioxidants"
Helen Harwatt, CH, UK	Author "Assessing the environmental sustainability of diets – an overview of approaches and identification of 5 key considerations for comprehensive assessments", "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	

Helene Bertheus Forslund, GU, SE	Author "Meal patterns"	
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Henna Vepsäläinen, UoH, FI	Author "Sweets and confectionaries", "Dietary patterns"	
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Jette Jakobsen, DTU, DK	Referee "Vitamin E"	

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Johanna E Torfadottir, UoI, IS	Author "Calcium", "Fish and seafood",	Referee "Milk and dairy products"
Johanna Tilkanen, CH, UK	Workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Josefin Edvall Löfvenborg, SFA, SE	Referee "Beverages"	
Joseph Lau, BU, US	Referee NNR2023 report and methodology background papers	
Juha Helenius, UoH, FI	Author "Moving food production and consumption toward sustainable diets in the Nordics: Challenges and opportunities"	
Jutta Dierkes, UoB, NO	Author 9 *de novo* systematic reviews	
Jyrki K. Virtanen, UEF, FI	Author "Meat and meatproducts", "Eggs",	
Jøran Hjelmesæth, HSØ, NO	Author "Human body weight, nutrients, and foods: a scoping review"	
Jørgen Eivind Olesen, AU, DK	Author "Moving food production and consumption toward sustainable diets in the Nordics: Challenges and opportunities"	
Jaana Lindström, THL, FI	Author "Dietary patterns"	
Karin Leander, KI, SE	Referee "Alcohol"	
Katja Borodulin, AI, FI	Author "Physical activity: associations with health and summary of guidelines", pre-project participant	
Kerry Ann Brown, LSHTM, UK	Author and workshop participant "Overview of food consumption and environmental sustainability – considerations in the Nordic and Baltic region"	
Kirsi Laitinen, FIHW, FI	Referee "Fish and seafood", "Breastfeeding"	
Kirsten Holven, UoO, NO	Author "Milk and dairy products"	
Kirsti Uusi-Rasi, UKK, FI	Author "Calcium"	
Kjetil Retterstøl, UoO, NO	Author "Fat and fatty acids"	
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Klaus Mittenzwei, Ruralis, NO	Reference group member "Assessing the environmental sustainability of diets – an overview of approaches and identification of 5 key considerations for comprehensive assessments"	
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Lars Ellegård, GU, SE	Author "Energy"	
Lars Rejnmark, ÅU, DK	Referee "Calcium", "Phosphorus"	
Lars T. Fadnes	Author "Cereals, "Vegetables, fruits and berries", Pulses", "Nuts"	
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Lise Madsen, UiB, NO	Referee "Protein"	
Liv Elin Torheim, NIPH, NO	Author "Pulses"	Referee "Zinc", "Cereals", "Meat and meat products"
Lotte Holm, UoC, DK	Author "Social and economic dimensions of food sustainability – summary of the SAPEA report"	
Magdalena Rosell, KI, SE	Author "Vegetables, fruits and berries", "Potatoes", "Nuts", "Fruit juice"	
Magnus Domellöf, UU, SE	Author "Iron"	
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Nanna Louise Riis, FH, DK	Author "Potassium"	
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Nina Øverby, UoA, NO	Author "Carbohydrates", "Beverages", "Milk and diary", "Sweets and confectionaries"	Referee "Ultraprocessed foods", "Dietary fibre"
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Stefan Einarsson, UAR, IS	Reference group member "Assessing the environmental sustainability of diets – an overview of approaches and identification of 5 key considerations for comprehensive assessments"
Stina Ramne, LU, SE	Referee "Sweets and confectionaries"
Stine Ulven, UoO, NO	Autho "Fish and seafood"
Susan Fairweather-Tait, NMS, UK	Referee NNR2023 report and methodology background papers
Susanna C. Larsson, KI, SE	Author "Eggs"
Susanne Bügel, UoC, DK	Author "Chromium"
Suvi T. Itkonen, UoH, FI	Author "Phosphorus"
Suvi Virtanen, FIHW, FI	Referee "Vegetables, fruits and berries", "Potatoes", "Fruit juice", "Nuts", "Milk and dairy"
Saari Hantunen, UEF, FI	Referee "Choline"
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Thomas Lind, UU, SE	Referee "Vitamin A"

Thomas Olsen, UoO, NO	Author "Vitamin A"
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Tor A Strand, UoB, NO	Author "Thiamin", "Biotin", "Zinc"
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Veronica Öhrvik, Axfoundation, SE	Referee "Sodium"
Vibeke Telle-Hansen, OsloMet, NO	Referee "Eggs", "Fats and oils"
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Åge Klepp, RF, NO	Resource group "Moving food production and consumption toward sustainable diets in the Nordics: Challenges and opportunities"
Åsa Svenfeldt, KTH, SE	Reference group member "Assessing the environmental sustainability of diets – an overview of approaches and identification of 5 key considerations for comprehensive assessments"

Appendix 2. List of qualified systematic reviews

1. Qualified systematic reviews: summary of exposures, outcomes, and methodology

Topic	Year	Authors/ organization (country)	Exposure(s)	Outcome(s)	Risk of bias assessment tool	SoE/evidence quality grading
Sodium and Potassium intake	2018	AHRQ (USA) Newberry et al. (2018)	Dietary sodium (sodium reduction), potassium	Blood pressure, risk for cardiovascular diseases, all-cause mortality, renal disease and related risk factors, adverse events	Cochrane RoB / NOS. Some nutrition-specific items added (e.g., sodium intake assessment)	"High", "Moderate", "Low" or "Insufficient". Based on: 1) Study limitations, 2) consistency, 3) directness, 4) precision, 5) reporting bias. Observational studies may be upgraded if very strong effects, a strong dose-response-relationship or if effects cannot be explained by uncontrolled confounding.
Vitamin D and Calcium	2014	AHRQ (USA) (Newberry et al., 2014)	Vitamin D and/or Calcium	Bone health, cardiovascular health, cancer, immune function, pregnancy, all-cause mortality, vitamin D status	CONSORT statement for RCTs, own checklist based on STROBE and nutrition-specific items	Grade A-B
Omega-3 Fatty Acids	2016	AHRQ (USA) Balk et al. (2016)	Omega-3 Fatty Acids	Cardiovascular Disease, risk factors	Cochrane RoB / NOS. Some nutrition-specific items added.	"High", "Moderate", "Low" or "Insufficient". Based on: 1) Study limitations, 2) consistency, 3) directness, 4) precision, 5) reporting bias, 6) number of studies
Omega-3 Fatty Acids	2016	AHRQ (USA) Newberry et al. (2016)	Omega-3 Fatty Acids	Maternal and Child Health: Gestational length, risk for preterm birth, birth weight, risk for low birth weight, risk for peripartum depression, risk for gestational hypertension / preeclampsia; postnatal growth, visual acuity, neurological development, cognitive development, autism spectrum disorder, ADHD, learning disorders, atopic dermatitis, allergies and respiratory disorders, adverse events	Cochrane RoB / NOS. Some nutrition-specific items added.	"High", "Moderate", "Low" or "Insufficient". Based on: 1) Study limitations, 2) consistency, 3) directness, 4) precision, 5) reporting bias, 6) number of studies
Vitamin, Mineral, and Multivitamin Supplementation	2021	AHRQ (USA) O'Connor et al. (2022)	Multivitamin and single nutrient supplements	Risk of cardiovascular disease, cancer, and mortality, other harms	Similar to Cochrane RoB	"High", "Moderate", "Low" or "Insufficient". Based on: 1) Study limitations, 2) consistency, 3) precision, 4) reporting bias
Nutrient Reference Values for Sodium	2017	Australian Government Department of Health/New Zealand Ministry of Health (Neale and Clark (2017)	Dietary sodium / sodium reduction	Blood pressure, cholesterol concentrations, stroke, myocardial infarction, all-cause mortality	Cochrane RoB, modified	GRADE and NHMRC level of evidence (from I to IV)

Alcohol	2023	Canadian Centre on Substance Use and Addiction (Health Canada) (2023)	Alcohol	Physical and mental health, and social impact	AMSTAR 2.0	GRADE
Dietary Patterns	2020	DGAC (USA) (Boushey et al., 2020b)	Dietary patterns; macronutrient distribution	Growth, Size, Body Composition, and/or Risk of Overweight or Obesity	Cochrane RoB 2.0 / Rob-Nobs*	Strength of Evidence: "Strong", "Moderate", "Limited" or "Not Assignable"; based on 1) risk of bias, 2) consistency, 3) directness, 4) precision, 5) generalizability
Dietary Patterns (update of 2015 DGAC review)	2020	DGAC (USA) (2020 Dietary Guidelines Advisory Committee, 2020)	Dietary patterns	Cardiovascular disease, CVD risk factors (blood pressure, blood lipids)		
Dietary Patterns and Risk of Type 2 Diabetes (update of 2015 DGAC review)	2020	DGAC (USA) (Boushey et al., 2020d)	Dietary patterns	Type 2 Diabetes		
Dietary Patterns (update of 2015 DGAC review)	2020	DGAC (USA) (Boushey et al., 2020e)	Dietary patterns	Breast cancer, colorectal cancer, lung cancer, prostate cancer		
Dietary Patterns (update of 2015 DGAC review)	2020	DGAC (USA) (Boushey et al., 2020f)	Dietary patterns	Bone health, e.g., risk of hip fracture, bone mineral density		
Dietary Patterns (update of 2015 DGAC review)	2020	DGAC (USA) Boushey et al. (2020g)	Dietary patterns	Neurocognitive health; age-related cognitive impairment, dementia		
Dietary Patterns	2020	DGAC (USA) (Boushey et al., 2020c)	Dietary patterns	Sarcopenia		
Dietary Patterns	2020	DGAC (USA) (Boushey et al., 2020a)	Dietary patterns	Mortality		
Dietary Patterns during Pregnancy	2020	DGAC (USA) (Donovan et al., 2020d)	Dietary patterns	Gestational weight gain		
Dietary Patterns during Lactation	2020	DGAC (USA) (Donovan et al., 2020c)	Dietary patterns	Human milk composition and quantity		
Folic Acid from Fortified Foods and/or Supplements during Pregnancy and Lactation	2020	DGAC (USA) (Donovan et al., 2020e)	Folic acid	Micronutrient status; gestational diabetes; hypertensive disorders during pregnancy; human milk composition; developmental milestones in child		
Omega-3 fatty acids from Supplements Consumed before and during Pregnancy and Lactation	2020	DGAC (USA) (Donovan et al., 2020a)	Omega-3 from supplements	Risk of Child Food Allergies and Atopic Allergic Disease		

Maternal Diet during Pregnancy and Lactation	2020	DGAC (USA) (Donovan et al., 2020b)	Dietary patterns, food allergen (e.g. Cow milk, eggs, fish, soybean, wheat, nuts etc.)	Risk of Child Food Allergies and Atopic Allergic Diseases (e.g. Atopic dermatitis, allergic rhinitis, asthma)
Exclusive Human Milk and/ or Infant Formula Consumption	2020	DGAC (USA) (Dewey et al., 2020a)	Human milk and/or infant formula	Overweight and Obesity
Exclusive Human Milk and/or Infant Formula Consumption	2020	DGAC (USA) (Dewey et al., 2020b)	Human milk and/or infant formula	Nutrient Status (e.g. Iron, zinc, iodine, vitamin B12 status)
Iron from Supplements Consumed During Infancy and Toddlerhood	2020	DGAC (USA) (Dewey et al., 2020d)	Iron from supplements	Growth, Size, and Body Composition
Vitamin D from Supplements Consumed during Infancy and Toddlerhood	2020	DGAC (USA) (Dewey et al., 2020c)	Vitamin D from supplements / fortified foods	Bone Health (e.g biomarkers, bone mass rickets, fracture) up to age 18 years
Beverage Consumption	2020	DGAC (USA) (Mayer-Davis et al., 2020b)	Beverages (milk, juice, sugar-sweetened beverages, low and no-calorie beverages vs. water)	Growth, Size, Body Composition, and Risk of Overweight and Obesity
Beverage Consumption During Pregnancy	2020	DGAC (USA) (Mayer-Davis et al., 2020a)	Beverages (Milk, Tea, Coffee, Sugar-Sweetened/Low- or no-calorie sweetened beverages, water)	Birth weight
Alcohol Consumption	2020	DGAC (USA) (Mayer-Davis et al., 2020c)	Alcoholic beverages (type and drinking pattern)	Mortality
Added Sugars (update of 2015 DGAC review)	2020	DGAC (USA) (Mayer-Davis et al., 2020d)	Added sugars; sugar-sweetened beverages	Cardiovascular Disease, CVD mortality, CVD risk factors
Types of Dietary Fat	2020	DGAC (USA) (Snetselaar et al., 2020a)	Types of fatty acids, individual fatty acids (e.g., ALA, DHA), dietary cholesterol or food sources of types of fat (e.g. Olive oil for MUFA, butter for SFA)	Cardiovascular Disease outcomes, intermediate outcomes (blood lipids and blood pressure)

Seafood consumption during pregnancy and lactation	2020	DGAC (USA) (Snetselaar et al., 2020d)	Maternal seafood / fish intake (e.g., fish, salmon, tuna, trout, tilapia; shellfish: shrimp, crab, oysters)	Neurocognitive development (e.g., cognitive and language development; behavioral development; attention deficit disorder, autism spectrum disorder) In the child		
Seafood consumption during childhood and adolescence (up to 18 years of age)	2020	DGAC (USA) (Snetselaar et al., 2020c)	Seafood (e.g., fish, salmon, tuna, trout, tilapia; shellfish: shrimp, crab, oysters)	Neurocognitive development (e.g., Cognition, depression, dementia, psychomotor performance, behaviour disorders, autism spectrum disorder, mental health … Academic achievement)		
Seafood consumption during childhood and adolescence (up to 18 years of age)	2020	DGAC (USA) (Snetselaar et al., 2020b)	Seafood (e.g., salmon, tuna, trout, tilapia; shellfish: shrimp, crab, oysters)	Cardiovascular Disease (and blood lipids or blood pressure)		
Frequency of eating	2020	DGAC (USA) (Heymsfield et al., 2020a)	Eating frequency	Overweight and Obesity		
Frequency of eating	2020	DGAC (USA) (Heymsfield et al., 2020c)	Eating frequency	Cardiovascular Disease		
Frequency of eating	2020	DGAC (USA) (Heymsfield et al., 2020b)	Eating frequency	Type 2 Diabetes		
Dietary patterns	2015	DGAC (USA) (Boushey et al., 2020e)	Dietary patterns	Cancer	NEL Bias assessment tool	"Strong", "Moderate", "Limited", "Expert opinion only", "Not assignable"; based on 1) risk of bias, 2) consistency, 3) quantity, 4) impact, 5) generalizability
Dietary patterns	2015	DGAC (USA) (Dietary Guidelines Advisory Committee, 2015)	Dietary patterns	Congenital anomalies		
Dietary patterns	2015	DGAC (USA) (Dietary Guidelines Advisory Committee, 2015)	Dietary patterns	Neurological and psychological illness		
Dietary patterns	2015	DGAC (USA) (Dietary Guidelines Advisory Committee, 2015)	Dietary patterns	Bone health		
Dietary patterns and long-term food sustainability and related food security	2015	DGAC (USA) (Dietary Guidelines Advisory Committee, 2015)	Dietary patterns	Environmental impact		
Sodium intake in children	2015	DGAC (USA) (Dietary Guidelines Advisory Committee, 2015)	Dietary sodium	Blood pressure		

