Carbohydrate intake for adults and children

WHO guideline

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WHO Steering Group: Ayoub Al-Jawaldeh, Anshu Banerjee, Hana Bekele, Fabio Da Silva Gomes, Padmini Angela De Silva, Jason Montez, Chizuru Nishida, Gojka Roglic, Juliawati Untoro, Kremlin Wickramasinghe

Guideline Development Group (WHO Nutrition Guidance Expert Advisory Group – Subgroup on Diet and Health): Hayder Al-Domi (University of Jordan, Jordan), John H Cummings (University of Dundee, United Kingdom of Great Britain and Northern Ireland), Ibrahim Elmadfa (University of Vienna, Austria), Lee Hooper (University of East Anglia, United Kingdom of Great Britain and Northern Ireland), Shiriki Kumanyika (University of Pennsylvania, United States of America), Mary L'Abbé (University of Toronto, Canada), Pulani Lanerolle (University of Colombo, Sri Lanka), Duo Li (Zhejiang University, China), Jim Mann (University of Otago, New Zealand), Joerg Meerpohl (University of Freiburg, Germany), Carlos Monteiro (University of Sao Paulo, Brazil), Laetitia Ouedraogo Nikièma (Institut de Recherche en Sciences de la Santé, Burkina Faso), Harshpal Singh Sachdev (Sitaram Bhartia Institute of Science and Research, India), Barbara Schneeman (University of California, Davis, United States of America), Murray Skeaff (University of Otago, New Zealand), Bruno Fokas Sunguya (Muhimbili University of Health and Allied Sciences, United Republic of Tanzania), HH (Esté) Vorster (North-West University, South Africa)

External peer review group: Charlotte Evans (University of Leeds, United Kingdom of Great Britain and Northern Ireland), Frank B Hu (Harvard University, United States of America), Aamos Laar (University of Ghana, Ghana), Reza Malekzadeh (Tehran University of Medical Sciences, Iran [Islamic Republic of]), Yang Yuexin (Chinese Center for Disease Control and Prevention, China)

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Abbreviations and acronyms

BMI	body mass index
CI	confidence interval
CVDs	cardiovascular diseases
eLENA	WHO e-Library of Evidence for Nutrition Actions
FAO	Food and Agriculture Organization of the United Nations
GINA	WHO Global database on the Implementation of Nutrition Action
GRADE	Grading of Recommendations Assessment, Development and Evaluation
kcal	kilocalorie
LDL	low-density lipoprotein
LMIC	low- and middle-income country
MD	mean difference
NCD	noncommunicable disease
NUGAG	WHO Nutrition Guidance Expert Advisory Group
PICO	population, intervention, comparator and outcome
RCT	randomized controlled trial
RR	relative risk
WHO	World Health Organization

Executive summary

Background

Non-communicable diseases (NCDs) are the leading cause of mortality in the world. Modifiable risk factors such as unhealthy diets, physical inactivity, tobacco use and harmful use of alcohol are major risk factors. Obesity is also a risk factor for diet-related NCDs and is linked to millions of deaths globally. Among other dietary factors, the "quality" of carbohydrates in the diet (e.g. proportion of sugars, nature of polysaccharides, amount of dietary fibre) has been extensively explored as a potential modulator of NCD and obesity risk.

The World Health Organization (WHO) has previously issued updated guidance on free sugars intake, but updated guidance is needed on carbohydrate quality, including dietary fibre intake. It was therefore considered important to review the evidence in a systematic manner, and update current WHO guidance on carbohydrate intake through the WHO guideline development process.

Objective, scope and methods

The objective of this guideline is to provide guidance on carbohydrate intake, including intake of dietary fibre and healthy food sources of carbohydrates, to be used by policy-makers, programme managers, health professionals and other stakeholders to promote healthy diets. The guideline was developed following the WHO guideline development process, as outlined in the *WHO handbook for guideline development*. This process includes a review of systematically gathered evidence by an international, multidisciplinary group of experts; assessment of the quality of that evidence via the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework; and consideration of additional, potentially mitigating factors[1] when translating the evidence into recommendations. The guidance in this guideline replaces previous WHO guidance on carbohydrate intake, including that from the 1989 WHO Study Group on Diet, Nutrition and the Prevention of Chronic Diseases and the 2002 Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases.

The evidence

Evidence from systematic reviews of randomized controlled trials (RCTs) and prospective observational studies conducted in adults found that higher dietary fibre intake may lead to small reductions in various measures of body fatness (*moderate* to *high* certainty evidence), and is associated with reduced risk of developing and/or dying from cardiovascular diseases (CVDs), type 2 diabetes and cancer (all *moderate* certainty evidence). Higher consumption of whole grains, vegetables, fruits and pulses is also associated with reduced risk of developing and/or dying from CVDs (*moderate* certainty evidence). Higher consumption of whole grains, vegetables and fruits is further associated with reduced risk of developing and/or dying from cancer (*moderate* certainty evidence). Higher consumption of whole grains (*moderate* certainty evidence) and pulses (*very low* certainty evidence) is associated with reduced risk of developing type 2 diabetes. Although evidence from studies assessing effects or associations of low glycaemic index and/ or low glycaemic load foods and diets was reviewed, little consistency was seen in benefit on mortality or NCDs from observational studies (*very low* to *moderate* certainty evidence), and little to no improvement

[1] These include desirable and undesirable effects of the intervention, priority of the problem that the recommendations address, values and preferences related to the recommendations in different settings, the cost of the options available to public health officials and programme managers in different settings, feasibility and acceptability of implementing the recommendations in different settings, and the potential impact on equity and human rights.

in cardiometabolic risk factors was seen in RCTs (*very low* to *high* certainty evidence). Direct evidence for health effects of dietary fibre, whole grains, vegetables, fruits and pulses in children was limited but was consistent with results observed for adults.

Recommendations and supporting information

All recommendations should be considered in the context of other WHO guidelines on healthy diets, including those on sugars, sodium, potassium, total fat, saturated fatty acids, *trans*-fatty acids, polyunsaturated fatty acids and non-sugar sweeteners.

WHO recommendations

1. WHO recommends that carbohydrate intake should come primarily from whole grains, vegetables, fruits and pulses (*strong recommendation*, relevant for all individuals 2 years of age and older).
2. In adults, WHO recommends an intake of at least 400 g of vegetables and fruits per day (*strong recommendation*).
3. In children and adolescents, WHO suggests the following intakes of vegetables and fruits (*conditional recommendation*):
   - 2–5 years old, at least 250 g per day
   - 6–9 years old, at least 350 g per day
   - 10 years or older, at least 400 g per day.
4. In adults, WHO recommends an intake of at least 25 g per day of naturally occurring dietary fibre as consumed in foods (*strong recommendation*).
5. In children and adolescents, WHO suggests the following intakes of naturally occurring dietary fibre as consumed in foods (*conditional recommendation*):
   - 2–5 years old, at least 15 g per day
   - 6–9 years old, at least 21 g per day
   - 10 years or older, at least 25 g per day.

Rationale for recommendation 1

- Recommendation 1 is based on evidence from seven systematic reviews that assessed the effects of higher compared with lower intakes of whole grains, vegetables and fruits, or pulses. These systematic reviews found that higher intakes of these foods reduced the risk of all-cause mortality and several NCDs. The overall certainty in the evidence for recommendation 1 was assessed as *moderate*.

  For adults, findings supporting the recommendation include the following.

  - Evidence of *moderate* certainty overall came from a systematic review of prospective observational studies demonstrating associations between higher intakes of whole grains and reduced risk of all-cause mortality, CVDs, coronary heart disease, type 2 diabetes and colorectal cancer.
  - Evidence of *moderate* certainty overall came from a systematic review of prospective observational studies demonstrating associations between higher intakes of vegetables and fruits and reduced risk of all-cause mortality, CVDs, stroke, coronary heart disease, type 2 diabetes and cancer.
  - Evidence of *moderate* certainty overall came from a systematic review of prospective observational studies demonstrating associations between higher intakes of pulses and reduced risk of CVDs, coronary heart disease and type 2 diabetes.

For children and adolescents, findings supporting the recommendation include the following.

- Direct evidence for health effects of consumption of whole grains, vegetables, fruits and pulses by children and adolescents is limited. Because the health benefits of consuming these foods observed in adults are expected to also be relevant for children and adolescents, and the benefits observed in adulthood are likely to begin accruing in childhood, the recommendation as it pertains to children and adolescents is based on extrapolation of adult data without downgrading the strength of the recommendation. Limited evidence from a systematic review of prospective observational studies of intake of dietary fibre, whole grains, vegetables, fruits and pulses by children and adolescents is consistent with that observed for adults. Results from studies included in this review were not amenable to meta-analysis. Although several studies suggested benefit from consumption of whole grains, vegetables, fruits or pulses in terms of body weight, blood lipids and glycaemic control, results from some studies suggested no effect, and results from a very small number of studies suggested increased body weight with increased vegetable intake (*very low* certainty evidence for all outcomes).

- Recommendation 1 was assessed as *strong* because evidence for benefit was observed directly for a number of critical health outcomes, and indirectly in the results for dietary fibre; the main dietary sources of dietary fibre were whole grains, vegetables, fruits and pulses. Although assessed in adults, this evidence was also considered to be highly relevant for children and adolescents. With the exception of a small increase in risk of prostate cancer with higher whole grain intake (*low* certainty evidence), no undesirable effects were identified, and no mitigating factors were identified that would argue against including whole grains, vegetables, fruits and pulses as the primary sources of carbohydrates in the diet.

Rationale for recommendations 2 and 3

- Recommendations 2 and 3 are based on evidence of *moderate* certainty overall from a systematic review of prospective observational studies conducted in adults that assessed the health effects of higher compared with lower intake of vegetables and fruits. The systematic review found that higher intakes of vegetables and fruits were associated with reduced risk of all-cause mortality, CVDs, stroke, coronary heart disease, type 2 diabetes and cancer.

- The threshold of at least 400 g of vegetables and fruits per day was selected because a dose–response relationship was observed in the observational studies: risk for all outcomes except cancer decreased with intakes of vegetables and fruits up to 800 g per day, and the greater the intake, the greater the benefit. Evidence for intakes more than 800 g per day was limited. Although the greatest benefit was observed at intakes of 800 g per day, the steepest reduction in risk was up to 400 g per day, after which the effect levelled off for some outcomes. Furthermore, intakes of more than 400 g per day may be difficult to achieve in many settings. The threshold of 400 g per day was therefore selected as a feasible minimal level that would provide significant health benefits.

- Because evidence from studies conducted in children and adolescents is insufficient to derive quantitative recommendations on intakes for children, and the observed health benefits of consuming vegetables and fruits in studies of adults are expected to be relevant for all age groups, intakes for children and adolescents are extrapolated from values for adults, based on the different levels of energy intake at different stages of childhood and adolescence. Limited evidence from a systematic review of prospective observational studies in children and adolescents suggested that higher vegetable and fruit intakes are generally associated with improvements in body weight, blood lipids and glycaemic control (*very low* certainty evidence for all outcomes), with no evidence of undesirable effects. This further supports the recommended levels of vegetable and fruit intake for children.

- Recommendation 2 was assessed as *strong* because evidence for benefit was observed for a number of critical health outcomes across a wide range of intakes. The minimal value selected for vegetable and fruit intake was both associated with a significant benefit and an amount that many should be able to achieve. No undesirable effects were identified with consuming 400 g per day or more of vegetables and fruits, and no mitigating factors were identified that would argue against consuming vegetables and fruits at this level.

- Recommendation 3 was assessed as *conditional* because, although the evidence observed for benefit in adults is robust and is expected to also be relevant for children and adolescents, the values were calculated based on extrapolation of adult values. Because the values are based both on extrapolated data and mean reference energy expenditures, a conservative approach was taken, leading to a *conditional* recommendation.