Sodium intake	2015	DGAC (USA) (Dietary Guidelines Advisory Committee, 2015)	Dietary sodium	Cardiovascular disease		
Added sugars	2015	DGAC (USA) (Dietary Guidelines Advisory Committee, 2015)	Added sugars & sugar-sweetened beverages	CVD, CVD mortality, hypertension, blood pressure, cholesterol, triglycerides		
Carbohydrates	2012	DGE (Germany) (Hauner et al., 2012)	Total carbohydrates, sugars, sugar-sweetened beverages, dietary fibre, whole-grain, glycaemic index / load	Obesity, type 2 diabetes, dyslipidaemia, hypertension, metabolic syndrome, coronary heart disease, cancer	WHO level of evidence (Ia-Ic, IIa-IIb) based on study design	WHO/WCRF (convincing, probable, possible, insufficient)
Fatty acids	2015	DGE (Germany) (Wolfram et al., 2015)	Dietary fats	Adiposity, type 2 diabetes, dyslipidaemia/ hyperlipidaemia, blood pressure, cardiovascular diseases, metabolic syndrome, cancer		
Dietary Reference Values for Sodium	2019	EFSA (EFSA, 2019b)	Sodium intake, as 24 hr sodium excretion (i.e., not self-reported)	Blood pressure, CVD, bone mineral density, osteoporotic fractures, sodium balance	OHAT/NTP Risk of bias tool (based on AHRQ, Cochrane, CLARITY etc.): selection, performance, attrition, detection and selective reporting bias	"Uncertainty analysis" based on consistency, precision, internal and external validity, etc.
Dietary References Values for Copper	2012	EFSA, review by ANSES (France) (Bost et al., 2012)	Copper	Copper status, bioavailability, cardiac arrythmia, cancer, arthritis, cognitive function, respiratory disease, cardiovascular mortality	EURRECA system (high, moderate, low or unclear), partly based on Cochrane	Consistency, strength, and quality of the studies (see Dhonukshe-Rutten et al. (2013) & EFSA, 2010 (principles) (EFSA, 2010))
Dietary Reference Values for Riboflavin	2014	EFSA, review by Pallas Health Research (Netherlands) (Buijssen et al., 2014)	Riboflavin	Riboflavin status, biomarkers; cancer; mortality; bone health, infant health etc		
Dietary Reference Values for Phosphorus, Sodium and Chloride	2013	EFSA, review by Pallas Health Research (Netherlands) (Eeuwijk et al., 2013)	Phosphorus, sodium, chloride	Status, adequacy, health outcomes including cancer, CVD, kidney disease, all-cause and CVD mortality		
Dietary Reference Values for Niacin, Biotin and Vitamin B6	2012	EFSA, review by Pallas Health Research (Netherlands) (Eeuwijk et al., 2012)	Niacin	Niacin / biotin / vitamin B6 status, adequacy, bioavailability, cancer, CVD, cognitive decline, infant health, all-cause mortality etc.		
Tolerable upper intake level for dietary sugars	2022	EFSA (2022)	Sugars (total / added / free), fructose, sources of sugars	Chronic metabolic diseases, pregnancy-related endpoints, and dental caries	OHAT/NTP risk of bias (RoB) tool	"Uncertainty analysis" based on consistency, precision, internal and external validity, etc.

Tolerable upper intake level for vitamin B6	2023	EFSA (2023a)	Vitamin B6	Absorption, distribution, metabolism and excretion. Peripheral neuropathy, developmental toxicity	OHAT/NTP risk of bias (RoB) tool	"Uncertainty analysis" based on consistency, precision, internal and external validity, etc.
Tolerable upper intake level for selenium	2023	EFSA (2023b)	Selenium	Absorption, distribution, metabolism and excretion. Clinical effects, potential biomarkers of effect, risk of chronic diseases and impaired neuropsychological development in humans	OHAT/NTP risk of bias (RoB) tool	"Uncertainty analysis" based on consistency, precision, internal and external validity, etc.
Tolerable upper intake level for folate	2023	Åkesson et al. (2023)	Folate / folic acid	Absorption, distribution, metabolism and excretion. Dose-response relationship with folate status. Neuropathy, cognitive function and dementia, cancer, other adverse effects	OHAT/NTP risk of bias (RoB) tool	"Uncertainty analysis" based on consistency, precision, internal and external validity, etc.
Tolerable upper intake level for manganese	In press	Halldorsson et al. (in press)	Manganese	Absorption, distribution, metabolism and excretion. Neurologic effects, other adverse effects.	OHAT/NTP risk of bias (RoB) tool	"Uncertainty analysis" based on consistency, precision, internal and external validity, etc.
Tolerable upper intake level for vitamin A	In press	Olsen et al. (in press)	Vitamin A	Absorption, distribution, metabolism and excretion. Teratogenicity. Hepatoxicity. Bone fractures / bone mineral density, other adverse effects.	OHAT/NTP risk of bias (RoB) tool	"Uncertainty analysis" based on consistency, precision, internal and external validity, etc.
Vegetable intake	2022	GBD (Stanaway et al., 2022)	Vegetables (including fresh, frozen, cooked, canned or dried), excluding starchy vegetables such as potatoes and corn	Mortality or incidence of: ischemic heart disease, stroke, type 2 diabetes and esophageal cancer	Own quality score (score 0, best to 5, worst) based on exposure assessment, outcome assessment and confounding	"Burden of Proof Risk Function" (BPRF) star rating (from 1 to 5): 1 = non-significant association, 2 =weak evidence, 3 = moderate evidence, 4 = strong evidence, 5 = very strong evidence
Red meat	2022	GBD (Lescinsky et al., 2022)	Unprocessed red meat (including beef, lamb and pork)	Mortality or incidence of: hemorrhagic stroke, type 2 diabetes, colorectal cancer, IHD and ischemic stroke; incidence of breast cancer	Own quality score (score 0, best to 5, worst) based on exposure assessment, outcome assessment and confounding	"Burden of Proof Risk Function" (BPRF) star rating (from 1 to 5): 1 = non-significant association, 2 =weak evidence, 3 = moderate evidence, 4 = strong evidence, 5 = very strong evidence
Protein intake	2022	Netherlands Health Council (Hengeveld et al., 2022)	Protein	Lean body mass, muscle strength, physical performance, bone health, blood pressure, serum glucose and insulin, serum lipids, kidney function, cognition	Cochrane RoB 2.0	"Convincing beneficial", "likely beneficial", "possible beneficial", "ambiguous", "likely no effect", "too few studies"
Milk and dairy consumption during pregnancy	2012	NNR2012: Brantsæter et al. (2012)	Milk and dairy products	Birth weight, fetal growth, large for gestational age, small for gestational age	NNR quality assessment tool (rated A, B or C)	WCRF (convincing, probable, limited - suggestive, limited - no conclusion)
Dietary iron	2013	NNR2012: Domellof et al. (2013)	Iron intake at different life stages	Requirements for adequate growth, development and maintenance of health (anaemia, cognitive / behavioural function, cancer, cardiovascular disease)		

Dietary macronutrients	2012	NNR2012 (Fogelholm et al., 2012)	Dietary macronutrient consumption	Primary prevention of long-term weight/WC/body fat changes, or changes after weight loss	
Weight loss before conception	2012	NNR2012 (Forsum et al., 2013)	Weight loss before conception in women with overweight or obesity	Birth outcomes, childhood obesity / BMI obstetric risk, preeclampsia, postpartum weight retention, gestational diabetes mellitus, hypertension, postpartum depression, lactation, infant growth	
Iodine	2012	NNR2012 (Gunnarsdottir & Dahl, 2012)	Iodine status	Requirements for adequate growth, development and maintenance of health (pregnancy, childhood development, thyroid function, metabolism	WCRF
Breastfeeding, introduction of other foods and effects on health	2013	NNR2012: Hörnell et al. (2013b)	Breastfeeding and introduction of other foods	Growth in infancy, overweight and obesity, atopic disease, asthma, allergy, health and disease outcomes including infectious disease, cognitive and neurological development, CVD, cancer, diabetes, blood pressure, glucose tolerance, insulin resistance)	
Protein intake from 0 to 18 years of age	2013	NNR2012: Hörnell et al. (2013a)	Protein intake in infancy and childhood	Functional/clinical outcomes, risk factors (including serum lipids, glucose and insulin, blood pressure, body weight, bone health)	
Vitamin D	2013	NNR2012: Lamberg-Allardt et al. (2013)	Vitamin D	Dietary reference values, vitamin D status, requirements for adequate growth, development and maintenance of health, upper limits, pregnancy outcomes, bone health, cancer, diabetes, obesity, all-cause mortality, CVD, infections	
Protein intake in elderly populations	2014	NNR2012 (Pedersen & Cederholm, 2014)	Protein intake in elderly populations	Dietary requirements (nitrogen balance), muscle mass, bone health, physical training, potential risks	
Protein intake in adults	2013	NNR2012: (Pedersen et al., 2013)	Protein intake, protein sources	Dietary requirements, markers of functional or clinical outcomes (including serum lipids, glucose and insulin, blood pressure), pregnancy or birth outcomes, CVD, body weight, cancer, diabetes, fractures, renal function, physical training, muscular strength, mortality	
Dietary fat	2014	NNR2012: Schwab et al. (2014)	Types of dietary fat	Body weight, diabetes, CVD, cancer, all-cause mortality, risk factors (including serum lipids, glucose and insulin, blood pressure, inflammation)	

Sugar consumption	2012	NNR2012 (Sonestedt et al., 2012)	Sugar intake; sugar-sweetened beverages	Type 2 Diabetes, CVD, metabolic risk factors (including glucose tolerance, insulin sensitivity, dyslipidaemia, blood pressure, uric acid, inflammation), all-cause mortality		
Calcium	2013	NNR2012 (Uusi-Rasi et al., 2013)	Calcium	Calcium requirements, upper intake level, adequate growth, development and maintenance of health; bone health, muscle strength, cancer, autoimmune diseases, diabetes, obesity / weight control, all-cause mortality, CVD		
Health effects associated with foods characteristic of the Nordic diet	2013	NNR2012 (Åkesson et al., 2013)	Potatoes, berries, whole grains, dairy products, red meat / processed meat	CVD incidence and mortality, Type 2 diabetes, inflammatory factors, colorectal, prostate and breast cancer, bone health, iron status	NNR quality assessment tool	WCRF
Carbohydrates	2015	SACN (UK) (2015)	Total carbohydrates, sugars, sugar-sweetened food / beverages, starch, starchy foods, dietary fibre, glycemic index/load	Obesity, cardio-metabolic health, energy intake, colorectal health (cancer, IBS, constipation), oral health	Cochrane RoB; observational studies: no formal grading, but markers of study quality = cohort size, attrition, follow-up time, sampling method and response rate, participant characteristics, dietary intake assessment	"Adequate", "moderate", "limited" (own grading system based on study quality, study size, methodological considerations, and specific criteria to upgrade, e.g., dose-response relationship)
Fish	2022	VKM (Norway), Scientific Committee for Food and Environment (2022)	Fish/fish products, nutrients and contaminants in fish	CVD-outcomes, mortality, neurodevelopmental outcomes, birth outcomes, type 2 diabetes, bone health, dental enamel changes, overweight and obesity, immunological diseases, male fertility	NNR quality assessment tool (rated A, B or C), AMSTAR version 1	WCRF
Alcohol	2018	WCRF/AICR (2018b)	Alcoholic drinks (beer, wine, spirits, fermented milk, mead, cider)	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, skin)	Cochrane RoB / NOS	WCRF
Body fatness & weight gain	2018	WCRF/AICR (2018a)	Body fatness: BMI, waist circumference, W-H ratio; adult weight gain	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)		
Energy balance	2018	WCRF/AICR (2018d)	Dietary patterns, foods, macronutrients, energy density, lactation, physical activity	Weight gain, overweight and obesity	From NICE (2014) report (low, moderate, high quality)	

Height and birthweight	2018	(WCRF/AICR, 2018c)	Attained height, growth, birthweight	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)	Cochrane RoB / NOS
Lactation	2018	WCRF/AICR (2018f)	Lactation	Cancer (including of breast, ovary, etc.) in the mother who is breastfeeding	
Meat, fish, dairy	2018	WCRF/AICR (2018g)	Meat, fish and dairy products, haem iron, diets high in calcium	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)	
Non-alcoholic drinks	2018	WCRF/AICR (2018h)	Non-alcoholic drinks: water / arsenic in drinking water, coffee, tea, mate	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)	
Other	2018	WCRF/AICR (2018i)	Dietary patterns, macronutrients, micronutrients in foods or supplements, glycemic load	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)	
Physical activity	2018	(WCRF/AICR, 2018b)	Physical activity, types of physical activity, intensity.	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)	
Preservation and processing	2018	WCRF/AICR (2018a)	Salting, curing, fermentation, smoking; processed meat and fish	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)	
Whole grains, fruit, vegetables	2018	WCRF/AICR (2018e)	Whole grains, pulses (legumes), vegetables, fruits, dietary fibre, aflatoxins, beta-carotene, carotenoids, vitamin C, isoflavones	Cancer (including of mouth, pharynx and larynx, oesophagus, liver, colorectal, breast, kidney, stomach, lung, pancreas, gallbladder, ovary, prostate etc.)	
Sugars	2015	WHO (2015)	Total, added or free sugars, sugar-sweetened beverages, fruit juice	Body weight, body fatness, dental caries	Cochrane RoB / cohort studies: own
Sodium	2012	WHO (2012)	Sodium intake/reduced sodium intake, sodium excretion	Cardiovascular diseases, all-cause mortality, blood pressure, renal function, blood lipids, potential adverse effects	Cochrane RoB
Potassium	2012	WHO (Aburto et al., 2013)	Potassium intake, 24 h urinary potassium excretion	Blood pressure, cardiovascular diseases, all-cause mortality, cholesterol, noradrenaline, creatinine, side effects	Cochrane RoB

Trans-fats	2016	WHO (de Souza et al., 2015); Brouwer (2016); Reynolds et al. (2022)	Trans fatty acids	All-cause mortality, cardiovascular disease, type 2 diabetes; blood lipids	Cochrane RoB (for TFA and blood lipids) / NOS
Saturated fats	2016	WHO (Hooper et al., 2015; Hooper et al., 2020; Mensink, 2016; Reynolds et al., 2022)	Saturated fat reduction	Cardiovascular disease, mortality, blood lipids, other risk factors, growth (children)	Cochrane RoB, other potential sources of bias, e.g. compliance
Carbohydrate quality	2019	WHO (Reynolds et al., 2019)	Markers of carbohydrate quality, i.e. dietary fibre, glycaemic index/ load, whole grains	All-cause mortality, coronary heart disease, stroke, type 2 diabetes, colorectal cancer, adiposity-related cancers, adiposity, fasting glucose/insulin/insulin sensitivity/HbA1c, blood lipids, blood pressure	Cochrane RoB / NOS / ROBIS
Omega-3, Omega- 6 and polyunsaturated fat	2020	WHO (Brainard et al., 2020)	Higher vs lower omega-3, omega-6, or polyunsaturated fats	New neurocognitive illness, newly impaired cognition, and/or continuous measures of cognition	Cochrane RoB
Non-sugar sweeteners	2022	WHO (Rios-Leyvraz & Montez, 2022)	Non-sugar sweeteners	Adiposity, type 2 diabetes, all-cause mortality, CVD, cancer, energy intake, sugars intake, pregnancy	Cochrane RoB / NOS / ROBINS-I

2. Qualified SRs by nutrient and food groups

Table 1. Macronutrients

Nutrient	Reference	Title	Published/ commissioned by
Fluid and water balance			
Energy	WCRF/AICR (2018a)	Body fatness and weight gain and the risk of cancer	WCRF/AICR
	WCRF/AICR (2018d)	Diet, nutrition and physical activity: Energy balance and body fatness	WCRF/AICR
Fat and fatty acids	Fogelholm et al. (2012)	Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review.	NNR2012
	Schwab et al. (2014)	Effect of the amount and type of dietary fat on cardiometabolic risk factors and risk of developing type 2 diabetes, cardiovascular diseases, and cancer: a systematic review	NNR2012
	Wolfram et al. (2015)	Evidence-Based Guideline of the German Nutrition Society: Fat Intake and Prevention of Selected Nutrition-Related Diseases	DGE
	de Souza et al. (2015)	Intake of saturated and trans unsaturated fatty acids and risk of all cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies	WHO
	Brouwer (2016)	Effects of trans-fatty acid intake on blood lipids and lipoproteins: a systematic review and meta-regression analysis	WHO
	Mensink (2016)	Effects of saturated fatty acids on serum lipids and lipoproteins: a systematic review and regression analysis	WHO
	Balk et al. (2016)	Omega-3 Fatty Acids and Cardiovascular Disease: An Updated Systematic Review	AHRQ
	Newberry et al. (2016)	Omega-3 Fatty Acids and Maternal and Child Health: An Updated Systematic Review	AHRQ
	Te Morenga and Montez (2017)	Health effects of saturated and trans-fatty acid intake in children and adolescents: Systematic review and meta-analysis	WHO
	Hooper et al. (2020)	Reduction in saturated fat intake for cardiovascular disease	WHO
	Brainard et al. (2020)	Omega-3, Omega-6, and Polyunsaturated Fat for Cognition: Systematic Review and Meta-analysis of Randomized Trials	WHO
	Snetselaar et al. (2020a)	Types of Dietary Fat and Cardiovascular Disease: A Systematic Review	DGAC2020
	Donovan et al. (2020a)	Omega-3 fatty acids from Supplements Consumed before and during Pregnancy and Lactation and Developmental Milestones, Including Neurocognitive Development, in the Child: A Systematic Review	DGAC2020
	Bärebring et al. (2022)	Supplementation with long chain n-3 fatty acids during pregnancy, lactation, or infancy in relation to risk of asthma and atopic disease during childhood: a systematic review and meta-analysis of randomized controlled clinical trials	NNR2023

	Nwaru et al. (2022)	Quality of dietary fat and risk of Alzheimer's disease and dementia in adults aged >/=50 years: a systematic review	NNR2023
	Reynolds et al. (2022)	Saturated fat and trans-fat intakes and their replacement with other macronutrients: a systematic review and meta-analysis of prospective observational studies	WHO
Carbohydrates	Hauner et al. (2012)	Evidence-based guideline of the German Nutrition Society: carbohydrate intake and prevention of nutrition-related diseases	DGE
	Sonestedt et al. (2012)	Does high sugar consumption exacerbate cardiometabolic risk factors and increase the risk of type 2 diabetes and cardiovascular disease?	NNR2012
	Fogelholm et al. (2012)	Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review	NNR2012
	WHO (2015)	Guideline: Sugars intake for adults and children	WHO
	SACN (2015)	Carbohydrates and Health	SACN
	Reynolds et al. (2019)	Carbohydrate quality and human health: a series of systematic reviews and meta-analyses	WHO
	Mayer-Davis et al. (2020e)	Added Sugars Consumption and Risk of Cardiovascular Disease: A Systematic Review	DGAC2020
Dietary fibre	Fogelholm et al. (2012)	Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review	NNR2012
	Hauner et al. (2012)	Evidence-based guideline of the German Nutrition Society: carbohydrate intake and prevention of nutrition-related diseases	DGE
	SACN (2015)	Carbohydrates and Health	SACN
	Reynolds et al. (2019)	Carbohydrate quality and human health: a series of systematic reviews and meta-analyses	WHO
	Dierkes et al. (2023)	Dietary fiber and growth, iron status and bowel function in children 0–5 years old: a systematic review	NNR2023
Protein	Fogelholm et al. (2012)	Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review	NNR2012
	Hörnell et al. (2013a)	Protein intake from 0 to 18 years of age and its relation to health: a systematic literature review for the 5th Nordic Nutrition Recommendations	NNR2012
	Pedersen et al. (2013)	Health effects of protein intake in healthy adults: a systematic literature review	NNR2012
	Pedersen & Cederholm (2014)	Health effects of protein intake in healthy elderly populations: a systematic literature review	NNR2012
	Hengeveld et al. (2022)	Health Effects of Increasing Protein Intake Above the Current Population Reference Intake in Older Adults: A Systematic Review of the Health Council of the Netherlands	Health Council of the Netherlands
	Arnesen et al. (2022)	Protein intake in children and growth and risk of overweight or obesity: A systematic review and meta-analysis	NNR2023
	Lamberg-Allardt et al. (2023b)	Animal versus plant-based protein and risk of cardiovascular disease and type 2 diabetes: A systematic review of randomized controlled trials and prospective cohort studies	NNR2023

Abbreviations: AHRQ: Agency for Healthcare Research and Quality; DGAC2020: 2020 Dietary Guidelines Advisory Committee; DGE: Deutsche Geschellschaft für Ernährung (German Nutrition Society); EFSA: European Food Safety Authority; NNR: Nordic Nutrition Recommendations; WCRF/AICR: World Cancer Research Fund/American Institute of Cancer Research; WHO: World Health Organization.

Table 2. Micronutrients

Nutrient	Reference	Title	Published/ commissioned by
Vitamin A	Olsen et al. (in press)	Preparatory work for the update of the tolerable upper intake levels for vitamin A	EFSA
Vitamin D	Lamberg-Allardt et al. (2013)	Vitamin D - a systematic literature review for the 5th edition of the Nordic Nutrition Recommendations	NNR2012
	Newberry et al. (2014)	Vitamin D and Calcium: A Systematic Review of Health Outcomes (Update)	AHRQ
	Dewey et al. (2020c)	Vitamin D from Supplements Consumed during Infancy and Toddlerhood and Bone Health: A Systematic Review	DGAC2020
	Lamberg-Allardt et al. (2023a)	Preparatory work for the update of the tolerable upper intake levels for vitamin D	EFSA
Riboflavin	Buijssen et al. (2014)	Literature search and review related to specific preparatory work in the establishment of Dietary Reference Values for Riboflavin	EFSA
Niacin	Eeuwijk et al. (2012)	Literature search and review related to specific preparatory work in the establishment of Dietary Reference Values for Niacin, Biotin and Vitamin B6	EFSA
Vitamin B6	Eeuwijk et al. (2012)	Literature search and review related to specific preparatory work in the establishment of Dietary Reference Values for Niacin, Biotin and Vitamin B6	EFSA
	EFSA (2023a)	Scientific opinion on the tolerable upper intake level for vitamin B6	EFSA
Folate	Donovan et al. (2020e)	Folic Acid from Fortified Foods and/or Supplements during Pregnancy and Lactation and Health Outcomes: A Systematic Review	DGAC 2020
	Åkesson et al. (2023)	Preparatory work for the update of the tolerable upper intake levels for folic acid/folate	EFSA
Vitamin B12	Bärebring et al. (2023)	Intake of vitamin B12 in relation to vitamin B12 status in groups susceptible to deficiency: A systematic review	NNR2023
Biotin	Eeuwijk et al. (2012)	Literature search and review related to specific preparatory work in the establishment of Dietary Reference Values for Niacin, Biotin and Vitamin B6	EFSA
Calcium	Uusi-Rasi et al. (2013)	Calcium intake in health maintenance - a systematic review	NNR2012
	Newberry et al. (2014)	Vitamin D and Calcium: A Systematic Review of Health Outcomes (Update)	AHRQ
Phos-phorus	Eeuwijk et al. (2013)	Literature search and review related to specific preparatory work in the establishment of Dietary Reference Values for Phosphorus, Sodium and Chloride	EFSA
Sodium	WHO (2012)	Guideline: Sodium intake for adults and children	WHO
	Eeuwijk et al. (2013)	Literature search and review related to specific preparatory work in the establishment of Dietary Reference Values for Phosphorus, Sodium and Chloride	EFSA
	Neale and Clark (2017)	Australian and New Zealand Nutrient Reference Values for Sodium Systematic Literature Review	Australian Department of Health and New Zealand Ministry of Health
	Newberry et al. (2018)	Sodium and Potassium Intake: Effects on Chronic Disease Outcomes and Risks	AHRQ

	EFSA (2019b)	Dietary reference values for sodium	EFSA
	NASEM (2019)	Dietary Reference Intakes for Sodium and Potassium	NASEM
Potassium	Aburto et al. (2013)	Effect of increased potassium intake on cardiovascular risk factors and disease: systematic review and meta-analyses	WHO
	Newberry et al. (2018)	Sodium and Potassium Intake: Effects on Chronic Disease Outcomes and Risks	AHRQ
	NASEM (2019)	Dietary Reference Intakes for Sodium and Potassium	NASEM
Iron	Domellöf et al. (2013)	Health effects of different dietary iron intakes: a systematic literature review for the 5th Nordic Nutrition Recommendations	NNR2012
	Dewey et al. (2020d)	Iron from Supplements Consumed During Infancy and Toddlerhood and Growth, Size, and Body Composition: A Systematic Review	DGAC2020
Iodine	Gunnarsdottir and Dahl (2012)	Iodine intake in human nutrition: a systematic literature review	NNR 2012
Selenium	EFSA (2023b)	Scientific opinion on the tolerable upper intake level for selenium	EFSA
Copper	Bost et al. (2012)	Literature search and review related to specific preparatory work in the establishment of Dietary References Values for Copper	EFSA
Manganese	Halldorsson et al. (in press)	Preparatory work for the update of the tolerable upper intake levels for manganese	EFSA
Phyto-chemicals and anti-oxidants	WCRF/AICR (2018c)	Diet, nutrition, physical activity, and lung cancer	WCRF/AICR
	O'Connor et al. (2022)	Vitamin, Mineral, and Multivitamin Supplementation for the Primary Prevention of Cardiovascular Disease and Cancer	AHRQ

Abbreviations: AHRQ: Agency for Healthcare Research and Quality; DGAC2020: 2020 Dietary Guidelines Advisory Committee; DGE: Deutsche Geschellschaft für Ernährung (German Nutrition Society); EFSA: European Food Safety Authority; GBD: Global Burden of Disease; NASEM: National Academies of Science, Engineering, and Medicine; NNR: Nordic Nutrition Recommendations; WCRF/AICR: World Cancer Research Fund/American Institute of Cancer Research; WHO: World Health Organization.