Rationale for recommendations 4 and 5

- Recommendations 4 and 5 are based on evidence of *moderate* certainty overall from a systematic review of randomized controlled trials and prospective observational studies conducted in adults that assessed higher compared with lower intakes of dietary fibre. This systematic review found that higher intakes of dietary fibre led to favourable improvements in obesity and NCDs risk factors, and were associated with reduced risk of all-cause mortality, CVDs, stroke, coronary heart disease, type 2 diabetes and cancer.
- The threshold of at least 25 g per day was selected based on the dose–response relationship seen in the observational studies between dietary fibre intake and reduced risk for several NCD and mortality outcomes. This relationship was observed at intakes up to 40 g per day, but the number of studies reporting data began to taper off at 30 g or more per day. Evidence for intakes more than 40 g per day was scarce. In studies comparing individuals with the lowest fibre intakes with those consuming discrete ranges of increasing intake, the range that demonstrated greatest benefit for the largest number of health outcomes was 25–29 g per day.
- Because evidence from studies conducted in children and adolescents is insufficient to derive quantitative recommendations on intakes for children, and the observed health benefits of consuming dietary fibre in studies of adults are expected to be relevant for all age groups, intakes for children and adolescents are extrapolated from values for adults, based on the different levels of energy intake and energy expenditure at different stages of childhood and adolescence. Limited evidence from a systematic review of prospective observational studies in children and adolescents suggested that higher dietary fibre intake is generally associated with improvements in body weight, blood lipids and glycaemic control (*very low* certainty evidence for all outcomes), with no evidence of undesirable effects. This further supports the recommended levels of dietary fibre intake for children.
- Recommendation 4 was assessed as *strong* because evidence for benefit was observed for a number of critical health outcomes across a wide range of intakes. The minimal value selected for dietary fibre intake was both associated with a significant benefit and an amount that many should be able to achieve. With the exception of increased risk of endometrial cancer with higher intakes of dietary fibre (*very low* certainty evidence), no undesirable effects were identified with dietary fibre intakes of at least 25 g per day, and no mitigating factors were identified that would argue against dietary fibre intake at this level.
- Recommendation 5 was assessed as *conditional* because, although the evidence observed for benefit in adults is robust and is expected to also be relevant for children and adolescents, the values were calculated based on extrapolation of adult values. Because the values are based both on extrapolated data and mean reference energy expenditures, a conservative approach was taken, leading to a *conditional* recommendation.

Remarks

- One of the original aims of updating the guidance on carbohydrate intake was to provide guidance on carbohydrate quality. Having considered the available evidence relating to food sources of carbohydrate and dietary fibre, starch digestibility and glycaemic response, as measured by glycaemic index and glycaemic load, the WHO Nutrition Guidance Expert Advisory Group (NUGAG) Subgroup on Diet and Health[1] concluded that providing guidance on dietary fibre and food sources of carbohydrate with consistently demonstrated benefit in terms of important health outcomes was the most effective means of addressing carbohydrate quality.

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[1] The guideline development group for this guideline.

- This guideline provides guidance on dietary fibre intake, and also updates the prior WHO recommendation on intakes of vegetables and fruits. The scope of this guideline does not include an update to the previously published range of carbohydrate intake as a percentage of total energy intake, which was determined largely by the energy intake remaining after defining amounts of dietary fat and protein intake. Consequently, this guideline does not include recommendations on the amount of carbohydrate that should be consumed, and carbohydrate intake should continue to be based on recommended levels of protein and fat intake. Results from a 2018 meta-analysis suggest that a range of total carbohydrate intake appears to be compatible with a healthy diet. Intakes of approximately 40–70% of total energy intake as carbohydrate are associated with reduced risk of mortality compared with lower (<40%) or higher (>70%) intakes. This is largely consistent with the range of carbohydrate intakes resulting from current WHO guidance on protein intake and updated guidance on total fat intake.
- In addition to the benefits of dietary fibre from whole grains, vegetables, fruits and pulses, these foods may also contain other compounds that have been associated with health benefits.
- The recommendations included in this guideline cover all types of whole grains, vegetables, fruits and pulses, with caveats relating to processing and preparation, as noted in the following remarks. A variety of such foods should be consumed, where possible.
- Although fresh vegetables and fruits are a good choice when and where they are available, in some settings they present a significant risk for foodborne illness. In areas where risk of foodborne illness is high, selecting vegetables and fruits with hard skins or peels that can be removed, thoroughly washing them with potable water, or consuming cooked or canned varieties can reduce the risk of illness.
- The recommendations covering vegetable and fruit intake are not limited to fresh vegetables and fruits. Evidence from the systematic reviews suggests health benefits from a wide range of vegetables and fruits, including those that are fresh, cooked, frozen or canned. However, an increased risk of all-cause mortality and CVDs was observed for tinned fruits in a small number of studies. Specific evidence for dried fruits and fruit juices in the systematic reviews is very limited, and results are inconsistent; however, both can be significant sources of sugars, as can fruit concentrates and fruit sugars (i.e. sugars and syrups obtained from whole fruits). All should therefore be consumed in accordance with WHO recommendations on free sugars intake. Similarly, although no specific evidence was identified for canned vegetables, some canned vegetables contain added sodium and should therefore be consumed in accordance with WHO recommendations on sodium intake.
- The method of preparation and the level of processing should be considered when consuming whole grains, vegetables, fruits and pulses, and should be compatible with other WHO macronutrient recommendations. For example, frying and addition of sauces or condiments can significantly increase the amount of fat, sugars or salt. Therefore, fresh foods, or foods that are minimally processed or modified beyond the treatment necessary to ensure edibility, without added fat, sugars or salt, are preferred.
- Whole grains contain the naturally occurring components of the kernel (i.e. bran, germ and endosperm). Some processed foods are labelled whole grain if these three components of the grain are included, regardless of the extent to which the grains have been processed, and highly processed products labelled as whole grain are becoming increasingly available (e.g. products containing flour from milled whole grains with added fat, sugar or salt). Because there is evidence to suggest that the naturally occurring structure of intact whole grains contributes to its observed health effects, minimal processing of whole grains beyond that necessary to ensure edibility is preferred.
- The source of dietary fibre in the prospective cohort studies included in the systematic reviews, upon which recommendations 4 and 5 are largely based, is fibre naturally occurring in foods and not extracted or synthetic fibre added to foods or consumed on its own (e.g. fibre supplements, capsules, powders). Although there was limited evidence for a reduction in total cholesterol with use of extracted or synthetic fibre, further research on disease outcomes associated with extracted or synthetic fibre is needed before conclusions on potential health benefits can be drawn. Therefore, the recommendations specifically cover dietary fibre that occurs naturally in foods.

- Plant-based foods – including whole grains, vegetables, fruits and pulses – contain some compounds that have been shown to inhibit absorption of certain nutrients, most notably minerals such as iron, zinc and calcium. These “antinutrients” include lectins, oxalates, phytates, goitrogens, phytoestrogens, tannins, saponins and glucosinolates, and many of these have also been shown to have health benefits unrelated to their impact on nutrient absorption. The extent to which an impact on nutrient absorption occurs varies from person to person. The inhibitory effect is generally observed only at very high intakes and in individuals with existing nutritional deficiencies; in the context of adequate, diverse diets, it is generally not significant. In addition, some simple methods of preparation, including soaking and heating, and more advanced methods, including germination and fermentation, appear to reduce the inhibitory potential. Therefore, most people can generally consume whole grains, vegetables, fruits and pulses with little to no risk. Those with nutritional deficiencies or at high risk for nutritional deficiencies – particularly undernourished children and those who rely heavily on foods containing these compounds as staple foods without much additional diversity in the diet – may need to adopt behaviours that minimize the ability of these compounds to inhibit absorption of other nutrients.
- These recommendations do not cover children under 2 years of age. However, whole grains, vegetables, fruits and pulses can be healthy sources of carbohydrates in complementary foods consumed by children from 6 months to 2 years of age, and are strongly preferred to foods containing free sugars.[1]

[1] WHO recommends that infants should be exclusively breastfed for the first 6 months of life to achieve optimal growth, development and health. Thereafter, to meet their evolving nutritional requirements, infants should receive nutritionally adequate and safe complementary foods, while continuing to breastfeed for up to 2 years or beyond.

Introduction

Background

Noncommunicable diseases (NCDs) are the world's leading cause of death, responsible for an estimated 41 million of the 55 million deaths in 2019 *(1)*. Nearly half of these deaths were premature (i.e. in people aged less than 70 years) and occurred in low- and middle-income countries (LMICs). Obesity is a risk factor for diet-related NCDs and is linked to millions of deaths globally *(2, 3)*. In 2016, more than 1.9 billion adults aged 18 years and older were overweight *(4)* and, of these, more than 600 million were obese. The spotlight on prevention and management of NCDs and obesity has intensified recently as a result of the COVID-19 pandemic, as there is increasing recognition that those with obesity or certain NCDs are at increased risk of adverse outcomes associated with COVID-19 *(5–9)*. Modifiable risk factors such as unhealthy diets, physical inactivity, tobacco use and harmful use of alcohol are major risk factors for NCDs and obesity. The quality of carbohydrates in the diet has been extensively explored as a potential modulator of NCD and obesity risk.

Carbohydrates are found in a wide variety of primarily plant-based foods and are the principal source of energy (i.e. calories) in the diets of many people. Metabolism of carbohydrates produces glucose, which is the primary source of metabolic "fuel" for the brain, and other organs and tissues of the body. Carbohydrates can be grouped in many different ways and referred to using a variety of terms. At the most basic level, carbohydrates comprise monosaccharide building blocks and can be categorized based on the degree of polymerization (i.e. number of connected monosaccharides) as either sugars (mono- and disaccharides), oligosaccharides (short-chain carbohydrates) or polysaccharides (i.e. starch) *(10)*.

The concept of carbohydrate "quality" refers to the nature and composition of carbohydrates in a food or in the diet, including the proportion of sugars, how quickly polysaccharides are metabolized and release glucose into the body (i.e. digestibility), and the amount of dietary fibre *(11–13)*. Carbohydrates that are slowly digested in the small intestine or pass through undigested are generally considered "high quality", and rapidly digested carbohydrates such as sugars are considered "low quality". Dietary fibre, in particular, is an important element of carbohydrate quality. It can be defined in various ways, although virtually all definitions share the concept that dietary fibre is resistant to digestion by enzymes in the small intestine of humans *(10)*.[1] Consumption of low-quality carbohydrates is often associated with poor overall dietary quality and may have a negative health impact, whereas consumption of high-quality carbohydrates is often associated with high overall dietary quality and has been shown to have a positive health impact *(14)*. A high intake of free sugars, for example, is associated with increased risk of obesity and diet-related NCDs. Consequently, the World Health Organization (WHO) has previously issued guidance on limiting intake of free sugars *(15)*. Conversely, high intakes of dietary fibre and consumption of foods generally containing high-quality carbohydrates – such as whole grains, fruits, vegetables and pulses – have been shown to broadly improve health *(16–20)*.

The inclusion of dietary fibre and high-quality carbohydrates in the diet from whole grains, vegetables, fruits and pulses has long been recommended to improve and maintain cardiometabolic and overall health. Although current intakes of these nutrients and foods are highly variable across and within populations in different settings, they are generally low at the global level relative to recommended intakes in this guideline, and other national reference values *(21–28)*. Low vegetable and fruit intake in LMICs is of particular concern: recent estimates suggest that less than 20–30% of individuals in many LMICs meet WHO recommendations for vegetable and fruit consumption *(29, 30)*.

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[1] Information on sources of dietary fibre for the purposes of this guideline can be found in the section *Recommendations and supporting information*.

Rationale

Following the work of the 1989 WHO Study Group on Diet, Nutrition and the Prevention of Chronic Diseases *(31)*, the 2002 Joint WHO/Food and Agriculture Organization of the United Nations (FAO) Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases updated guidance on carbohydrate intake as part of the guidance on population nutrient intake goals for the prevention of NCDs *(32)*. WHO guidance on free sugars intake was further updated and released in 2014 *(15)*. The guidance on carbohydrate intake from the 2002 Joint WHO/FAO Expert Consultation includes a statement that dietary fibre should come from foods; however, the evidence available at the time was insufficient to support a recommended level of dietary fibre intake. Since the guidance was released, new evidence has become available that was expected to facilitate the setting of quantitative recommendations on dietary fibre, and offer an opportunity to re-evaluate the recommended level of vegetable and fruit consumption. In addition, the available evidence was expected to facilitate the development of guidance on carbohydrate quality. Therefore, it was considered important to review the evidence in a systematic manner, and update the WHO guidance on carbohydrate intake through the WHO guideline development process.

Scope

This guideline is part of the larger effort to update the population nutrient intake goals for the prevention of NCDs established by the 2002 Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases *(32)*. It is intended to complement other WHO guidance on healthy diets, particularly the WHO guideline on free sugars intake *(15)*. The recommendations in this guideline are intended for the general population of adults and children. Setting a recommended level of carbohydrate intake (i.e. the amount of carbohydrate that should be consumed as a percentage of overall energy intake) was not included in the updating of the guidance on carbohydrate intake because the amount of carbohydrate, as determined by the 2002 Joint WHO/FAO Expert Consultation, was based on the percentage of energy intake remaining after accounting for empirically determined total fat and protein intakes *(32)*. The guidance in this guideline replaces previous WHO guidance on carbohydrate intake, including that from the 1989 WHO Study Group on Diet, Nutrition and the Prevention of Chronic Diseases *(31)* and the 2002 Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases *(32)*.

Objective

The objective of this guideline is to provide evidence-informed guidance on carbohydrate intake.[1] The recommendations in this guideline can be used by policy-makers and programme managers to address various aspects of carbohydrate intake in their populations through a range of policy actions and public health interventions.

Updating the WHO recommendations on carbohydrate intake is an important element of WHO's efforts to implement the NCD agenda and achieve the "triple billion" targets set by the 13th General Programme of Work (2019–2023), including 1 billion more people enjoying better health and well-being. In addition, the recommendations and other elements of this guideline will support:

- implementation of the political declarations of the United Nations (UN) high-level meetings on the prevention and control of NCDs held in New York in September 2011 and 2018, and the outcome document of the high-level meeting of the UN General Assembly on NCDs (A/RES/68/300) held in New York in July 2014;
- implementation of the WHO Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013–2030, which was adopted by the 66th World Health Assembly held in May 2013 (the timeline was extended to 2030 at the 72nd World Health Assembly held in May 2019);

[1] One of the original aims of updating the guidance on carbohydrate intake was to provide guidance on carbohydrate quality. Having considered the available evidence relating to food sources of carbohydrate and dietary fibre, starch digestibility and glycaemic response, as measured by glycaemic index and glycaemic load, the WHO Nutrition Guidance Expert Advisory Group Subgroup on Diet and Health concluded that providing guidance on dietary fibre and food sources of carbohydrate with proven benefit in terms of important health outcomes was the most effective means of addressing carbohydrate quality.

- implementation of the recommendations of the high-level Commission on Ending Childhood Obesity established by the WHO Director-General in May 2014;
- Member States in implementing the commitments of the Rome Declaration on Nutrition and recommended actions in the Framework for Action, including a set of policy options and strategies to promote diversified, safe and healthy diets at all stages of life – these were adopted by the Second International Conference on Nutrition (ICN2) in 2014 and endorsed by the 136th Session of the WHO Executive Board held in January 2015 and the 68th World Health Assembly held in May 2015, which called on Member States to implement the commitments of the Rome Declaration across multiple sectors;
- achievement of the goals of the UN Decade of Action on Nutrition (2016–2025), declared by the UN General Assembly in April 2016, which include increased action at the national, regional and global levels to achieve the commitments of the Rome Declaration, through implementing policy options included in the Framework for Action and evidence-informed programme actions; and
- the 2030 Agenda on Sustainable Development and achieving the Sustainable Development Goals, particularly Goal 2 (Zero hunger) and Goal 3 (Good health and well-being).

Target audience

This guideline is intended for a wide audience involved in the development, design and implementation of policies and programmes in nutrition and public health. The end users for this guideline are thus:

- policy-makers at the national, local and other levels;
- managers and implementers of programmes relating to nutrition and NCD prevention;
- nongovernmental and other organizations, including professional societies, involved in managing and implementing programmes relating to nutrition and NCD prevention;
- health professionals in all settings;
- scientists and others involved in nutrition and NCD-related research;
- educators teaching nutrition and prevention of NCDs at all levels; and
- representatives of the food industry and related associations.

How this guideline was developed

This guideline was developed in accordance with the WHO evidence-informed process for guideline development outlined in the *WHO handbook for guideline development (33)*. Because of the complex nature of the guideline topic and the evolving evidence base, the guideline was developed over several meetings of the WHO Nutrition Guidance Expert Advisory Group (NUGAG) Subgroup on Diet and Health, beginning in 2016.[1]

Contributors to the development of this guideline

This guideline was developed by the WHO Department of Nutrition and Food Safety (formerly the Department of Nutrition for Health and Development). Several groups contributed to the development of this guideline, and additional feedback was received from interested stakeholders via public consultation, as described below.

WHO steering group

The work was guided by an internal steering group, which included technical staff from WHO with varied perspectives and an interest in the provision of scientific advice on healthy diets (**Annex 1**).

Guideline development group

The guideline development group – the NUGAG Subgroup on Diet and Health – was convened to support the development of this guideline (**Annex 2**). This group included experts who had previously participated in various WHO expert consultations or were members of WHO expert advisory panels, and others identified through open calls for experts. In forming the group, the WHO Secretariat took into consideration the need for expertise in multiple disciplinary areas, representation from all WHO regions and a balanced gender mix. Efforts were made to include subject matter experts (e.g. in nutrition, epidemiology, paediatrics, physiology); experts in systematic review, programme evaluation and Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodologies; and representatives of potential stakeholders (e.g. programme managers, policy advisers, other health professionals involved in the healthcare process). Professor Shiriki Kumanyika served as the chair at the meetings of the NUGAG Subgroup on Diet and Health. The names, institutional affiliations and summary background information of the members of the NUGAG Subgroup on Diet and Health are available on the WHO website,[1] along with information on each meeting of the group.

External peer review group

External experts with diverse perspectives and backgrounds relevant to the topic of this guideline were invited to review the draft guideline to identify any factual errors, and comment on the clarity of the language, contextual issues and implications for implementation (**Annex 3**).

Systematic review teams

Systematic review teams with expertise in both systematic review methodologies and the subject matter were identified.

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[1] For a complete list of meetings and information on members of the NUGAG Subgroup on Diet and Health, see https://www.who.int/groups/nutrition-guidance-expert-advisory-group-(nugag)/diet-and-health.

- A team from Otago University in New Zealand and the University of Dundee in Scotland, consisting of Andrew Reynolds, Jim Mann, John Cummings, Nicola Winter, Evelyn Mete and Lisa Te Morenga, completed a systematic review on carbohydrate intake and risk of NCDs in adults as assessed in randomized controlled trials (RCTs) and prospective observational studies, and in children as assessed in RCTs *(34)*.
- A team from Otago University in New Zealand and WHO, consisting of Andrew Reynolds, Huyen Tran Diep Pham, Jason Montez and Jim Mann, completed a systematic review on carbohydrate intake and prioritized health outcomes in children as assessed in prospective observational studies *(35)*.
- A team based at Newcastle University and Queen Mary University of London in the United Kingdom of Great Britain and Northern Ireland, consisting of Kristoffer Halvorsrud, Jonathan Lewney, Dawn Craig and Paula Moynihan, completed a systematic review on carbohydrate intake and oral health outcomes *(36)*.

Teams consulted frequently with the WHO Secretariat to ensure that the reviews met the needs of the WHO guideline development process.

In addition, several existing systematic reviews were identified:

- a 2017 systematic review by Aune et al. on vegetable and fruit intake and risk of NCDs in adults as assessed in prospective observational studies *(19)*;
- a 2014 systematic review by Mytton et al. on vegetable and fruit intake and body weight in adults as assessed in RCTs *(37, 38)*;
- a 2014 systematic review by Afshin et al. on pulse intake and risk of NCDs in adults as assessed in RCTs and prospective observational studies *(39)*; and
- a 2017 systematic review by Marventano et al. on pulse intake and risk of cardiovascular diseases (CVDs) in adults as assessed in prospective observational studies *(40)*.

Stakeholder feedback via public consultation

Two public consultations were held during the development of this guideline: one at the scoping phase of the process in 2016 (feedback was received from a total of 15 individuals and organizational stakeholders) and one on the draft guideline in October 2022 (feedback was received from a total of 19 individuals and organizational stakeholders). Stakeholders and others with an interest in the guideline were invited to provide feedback on overall clarity, any potentially missing information, setting-specific or contextual issues, considerations and implications for adaptation and implementation of the guideline, and additional gaps in the evidence to be addressed by future research. The consultation was open to everyone. Declaration of interest forms were collected from all those submitting comments, which were assessed by the WHO Secretariat, following the procedures for management of interests described in the next section. Comments were summarized, and together with WHO responses to the summary comments, posted on the WHO website.[1] Comments that helped to focus the scope of the guideline or improve clarity and usability of the draft guideline were considered in finalizing the scope and the guideline document.

Management of conflicts of interest

Financial and intellectual interests of the members of the NUGAG Subgroup on Diet and Health, those serving as external peer reviewers, and individuals who prepared systematic reviews or contributed other analyses were reviewed by members of the WHO Secretariat, in consultation with the WHO Department of Compliance and Risk Management and Ethics, where necessary. Declared interests of members of the NUGAG Subgroup on Diet and Health and of the systematic review teams were reviewed before their original engagement in the guideline development process and before every meeting. In addition, each member of the NUGAG Subgroup on Diet and Health (and members of the systematic review teams, if present) verbally declared their interests, if required, at the start of each meeting of the group. Declared interests of external reviewers were assessed before they were invited to review the draft guideline. In addition to reviewing

[1] https://www.who.int/groups/nutrition-guidance-expert-advisory-group-(nugag)/diet-and-health

interests declared by the individuals themselves, an internet search was conducted for each contributor to independently assess financial and intellectual interests for the 4 years before their engagement in the the development of the guideline, which was repeated as necessary. The overall procedures for management of interests outlined in the *WHO handbook for guideline development (33)* were followed.

Interests declared by members of the NUGAG Subgroup on Diet and Health, external reviewers and members of the systematic review teams, and the process for managing any identified conflicts of interest are summarized in **Annex 4**.

Guideline development process

Scoping of the guideline

The scientific literature was reviewed to identify important populations, outcomes and other topics relevant to the health effects of carbohydrate intake. Existing systematic reviews on the topic were identified. The information gathered was compiled and used to generate the key questions and outcomes that would guide the selection of existing systematic reviews or the undertaking of new systematic reviews.

Defining key questions and prioritizing outcomes

The questions were based on the needs of Member States and international partners for policy and programme guidance. The population, intervention, comparison and outcome (PICO) format was used in generating the questions (**Annex 5**). The PICO questions were first discussed and reviewed by the WHO Secretariat and the NUGAG Subgroup on Diet and Health, and were then made available for public comment in 2016.

Two key questions to guide the systematic reviews were originally identified: one for dietary fibre, and one for carbohydrate quality, initially framed in the context of digestibility of starch (i.e. rapidly digestible versus slowly digestible), as follows.