Table 3. Food groups and diet patterns

Food group	Qualified SR	Title	Published/ commissioned by
Breast-feeding	Victora et al. (2016)	Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect	WHO
	WCRF/AICR (2018d)	Energy balance and body fatness	WCRF/AICR
	Dewey et al. (2020b)	The Duration, Frequency, and Volume of Exclusive Human Milk and/or Infant Formula Consumption and Nutrient Status: A Systematic Review	DGAC2020
	Dewey et al. (2020a)	The Duration, Frequency, and Volume of Exclusive Human Milk and/or Infant Formula Consumption and Overweight and Obesity: A Systematic Review	DGAC2020
	Güngör et al. (2019b)	Infant milk-feeding practices and food allergies, allergic rhinitis, atopic dermatitis, and asthma throughout the life span: a systematic review	DGAC2020
	Güngör et al. (2019e)	Infant milk-feeding practices and diagnosed celiac disease and inflammatory bowel disease in offspring: a systematic review	DGAC2020
	Güngör et al. (2019a)	Infant milk-feeding practices and childhood leukemia: a systematic review	DGAC2020
	Güngör et al. (2019c)	Infant milk-feeding practices and cardiovascular disease outcomes in offspring: a systematic review	DGAC2020
	Güngör et al. (2019d)	Infant milk-feeding practices and diabetes outcomes in offspring: a systematic review	DGAC2020
Comple-mentary feeding	Obbagy et al. (2019a)	Complementary feeding and micronutrient status: a systematic review	DGAC2020
	Obbagy et al. (2019c)	Complementary feeding and bone health: a systematic review	DGAC2020
	Obery et al. (2019b)	Complementary feeding and food allergy, atopic dermatitis/eczema, asthma, and allergic rhinitis: a systematic review	DGAC2020
	EFSA (2019a)	Appropriate age range for introduction of complementary feeding into an infant's diet	EFSA
	de Silva et al. (2020)	Preventing food allergy in infancy and childhood: Systematic review of randomised controlled trials.	EAACI
	English et al. (2019b)	Timing of introduction of complementary foods and beverages and growth, size, and body composition: a systematic review	DGAC2020
	English et al. (2019c)	Types and amounts of complementary foods and beverages consumed and growth, size, and body composition: a systematic review	DGAC2020
	English et al. (2019a)	Complementary feeding and developmental milestones: a systematic review	DGAC2020
	Spill et al. (2019)	Repeated exposure to food and food acceptability in infants and toddlers: a systematic review	DGAC 2020
	Arnesen et al. (2022)	Protein intake in children and growth and risk of overweight or obesity: A systematic review and meta-analysis	NNR2023
	Padhani et al. (2023)	Optimal timing of introduction of complementary feeding: a systematic review and meta-analysis.	WHO

Beverages	Sonestedt et al. (2012)	Does high sugar consumption exacerbate cardiometabolic risk factors and increase the risk of type 2 diabetes and cardiovascular disease?	NNR2012
	WHO (2015)	Guideline: Sugars intake for adults and children	WHO
	SACN (2015)	Carbohydrates and Health	SACN
	WCRF/AICR (2018h)	Non-alcoholic drinks and the risk of cancer	WCRF/AICR
	Mayer-Davis et al. (2020e)	Added Sugars Consumption and Risk of Cardiovascular Disease: A Systematic Review	DGAC2020
	Mayer-Davis et al. (2020b)	Beverage Consumption and Growth, Size, Body Composition, and Risk of Overweight and Obesity: A Systematic Review	
	EFSA (2022)	Tolerable upper intake level for dietary sugars	EFSA
	Rios-Leyvraz & Montez (2022)	Health effects of the use of non-sugar sweeteners: a systematic review and meta-analysis	WHO
	Rousham et al. (2022)	Unhealthy Food and Beverage Consumption in Children and Risk of Overweight and Obesity: A Systematic Review and Meta-Analysis	WHO
Cereals (grains)	Reynolds et al. (2019)	Carbohydrate quality and human health: a series of systematic reviews and meta-analyses	WHO
	WCRF/AICR (2018e)	Wholegrains, vegetables and fruit and the risk of cancer	WCRF/AICR
Vegetables, fruits and berries	Fogelholm (2012)	Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review	NNR2012
	WCRF/AICR 2018 (2018e)	Wholegrains, vegetables and fruit and the risk of cancer	WCRF/AICR
	Stanaway et al. (2022)	Health effects associated with vegetable consumption: a Burden of Proof study	GBD
Potatoes	Åkesson et al. (2013)	Health effects associated with foods characteristic of the Nordic diet: a systematic literature review	NNR2012
	SACN (2015)	Carbohydrates and Health	SACN
Fruit juice	SACN (2015)	Carbohydrates and Health	SACN
	WCRF/AICR (2018d)	Energy balance and body fatness	WCRF/AICR
	Mayer-Davis et al. (2020b)	Beverage consumption	DGAC2020
Pulses (legumes)	SACN (2015)	Carbohydrates and Health	SACN
	WCRF (2018e)	Wholegrains, vegetables and fruit and the risk of cancer	WCRF/AICR
	Lamberg-Allardt et al. (2023b)	Animal versus plant-based protein and risk of cardiovascular disease and type 2 diabetes: A systematic review of randomized controlled trials and prospective cohort studies	NNR2023
	Thorísdottír et al. (2023)	Legume consumption in adults and risk of cardiovascular disease or type 2 diabetes: A systematic review and meta-analysis	NNR2023
Nuts and seeds	Arnesen et al.(2023)	Nuts and seeds consumption and risk of cardiovascular disease, type 2 diabetes and their risk factors: a systematic review and meta-analysis	NNR2023

Fish and seafod	WCRF/AICR (2018g)	Meat, fish, and dairy products and the risk of cancer	WCRF/AICR
	Snetselaar et al. (2020d)	Seafood Consumption during Pregnancy and Lactation and Neurocognitive Development in the Child: A Systematic Review	DGAC2020
	Snetselaar et al. (2020c)	Seafood Consumption during Childhood and Adolescence and Neurocognitive Development: A Systematic Review	DGAC2020
	Norwegian Scientific Committee for Food and Environment (2022)	Benefit and risk assessment of fish in the Norwegian diet	Norwegian Scientific Committee for Food and Environment
Red meat	WCRF/AICR (2018g)	Meat, fish, and dairy products and the risk of cancer	WCRF/AICR
	Lescinsky et al. (2022)	Health effects associated with consumption of unprocessed red meat: a Burden of Proof study	GBD
White meat	WCRF/AICR (2018g)	Meat, fish, and dairy products and the risk of cancer	WCRF/AICR
	Ramel et al. (in press)	White meat consumption and risk of cardiovascular disease and type 2 diabetes: a systematic review and meta-analysis	NNR2023
Milk and dairy products	Åkesson et al. (2013)	Health effects associated with foods characteristic of the Nordic diet: a systematic literature review	NNR2012
	WCRF/AICR (2018g)	Meat, fish, and dairy products and the risk of cancer	WCRF/AICR
	Lamberg-Allardt et al. (2023b)	Animal versus plant-based protein and risk of cardiovascular disease and type 2 diabetes: A systematic review of randomized controlled trials and prospective cohort studies	NNR2023
Sweets	EFSA (2022)	Tolerable upper intake level for dietary sugars	EFSA
	Mayer-Davis et al. (2020e)	Added Sugars Consumption and Risk of Cardiovascular Disease: A Systematic Review	DGAC2020
	WHO (2015)	Guideline: Sugars intake for adults and children	WHO
	Rousham et al. (2022)	Unhealthy Food and Beverage Consumption in Children and Risk of Overweight and Obesity: A Systematic Review and Meta-Analysis	WHO
Alcohol	WCRF/AICR, 2018 (2018b)	Alcoholic drinks and the risk of cancer	WCRF/AICR
	Mayer-Davis et al. (2020c)	Alcohol Consumption and All-Cause Mortality: A Systematic Review	DGAC2020
	Canadian Centre on Substance Use and Addiction (2023)	Canada's Guidance on Alcohol and Health: Final Report	Health Canada
	2020 Dietary Guidelines Advisory Committee (2020)	Dietary Patterns and Risk of Cardiovascular Disease: A Systematic Review	DGAC2020
Dietary patterns	Boushey et al. (2020d)	Dietary Patterns and Risk of Type 2 Diabetes: A Systematic Review	DGAC2020
	Boushey et al. (2020b)	Dietary Patterns and Growth, Size, Body Composition, and/or Risk of Overweight or Obesity: A Systematic Review	DGAC2020
	Boushey et al. (2020a)	Dietary Patterns and All-Cause Mortality: A Systematic Review.	DGAC2020
	Boushey et al. (2020c)	Dietary Patterns and Sarcopenia: A Systematic Review	DGAC2020

	Boushey et al. (2020e)	Dietary Patterns and Breast, Colorectal, Lung, and Prostate Cancer: A Systematic Review	DGAC2020
	Boushey et al. (2020f)	Dietary Patterns and Bone Health: A Systematic Review	DGAC2020
	Boushey et al. (2020g)	Dietary Patterns and Neurocognitive Health: A Systematic Review.	DGAC2020
	Heymsfield et al. (2020c)	Frequency of Eating and Cardiovascular Disease: A Systematic Review	DGAC2020
Meal patterns	Heymsfield et al. (2020a)	Frequency of Eating and Growth, Size, Body Composition, and Risk of Overweight and Obesity: A Systematic Review	DGAC2020
	Heymsfield et al. (2020b)	Frequency of Eating and Type 2 Diabetes: A Systematic Review	DGAC2020

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Appendix 3. NNR2023 modified AMSTAR 2

As explained in the background paper on the AMSTAR 2 tool (Shea et al., 2017), reviewers of systematic reviews should agree on how AMSTAR 2 should be used. It also emphasizes that the "critical" domains are suggestions, and that reviewers add or substitute other critical domains. Further, their criteria for overall rating of reviews are "advisory". These aspects are often overlooked.

To harmonize the quality appraisal, we have created a modified version of AMSTAR 2 that conforms better to the research questions for NNR2023, instructions for scoping reviews, as well as the "Handbook" for de novo systematic reviews (Arnesen et al., 2020). We have also tried to make it more focussed on sources of bias in the review methodology.

It is emphasized that this tool also applies to systematic reviews including only observational studies. Of major changes, we have removed question 3, "Did the review authors explain their selection of the study designs for inclusion in the review?", while question 12 and 13 have been combined into one question (question 11 in this version).

For the list of "critical" domains, we have changed question 7 (now 6), "Did the review authors provide a list of excluded studies and justify the exclusions?" to a non-critical domain, as it does not clearly address the internal validity of the review, and as it may have been subject to the journals' space limitations. The Cochrane handbook also states that "The list of excluded studies should be as brief as possible". We do still acknowledge that it is good practice to report excluded studies with justifications (and in line with the NNR 2022 "Handbook"), and have therefore not removed the item itself.

Finally, we have developed an "algorithm" for making the overall rating:

	Critical domains	Non-critical domains
High confidence	All YES, ***and***	0-2 NO
Moderate confidence	All YES, ***and***	3 or more NO
Low confidence	1 NO, ***and***	0-2 NO
Critically low confidence	1 NO, ***and***	3 or more NO
Critically low confidence	2 or more NO	

Thus, for “high” or “moderate” ratings, all critical domains must be fulfilled. If there are 2 or more critical domains lacking, it will receive a “critically low” rating regardless of the number of non-critical domains fulfilled.

The modified AMSTAR 2 form is presented below:

Download form from online publication, Appendix 3: https://pub.norden.org/nord2023-003/appendix

References for Appendix 3

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Appendix 4. Body size and energy requirement estimations

Reference weights

To determine reference weights for adults (Table 1), weights were calculated based on heights of recent population-based surveys of the Nordic and Baltic countries and scaled to a BMI of 23 kg/m^2
.

For infants and children up to 6 years of age, data are measured body weights and heights from published growth curves from Denmark (2014), Estonia (2013), Finland (2011), Norway (2013), and Sweden (2002) (Table 2).

Weights for 6–17-year-olds were calculated from measured heights from growth curves from Denmark (2014), Estonia (2013), Finland (2011), Norway (2013), and Sweden (2002), and BMI according to WHO's reference percentiles (2007).

Table 1 Reference body weights and heights, adults

Age	Body weight (kg)		Height (cm)	
	F	M	F	M
18–24 y	64.2	75.2	167	181
25–50 y	64.1	74.8	167	180
51–70 y	62.5	73.0	165	178
>70 y	60.6	70.6	162	175
Pregnant	76.4		167	
Lactating	62.4		167	

Table 2 Weight and height in children

A) Girls

Age (years)	Height (cm)	Weight (kg)	BMI 50th percentiles
0	50.3	3.5	
1	75.3	9.7	
2	87.2	12.4	
3	95.7	14.6	
4	103.5	16.8	
5	110.6	19.0	15.2
6	118.7	21.6	15.3
7	124.7	24.0	15.4
8	130.5	26.7	15.7
9	136.1	29.8	16.1
10	142.0	33.5	16.6
11	148.1	37.7	17.2
12	154.4	42.9	18.0
13	159.8	48.0	18.8
14	163.4	52.3	19.6
15	165.4	55.3	20.2
16	166.7	57.5	20.7
17	167.4	58.8	21.0

B) Boys

Age (years)	Height (cm)	Weight (kg)	BMI 50th percentiles
0	50.9	3.6	
1	77.1	10.4	
2	88.6	13.2	
3	96.9	15.2	
4	104.6	17.4	
5	111.5	19.3	15.3
6	119.7	21.9	15.3
7	125.9	24.6	15.5
8	131.6	27.2	15.7
9	137.1	30.1	16.0
10	142.5	33.3	16.4
11	147.8	36.9	16.9
12	153.7	41.4	17.5
13	160.7	47.0	18.2
14	167.3	53.2	19.0
15	173.3	59.4	19.8
16	177.0	64.2	20.5
17	179.3	67.8	21.1

Calculation of energy requirements

Infants. As described by Cloetens and Ellegård (2023), the estimated daily energy requirement (per kg body weight) for infants was based upon the approach of FAO/WHO/UNU (Table 3).

Table 3 Estimated average daily energy requirements (per kg body weight) for infants 1–12 months (adapted from Cloetens & Ellegård, 2023).

Age (months)	Average daily energy requirements kJ/kg body weight	
	Boys	Girls
1	486	469
3	411	404
6	339	342
12	337	333

Children >1 y and adults. To calculate resting energy expenditure (REE) for children, adolescents and adults, we used the predictive equations by Henry (2005) (also called Oxford equations), shown in Table 4, as described by Cloetens & Ellegård (2023). The estimated REE is shown in Table 5.

Table 4. Equations for resting energy expenditure (BEE), adapted from Cloetens & Ellergård (2023).

Age (Years)	BEE
Girls <3 3–10 11–18	 0.127 W + 2.94 H – 1.20 0.0666 W + 0.878 H + 1.46 0.0393 W + 1.04 H + 1.93
Women 19–30 31–60 61–70 >70	 0.0433 W + 2.57 H – 1.180 0.0342W + 2.10 H – 0.0486 0.0356 W + 1.76 H + 0.0448 0.0356 W + 1.76 H + 0.0448
Boys <3 3–10 11–18	 0.118 W + 3.59 H – 1.55 0.0632 W + 1.31 H +1.28 0.0651 W + 1.11 H + 1.25
Men 19–30 31–60 61–70 >70	 0.0600 W + 1.31 H + 0.473 0.0476 W + 2.26 H – 0.574 0.0478 W 0+ 2.26 H – 1.070 0.0478 W 0+ 2.26 H – 1.070

As can be seen in Table 4, the equations by Henry (2005) were originally developed (and used in NNR2012) for the age groups 0–3 y, 3–10 y, 10–18 y, 18–30 y, 30–60 and >60 y, which is different than the age bands used in NNR2023.

Therefore, the Henry equations originally for children aged <3 y were used for the group 1–3 y in NNR2023, 3–10 y were used for 4–6 y and 7–10 y, and 11–18 y were used for age groups 11–14 y and 15–17 y (Table 5). For adults, we used the equation originally for 19–30-year-olds for the group 18–24 y, 31–60 y for the group 25–50 y, and 61 y for 51–70 y and >70 y (Table 5).