- What is the effect on prioritized health outcomes in adults and children of increasing dietary fibre intake (or higher versus lower dietary fibre intake)?
- What is the effect on prioritized health outcomes in adults and children of replacing rapidly digested starches with slowly digested starches (or higher versus lower intake of slowly digested starches)?

Although one of the original aims of updating the guidance on carbohydrate intake was to provide guidance on carbohydrate quality through an assessment of the health effects of starch digestibility, the NUGAG Subgroup on Diet and Health noted when formulating the key questions that it would be challenging to identify studies that accurately assessed starch digestibility. Therefore, the NUGAG Subgroup on Diet and Health acknowledged that carbohydrate quality might need to be addressed through higher or lower intakes of food sources of starch, or potential markers of digestibility. After further reviewing the evidence compiled during the scoping review, the NUGAG Subgroup on Diet and Health concluded that it would be necessary to review evidence for both intakes of food sources of starch and potential markers of digestibility.

Additionally, the original PICO questions did not include re-evaluation of the recommended level of vegetable and fruit intake as established by the 2002 Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases *(32)*. However, when the NUGAG Subgroup on Diet and Health decided to review food sources of starch in the context of carbohydrate quality, and it was clear that vegetables and fruits would be part of that review, it was considered important to also re-evaluate the current recommended level of vegetable and fruit intake.

Based on the discussions, the key questions were revised as follows.

- What is the effect on prioritized health outcomes in adults and children of higher intake of dietary fibre compared with lower intake?
- What is the effect on prioritized health outcomes in adults and children of higher intake of high-quality carbohydrate compared with lower intake, assessed as

- replacing rapidly digested starches with slowly digested starches (or higher compared with lower intake of slowly digested starches) as assessed by potential markers of digestibility

and/or

- consuming foods containing higher-quality carbohydrate compared with consuming foods containing lower-quality carbohydrate (i.e. higher intake of foods containing higher-quality carbohydrate compared with lower intake)?

Priority health outcomes considered for adults were overweight and obesity, all-cause mortality, CVDs, cancer and type 2 diabetes. Priority health outcomes considered for children were overweight and obesity, biomarkers of type 2 diabetes and CVDs (e.g. glucose, insulin, blood lipids), and growth.

Evidence gathering and review

Three systematic reviews were commissioned, and four existing reviews were identified to assess the relationship between carbohydrate intake and health outcomes of interest in adults and children.

Commissioned reviews

- A systematic review on carbohydrate quality and prioritized health outcomes in adults as assessed in RCTs and prospective observational studies, and in children as assessed in RCTs was published in 2019 *(34)*.
- A systematic review on carbohydrate quality and prioritized health outcomes in children as assessed in prospective observational studies was published in 2020 *(35)*.
- A systematic review on carbohydrate quality and oral health outcomes in adults and children as assessed in studies of different designs was published in 2019 *(36)*.

Existing reviews

- A systematic review on vegetable and fruit intake and risk of NCDs in adults as assessed in prospective observational studies was published in 2017 *(19)*. This review included a dose–response assessment of associations between vegetable and fruit intake and risk of NCDs. A subsequent scan of the literature covering the period from when the literature was searched for the original review to May 2021 was conducted; no studies were identified that would significantly change the results or conclusions of the original review, nor were any other reviews identified that included detailed dose–response assessments or were directly relevant to the key questions. Therefore, the 2017 systematic review was used to inform the formulation of recommendations 1, 2 and 3.
- A systematic review on vegetable and fruit intake and body weight in adults as assessed in RCTs was published in 2014 *(37, 38)*. A subsequent scan of the literature covering the period from when the literature was searched for the original review to May 2021 was conducted; no studies were identified that would significantly change the results or conclusions of the original review. A 2015 systematic review of prospective cohort studies reported results consistent with the 2014 review *(41)*. Therefore, the 2014 systematic review was used to inform the formulation of recommendation 1.
- Systematic reviews on pulse intake and risk of NCDs in adults as assessed in RCTs and prospective observational studies *(39)*, and on pulse intake and risk of CVDs in adults as assessed in prospective observational studies *(40)* were published in 2014 and 2016, respectively. The 2019 Reynolds et al. systematic review *(34)* also contributed results for pulse intake and body weight outcomes.[1] A subsequent scan of the literature covering the period from when the literature was searched for the original reviews to May 2021 was conducted. Several systematic reviews on pulse intake and prioritized outcomes of interest were identified that were published after the recommendations were formulated *(20, 43–45)*. However, very few studies not already identified in the 2014 and 2016 reviews were included,

[1] A 2016 systematic review on the effects of pulse intake on body weight as assessed in RCTs *(42)* was identified during the development of the commissioned review by Reynolds et al. *(34)*. However, because the scope was similar between the reviews and the results from the 2016 review were consistent with those from the Reynolds et al. review, it was not included in the evidence based that informed the formulation of recommendations on carbohydrate intake.

and results were consistent with the original 2014 and 2016 reviews. Nothing else was identified that would significantly change the results or conclusions of the original reviews. Therefore, the 2014 and 2016 systematic reviews were used to inform the formulation of recommendation 1.

Assessment of certainty in the evidence

GRADE[1] methodology was used to assess the certainty of (i.e. confidence in) the evidence identified in the systematic reviews. GRADE assessments assigned by the systematic review teams were discussed by the NUGAG Subgroup on Diet and Health and the systematic review teams, and refined as necessary under the guidance of an expert with extensive expertise in GRADE methodology. GRADE assessments are summarized in **Annex 6**.

Formulation of the recommendations

In formulating the recommendations and determining their strength, the NUGAG Subgroup on Diet and Health assessed the evidence in the context of the certainty in the evidence, desirable and undesirable effects of the recommended intervention, the priority of the problem that the intervention would address, values and preferences related to the effects of the intervention in different settings, the cost of the options available to public health officials and programme managers in different settings, the feasibility and acceptability of implementing the intervention in different settings, and the potential impact on equity and human rights (**Annex 7**).

Because much of the evidence that NUGAG Subgroup on Diet and Health reviewed came from assessment of individuals, and dose–response relationships were observed for many outcomes, the decision was made to formulate the recommendations such that the recommended levels of intake of dietary fibre, and vegetables and fruits are targets for individuals to achieve, not population goals. NUGAG Subgroup on Diet and Health further concluded that individual targets would be easier to implement, particularly in terms of updating food-based dietary guidelines, education/awareness campaigns, and other interventions aimed at eliciting desired behavioural change at the individual level.

Based on the evidence and additional factors, the NUGAG Subgroup on Diet and Health developed the recommendations and associated remarks by consensus.

[1] http://www.gradeworkinggroup.org/

Summary of evidence

Results from seven systematic reviews that assessed the effects of carbohydrate intake on prioritized health outcomes in adults and children *(19, 34–40)* were considered by the NUGAG Subgroup on Diet and Health in formulating the recommendations on carbohydrate intake.

Systematic review characteristics

Review 1

A systematic review of RCTs and observational studies that assessed the health effects of dietary fibre and whole grain intake in adults and children (for children, only RCTs were included) identified 185 prospective observational studies and 58 RCTs in adults *(34)*. Only one relevant RCT was identified for children. The majority of prospective observational studies and RCTs were conducted in Europe and North America; however, a small number were conducted elsewhere, including China, Iran (Islamic Republic of), Israel, Japan and Singapore. The analyses of dietary fibre included 100 prospective observational studies of 80 million person-years and 49 RCTs of 3574 people (RCTs of fruits, vegetables and pulses were a subset of the dietary fibre trials). The analyses of whole grains included 28 studies of 23 million person-years and 24 RCTs of 1859 people.

Review 2

A systematic review of observational studies that assessed associations between dietary fibre intake and health outcomes in children identified 45 studies reporting on 44 350 participants from 30 cohorts, providing 260 837 person-years of data *(35)*. The median age at which diet was assessed in children was 9.6 years (range 1–19.3 years), and the median follow-up duration was 4 years (range 4 months – 27 years). Of the 30 cohorts, 14 (47%) were from North America, 11 (37%) were from Europe, three (10%) were from Australia, and one each (3%) were from Iran (Islamic Republic of) and Japan.

Review 3

A systematic review of a variety of study types – intervention studies, observational studies, ecological studies and experimental studies – that assessed the health effects of intake of non-sugars carbohydrates and carbohydrate quality on oral health outcomes in adults and children identified 50 studies *(36)*. Studies were primarily conducted in Europe and North America; however, a small number were conducted elsewhere, including Australia, Tristan da Cunha and Uruguay. Two of the studies were multi-country ecological studies. Age of study participants ranged from infants to older adults.

Review 4

A systematic review of observational studies that assessed associations between vegetable and fruit intake and health outcomes in adults identified 95 prospective cohort studies, of which 44 were from Europe, 26 from North America, 20 from Asia and five from Australia *(19)*. The number of cases or deaths ranged between 17 742 and 43 336 for coronary heart disease, 10 560 and 46 951 for stroke, 20 329 and 81 807 for CVDs, 52 872 and 112 370 for total cancer, and 71 160 and 94 235 for all-cause mortality. The number of participants in each analysis ranged from 226 910 to 2 123 415 across outcomes.

Review 5

A systematic review of RCTs that assessed the health effects of vegetable and fruit intake in adults and children identified eight trials with a total of 1026 participants *(37, 38)*. The mean study duration was

14.7 weeks (range 4–52 weeks), and the mean difference in vegetable and fruit intake between arms was 133 g (range 50–456 g). No RCTs conducted in children were identified. Five trials were conducted in North America, two in Europe and one in India. Most studies recruited participants with existing disease (type 2 diabetes, colorectal polyps) or at risk for disease (e.g. obese, high risk for CVDs); only two studies recruited participants with a mean body mass index (BMI) below 25 kg/m^2. A variety of interventions designed to increase vegetable and fruit consumption were employed; all resulted in a difference in intake between control and intervention arms of at least 50 g/day.

Review 6

A systematic review of observational studies that assessed associations between pulse intake and risk of type 2 diabetes[1] in adults identified two prospective cohort studies with 100 179 participants and 2746 events, conducted in China and the United States of America (the United States) *(39)*.

Review 7

A systematic review of observational studies that assessed associations between pulse intake and risk of CVDs in adults identified 14 studies of 11 cohorts, which included 367 000 individuals and 18 475 cases of CVDs, 7451 cases of coronary heart disease and 6336 cases of stroke *(40)*. The studies were conducted in Finland, Greece, Japan, Iran (Islamic Republic of), Spain and the United States.

Results of systematic reviews

Adults

Whole grains, vegetables, fruits and pulses

Results for adults are summarized in **Table 1**.

Systematic review and meta-analysis of prospective observational studies found that consuming more whole grains, vegetables and fruits, and pulses was associated with significant decreases in risk of mortality and disease. This included a nearly 20% decrease in risk of all-cause mortality with higher intake of whole grains or vegetables and fruits; a 10–20% decrease in risk of coronary heart disease (and CVDs more broadly) with higher intake of whole grains, vegetables and fruits, or pulses; a greater than 20% decrease in risk of type 2 diabetes with higher intake of whole grains or pulses; and a 16% reduction in risk of colorectal cancer and overall cancer mortality with higher intake of whole grains. Higher intake of whole grains was associated with a 10% increase in risk of prostate cancer *(34)*. Various sensitivity analyses of the observed associations did not change the direction or significance of the results. Small reductions in body weight were observed for whole grains, and vegetables and fruits in RCTs. Favourable changes in a small number of risk factors and biomarkers for risk of cardiometabolic disease were also observed in RCTs, but for most outcomes assessed effects were not statistically significant, were of uncertain clinical significance or were not observed. There was no evidence that higher intake of whole grains, vegetables and fruits, or pulses increased risk of disease or resulted in unfavourable changes in biomarkers of disease risk. Data for all outcomes assessed in RCTs can be found in the 2019 systematic review by Reynolds et al. *(34)*.