Note that Cloetens & Ellegård (2023) recommend in their review that for people above 75 y, 0.5–1.0 kg should be subtracted from the average weights for every 5 years above the age of 75 y.

For pregnant women (50 years), we used an average of the REE predicted for adolescents 16–18 y, adults aged 18–24, and 25–50 y. We did not add extra energy need during pregnancy beyond the assumed weight gain (14 kg).

For lactating women, we added 2.0 MJ to the REE predicted for adolescents and adults aged 16–50 y, assuming a need for about 2.7 MJ/d for exclusive breastfeeding for the first 6–8 months and on average 0.72 MJ/d mobilized from fat stores (see Cloetens & Ellegård, 2023)

Table 5. Estimated BEE per life-stage group used in NNR2023

Life stage	Reference weight (kg)	Reference height (m)	BEE equation from Henry (2005)	BEE (MJ/d)
CHILDREN				
1-3 y	13.6	0.92	Girls: 0.127 W + 2.94 H – 1.20 Boys: 0.118 W + 3.59 H – 1.55	3.3
4-6 y	20.7	1.15	Girls: 0.0666 W + 0.878 H + 1.46 Boys: 0.0632 W + 1.31 H +1.28	4.0
7-10 y	30.8	1.37	Girls: 0.0666 W + 0.878 H + 1.46 Boys: 0.0632 W + 1.31 H +1.28	4.9
FEMALES				
11-14 y	46.5	1.57	0.0393 W + 1.04 H + 1.93	5.4
15-17 y	57.8	1.67	0.0393 W + 1.04 H + 1.93	5.9
18-24 y	64.2	1.67	0.0433 W + 2.57 H – 1.180	5.9
25-50 y	64.1	1.67	0.0342W + 2.10 H – 0.0486	5.7
51-70 y	62.5	1.65	0.0356 W + 1.76 H + 0.0448	5.2
> 70 y	60.6	1.62	0.0356 W + 1.76 H + 0.0448	5.1
Pregnancy				
≤ 50 y	76.4	1.67	Average of 16–50y	6.4
Lactation				
≤ 50 y	62.4	1.67	Average of 16–50y	7.8
MALES				
11-14 y	48.2	1.61	0.0651 W + 1.11 H + 1.25	6.2
15-17 y	65.6	1.77	0.0651 W + 1.11 H + 1.25	7.5
18-24 y	75.2	1.81	0.0600 W + 1.31 H + 0.473	7.4
25-50 y	74.8	1.80	0.0476 W + 2.26 H – 0.574	7.1
51-70 y	73.0	1.78	0.0478 W 0+ 2.26 H – 1.070	6.4
> 70 y	70.6	1.75	0.0478 W 0+ 2.26 H – 1.070	6.3

The reference energy intakes were determined by multiplying the BEE predicted by the Henry equations by PAL. PAL values of 1.4, 1.6 and 1.8 reflect a low/sedentary, moderate and active physical lifestyle, respectively.

Table 6. Reference values for daily energy expenditure for adults expressed as kcal/day[1]

Age, years	Reference weight, kg	BEE, kcal/d	Average PAL 1.4, kcal/d	Average PAL 1.6, kcal/d	Active PAL 1.8, kcal/d
FEMALES					
18-24 y	64.2	1410	1984	2247	2533
25-50 y	64.1	1362	1912	2151	2438
51-70 y	62.5	1243	1721	1984	2223
>70 y	60.6	1219	1697	1960	2199
MALES					
18-24 y	75.2	1769	2486	2820	3155
25-50 y	74.8	1697	2366	2701	3035
51-70 y	73.0	1530	2151	2462	2772
>70 y	70.6	1506	2103	2414	2701
Pregnancy					
≤50 y	76.4	1530	2141	2447	2753
Lactation[3]					
≤50 y	62.4	1864	2610	2983	3356

[1] 1 MJ = 239 kcal

Table 7. Reference values for daily energy expenditure for children and adolescents, 1–17 years, expressed as kcal/day[1]

Age	Reference weight, kg[1]	BEE, kcal/d	Estimated energy requirement, kcal/d[2]
1-3 y	13.6	789	1099
4-6 y	20.7	956	1506
7-10 y	30.8	1171	1864
FEMALES			
11-14 y	46.5	1291	2199
15-17 y	57.8	1410	2414
MALES			
11-14 y	48.2	1482	2510
15-17 y	65.6	1793	3035

[1] 1 MJ = 239 kcal
[2] PAL values: 1.4 for age 1–3 y, 1.6 for age 4–10 y, 1.7 for age 11–17 y

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Appendix 5. Calculation of DRVs

Table 1. Adults

Vitamins

Nutrient	Criteria of adequacy for deriving DRVs	Source for deriving DRVs	Type of data	Factorial approach	CV % to derive RI	Type of DRV
Vitamin A RE	Maintenance of liver stores (20 µg retinol/g liver)	EFSA	Factorial method	Target liver concentration (20 µg retinol/g) × body/liver retinol stores ratio [1.25] × liver/body weight ratio (%) [2.4 %] × fractional catabolic rate of retinol (%) [0.7 %] × (1/efficiency of body storage (%) [50 %]) × reference body weight (kg) × 10^3	15	AR RI
Thiamin mg	Biomarker and erythrocyte transketolase activity coefficient	EFSA	Dose-response	0.072 mg/MJ	20	AR RI
Riboflavin mg	Biomarker	EFSA	Dose-response		10	AR RI
Niacin NE	Biomarker	EFSA	Dose-response	1.3 NE/MJ	10	AR RI
Pantothenic acid mg	Observed intake	EFSA	Dietary surveys			AI p-AR
Vitamin B6 mg	Biomarker (plasma pyridoxal 5-phosphate of 30 nmol/l)	EFSA	Dose-response		10	AR RI
Folate µg DFE	Biormarkers (serum and red blood cell folate of ≥10 and ≥340 nmol/L, respectively; plasma homocysteine)	EFSA	Dose-response		15	AR RI
Vitamin B12 µg	Vitamin B12 biomarkers; observed intakes	EFSA	Interventional and cross-sectional studies; dietary surveys			AI p-AR
Biotin µg	Observed intakes	EFSA	Dietary surveys			AI p-AR
Vitamin C mg	Biomarker Females: Extrapolated from males	EFSA	Dose-response, corrected for losses and absorption efficiency [80 %] Females: Extrapolated from males with isometric scaling		10	AR RI
Vitamin D µg	Biomarker (25(OH)D above 50 nmol/l)	NNR2023: Brustad and Meyer (2023)	Dose-response, regression		15	AR RI
Vitamin E mg	Basal requirement + prevention of PUFA oxidation	Raederstorff et al. (2015)	Factorial approach	Basal requirement [4 mg TE/d] + 0,5 x PUFA in grams (at 5 E%)		AI p-AR

Vitamin K μg	Biomarkers (functional prothrombin, g-carboxyglutamic acid)	EFSA	Dose-response	1 μg/kg bodyweight		AI p-AR
Choline mg	Observed intake; prevention of deficiency symptoms	EFSA	Dietary surveys; depletion-repletion study			AI p-AR

p-AR = Provisional AR derived from AI

Minerals

Nutrient	Criteria for deriving DRVs	Source for deriving DRVs	Type of data	Factorial approach	CV % to derive RI	Type of DRV
Calcium mg	Replacement of calcium losses	EFSA	Dose-response		RI based on 97.5th percentile of calcium null balance	AR RI
Phosphorus mg	Recommended calcium intake; molar ratio of calcium to phosphorus (1.4:1)	EFSA	Studies on bone mineral content			AI p-AR
Potassium mg	Blood pressure and stroke risk	EFSA	Intervention and prospective observational studies			AI p-AR
Magnesium mg	Observed intake	EFSA	Dietary surveys			AI p-AR
Copper μg	Biomarkers (including plasma copper, serum ceruloplasmin and erythrocyte superoxide dismutase activity)	IOM	Depletion-repletion studies		15	AR RI
Fluoride μg	Prevention of caries	EFSA	Intervention and observational studies in children	0.05 mg/kg body weight		AI p-AR
Iron mg	Replacement of daily iron loss	NNR2023: Domellöf and Sjöberg (2023)		Basal loss (14 μg/kg/day) + menstrual loss in females (0.45 mg/day), absorption efficiency 15 %	RI based on 95th percentile menstrual loss in females (1.32 mg/day); CV 15 % in males	AR RI
Zinc mg	Zinc balance, accounting for absorption efficiency based on phytate intake	EFSA	Modelling, isotope dilution and balance studies	Physiological requirement (0.642 + 0.038 x kg body weight), absorption efficiency based phytate intake (600 mg/day used in NNR2023)	10	AR RI
Iodine μg	Urinary iodine associated with prevention of goitre (extrapolated from children)	EFSA	Cross-sectional study in children			AI p-AR
Selenium μg	Biomarker	NNR2023: Alexander and Olsen (2023), EFSA	Intervention study	1.2 μg/kg body weight		AI p-AR

Manga-nese mg	Observed intake Manganese homeostasis	EFSA	Dietary surveys, balance studies				AI p-AR
Molybde-num µg	Observed intake (lower end) Molybdenum homeostasis	EFSA	Dietary surveys, balance studies				AI p-AR

p-AR = Provisional AR derived from AI

Table 2. Pregnant/Lactating

Vitamins

Nutrient	Criteria of adequacy for deriving DRVs	Source for deriving DRVs	Type of data	Type of scaling	Factorial approach	CV % to derive RI	Type of DRV
Vitamin A RE	Maintenance of liver stores (20 µg retinol/g liver)	EFSA	Factorial method		Pregnant: AR for non-pregnant females + fetal and maternal tissues accumulation [3600 µg], correcting for retinol efficiency of storage [50 %] Lactating: AR for non-lactating women + amount secreted in breast milk [424 µg/d], correcting for absorption efficiency [80 %]	15	AR RI
Thiamin mg	Biomarker and erythrocyte transketolase activity coefficient	EFSA	Dose-response		0.072 mg/MJ	20	AR RI
Riboflavin mg	Biomarker	EFSA	Dose-response	Pregnant: Allometric from non-pregnant	Lactating: AR for non-lactating + amount secreted in breast milk [0.291 mg], correcting for absorption efficiency [95 %]	10	AR RI
Niacin NE	Biomarker	EFSA	Dose-response		1.3 NE/MJ	10	AR RI
Pantothenic acid mg	Observed intake	EFSA	Dietary surveys		Lactating: AI for non-lactating + amount secreted in breast milk [2 mg]		AI p-AR
Vitamin B6 mg	Biomarker (plasma pyridoxal 5-phosphate of 30 nmol/l)	EFSA	Dose-response		Pregnant: Non-pregnant + (Vitamin B6 in human tissue [0.0037] x gestational weight gain [14 kg] /bioavailability [75%])/pregnancy duration in days [280] Lactating: Non-lactating + breast milk concentration [0,13 mg/l], correcting for absorption efficiency [75%]	10	AR RI
Folate µg DFE	Biomarkers (serum and red blood cell folate ≥10 and ≥340 nmol/L, respectively; plasma homocysteine)	EFSA	Pregnant: Controlled study Dose-response		Pregnant:		AI

					Lactating: AR for non-lactating + breast milk excretion, 50 % absorption	15	AR RI
Vitamin B12 **µg**	Vitamin B12 biomarkers; observed intakes	EFSA	Interventional and cross-sectional studies; dietary surveys		Pregnant: AI for non-pregnant + 0,5 µg/d		AI p-AR
					Lactating: AI for non-lactating + breast milk extraction [0.5 µg/l], 40 % absorption		
Biotin **µg**	Observed intakes	EFSA	Dietary surveys		Lactating: AI for non-lactating + 4 µg		AI p-AR
Vitamin C **mg**	Biomarker Females: Extrapolated from males	EFSA	Dose-response, corrected for losses and absorption efficiency [80 %] Females: Extrapolated from males with isometric scaling	Isometric, from men		10	AR RI
Vitamin D **µg**	Biomarker (25(OH)D above 50 nmol/l)	NNR2023: Brustad and Meyer (2023)	Dose-response, regression			15	AR RI
Vitamin E **mg**	Basal requirement + prevention of PUFA oxidation	Raederstorff et al. (2015)	Factorial approach		Basal requirement [4 mg TE/d] + 0,5 x PUFA in grams (at 5 E%)		AI p-AR
Vitamin K **µg**	Biomarkers (functional prothrombin, g-carboxyglutamic acid)	EFSA	Dose-response		1 µg/kg bodyweight		AI p-AR
Choline **mg**	Observed intake; prevention of deficiency symptoms	EFSA	Dietary surveys; depletion-repletion study	Pregnant: Isometric, from non-pregnant	Lactating: AI for non-lactating + breast milk secretion [120 mg]		AI p-AR

p-AR = Provisional AR derived from AI

Minerals

Nutrient	Criteria for deriving DRVs	Source for deriving DRVs	Type of data	Factorial approach	CV % to derive RI	Type of DRV
Calcium **mg**	Replacement of calcium losses	EFSA	Dose-response		RI based on 97.5th percentile of calcium null balance	AR RI
Phosphorus **mg**	Recommended calcium intake; molar ratio of calcium to phosphorus (1.4:1)	EFSA	Studies on bone mineral content			AI p-AR
Potassium **mg**	Blood pressure and stroke risk	EFSA	Intervention and prospective observational studies			AI p-AR
Magnesium **mg**	Observed intake	EFSA	Dietary surveys			AI p-AR