Dose–response relationships were observed between vegetable and fruit intake and all outcomes assessed – that is, the greater the intake of vegetables and fruits, the greater the magnitude of the effect on an outcome. For each 200 g of vegetables and fruits consumed per day, the following changes in risk of death and disease were observed:

- All-cause mortality: 10% reduction in risk (relative risk [RR] 0.90; 95% confidence interval [CI]: 0.87 to 0.93).
- CVDs: 8% reduction in risk (RR 0.92; 95% CI: 0.90 to 0.95).
- Coronary heart disease: 8% reduction in risk (RR 0.92; 95% CI: 0.90 to 0.94).

[1] This systematic review also reported results for coronary heart disease and stroke that were consistent with results reported in the second systematic review on pulses, the latter of which were used in formulating recommendation 1.

- Stroke: 16% reduction in risk (RR 0.84; 95% CI: 0.76 to 0.92).
- Cancer: 3% reduction in risk (RR 0.97; 95% CI: 0.95 to 0.99).

The cumulative benefits of increased vegetable and fruit intake continued up to approximately 800 g of vegetables and fruits per day.

Table 1. Summary of results from meta-analyses of prospective observational studies for higher compared with lower intake of whole grains, vegetables and fruits, and pulses

Outcome	Pooled estimate (95% CI)	No. studies	No. participants	Certainty
All-cause mortality				
Whole grains	RR 0.81 (0.72 to 0.90)	9	717 331	Low
Vegetables, fruits	RR 0.82 (0.79 to 0.86)	22	1 035 556	Low
CVD mortality				
Whole grains	RR 0.77 (0.69 to 0.86)	6	520 590	Low
CVDs				
Whole grains	RR 0.89 (0.81 to 0.98)	3	68 488	Moderate
Vegetables, fruits[a]	RR 0.84 (0.79 to 0.90)	16	963 240	Low
Pulses	RR 0.90 (0.84 to 0.97)	5	129 692	Low
CHD mortality				
Whole grains	RR 0.66 (0.56 to 0.77)	2	147 321	Low
CHD				
Whole grains	RR 0.80 (0.70 to 0.91)	6	232 886	Low
Vegetables, fruits[a]	RR 0.87 (0.83 to 0.91)	16	792 197	Moderate
Pulses	RR 0.90 (0.84 to 0.97)	10	313 414	Moderate
Stroke mortality				
Whole grains	RR 0.74 (0.58 to 0.94)	2	147 321	Low
Stroke				
Whole grains	RR 0.86 (0.61 to 1.21)	3	364 204	Very low
Vegetables, fruits[a]	RR 0.79 (0.71 to 0.88)	8	226 910	Moderate
Pulses	RR 1.01 (0.89 to 1.14)	6	266 241	Low
Type 2 diabetes				
Whole grains	RR 0.67 (0.58 to 0.78)	8	363 546	Low
Pulses	RR 0.79 (0.71 to 0.87)	2	100 179	Very low
Cancer mortality				
Whole grains	RR 0.84 (0.76 to 0.92)	5	844 225	Moderate
Cancer				
Vegetables, fruits[a]	RR 0.93 (0.87 to 0.98)	13	904 300	Moderate
Colorectal cancer				
Whole grains	RR 0.84 (0.78 to 0.89)	22	1 560 045	Moderate
Body weight (kg)[b]				
Whole grains	MD −0.62 (−1.19 to −0.05)	11	919	Moderate
Vegetables, fruits	MD −0.54 (−0.04 to −1.05)	8	536	Very low
Pulses	MD −0.18 (−0.52 to 0.16)	3	356	High

CHD: coronary heart disease; CI: confidence interval; CVD: cardiovascular disease; MD: mean difference; RR: relative risk.
[a] Fatal and non-fatal events were assessed together.
[b] Assessed in RCTs.

Dose–response relationships were also observed between intake of whole grains and most outcomes. However, because quantitative recommendations on whole grain intake were not formulated (see the section *Interpreting the evidence*), the results of the dose–response analyses for whole grains are not presented in this guideline. Results for the dose–response analyses can be found in the 2019 systematic review by Reynolds et al. *(34)*.

The overall certainty in the available evidence for an association between intake of whole grains, vegetables and fruits, and pulses and outcomes in adults was assessed as *moderate*.[1] GRADE assessments for each outcome can be found in **Annex 6**, GRADE evidence profiles 1–3.

Dietary fibre

Results for adults are summarized in **Table 2**.

Systematic review and meta-analysis of prospective observational studies found that higher dietary fibre intake was associated with a 15% decrease in risk of all-cause mortality, a greater than 20% decrease in risk of CVDs and coronary heart disease (risk of stroke reduced by approximately 20%), a 13% decrease in risk of overall cancer mortality (with significant reductions in risk of colorectal and breast cancer), and a 16% decrease in risk of type 2 diabetes *(34)*. Higher dietary fibre intake was associated with a 16% increase in risk of endometrial cancer. Various sensitivity analyses of the observed associations did not change the direction or significance of the results. Small reductions in measures of body fatness, and favourable changes in several risk factors and biomarkers of risk of cardiometabolic disease – including reduced fasting glucose, low-density lipoprotein (LDL) cholesterol and systolic blood pressure – were observed with higher intake of dietary fibre in RCTs. Effects for other biomarkers of cardiometabolic disease risk were statistically non-significant or not observed. There was no evidence that higher intake of whole grains, vegetables and fruits, or pulses increased risk of disease or resulted in unfavourable changes in biomarkers of disease risk. Data for all outcomes assessed in RCTs can be found in the 2019 systematic review by Reynolds et al. *(34)*.

Dose–response relationships were observed between dietary fibre intake and most outcomes assessed – that is, the greater the intake of dietary fibre, the greater the magnitude of the effect on an outcome – with an approximate 10–20% reduction in risk per 8 g of dietary fibre consumed per day across outcomes. Meta-analysis comparing individuals with the lowest dietary fibre intake with those consuming 15–19 g, 20–24 g, 25–29 g, 30–34 g and 35–39 g of dietary fibre per day showed that consuming 25–29 g per day of fibre was associated with reductions in risk of all-cause mortality, coronary heart disease, CVDs, stroke, type 2 diabetes, and colorectal and breast cancer *(34)*. Data from these analyses suggested additional benefits with dietary fibre intakes greater than 30 g per day; however, data for this range of intake were more limited.

The overall certainty in the available evidence for an association between intake of dietary fibre and outcomes in adults was assessed as *moderate*. GRADE assessments for each outcome can be found in **Annex 6**, GRADE evidence profile 4.

Glycaemic index and glycaemic load

Results for adults are summarized in **Table 3**.

Systematic review and meta-analysis of prospective observational studies found that consuming diets with lower glycaemic index was associated with significant decreases in risk of mortality and disease. This included a 19% reduction in risk of CVD mortality; a 16% and 37% decrease in risk of stroke incidence and mortality, respectively; an 11% reduction in risk of type 2 diabetes; and reductions in risk of breast and oesophageal cancer, as noted in **Table 3**. Decreasing dietary glycaemic index reduced BMI by 0.28 units, but did not affect body weight or markers of cardiometabolic disease.

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[1] Based on the grades of evidence set by the GRADE Working Group. High certainty means that we are very confident that the true effect lies close to that of the estimate of the effect; moderate certainty means that we are moderately confident in the effect estimate – the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different; low certainty means that our confidence in the effect estimate is limited – the true effect may be substantially different from the estimate of the effect; and very low certainty means that we have very little confidence in the effect estimate – the true effect is likely to be substantially different from the estimate of the effect *(33)*.

Table 2. Summary of key results from meta-analyses of RCTs and observational studies for higher compared with lower intake of dietary fibre in adults

Outcome	Pooled estimate (95% CI)	No. studies[a]	No. participants[a]	Certainty	Dose–response (95% CI)[b]
All-cause mortality					
Observational	RR 0.85 (0.79 to 0.91)	10	947 111	Moderate	RR 0.93 (0.90 to 0.95)
CVD mortality					
Observational	RR 0.77 (0.71 to 0.83)	7	947 870	Moderate	RR 0.87 (0.84 to 0.91)
CVDs					
Observational	RR 0.76 (0.68 to 0.85)	8	200 143	Moderate	RR 0.78 (0.68 to 0.90)
CHD mortality					
Observational	RR 0.69 (0.60 to 0.80)	10	596 887	Moderate	RR 0.85 (0.79 to 0.92)
CHD					
Observational	RR 0.76 (0.69 to 0.83)	9	299 386	Moderate	RR 0.81 (0.73 to 0.90)
Stroke mortality					
Observational	RR 0.80 (0.56 to 1.14)	2	89 761	Very low	RR 0.93 (0.79 to 1.08)
Stroke					
Observational	RR 0.82 (0.75 to 0.90)	9	364 204	Moderate	RR 0.90 (0.85 to 0.95)
Type 2 diabetes					
Observational	RR 0.84 (0.78 to 0.90)	17	640 656	Moderate	RR 0.85 (0.82 to 0.89)
Cancer mortality					
Observational	RR 0.87 (0.79 to 0.95)	5	844 225	Moderate	RR 0.94 (0.92 to 0.96)
Colorectal cancer					
Observational	RR 0.84 (0.78 to 0.89)	22	1 560 045	Moderate	RR 0.92 (0.89 to 0.95)
Breast cancer					
Observational	RR 0.93 (0.90 to 0.97)	18	1 283 089	Moderate	RR 0.96 (0.95 to 0.98)
Endometrial cancer					
Observational	RR 1.16 (1.01 to 1.33)	4	417 031	Very low	RR 1.10 (0.99 to 1.21)
Oesophageal cancer					
Observational	RR 0.57 (0.36 to 0.92)	1	34 351	Very low	RR 0.87 (0.78 to 0.97)
Prostate cancer					
Observational	RR 1.02 (0.89 to 1.17)	5	247 400	Very low	RR 0.98 (0.89 to 1.08)
Body weight (kg)					
RCT	MD −0.37 (−0.63 to −0.11)	27	2 495	High	--
BMI (kg/m²)					
RCT	MD −0.17 (−0.33 to −0.01)	9	1 857	Moderate	--
Fasting glucose (mmol/L)					
RCT	MD −0.09 (−0.15 to −0.02)	39	3 263	Low	--
LDL cholesterol (mmol/L)					
RCT	MD −0.09 (−0.15 to −0.04)	34	3 441	Moderate	--
Systolic blood pressure (mmHg)					
RCT	MD −1.27 (−2.50 to −0.04)	15	2 052	Moderate	--
Diastolic blood pressure (mmHg)					
RCT	MD −1.34 (−2.96 to 0.27)	13	2 052	High	--

--: not applicable; BMI: body mass index; CHD: coronary heart disease; CI: confidence interval; CVD: cardiovascular disease; LDL: low-density lipoprotein; MD: mean difference; RCT: randomized controlled trial; RR: relative risk.

[a] Numbers of studies and participants listed are for higher vs lower pooled estimate and generally differ from those for assessment of dose–response relationships. See the 2019 systematic review by Reynolds et al. *(34)* for further information on the dose–response analyses.

[b] Change in relative risk per 8 g of dietary fibre consumed per day.

Table 3. Summary of key results from meta-analyses of RCTs and observational studies for diets with lower compared with higher glycaemic index or glycaemic load in adults

Outcome[a]	Pooled estimate (95% CI)	No. studies[b]	No. participants[b]	Certainty	Dose–response (95% CI)[c]
All-cause mortality					
GI	RR 0.89 (0.70 to 1.13)	3	68 185	Very low	RR 1.13 (0.90 to 1.41)
GL	RR 1.13 (0.96 to 1.31)	3	68 185	Very low	RR 0.98 (0.97 to 1.00)
CVD mortality					
GI	RR 0.81 (0.70 to 0.94)	2	64 602	Very low	RR 1.16 (0.90 to 1.51)
GL	RR 1.02 (0.88 to 1.18)	2	64 602	Very low	RR 1.00 (0.98 to 1.02)
CVDs					
GI	RR 0.95 (0.50 to 1.82)	2	33 138	Very low	RR 0.69 (0.41 to 1.18)
GL	RR 0.83 (0.68 to 1.02)	1	15 714	Very low	RR 1.04 (1.00 to 1.09)
CHD mortality					
GI	RR 1.10 (0.69 to 1.75)	1	--[d]	Very low	--
GL	RR 0.79 (0.49 to 1.30)	1	20 275	Very low	RR 1.02 (0.98 to 1.06)
CHD					
GI	RR 0.93 (0.83 to 1.04)	10	274 085[e]	Low	RR 1.09 (0.94 to 1.28)
GL	RR 0.85 (0.76 to 0.95)	10	353 914	Moderate	RR 1.02 (1.01 to 1.04)
Stroke mortality					
GI	RR 0.63 (0.52 to 0.77)	3	95 087	Low	RR 1.43 (0.87 to 2.35)
GL	RR 0.70 (0.46 to 1.06)	2	92 190	Very low	RR 1.10 (1.06 to 1.14)
Stroke					
GI	RR 0.84 (0.72 to 0.99)	5	243 276	Very low	RR 1.16 (0.97 to 1.39)
GL	RR 0.84 (0.72 to 0.98)	5	243 276	Very low	RR 1.02 (1.00 to 1.05)
Type 2 diabetes					
GI	RR 0.89 (0.82 to 0.97)	14	499 989	Very low	RR 1.10 (1.00 to 1.20)
GL	RR 0.99 (0.90 to 1.09)	15	575 501	Very low	RR 0.99 (0.98 to 1.00)
Cancer mortality					
GI	RR 1.11 (0.90 to 1.38)	1	28 356	Very low	RR 0.93 (0.80 to 1.09)
GL	RR 1.30 (1.01 to 1.67)	1	28 356	Very low	RR 0.97 (0.95 to 1.00)
Colorectal cancer					
GI	RR 0.91 (0.82 to 1.01)	10	941 652	Very low	RR 1.05 (1.00 to 1.10)
GL	RR 1.08 (0.99 to 1.17)	12	1 181 780	Low	RR 0.99 (0.99 to 1.00)
Breast cancer					
GI	RR 0.95 (0.91 to 0.99)	11	807 741	Low	RR 1.01 (0.98 to 1.03)
GL	RR 1.00 (0.95 to 1.06)	11	807 741	Low	RR 1.00 (0.99 to 1.01)
Endometrial cancer					
GI	RR 1.02 (0.92 to 1.14)	6	627 030	Low	RR 1.00 (0.97 to 1.04)
GL	RR 0.89 (0.75 to 1.07)	7	695 100	Very low	RR 1.01 (0.99 to 1.03)
Oesophageal cancer					
GI	RR 0.68 (0.51 to 0.91)	1	446 177	Very low	RR 1.15 (1.04 to 1.26)
GL	RR 1.30 (0.79 to 2.13)	1	446 177	Very low	RR 0.99 (0.98 to 1.01)
Prostate cancer					
GI	RR 1.02 (0.97 to 1.07)	4	344 551	Low	RR 1.00 (0.98 to 1.01)
GL	RR 1.05 (0.97 to 1.14)	4	344 551	Low	RR 0.99 (0.99 to 1.00)

Outcome[a]	Pooled estimate (95% CI)	No. studies[b]	No. participants[b]	Certainty	Dose–response (95% CI)[c]
Body weight (kg)					
GI (RCT)	MD −0.29 (−0.62 to 0.03)	8	819	High	--
BMI (kg/m²)					
GI (RCT)	MD −0.28 (−0.50 to −0.06)	3	145	Moderate	--
Fasting glucose (mmol/L)					
GI (RCT)	MD 0.00 (−0.08 to 0.07)	11	1 084	Moderate	--
LDL cholesterol (mmol/L)					
GI (RCT)	MD 0.05 (−0.13 to 0.22)	8	1 083	Moderate	--
Systolic blood pressure (mmHg)					
GI (RCT)	MD −0.17 (–1.03 to 0.69)	4	916	High	--
Diastolic blood pressure (mmHg)					
GI (RCT)	MD −0.13 (−0.46 to 0.72)	4	916	High	--

--: not applicable; BMI: body mass index; CHD: coronary heart disease; CI: confidence interval; CVD: cardiovascular disease; GI: glycaemic index; GL: glycaemic load; LDL: low-density lipoprotein; MD: mean difference; RCT: randomized controlled trial; RR: relative risk.

[a] Unless otherwise noted, data for outcomes came from prospective cohort studies.

[b] Numbers of studies and participants listed are for higher vs lower pooled estimate and generally differ from those for the assessment of dose–response relationships. See the 2019 systematic review by Reynolds et al. *(34)* for further information on the dose–response analyses.

[c] Diets with higher compared with lower GI. The majority of prospective observational studies provided their data comparing diets with higher GI with diets with lower GI; consequently, dose–response analyses were also conducted on higher compared with lower.

[d] Results only presented in person-years.

[e] In addition to the number listed, one study in which results were only presented in person-years.

The overall certainty in the available evidence for an association between consumption of lower glycaemic index diets and outcomes in adults was assessed as *low*. GRADE assessments for each outcome can be found in **Annex 6**, GRADE evidence profile 5.

Systematic review and meta-analysis of prospective observational studies found that consuming diets with lower glycaemic load was associated with significant decreases in risk of mortality and disease. This included a 15% decrease in risk of coronary heart disease and a 16% decrease in risk of stroke; however, it also included a 30% increase in total cancer mortality. No RCTs assessing effects of glycaemic load were identified.

The overall certainty in the available evidence for an association between consumption of lower glycaemic load diets and outcomes in adults was assessed as *low*.[1] GRADE assessments for each outcome can be found in **Annex 6**, GRADE evidence profile 6.

Children

Evidence for associations between intake of dietary fibre, whole grains, vegetables and fruits, and pulses and priority outcomes for children was much more limited than the evidence identified for adults. Data from a systematic review of the literature could not be meta-analysed. Results from most of the individual studies identified were null, although a small number showed favourable associations between intake of dietary fibre, whole grains, vegetables and fruits, or pulses and priority outcomes. Because outcomes in individual studies were assessed in different ways, interpreting the results across studies was difficult. Results are summarized in GRADE evidence profiles 7–10 in **Annex 6**.

The overall certainty in the available evidence for an association between intake of dietary fibre, whole grains, vegetables and fruits, and pulses and outcomes in children was assessed as *very low*.

[1] Although the evidence for an association between lower glycaemic load and coronary heart disease incidence was rated as *moderate* certainty based on a statistically significant dose–response relationship, the relationship itself was very weak. Together with the fact that most other outcomes were rated *low* to *very low*, this led to an overall certainty rating of *low* for glycaemic load.

Oral health outcomes

Systematic review of different study types found no association between non-sugar carbohydrate intake and oral cancer risk (*very low* certainty evidence) or dental caries (*low* certainty evidence), increased risk of dental caries with rapidly digested starches (*low* certainty evidence), and reduced risk of oral cancer (*low* certainty evidence) and periodontitis (*very low* certainty evidence) with slowly digestible starches such as whole grains *(36)*. However, evidence was limited, and results from studies were generally not amenable to meta-analysis.

Interpreting the evidence

Several observations were made in interpreting the results of the systematic reviews, some based directly on data from the review and others supported by background questions and information that helps to establish the context for the recommendations *(33)*. They are summarized below.

Impact on measures of body fatness. Evidence of minor weight loss was observed with higher intakes of dietary fibre, whole grains, vegetables, fruits and pulses[1] in short-term RCTs of generally less than 6 months. Evidence for longer-term associations with body weight from prospective observational studies was consistent with effects observed in RCTs and generally suggestive of benefit *(20, 41, 46, 47)*; however, the evidence from prospective observational studies is much more limited than the evidence from RCTs and was not formally included in the evidence base. Because the evidence for long-term impact on body weight is limited but consistent with both observed short-term effects on body weight assessed in RCTs and associations with disease outcomes observed in prospective cohort studies, and the evidence for disease outcomes was so robust and therefore sufficient on its own to justify the formulation of recommendations, emphasis was placed on the evidence for associations with disease outcomes in formulating the recommendations.

Impact on intermediate markers and risk factors for cardiometabolic disease. Evidence of favourable changes in some intermediate markers and risk factors for cardiometabolic disease – including LDL cholesterol and fasting glucose levels – was observed with higher intakes of dietary fibre in short-term RCTs of generally less than 6 months. However, when subgrouped by different sources of fibre (i.e. from whole grains, vegetables, fruits and pulses), evidence was less consistent, with little evidence of effects on intermediate markers and risk factors observed. This was somewhat unexpected, given the strong associations between intake of dietary fibre, whole grains, vegetables, fruits and pulses, but may reflect methodological considerations in the RCTs, including variation in trial duration and nature of the interventions employed. Nevertheless, the results are not inconsistent with results observed for disease outcomes in prospective cohort studies – that is, there is no evidence of unfavourable effects on intermediate markers or risk factors for cardiometabolic disease with higher intakes of dietary fibre, whole grains, vegetables, fruits or pulses.

Oral health outcomes. Lesser emphasis was placed on the results from the systematic review on oral health outcomes *(36)* when formulating recommendations because the data were limited, came from many different study types, were based on exposures not strictly consistent with the PICO questions, and were generally consistent with results from the other systematic reviews. Consequently, the results from this review are not reported in the GRADE evidence profiles.

Glycaemic index and glycaemic load. In interpreting the results observed for lower glycaemic index and glycaemic load, the NUGAG Subgroup on Diet and Health noted that there was a lack of consistent benefit from diets with lower glycaemic index or glycaemic load in observational studies, and little to no improvement in cardiometabolic risk factors in RCTs associated with lower glycaemic index and glycaemic load. In addition, because the recommendations on carbohydrate intake were formulated in the context of other WHO guidance on healthy diets, a key consideration for the NUGAG Subgroup on Diet and Health is that glycaemic index and glycaemic load only provide information about how a food affects postprandial glucose levels; they do not take into consideration other potentially undesirable components of the food that may contribute to a reduction in diet quality. Because more robust, consistent evidence was available

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[1] The 2019 systematic review *(34)* included a limited number of RCTs assessing the effects of pulse intake on measures of body fatness in the context of their dietary fibre content and found no significant effect on body weight. Evidence from a 2016 systematic review not formally included in the evidence base and more broadly assessing the effects of pulses on body weight with a larger number of trials reported a reduction in body weight with consumption of pulses *(42)*.

for the health benefits of foods containing dietary fibre and whole carbohydrate, the NUGAG Subgroup on Diet and Health concluded that providing guidance on dietary fibre and food sources of carbohydrate was the most effective means of addressing carbohydrate quality. Recommendations on glycaemic index and glycaemic load were therefore not made.

Identifying recommended levels of intake. Data from the dose–response analyses suggested additional benefits with dietary fibre intakes greater than 30 g per day, and vegetable and fruit intakes up to 800 g per day. However, the data on intakes at these levels were more limited and precluded definitive conclusions. Additionally, from a practical standpoint, it was considered prudent to identify recommended intakes at levels that had both robust evidence for health benefit and a likelihood that the intakes could be achieved in most, if not all, settings. Recommended intakes for dietary fibre, and vegetables and fruits were formulated accordingly.