Copper µg	Biomarkers (including plasma copper, serum ceruloplasmin and erythrocyte superoxide dismutase activity)	IOM	Depletion-repletion studies	Pregnant: AR for non-pregnant + 1000 µg	15	AR RI
				Lactating: AR for non-lactating + breast milk secretion, 67 % absorption		
Fluoride µg	Prevention of caries	EFSA	Intervention and observational studies in children	0.05 mg/kg body weight (based on pre-pregnancy weight)		AI p-AR
Iron mg	Replacement of daily iron loss	NNR2023: Domellöf and Sjöberg (2023)		Pregnant: Basal loss [14 µg/kg/day] + 1.91 µg/day needed for fetal growth, placenta and umbilical cord, and average blood loss	Pregnant: 15	AR RI
				As non-lactating	Lactating: RI based on 95th percentile of menstrual loss (1.32 mg/day)	
Zinc mg	Zinc balance, accounting for absorption efficiency based on phytate intake	EFSA	Modelling, isotope dilution and balance studies	Pregnant: AR for non-pregnant + 0.4 mg corrected for fractional absorption of 30 % [AR + 1.3 mg/d]	10	AR RI
				Lactating: AR for non-lactating + 1.1 mg corrected for fractional absorption of 45 % [AR + 2.4 mg/d]		
Iodine µg	Urinary iodine associated with prevention of goitre (extrapolated from children)	EFSA	Cross-sectional study in children	Pregnant: AI for non-pregnant + 50 µg/d for increased thyroid hormone production and iodine uptake by the fetus, placenta and amniotic fluid		AI p-AR
				Lactating: AI for non-lactating + 50 µg/d		
Selenium µg	Biomarker	NNR2023: Alexander and Olsen (2023), EFSA	Intervention study	1.2 µg/kg body weight Lactating: AI for non-lactating + 10 µg		AI p-AR
Manganese mg	Observed intake Manganese homeostasis	EFSA	Dietary surveys, balance studies			AI p-AR
Molybdenum µg	Observed intake (lower end) Molybdenum homeostasis	EFSA	Dietary surveys, balance studies			AI p-AR

Table 3. Children (1–17 years)

Vitamins

Nutrient	Criteria of adequacy for deriving DRVs	Source for deriving DRVs	Type of data	Type of scaling	Factorial approach	CV % to derive RI	Type of DRV
Vitamin A RE	Maintainance of liver stores (20 µg retinol/g liver)	EFSA	Factorial method		Target liver concentration (20 µg retinol/g) × body/liver retinol stores ratio [1.25] × liver/body weight ratio (%) [age-specific values] × fractional catabolic rate of retinol (%) [0.7 %] × (1/efficiency of body storage (%) [50 %]) × reference body weight (kg) × 1 + growth factor) x 10^3	15	AR RI
Thiamin mg	Biomarker and erythrocyte transketolase activity coefficient	EFSA	Dose-response		0.072 mg/MJ	20	AR RI
Riboflavin mg	Extrapolated from adult AR	EFSA		Allometric + growth factors		10	AR RI
Niacin NE	Biomarker	EFSA	Dose-response		1.3 NE/MJ	10	AR RI
Pantothenic acid mg	Observed intake	EFSA	Dietary surveys				AI p-AR
Vitamin B6 mg	Extrapolated from adult AR	EFSA		Allometric + growth factors		10	AR RI
Folate µg DFE	Extrapolated from adult AR	EFSA		Allometric + growth factors		15	AR RI
Vitamin B12 µg	Extrapolated from adult AI	EFSA		Allometric + growth factors			AI p-AR
Biotin µg	Observed intake	EFSA	Dietary surveys				AI p-AR
Vitamin C mg	Extrapolated from adult AR	EFSA		Isometric		10	AR RI
Vitamin D µg	Biomarker (25(OH)D above 50 nmol/l)	NNR2023: Brustad and Meyer (2023)				15	AR RI
Vitamin E mg	Basal requirement + prevention of PUFA oxidation	Raederstorff et al. (2015)	Factorial approach		Basal requirement [4 mg TE/d] + 0,5 x PUFA in grams (at 5 E%)		AI p-AR
Vitamin K µg	As adults	EFSA			1 µg/kg bodyweight		AI p-AR
Choline mg	Extrapolation from adult AI	EFSA		Allometric + growth factors			AI p-AR

p-AR = Provisional AR derived from AI

Minerals

Nutrient	Criteria for deriving DRVs	Source for deriving DRVs	Type of data	Type of scaling	Factorial approach	CV % to derive RI	Type of DRV
Calcium mg	Calcium accretion in bone + replacement of obligatory losses	EFSA	Observational, isotope and controlled feeding studies		Age-specific (urinary losses + faecal losses + dermal losses + calcium accretion in bone)/fractional absorption	10	AR RI Average AR and RI for used for girls and boys 11–17 y
Phosphorus mg	Recommended calcium intake; molar ratio of calcium to phosphorus (1.4:1)	EFSA	Studies on bone mineral content				AI p-AR
Potassium mg	Extrapolated from adult AI	EFSA		Isometric + growth factors			AI p-AR
Magnesium mg	Observed intake	EFSA	Dietary surveys				AI p-AR
Copper µg	Extrapolated from adult AR	IOM		Allometric + growth factors		15	AR RI
Fluoride µg	Prevention of caries	EFSA	Intervention and observational studies in children		0.05 mg/kg body weight		AI p-AR
Iron mg	Replacement of daily iron loss + requirement for growth	NNR2023: Domellöf and Sjöberg (2023)			Basal loss (age-specific) + iron need for daily growth (+ menstrual loss [0.45 mg/day] in girls 11–17 y), absorption efficiency (1–10 y: 10 %, 11–17 y: 15 %)	Children 1–10 y and boys 15–17 y: 15 Adolescents 11–17: RI based on 95th percentile menstrual loss in girls (0.89 mg/day in 11–14 y, 1.32 mg/day in 15–17 y)	AR RI
Zinc mg	Zinc balance, loss extrapolated from adults + requirement for growth	EFSA		Urinary loss: isometric Sweat loss: allometric	Zinc loss (urinary, integumenal, faecal, menses in girls 11–17 y, semen in boys 15–17 y) + requirement for growth, absorption efficiency 30 %	10	AR RI
Iodine µg	Urinary iodine associated with prevention of goitre	EFSA	Cross-sectional		100 µg/L x urinary volume [L/day), absorption efficiency 92 %		AI p-AR
Selenium µg	Extrapolated from adult AI	NNR2023: Alexander and Olsen (2023); EFSA		Isometric + growth factor			AI p-AR
Manganese mg	Extrapolated from adult AI	EFSA		Isometric			AI p-AR
Molybdenum µg	Extrapolated from adult AI	EFSA		Isometric			AI p-AR

p-AR = Provisional AR derived from AI

Table 4. Infants (7–11 months)

Vitamins

Nutrient	Criteria of adequacy for deriving DRVs	Source for deriving DRVs	Type of data	Type of scaling	Factorial approach	CV % to derive RI	Type of DRV
Vitamin A RE	Maintainance of liver stores (20 µg retinol/g liver)	EFSA	Factorial method		Target liver concentration (20 µg retinol/g) × body/liver retinol stores ratio [1.25] × liver/body weight ratio (%) [4 %] × fractional catabolic rate of retinol (%) [0.7 %] × (1/efficiency of body storage (%) [50 %]) × body weight (kg) × 1 + growth factor) x 10^3	15	AR RI
Thiamin mg	Biomarker and erythrocyte transketolase activity coefficient	EFSA	Dose-response		0.072 mg/MJ	20	AR RI
Riboflavin mg	Extrapolated from exclusively breastfed infants 0–6 months	EFSA	Breastmilk composition	Allometric			AI p-AR
Niacin NE	Biomarker	EFSA	Dose-response		1.3 NE/MJ	10	AR RI
Pantothenic acid mg	Extrapolated from exclusively breastfed infants 0–6 months	EFSA	Breastmilk composition	Allometric			AI p-AR
Vitamin B6 mg	Average of upwards extrapolation from exclusively breastfed infants 0–6 months and downwards extrapolation from adults	EFSA	Breastmilk composition	Allometric (+ growth factors when extrapolating from adults)			AI p-AR
Folate µg DFE	Extrapolated from exclusively breastfed infants 0–6 months	EFSA	Breastmilk composition	Allometric			AI p-AR
Vitamin B12 µg	Extrapolated from adult AI	EFSA		Allometric + growth factors			AI p-AR
Biotin µg	Extrapolated from exclusively breastfed infants 0–6 months	EFSA	Breastmilk composition	Allometric			AI p-AR
Vitamin C mg	Prevention of scurvy	EFSA			Three times higher than the amount known to prevent scurvy		AI p-AR
Vitamin D µg	Biomarker (25(OH)D above 50 nmol/l)	NNR2023: Brustad and Meyer (2023)				15	AR RI
Vitamin E mg	Extrapolated from exclusively breastfed infants 0–6 months	EFSA	Breastmilk composition	Allometric			AI p-AR
Vitamin K µg	As adults	EFSA			1 µg/kg bodyweight		AI p-AR
Choline mg	Extrapolated from exclusively breastfed infants 0–6 months	EFSA	Breastmilk composition	Allometric			AI p-AR

Minerals

Nutrient	Criteria for deriving DRVs	Source for deriving DRVs	Type of data	Type of scaling	Factorial approach	CV % to derive RI	Type of DRV
Calcium mg	Extrapolated from exclusively breastfed infants 0–6 months, assuming 60 % absorption from breastmilk	EFSA	Breastmilk composition	Isometric			AI p-AR
Phosphorus mg	AI for calcium; molar ratio of calcium to phosphorus (1.4:1)	EFSA					AI p-AR
Potassium mg	Extrapolated from adult AI	EFSA		Isometric + growth factor			AI p-AR
Magnesium mg	Midpoint between extrapolation from exclusively breastfed infants 0–6 months and the highest range of observed intake (= 120 mg)	EFSA	Breastmilk composition Dietary surveys	Isometric			AI p-AR
Copper µg	Combination of intake from breastmilk and observed intakes from complementary foods	IOM	Breastmilk composition Dietary surveys				AI p-AR
Fluoride µg	Prevention of caries, extrapolated from older children	EFSA			0.05 mg/kg body weight		AI p-AR
Iron mg	Replacement of daily iron loss + requirement for growth	NNR2023: Domellöf and Sjöberg (2023)			Basal loss (22 µg/kg) + iron need for daily growth (40 mg/kg/day), absorption efficiency 10 %	15	AR RI
Zinc mg	Zinc balance, loss extrapolated from adults + requirement for growth	EFSA		Urinary loss: isometric Sweat loss: allometric	Zinc loss (urinary, faecal, sweat) + requirement for growth (20 µg/g/day), absorption efficiency 30 %	10	AR RI
Iodine µg	Iodine balance	NNR2023: Gunnarsdóttir and Brantsæter (2023)	Balance study				AI p-AR
Selenium µg	Extrapolated from exclusively breastfed infants 0–6 months	EFSA	Breastmilk composition	Isometric			AI p-AR
Manganese mg	Range based on upwards extrapolation from exclusively breastfed infants 0–6 months and the mean of observed intakes (75 µg/kg bw) and downwards extrapolation from adult AI	EFSA	Breastmilk composition Dietary surveys	Isometric			AI p-AR
Molybdenum µg	Extrapolated from adult AI	EFSA		Isometric			AI p-AR

p-AR = Provisional AR derived from AI

Table 5. Reference body weights and heights

Life stage	Body weight (kg)		Height (cm)		Source[1]
Infants					
0–6 months	5.7		59		1
6–11 months	9.0		72		1
Children					
1–3 y	13.6		90		1
4–6 y	20.7		115		1, 2
7–10 y	30.8		137		2
Adolescents	**F**	**M**	**F**	**M**	
11–14 y	46.5	48.2	157	161	2
15–17 y	57.8	65.6	167	177	2
Adults	**F**	**M**	**F**	**M**	
18–24 y	64.2	75.2	167	181	3
25–50 y	64.1	74.8	167	180	3
51–70 y	62.5	73.0	165	178	3
>70 y	60.6	70.6	162	175	3

[1] Sources for weight and height data:
1. Measured body height and weight from Denmark (2014), Estonia (2013-15), Finland (2011), Norway (2013), and Sweden (2002) from birth up to 6 years.
2. Measured height from Denmark (2014), Estonia (2013), Finland (2011), Norway (2013), and Sweden (2002). Weights for 6-17 years calculated from measured height and BMI accord. to WHO 2007 (https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age).
3. Average heights for adults from dietary surveys in Denmark (2011-13), Estonia (2017), Finland (2017), Iceland (2019–21), Latvia (2018), Norway (2020), and Sweden (2010–11), weights calculated by scaling to BMI 23 kg/m^2.

Table 6. Growth factors[1]

Age	Growth factor	
7–11 months	0.57	
1 y	0.44	
2 y	0.2	
3 y	0.11	
4 y	0.05	
5 y	0.05	
6 y	0.09	
7 y	0.12	
8 y	0.14	
9 y	0.14	
10 y	0.14	
1–3 y	0.25	
4–6 y	0.06	
7–10 y	0.13	
Adolescents	F	M
11 y	0.11	0.14
12 y	0.09	0.12
13 y	0.08	0.11
14 y	0.06	0.09
15 y	0.05	0.09
16 y	0.03	0.08
17 y	0.02	0.06
11–14 y	0.08	0.11
15–17 y	0.03	0.08

[1] Source: EFSA Panel on Dietetic Products, Nutrition and Allergies. Scientific Opinion on Dietary Reference Values for protein. EFSA J. 2012; 10(2):2557. doi: https://doi.org/10.2903/j.efsa.2012.2557.

Appendix 6. DRVs for children

Vitamins

Average requirements (AR) for vitamins in children

Age group	Vitamin A RE[2]	Vitamin D µg	Thiamin mg/MJ	Ribo-flavin mg	Niacin NE/MJ[3]	Vitamin B6 mg	Folate µg	Vitamin C mg
≤6 mo[1]				*0.2*		*0.1*	*50*	*16*
7-11 mo	200	7.5	0.07	*0.3*[4]	1.3	*0.3*[4]	*70*[4]	*16*[4]
Children								
1 y	200	7.5	0.07	0.5	1.3	0.5	90	20
2 y	220	7.5	0.07	0.5	1.3	0.5	90	20
3 y	230	7.5	0.07	0.5	1.3	0.5	90	20
4 y	220	7.5	0.07	0.5	1.3	0.5	90	25
5 y	250	7.5	0.07	0.5	1.3	0.6	100	25
6 y	290	7.5	0.07	0.6	1.3	0.6	120	30
7 y	270	7.5	0.07	0.7	1.3	0.7	130	35
8 y	300	7.5	0.07	0.8	1.3	0.8	140	40
9 y	340	7.5	0.07	0.8	1.3	0.9	150	45
10 y	370	7.5	0.07	0.9	1.3	0.9	170	50
Females								
11 y	410	7.5	0.07	1.0	1.3	1.1	190	60
12 y	460	7.5	0.07	1.1	1.3	1.1	200	65
13 y	510	7.5	0.07	1.2	1.3	1.2	220	75
14 y	540	7.5	0.07	1.2	1.3	1.3	230	80
15 y	490	7.5	0.07	1.3	1.3	1.3	240	85
16 y	500	7.5	0.07	1.3	1.3	1.3	240	85
17 y	500	7.5	0.07	1.3	1.3	1.4	240	85
Males								
11 y	410	7.5	0.07	0.9	1.3	1.0	170	50
12 y	450	7.5	0.07	1.0	1.3	1.0	180	55

13 y	510	7.5	0.07	1.1	1.3	1.1	200	65
14 y	570	7.5	0.07	1.1	1.3	1.2	210	70
15 y	540	7.5	0.07	1.2	1.3	1.3	230	80
16 y	580	7.5	0.07	1.3	1.3	1.4	240	85
17 y	600	7.5	0.07	1.3	1.3	1.4	250	90

[1] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk.
[2] RE = Retinol equivalents (1 RE = 1 µg retinol = 2 µg of supplemental β-carotene, 6 µg of dietary β-carotene or 12 µg other dietary provitamin A carotenoids (e.g., α-carotene and β-cryptoxanthin).
[3] NE = Niacin equivalent (1 NE = 1 mg niacin = 60 mg tryptophan).
[4] Provisional AR, extrapolated from exclusively breast-fed infants 0-6 months.