A dose–response relationship was also observed between intake of whole grains and several outcomes. However, the NUGAG Subgroup on Diet and Health concluded that quantitative recommendations for whole grains would likely be more challenging to implement than those for dietary fibre or vegetables and fruits. This is because, unlike vegetables and fruits, whole grains are often not consumed directly but are consumed as part of prepared foods such as bread or pasta. As well, unlike dietary fibre, whole grains are generally not included in nutrient declarations and labels on packaged foods. Results for the dose–response relationships can be found in the 2019 systematic review by Reynolds et al. *(34)*.

Adverse effects. Very few adverse effects were observed with higher intakes of dietary fibre, whole grains, vegetables, fruits or pulses. However, higher intake of dietary fibre or whole grains was associated with increased risk of endometrial cancer and prostate cancer, respectively, in prospective cohort studies. The certainty in the evidence for these two outcomes was *very low* and *low*, respectively, and there are no clear biological mechanisms that would explain these potential relationships. Additional evidence from case–control studies not formally included in the evidence review shows reduced risk of endometrial cancer with higher fibre intake *(48)* and reduced risk of prostate cancer with higher intake of whole grains *(49)*. Consequently, the NUGAG Subgroup on Diet and Health did not feel that these observed associations outweighed the robust associations observed between intake of dietary fibre and whole grains and reduced risk of cardiometabolic disease, other types of cancer and mortality. They further noted that additional research is needed to explore the observed associations. Additionally, consuming a diet with lower glycaemic load was associated with increased risk of cancer mortality; however, the evidence comes from a single prospective cohort study of *very low* certainty. As noted above, there is no clear biological mechanism that would explain this potential relationship, but given the limitations of glycaemic index and glycaemic load as described in bullet 4 above, it is difficult to make any firm conclusions about this observation.

Evaluating the evidence for children. Evidence for the health effects in children of consuming dietary fibre, whole grains, vegetables, fruits and pulses is limited, but is consistent with results observed in studies conducted in adults. Consequently, the NUGAG Subgroup on Diet and Health concluded that it would be appropriate to extrapolate the results obtained for adults to children. The calculations used in deriving the quantitative levels of intake of dietary fibre, and vegetables and fruit are described in **Annex 8**.

Evidence to recommendations

In translating evidence into recommendations, the NUGAG Subgroup on Diet and Health assessed the evidence in the context of the certainty in the evidence, desirable and undesirable effects of the interventions, the priority of the problem that the interventions would address, values and preferences related to the effects of the interventions in different settings, the feasibility and acceptability of implementing the interventions in different settings, the potential impact on equity and human rights, and the cost of the options available to public health officials and programme managers in different settings.

Because the recommended "interventions" in this guideline are in fact dietary goals, they can be translated into policies and actions in a number of ways, including behaviour change interventions, fiscal policies, regulation of marketing, labelling schemes and reformulation of manufactured products, among others. Because each of these interventions has its own substantial evidence base (which was not reviewed by the NUGAG Subgroup on Diet and Health) and requires individual consideration of the additional evidence to recommendation factors, a detailed discussion of these factors for each of the possible interventions is beyond the scope of this guideline. However, forthcoming WHO guidelines will provide specific guidance on nutrition labelling policies, policies on marketing of food and non-alcoholic beverages to children, fiscal and pricing policies, and school food and nutrition policies, which will enable policy-makers to translate dietary goals into evidence-informed policies.[1] Therefore, in assessing the factors relevant to translating the evidence into recommendations for this guideline, the NUGAG Subgroup on Diet and Health primarily considered each recommendation in the context of achieving the recommended dietary goals.

Evidence for this process was gathered via comprehensive searches of relevant scientific databases and identification of high-quality studies, including recent systematic reviews, where available. An evidence to recommendations table can be found in **Annex 7**.

Overall certainty in the evidence

The overall certainty in the available evidence for associations between intake of dietary fibre, whole grains, vegetables and fruits, or pulses and outcomes in adults was assessed as *moderate*. The overall certainty in the evidence for associations between intake of dietary fibre, whole grains, vegetables and fruits, or pulses and outcomes in children was assessed as *very low*.

Balance of desirable and undesirable effects

There was robust evidence for wide-ranging health benefit associated with higher intakes of dietary fibre, whole grains, vegetables, fruits and pulses from prospective cohort studies and RCTs. There were no adverse effects on any outcome assessed in RCTs, but increased risks of endometrial cancer with higher dietary fibre intake and of prostate cancer with higher whole grain intake were observed in prospective cohort studies. The certainty in the evidence for these two outcomes was *very low* and *low*, respectively, and there are no clear biological mechanisms that would explain these potential relationships. Weighed against the strong benefit observed for a large number of NCD outcomes – including significant reductions in mortality – with higher intakes of dietary fibre, whole grains, vegetables, fruits and pulses, the robust desirable effects of the recommended dietary goals were considered to strongly outweigh these potential undesirable effects observed in the prospective cohort studies.

[1] https://www.who.int/groups/nutrition-guidance-expert-advisory-group-(nugag)/policy-actions

Plant-based foods – including whole grains, vegetables, fruits and pulses – contain some compounds that have been shown to inhibit the absorption of certain nutrients, most notably minerals such as iron, zinc and calcium. These compounds include lectins, oxalates, phytates, goitrogens, phytoestrogens, tannins, saponins and glucosinolates; many of these have also been shown to have health benefits unrelated to their impact on nutrient absorption *(77)*. The extent to which these compounds inhibit absorption of other nutrients varies from person to person. The inhibitory effect is generally observed only at very high intakes and in people with existing nutritional deficiencies; in the context of adequate, diverse diets, it is generally not significant *(77)*.

Overall, the desirable effects of higher intakes of dietary fibre, whole grains, vegetables, fruits and pulses were considered to strongly outweigh any potential undesirable effects.

Priority of the problem, and values and preferences

These recommendations primarily address a wide range of NCDs and all-cause mortality, as well as overweight and obesity.

NCDs are the leading causes of death globally *(50)*, and escalating rates of obesity threaten the health and lives of hundreds of millions of individuals worldwide *(2, 3)*. Therefore, interventions and programmes targeting reduction in risk of these outcomes are valuable in all contexts and a high priority for many countries. Despite the global burden of these outcomes, the priority placed on this problem by authorities at different levels may vary depending on the real or perceived magnitude of the problem within a particular country or region. The spotlight on prevention and management of NCDs and obesity has intensified recently as a result of the COVID-19 pandemic, as there is increasing recognition that people with obesity or certain NCDs are at increased risk of adverse outcomes associated with COVID-19 *(5–9)*.

The recommendations in this guideline place a high value on reducing the risk of mortality, NCDs and obesity. Although individuals almost universally value the prevention of premature mortality, those affected by the recommendations may place different values on the benefit of reducing risk of NCDs and obesity, based on personal preferences, beliefs and customs. Because CVDs are a high-profile public health topic, including in many LMICs where these diseases represent a growing threat *(51)*, it is expected that most individuals would value efforts to reduce risk. However, in real-world settings, perception of the risk varies considerably *(52–56)*, and outreach and communication efforts may be needed to improve understanding. Similarly, although many people in LMICs are increasingly aware of negative health effects associated with being overweight or obese, some cultures still consider overweight to be a desirable or positive attribute *(57–59)*. Others believe body weight to be hereditary and therefore not amenable to management via lifestyle changes *(56, 60)*. And many people, regardless of personal beliefs, incorrectly perceive their own body weight in the context of overweight and obesity – that is, they believe that they are at a healthy body weight when in fact they are overweight or obese according to accepted standards for assessing body weight outcomes *(56, 60, 61)*.

Feasibility

Large-scale achievement of the dietary goals in this guideline is possible. However, current intakes of dietary fibre, whole grains, vegetables, fruits and pulses, while variable (see *Acceptability* below), are generally low at the global level relative to recommended intakes in this guideline and other national reference values *(21–28)*. Low vegetable and fruit intake in LMICs are of particular concern: recent estimates suggest that less than 20–30% of individuals in many LMICs meet WHO recommendations for vegetable and fruit intake *(29, 30)*. Although the reasons underlying the variability in intakes of dietary fibre, whole grains, vegetables, fruits and pulses are complex and varied across different settings, common issues are supply, access and availability, and individual behaviour and preferences. Detailed discussion of these themes is beyond the scope of this guideline; however, they are summarized below.

Supply. For most or all individuals to achieve the dietary goals in this guideline, a stable and consistent supply of whole grains, vegetables, fruits and pulses will be necessary. Supply issues currently exist in some settings, particularly for fresh vegetables and fruits *(62, 63)*, which are generally more perishable than grains and pulses, and are thus subject to spoilage and waste during storage and transport.

Access and availability. Even if sufficient quantities of whole grains, vegetables, fruits and pulses are produced, large-scale achievement of the dietary goals in this guideline will be difficult if individuals cannot afford them or otherwise cannot obtain them. Access to, and availability of, vegetables and fruits, in particular, have long posed a problem for people in LMICs and more generally people of lower socioeconomic status, regardless of country or region of the world *(64–67)*. Those of lower socioeconomic status generally need to spend a significant percentage of their household income when purchasing vegetables and fruits, leading to lower consumption *(27, 63)*. Data suggest that there is greater access to pulses and whole grains in many settings, particularly where these foods traditionally form part of the staple diet *(23, 25, 68)*. Global prices of pulses fluctuate; although prices have generally increased during the past several years, pulses remain affordable to many *(25, 68, 69)*. Foods prepared with whole grains have historically been more expensive than refined grain counterparts, but costs are decreasing as public interest in whole grains increases.

Individual behaviour. Ultimately, achieving the dietary goals will require most individuals to consume more dietary fibre, whole grains, vegetables, fruits and pulses, which may require significant modifications to diets. Willingness to modify the diet will vary significantly across populations and from individual to individual, and will be based on numerous considerations, including personal preferences and tastes, as well as cultural customs and traditions. For example, pulses, whole grains and staple foods rich in dietary fibre are already traditionally consumed in many settings (e.g. India, Scandinavian countries, parts of Africa, South-East Asia, South America), whereas, in others, pulses are not consumed regularly and/or refined grains are more commonly consumed than whole grains *(23, 25, 68, 69)*. In many settings, fibre-containing foods such as pulses and whole grains are perceived as expensive, bland or unpleasant tasting, and difficult to prepare *(22, 70)*. In some settings experiencing rapid economic growth, pulses and whole grains are associated with cultural stigma because they are viewed as something that people of lower socioeconomic status eat *(25)*. Even where there is awareness of the health benefits of these foods, there may be confusion about what whole grains and pulses are, and more generally which foods are good sources of dietary fibre *(22, 70)*.

As noted elsewhere in this guideline, achieving the dietary goals can be achieved in numerous ways, including through behaviour change interventions, fiscal policies, regulation of marketing of foods and beverages, product labelling schemes, and reformulation of manufactured products. Feasibility varies depending on the approach used. Regardless of specific modes of implementation, the recommendations can be incorporated into existing activities designed to promote healthy diets. Although assessment of the feasibility of all possible policies and interventions is beyond the scope of this guideline, recent evidence suggests that a variety of interventions can be effective. Effectiveness is increased when multiple interventions are implemented together in multifaceted strategies, involving multiple stakeholders, across multiple aspects of the food system *(22, 63, 71–74)*.

Acceptability

The recommendations in this guideline are already in line with existing national guidance in some countries. However, institutional acceptability may vary across different countries and cultural contexts.

Acceptability may be influenced by:

- how the recommendations are translated into policies and actions – some means of implementation may be more acceptable than others;
- level of awareness of the potential health problems associated with inadequate or low intake of dietary fibre, whole grains, vegetables, fruits and pulses – interventions may be less acceptable in settings where awareness is low;
- potential impact on national economies; and
- compatibility with existing policies.