Provisional average requirements (AR) for vitamins in children[1]

Age group	Vitamin E α-TE[4]	Vitamin K µg	Pantothenic acid mg	Biotin µg	Vitamin B_{12} µg	Choline mg
≤6 mo[2]	3		1.6	3	0.3	96
7-11 mo	4[3]	5	2.2[3]	4[3]	1.2	134[3]
Children						
1 y	5	10	3.2	16	1.1	110
2 y	5	10	3.2	16	1.1	110
3 y	6	10	3.2	16	1.1	114
4 y	7	15	3.2	20	1.2	119
5 y	6	15	3.2	20	1.3	130
6 y	7	15	3.2	20	1.5	148
7 y	7	20	3.2	20	1.7	165
8 y	7	20	3.2	20	1.8	182
9 y	7	25	3.2	20	2.0	197
10 y	8	25	3.2	20	2.1	214
Females						
11 y	8	30	4	28	2.4	242
12 y	8	35	4	28	2.5	262
13 y	8	40	4	28	2.8	282
14 y	8	40	4	28	3.0	295
15 y	8	45	4	28	3.0	305

16 y	9	45	4	28	3.1	308
17 y	9	45	4	28	3.1	310
Males						
11 y	8	30	4	28	2.2	218
12 y	8	35	4	28	2.3	233
13 y	9	40	4	28	2.5	254
14 y	9	45	4	28	2.7	274
15 y	10	50	4	28	3.0	298
16 y	10	50	4	28	3.1	313
17 y	10	55	4	28	3.2	320

[1] Provisional average requirements (AR) calculated as 0.8 times the adequate intake (AI), assuming a CV of 12.5 %. This likely overestimates the true AR.
[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk.
[3] Extrapolated from exclusively breast-fed infants 0-6 months
[4] Assuming a PUFA intake of 5 % of energy intake. α-TE = α-tocopherol equivalents (i.e., 1 mg RRR α-tocopherol).

Recommended intakes (RI) of vitamins in children

Age group	Vitamin A RE[2]	Vitamin D µg[3]	Thiamin mg/MJ	Ribo-flavin mg	Niacin NE/MJ[4]	Vitamin B6 mg	Folate µg	Vitamin C mg
≤6 mo[1]				0.3		0.1	64	20
7-11 mo	250	10	0.1	*0.4*[5]	1.6	*0.4*[5]	*89*[6]	*20*[5]
Children								
1 y	250	10	0.1	0.6	1.6	0.6	110	25
2 y	300	10	0.1	0.6	1.6	0.6	110	25
3 y	300	10	0.1	0.6	1.6	0.6	120	25
4 y	300	10	0.1	0.6	1.6	0.6	120	30
5 y	300	10	0.1	0.7	1.6	0.7	130	30
6 y	400	10	0.1	0.7	1.6	0.8	150	40
7 y	350	10	0.1	0.8	1.6	0.9	170	45
8 y	400	10	0.1	0.9	1.6	1.0	180	50
9 y	450	10	0.1	1.0	1.6	1.0	200	55
10 y	500	10	0.1	1.1	1.6	1.1	220	60
Females								

11 y	550	10	0.1	1.2	1.6	1.3	250	70
12 y	600	10	0.1	1.3	1.6	1.4	270	80
13 y	650	10	0.1	1.4	1.6	1.5	290	90
14 y	700	10	0.1	1.5	1.6	1.6	300	95
15 y	650	10	0.1	1.5	1.6	1.6	310	100
16 y	650	10	0.1	1.5	1.6	1.6	310	100
17 y	650	10	0.1	1.6	1.6	1.6	320	103
Males								
11 y	550	10	0.1	1.1	1.6	1.1	220	60
12 y	600	10	0.1	1.2	1.6	1.2	240	70
13 y	650	10	0.1	1.3	1.6	1.3	260	75
14 y	750	10	0.1	1.4	1.6	1.4	280	85
15 y	700	10	0.1	1.5	1.6	1.6	300	95
16 y	750	10	0.1	1.6	1.6	1.6	320	100
17 y	800	10	0.1	1.6	1.6	1.7	320	105

[1] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional RIs based on estimated intake from human milk.
[2] RE = Retinol equivalents (1 RE = 1 µg retinol = 2 µg of supplemental β-carotene, 6 µg of dietary β-carotene, or 12 µg other dietary provitamin A carotenoids (e.g., α-carotene and β-cryptoxanthin).
[3] From 1-2 weeks of age, infants should receive 10 µg vitamin D_3 per day as a supplement.
[4] NE = Niacin equivalent (1 NE = 1 mg niacin = 60 mg tryptophan).
[5] AI, extrapolated from exclusively breast-fed infants 0-6 months.

Adequate intakes (AI) of vitamins in children[1]

Age group	Vitamin E α-TE[4]	Vitamin K µg	Pantothenic acid mg	Biotin µg	Vitamin B_{12} µg	Choline mg
≤6 mo[2]	4		2	4	0.4	120
7-11 mo	5[3]	10	3[3]	5[3]	1.5	170[3]
Children						
1 y	6	10	4	20	1.5	140
2 y	7	15	4	20	1.5	140
3 y	7	15	4	20	1.5	140
4 y	8	15	4	25	1.5	150
5 y	8	20	4	25	1.5	160

6 y	8	20	4	25	2	190
7 y	9	25	4	25	2	210
8 y	9	25	4	25	2.5	230
9 y	9	30	4	25	2.5	250
10 y	9	35	4	25	2.5	270
Females						
11 y	10	40	5	35	3	300
12 y	10	45	5	35	3	330
13 y	10	50	5	35	3.5	350
14 y	10	50	5	35	3.5	370
15 y	11	55	5	35	4	380
16 y	11	60	5	35	4	390
17 y	11	60	5	35	4	390
Males						
11 y	10	35	5	35	2.5	270
12 y	10	40	5	35	3	390
13 y	11	45	5	35	3	320
14 y	11	55	5	35	3.5	340
15 y	12	60	5	35	3.5	370
16 y	12	65	5	35	4	390
17 y	13	70	5	35	4	400

[1] Adequate intake (AI) based on observed intakes in healthy people or approximations from experimental studies, used when an RI cannot be determined.

[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are based on estimated intake from human milk.

[3] Extrapolated from exclusively breast-fed infants 0-6 months

[4] Assuming a PUFA intake of 5 % of energy intake. α-TE = α-tocopherol equivalents (i.e., 1 mg RRR α-tocopherol).

Minerals

Average requirements (AR) for minerals in children

Age group	Calcium mg	Copper µg	Iron mg	Zinc mg[2]
≤6 mo[1]	96	160		
7-11 mo	250[3]	180[3]	7	2.5
Children				
1 y	370	240	5	3.3
2 y	395	240	5	3.6
3 y	415	250	6	3.9
4 y	650	260	4	4.3
5 y	680	280	5	4.6
6 y	715	320	5	5.0
7 y	675	360	6	5.4
8 y	675	400	7	5.4
9 y	675	430	7	6.4
10 y	675	470	8	6.9
Females				
11 y	980[4]	530	10	7.9
12 y		570	10	8.7
13 y		620	10	9.2
14 y		650	9	9.6
15 y		670	9	9.9
16 y		670	9	10.0
17 y		680	9	10.3
Males				
11 y	980[4]	480	7	7.5
12 y		510	8	8.3
13 y		560	9	9.2
14 y		600	10	10.1
15 y		650	9	10.6

16 y		680	8	11.1
17 y		700	9	11.6

[1] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk.
[2] Assuming a mixed animal/vegetable diet.
[3] Provisional AR, extrapolated from exclusively breast-fed infants 0-6 months.
[4] Average of AR for females and males 11-14 years old.

Provisional average requirements (AR) for minerals in children[1]

Age group	Phosphorus mg[3]	Potassium mg	Magnesium mg	Iodine µg	Selenium µg	Fluoride mg[4]	Manganese mg	Molybde-num mg
≤6 mo[2]		320	20	64-72	10		9.6	
7-11 mo	140	600	64[5]	64-72	15[5]	0.4	0.02-0.4[6]	7
Children								
1 y	160	600	136	60	15	0.4	0.4	8
2 y	140	600	136	80	15	0.5	0.6	10
3 y	180	700	136	90	15	0.6	0.7	11
4 y	290	700	184	50	15	0.7	0.8	13
5 y	300	800	184	60	20	0.8	0.8	15
6 y	320	1000	184	60	25	0.9	1.0	17
7 y	300	1100	184	60	25	1.0	1.1	19
8 y	300	1300	184	70	30	1.1	1.2	21
9 y	300	1400	184	80	35	1.2	1.3	23
10 y	300	1600	184	80	35	1.3	1.5	25
Females								
11 y		1900	200	80	40	1.5	1.8	31
12 y		2100	200	90	45	1.7	2.0	35
13 y		2300	200	100	50	1.9	2.3	40
14 y	510[7]	2500	200	110	55	2.1	2.5	43
15 y		2500	200	90	55	2.2	2.6	46
16 y		2600	200	100	55	2.3	2.7	48
17 y		2700	200	100	60	2.4	2.8	49
Males								
11 y		1600	240	80	40	1.5	1.5	26

12 y		1800	240	90	45	1.7	1.7	29
13 y		2000	240	100	50	1.9	1.9	33
14 y	510[7]	2200	240	110	55	2.1	2.2	38
15 y		2500	240	100	60	2.4	2.4	42
16 y		2600	240	110	65	2.6	2.6	45
17 y		2700	240	110	70	2.7	2.8	48

[1] Provisional average requirements (AR) calculated as 0.8 times the adequate intake (AI), assuming a CV of 12.5 %. This likely overestimates the true AR.
[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional AR based on estimated intake from human milk.
[3] Assuming the recommended intake (RI) of calcium is consumed.
[4] Based on an adequate intake of 0.05 mg/kg bodyweight, using population reference weights.
[5] Extrapolated from exclusively breast-fed infants 0-6 months
[6] Range based on upwards extrapolation from intake of infants 0-6 months, the mean of observed intakes and downwards extrapolation from adult AI.
[7] Average of provisional AR for females and males 11-14 years old.

Recommended intakes (RI) of minerals in children

Age group	Calcium mg	Iron Mg[2]	Zinc mg[2]	Copper µg
≤6 mo[1]	*120*			*200*
7-11 mo	*310[3]*	10	3	*220[3]*
Children				
1 y	400	7	4.0	310
2 y	450	7	4.3	310
3 y	450	7	4.7	320
4 y	750	6	5.1	430
5 y	800	7	5.6	370
6 y	850	7	6.0	420
7 y	800	8	6.5	470
8 y	800	8	6.4	520
9 y	800	10	7.6	560
10 y	800	11	8.3	610
Females				
11 y		13[5,6]	9.5	700
12 y		13[5,6]	10.4	700
13 y		13[5,6]	11.1	800

14 y	1150[4]	12[5,6]	11.5	800
15 y		15[6]	11.9	900
16 y		14[6]	12.1	900
17 y		15[6]	12.3	900
Males				
11 y	1150[4]	9	9.0	600
12 y		11	10.0	700
13 y		12	11.0	700
14 y		13	12.1	800
15 y		12	12.8	800
16 y		11	13.3	900
17 y		11	14.0	900

[1] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are adequate intakes (AI) based on estimated intake from human milk.
[2] Assuming a mixed animal/vegetable diet.
[3] Adequate intake (AI), extrapolated from exclusively breast-fed infants 0-6 months.
[4] Average of RI for females and males 11-14 years old.
[5] If menstruating, RI is 15 mg.
[6] Based on 95th percentile of menstrual loss. If large menstruation bleedings, screening of iron status and supplementation as indicated.

Adequate intakes (AI) of minerals in children[1]

Age group	Phosphorus[3]	Potassium	Magnesium	Iodine	Selenium	Fluoride[6]	Manganese	Molybdenum
≤6 mo[2]		400	25	80-90	10		12.0 µg	
7-11 mo	160	700	80[4]	80-90[5]	20[4]	0.4	0.02-0.5[7]	10
Children								
1 y	200	750	170	100	15	0.5	0.5	10
2 y	220	800	170	100	20	0.6	0.5	15
3 y	230	850	170	100	20	0.7	0.5	15
4 y	360	900	230	60	20	0.9	1	15
5 y	380	1050	230	70	25	1.0	1	20
6 y	400	1200	230	80	30	1.1	1	20
7 y	370	1400	230	80	35	1.2	1	25
8 y	370	1600	230	80	35	1.3	1	25
9 y	370	1750	230	90	40	1.5	1.5	30

10 y	370	2000	230	100	45	1.7	1.5	35
Females								
11 y	640[8]	2350	250	100	50	1.9	2	40
12 y		2600	250	110	55	2.1	2	45
13 y		2900	250	130	60	2.4	2.5	50
14 y		3100	250	140	65	2.6	2.5	55
15 y		3250	250	120	70	2.8	2.5	60
16 y		3300	250	120	70	2.9	2.5	60
17 y		3350	250	120	70	2.9	3	60
Males								
11 y	640[8]	2000	300	100	50	1.8	1.5	35
12 y		2200	300	110	55	2.1	1.5	40
13 y		2500	300	120	65	2.3	2	45
14 y		2750	300	140	70	2.7	2	50
15 y		3000	300	120	80	3.0	2.5	55
16 y		3300	300	130	85	3.2	2.5	60
17 y		3450	300	140	85	3.4	3	60

[1] Adequate intake based on observed intakes in healthy people or approximations from experimental studies, used when an RI cannot be determined.
[2] Exclusive breastfeeding is the preferable source of nutrition for infants during the first six months of life. Values for infants 0-6 months are provisional RI based on estimated intake from human milk.
[3] Assuming the RI of calcium is consumed.
[4] Extrapolated from exclusively breast-fed infants 0-6 months.
[5] The RI for iodine in infants < 1 y is presented as a range with 80 µg/d in iodine sufficient populations and 90 µg/d in populations with mild to moderate iodine deficiency. The WHO recommends 90 µg/d for all infants.
[6] Based on an adequate intake of 0.05 mg/kg bodyweight, using population reference weights.
[7] Range based on upwards extrapolation from intake of infants 0-6 months, the mean of observed intakes and downwards extrapolation from adult AI.
[8] Average of AI for females and males 11-14 years old.

Appendix 7. Vitamin D intake and serum 25OHD concentrations: Approaches to dose–response analyses

Rikke Andersen and Inge Tetens

Serum or plasma 25-hydroxyvitamin D (25OHD) concentration serves as a biomarker of total vitamin D exposure (D2 and D3) from oral sources (foods, fortification, supplements) and cutaneous synthesis. When obtained during periods of low exposure to UV-B irradiation from sunlight serum or plasma 25OHD concentration can be used as a biomarker of oral vitamin D intake.

A 25OHD concentration of 25 or 30 nmol/l represents a cut-of below which the risk of clinical vitamin D deficiency increases, manifested as nutritional rickets in children and osteomalacia in adults. Most expert agencies consider a 25OHD concentration of 50 nmol/l to reflect a sufficient vitamin D status concerning bone health.

In setting DRVs, different approaches have been used to analyse the dose-response relationship between vitamin D intake and 25OHD concentration. In this Appendix the different approaches are described.

Institute of Medicine

Regression analyses of the relationship between serum 25OHD concentrations and log-transformed total intake of vitamin D were undertaken by Institute of Medicine (IOM) in 2011 [1]. In this approach total vitamin D intake from diet and supplements are included in the analyses.

The analyses included results from randomized controlled (RCT) intervention trials with the following inclusion criteria:

- using total vitamin D intake (from food and supplements)
- carried out at latitudes above 49.5°N in Europe or Antarctica
- conducted during winter with limited sun exposure

In the first step in the dose-response analysis the analyses were performed separately on:

- children and adolescents (1-18 years), based on 3 studies
- young and middle-aged adults (19-60 years), based on 3 studies
- older adults (>61 years), based on 5 studies

In total 11 RCTs were included.

The response of serum 25OHD concentration to vitamin D intake was found to be non-linear, the rise being steeper below 25 µg/day and flattening above 25 µg/day. Regression analysis (n = 1376), was preceded by a log transformation of the total vitamin D intake data, since the log transformation was the best curvilinear fit. A significant association between dose and serum 25OHD levels was found. Baseline 25OHD concentrations and age was found to have no significant effect in the response of 25OHD concentration to total vitamin D intake.

Given the lack of an age effect, the second step included a single, combined regression analysis with study as a random effect. Besides, an analysis for latitudes 40–49°N during winter found that achieved 25OHD concentration was around 24% higher for a given total intake compared to that achieved in the previous analysis at higher latitudes, besides it explained less variability than the model at higher latitudes. Therefore, IOM decided to focus on latitude above 49.5°N to set DRVs for vitamin D.

IOM selected the estimated intakes needed to reach the targeted serum 25OHD values of 40 and 50 nmol/l. Using the dose-response curve and the lower limit of 95% CI, it was found that at a total intake of 10 μg/day, the predicted mean 25OHD concentration was 59 nmol/l in children and adolescents, young and middle-aged adults, and older adults with a lower limit of the CI of about 52 nmol/l. With the same approach it was found that at a total intake of 15 μg/day, the predicted mean 25OHD concentration was 63 nmol/l with a lower limit of the CI of 56 nmol/l. These results were used to set EARlike and RDAlike for vitamin D, respectively, which take into account the uncertainties in these analyses.

Nordic Council of Ministers

Regression analyses estimating the overall dose-response relationship between intake and serum 25OHD concentrations were undertaken by the Nordic Council of Ministers (NCM) in 2014 [2].

The analyses included results from RCTs with the following inclusion criteria:

- using vitamin D supplements at various levels
- carried out at latitudes covering the Nordic region or just south of (latitudes 50°-61° N)
- conducted during winter with limited sun exposure
- administered doses of vitamin D ≤ 30 μg/day.

The analyses were performed separately on:

- children and adults (up to about 60 years of age), based on 7 RCT studies
- older adults and elderly (above 65 years of age), based on 4 studies.

In total of 10 different RCTs conducted in the Nordic countries were included. However, due to the limited number of RCTs with elderly above 65 y, a repeated cross-sectional study with 8 sub-groups was also included.

The relationship between vitamin D supplementation intake and serum 25OHD concentrations (log transformed) was analysed using fitted line plot. The outcome was displayed by graphs.

Using the lower 95% confidence interval in the graph, an intake of about 10 μg/d was considered to be sufficient to ensure a serum 25OHD concentration about 50 nmol/l in the majority of the population. The AR was set as the intake maintaining a mean serum 25OHD concentration in half of the subjects of about 50 nmol/l. Using the lower 95% confidence interval in the graph, intakes sufficient to ensure a serum 25OHD concentration in the majority of the population were estimated, and used to set RI.

Scientific Advisory Committee on Nutrition

Meta-regression analyses and modelling of data on dose-response between vitamin D intake and 25OHD concentration from vitamin D RCTs in adults and adolescent girls were undertaken by Scientific Advisory Committee on Nutrition (SACN) in 2016 [3] by use of two different approaches: A meta-regression approach based on group means and an approach using data from individual participant data in vitamin D RCTs. The relationship between vitamin D intake and serum 25OHD concentration was explored during winter in various age-groups.

In the meta-regression approach, group mean or median serum 25OHD data from the intervention arms from selected RCTs were used together with an estimate of total vitamin D intake (from foods and supplements). The resulting regression line and its 95% confidence intervals were used to estimate average requirements (EAR) at group level.

In the approach using individual participant data from three vitamin D RCTs covering three different age groups [4–6], inter-individual variability estimates were obtained with the possibility to estimate the distribution of individual intakes required to achieve what SACN considered estimations of the distribution of intakes required to achieve specified serum 25OHD concentrations at the individual level. The mean serum 25OHD concentration was modelled as a linear function of vitamin D intake and 95% confidence intervals were calculated.

The inclusion criteria for the RCTs were that studies were conducted during winter with limited sun exposure.

The modelling exercise estimated average daily vitamin D intake required to maintain serum 25OHD concentration ≥25 nmol/l in winter by 97.5% of the population based on different analytical methods to measure 25OHD concentration.

Applying a precautionary basis, a serum 25OHD concentration of 25 nmol/l was selected as the target concentration to protect all individuals from the risk of poor musculoskeletal health. This concentration was considered to be a 'population protective level'; i.e., the concentration that 97.5% of individuals in the UK should be above, throughout the year, in terms of protecting musculoskeletal health.

The next step in estimating DRVs for vitamin D was translation of the serum 25OHD concentration of 25 nmol/l into a dietary intake value that represents the RNI for vitamin D; i.e., the average daily vitamin D intake that would be sufficient to maintain serum 25OHD concentration ≥ 25 nmol/l in 97.5% of individuals in the UK. The average vitamin D intake refers to the mean or average intake over the long term and takes account of day-to-day variations in vitamin D intake. The RNI was estimated by modelling data from individual RCTs in adults (men & women, 20-40 y and 64+ y) and adolescent girls (11 y). The RCTs had been conducted in winter so that dermal production of vitamin D was minimal.

The modelling exercise of individual data indicated that the estimated average daily vitamin D intake needed to maintain serum 25OHD concentration ≥ 25 nmol/l in winter by 97.5% of individuals in the population was 12 μg/d based on serum 25OHD analysis by LC-tandem MS or 9 μg/d based on analysis of the same sera by immunoassay. Since the target threshold serum 25OHD concentration of 25 nmol/l was based on studies which had used a range of different assays to measure serum 25OHD concentration, the RNI (safe level) was set between these 2 estimates, at 10 μg/d.

The work with Individual participant data (IPD) meta-regression analysis were continued years later among light-skin participants in RCTs with vitamin D fortified foods [7] and among dark-skinned participants in RCTs with supplements or vitamin D fortified foods [8]. One-stage IPD meta-analysis was performed in both studies.

The analyses included results from randomized controlled (RCT) intervention trials. The inclusion criteria were [7,8]:

- Age ≥2 years
- Latitudes ≥40°N
- Endpoint in winter
- Duration ≥6 weeks
- In [7]: Light-skinned participants (Fitzpatrick skin types V or VI was excluded)
- In [8]: Dark-skinned participants of Black or South Asian descent

In total 11 [7] and 10 [8] (6 studies on Blacks, 3 in South Asians and 1 mixed group dark-skinned) RCTs were included.

In [7] a log-log model was judged to be the best fit, and the analysis included an unadjusted model and a model adjusted for covariates (mean values for baseline 25OHD, age and BMI). In [8] a linear mixed regression model with vitamin D intake as the independent variable (a fixed effect) and square root-transformed 25OHD concentration as the dependent variable was used, and the analysis included an unadjusted model, as well as a model adjusted for covariates (mean values for baseline 25OHD, age and BMI). In both studies, the results are presented as vitamin D intake estimates required to maintain serum 25OHD above 25, 30 and 50 nmol/l.

European Food Safety Authority

Meta-analyses, meta-regression analyses and dose-response models estimating the dose-response relationship between total vitamin D intake and serum/plasma 25OHD concentration were undertaken by the European Food Safety Authority (EFSA) in 2016 [9]. As preparatory work, a comprehensive literature review was performed to identify and summarise studies that could be used to assess the dose-response relationship [10]. Data from prospective observational studies were analysed but not included in the meta-regression dose-response model, which was based on RCTs.

Meta-analyses:

- Inclusion criteria were:
    - Young and older adults as well as children
    - Vitamin D3 only
    - Summary data available or possible to estimate/impute
    - Dose of supplemented vitamin D ≤ 100 μg/day

After applying the inclusion criteria to the 57 RCTs from the review, the final data set included 83 arms from 35 RCTs, 4 of the RCTs (9 arms) were carried out on children. Absolute achieved mean values and mean differences were analysed to check for the inclusion of trials/arms in the dose-response analysis and to complement the results from the dose-response models. Mean differences in achieved mean 25OHD concentration were calculated for 30 RCTs (5 did not have control group).

Meta-regression and dose-response models:

The final data set included 83 arms from 35 RCTs, 4 of the RCTs (9 arms) were carried out on children. Weighted linear meta-regression analyses of total vitamin intake (habitual plus supplemental intake) vs. mean achieved serum or plasma 25OHD concentration measured at the end of the winter sampling points

- Two model constructs were explored:
    - Non-linear (log linear): total vitamin D intake was transformed to the natural log (ln) before regression analysis
    - Linear: mean achieved 25OHD concentrations were regressed to total vitamin D intake on its original scale (for doses > 35 μg/day)
- The log linear model was retained to better describe the dose-response shape and to be able to include results from higher dose trials.
- The models were adjusted and a detailed description of the regression analysis including handling of model fitting, baseline measurements, inter-individual variability on dietary intake, model checking diagnostics and influencing factors is described in EFSA 2016.
- Interpretation of the intervals drawn around the meta-regression lines:
    - Confidence Intervals (CI): illustrates the uncertainty about the position of the line, i.e. across-study conditional means.
    - Prediction Intervals (PI): illustrates the uncertainty about the true mean that would be predicted in a future study, i.e. the dispersion of the true effects around the mean.

The same equations were used both to predict the achieved mean serum 25OHD concentrations conditional to total vitamin D intakes of 5, 10, 15, 20, 50, 100 μg/day and to estimate the total vitamin D intakes that would achieve serum 25OHD concentrations of 50, 40, 30, 25 nmol/l and applied to all and to adults and children separately, respectively.

EFSA concludes that based on the available data, ARs and PRIs for vitamin D cannot be derived, and therefore defines AIs for all population groups and that the dietary intake of vitamin D estimated to achieve a serum 25OHD concentration of 50 nmol/l should be used for all age and sex groups.

Setting the AI was based on the prediction interval in the adjusted model of the meta-regression analysis of serum 25OHD concentration according to total vitamin D intake (natural log of the sum of habitual diet, and fortified foods and supplements using vitamin D3).

Summary

The different approaches that were used by different agencies [1–3,9] to define the relationship between vitamin D intake and serum 25OHD concentrations included meta-regression or regression analyses based at group mean (aggregate data) level. Also, an approach based on meta-regression analyses based on individual participant data (IPD) has been applied [3]. All approaches applied data from RCT studies conducted during the wintertime with no or little UV expose.

Using mean group level data for dose-response relationship follows the conventional approach used by IOM and NCM [1,2] in setting DRVs, using the mean findings from a group of individuals in a (meta)-regression line to estimate the AR value to achieve a specific and pre-defined serum 25OH concentration and its lower 95% confidence intervals to estimate the RI which theoretically covers the majority – or 97.5% of the population - at group level to reach a certain pre-defined threshold. This threshold is set based on separate analysis on the relationship between 25OHD concentration and health outcomes, which is also based on mean group level. The advantage of this approach is that it follows the conventional approach to set DRVs (AR and RI) [11] at group level, which is in accordance with the approach used setting the thresholds of sufficiency in the relationship between status and health outcomes. However, this group mean level does not take into account the inter-individual variability.

SACN used the dose-response relationship data to identify a safe level or RNI of vitamin D intake to maintain a 25OHD concentration above 25 nmol/l for 97.5% of the population. EFSA concluded that the available evidence does not allow the setting of ARs and PRIs for vitamin D, and therefore defines adequate intake (AI) for all population groups and that the dietary intake of vitamin D estimated to achieve a serum 25OHD concentration of 50 nmol/l should be used.

Using individual data from RCTs studying the dose-response relationship has the advantage that it takes into account the inter-individual variability. The available data from the IPD-papers [7,8] would allow the possibility to identify the intakes of vitamin D needed at the individual level to reach a certain threshold for 25OHD concentration. However, this approach requires that the threshold for sufficiency for the relationship between 25OHD concentration and health outcomes, which is up to now set based on mean group levels, is reconsidered.

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