At an individual level, acceptability of increasing intake of dietary fibre, whole grains, vegetables, fruits and pulses varies widely within and across countries (see *Feasibility*, above). Acceptability of the recommendations can be improved with appropriate public health messaging on the health benefits of dietary fibre, whole grains, vegetables, fruits and pulses, and more broadly on an overall healthy diet, including the message that whole fruits can provide a healthy source of sweetness in the diet.

Equity and human rights

The recommendations in this guideline have the potential to reduce health inequity by improving the health of people of lower socioeconomic status, who are generally disproportionately affected by overweight, obesity and NCDs *(75–79)*. However, in some LMIC settings, people of higher socioeconomic status may be more at risk than those of lower socioeconomic status and may benefit more from relevant interventions *(80, 81)*. Regardless, results of several modelling studies (primarily targeting vegetable and fruit intake) suggest that the effect on equity and human rights would likely depend on how the recommendations are translated into policies and actions (e.g. fiscal policies, reformulation); some interventions are likely to reduce health inequity, whereas others might increase it *(82–86)*. More generally speaking, a small number of studies suggest that fiscal policies targeting foods and beverages, front-of-pack labelling and restrictions on marketing unhealthy foods may increase health equity *(87)*; however, if measures affect all individuals in a population equally, relevant inequalities may not be addressed *(88)*. The impact of interventions on the pricing of manufactured foods would require careful consideration, as any increase in costs borne by manufacturers might be passed on to the consumer; this would likely disproportionately affect people of lower socioeconomic status.

Resource implications

Absolute costs of translating the recommendations in this guideline into policies and actions will vary widely depending on which approaches are taken, but in cases where this can be coupled to existing efforts to promote healthy diets, costs may be minimized. Implementation of the recommendations will likely require consumer education and public health communication. These actions can also be incorporated into existing public health nutrition education campaigns and other existing nutrition programmes at the global, regional, national and subnational levels and which therefore might limit the resources required to implement the recommendations.

Several modelling studies have estimated the potential savings in health-care costs of increasing intake of dietary fibre, whole grains, vegetables, fruits or pulses, independently of how the increase is achieved (most studies of vegetables and fruits assess specific interventions). Results of these modelling studies, all of which were simulated in populations in high-income countries, suggest that increasing intake of dietary fibre, whole grains, vegetables, fruits or pulses would result in cost-savings in terms of lower health-care costs *(89–98)*.

The cost-effectiveness of achieving the recommended dietary goals in this guideline cannot be determined because published cost-effectiveness analyses relate to specific policies or interventions. A large number of such studies have assessed the cost-effectiveness of a variety of policies and interventions, finding that cost-effectiveness varies; however detailed assessment of cost-effectiveness for all possible policies and interventions is beyond the scope of this guideline.

Recommendations and supporting information

All recommendations should be considered in the context of other WHO guidelines on healthy diets, including those on sugars *(15)*, sodium *(99)*, potassium *(100)*, total fat *(101)*, saturated fatty acids *(102)*, *trans*-fatty acids *(102)*, polyunsaturated fatty acids *(32)*[1] and non-sugar sweeteners *(103)*. An explanation of the strength of WHO recommendations can be found in **Box 1**.

WHO recommendations

1. WHO recommends that carbohydrate intake should come primarily from whole grains, vegetables, fruits and pulses (*strong recommendation*; relevant for all individuals 2 years of age and older).
2. In adults, WHO recommends an intake of at least 400 g of vegetables and fruits per day (*strong recommendation*).
3. In children and adolescents, WHO suggests the following intakes of vegetables and fruits (*conditional recommendation*):
   - 2–5 years old, at least 250 g per day
   - 6–9 years old, at least 350 g per day
   - 10 years or older, at least 400 g per day.
4. In adults, WHO recommends an intake of at least 25 g per day of naturally occurring dietary fibre as consumed in foods (*strong recommendation*).
5. In children and adolescents, WHO suggests the following intakes of naturally occurring dietary fibre as consumed in foods (*conditional recommendation*):
   - 2–5 years old, at least 15 g per day
   - 6–9 years old, at least 21 g per day
   - 10 years or older, at least 25 g per day.

Rationale and remarks

The following provides the reasoning (rationale) behind the formulation of the recommendations, as well as remarks designed to provide context for the recommendations and facilitate their interpretation and implementation.

Rationale for recommendation 1

- Recommendation 1 is based on evidence from seven systematic reviews that assessed the effects of higher compared with lower intakes of whole grains, vegetables and fruits, or pulses *(19, 34–40)*. These systematic reviews found that higher intake of these foods reduced the risk of all-cause mortality and several NCDs. The overall certainty in the evidence for recommendation 1 was assessed as *moderate*.

[1] WHO guidance on polyunsaturated fatty acids is currently being updated.

Box 1. Strength of WHO recommendations

WHO recommendations can either be *strong* or *conditional*, based on a number of factors including overall certainty in the supporting scientific evidence, balance of desirable and undesirable consequences, and others as described in the *Evidence to recommendations* section of the guideline.

Strong recommendations are those recommendations for which the WHO guideline development group is confident that the desirable consequences of implementing the recommendation outweigh the undesirable consequences. *Strong* recommendations can be adopted as policy in most situations.

Conditional recommendations are those recommendations for which the WHO guideline development group is less certain that the desirable consequences of implementing the recommendation outweigh the undesirable consequences or when the anticipated net benefits are very small. Therefore, substantive discussion amongst policy-makers may be required before a *conditional* recommendation can be adopted as policy.

The reasoning behind the strength of recommendations in this guideline is provided in the rationale for each recommendation. Additional information on assessing the strength of WHO recommendations can be found in the *WHO handbook for guideline development (33)*.

For adults, findings supporting the recommendation include the following.

- Evidence of *moderate* certainty overall came from a systematic review of prospective observational studies demonstrating associations between higher intakes of whole grains and reduced risk of all-cause mortality, CVDs, coronary heart disease, type 2 diabetes and colorectal cancer *(34)*.
- Evidence of *moderate* certainty overall came from a systematic review of prospective observational studies demonstrating associations between higher intakes of vegetables and fruits and reduced risk of all-cause mortality, CVDs, stroke, coronary heart disease, type 2 diabetes and cancer *(19)*.
- Evidence of *moderate* certainty overall came from a systematic review of prospective observational studies demonstrating associations between higher intakes of pulses and reduced risk of CVDs, coronary heart disease and type 2 diabetes *(39, 40)*.

For children and adolescents, findings supporting the recommendation include the following.

- Direct evidence for health effects of consumption of whole grains, vegetables, fruits and pulses by children and adolescents is limited. Because the health benefits of consuming these foods observed in adults are expected to also be relevant for children and adolescents, and the benefits observed in adulthood are likely to begin accruing in childhood, the recommendation as it pertains to children and adolescents is based on extrapolation of adult data without downgrading the strength of the recommendation. Limited evidence from a systematic review of prospective observational studies of intake of dietary fibre, whole grains, vegetables, fruits and pulses by children and adolescents is consistent with that observed for adults *(35)*. Results from studies included in this review were not amenable to meta-analysis. Although several studies suggested benefit from consumption of whole grains, vegetables, fruits or pulses in terms of body weight, blood lipids and glycaemic control, results from some studies suggested no effect, and results from a very small number of studies suggested increased body weight with increased vegetable intake (*very low* certainty evidence for all outcomes).

- Recommendation 1 was assessed as *strong* because evidence for benefit was observed directly for a number of critical health outcomes, and indirectly in the results for dietary fibre; the main dietary sources of dietary fibre were whole grains, vegetables, fruits and pulses. Although assessed in adults, this evidence was also considered to be highly relevant for children and adolescents. With the exception of a small increase in risk of prostate cancer with higher whole grain intake (*low* certainty evidence), no undesirable effects were identified, and no mitigating factors were identified that would argue against including whole grains, vegetables, fruits and pulses as the primary sources of carbohydrates in the diet.

Rationale for recommendations 2 and 3

- Recommendations 2 and 3 are based on evidence of *moderate* certainty overall from a systematic review of prospective observational studies conducted in adults that assessed the health effects of higher compared with lower intake of vegetables and fruits *(19)*. The systematic review found that higher intakes of vegetables and fruits were associated with reduced risk of all-cause mortality, CVDs, stroke, coronary heart disease, type 2 diabetes and cancer.
- The threshold of at least 400 g of vegetables and fruits per day was selected because a dose–response relationship was observed in the observational studies: risk for all outcomes except cancer decreased with intakes of vegetables and fruits up to 800 g per day, and the greater the intake, the greater the benefit. Evidence for intakes more than 800 g per day was limited. Although the greatest benefit was observed at intakes of 800 g per day, the steepest reduction in risk was up to 400 g per day, after which the effect levelled off for some outcomes. Furthermore, intakes of more than 400 g per day may be difficult to achieve in many settings. The threshold of 400 g per day was therefore selected as a feasible minimal level that would provide significant health benefits.
- Because evidence from studies conducted in children and adolescents is insufficient to derive quantitative recommendations on intakes for children, and the observed health benefits of consuming vegetables and fruits in studies of adults are expected to be relevant for all age groups, intakes for children and adolescents are extrapolated from values for adults, based on the different levels of energy intake at different stages of childhood and adolescence. Limited evidence from a systematic review of prospective observational studies in children and adolescents suggested that higher vegetable and fruit intakes are generally associated with improvements in body weight, blood lipids and glycaemic control (*very low* certainty evidence for all outcomes), with no evidence of undesirable effects *(35)*. This further supports the recommended levels of vegetable and fruit intake for children.
- Recommendation 2 was assessed as *strong* because evidence for benefit was observed for a number of critical health outcomes across a wide range of intakes. The minimal value selected for vegetable and fruit intake was both associated with a significant benefit and an amount that many should be able to achieve. No undesirable effects were identified with consuming 400 g per day or more of vegetables and fruits, and no mitigating factors were identified that would argue against consuming vegetables and fruits at this level.
- Recommendation 3 was assessed as *conditional* because, although the evidence observed for benefit in adults is robust and is expected to also be relevant for children and adolescents, the values were calculated based on extrapolation of adult values. Because the values are based both on extrapolated data and mean reference energy expenditures, a conservative approach was taken, leading to a *conditional* recommendation.

Rationale for recommendations 4 and 5

- Recommendations 4 and 5 are based on evidence of *moderate* certainty overall from a systematic review of randomized controlled trials and prospective observational studies conducted in adults that assessed higher compared with lower intakes of dietary fibre *(34)*. This systematic review found that higher intakes of dietary fibre led to favourable improvements in obesity and NCDs risk factors, and were associated with reduced risk of all-cause mortality, CVDs, stroke, coronary heart disease, type 2 diabetes and cancer.
- The threshold of at least 25 g per day was selected based on the dose–response relationship seen in the observational studies between dietary fibre intake and reduced risk for several NCD and mortality outcomes. This relationship was observed at intakes up to 40 g per day, but the number of studies reporting data began to taper off at 30 g or more per day. Evidence for intakes more than 40 g per day was scarce. In studies comparing individuals with the lowest fibre intakes with those consuming discrete ranges of increasing intake, the range that demonstrated greatest benefit for the largest number of health outcomes was 25–29 g per day.

- Because evidence from studies conducted in children and adolescents is insufficient to derive quantitative recommendations on intakes for children, and the observed health benefits of consuming dietary fibre in studies of adults are expected to be relevant for all age groups, intakes for children and adolescents are extrapolated from values for adults, based on the different levels of energy intake and energy expenditure at different stages of childhood and adolescence. Limited evidence from a systematic review of prospective observational studies in children and adolescents suggested that higher dietary fibre intake is generally associated with improvements in body weight, blood lipids and glycaemic control (*very low* certainty evidence for all outcomes), with no evidence of undesirable effects *(35)*. This further supports the recommended levels of dietary fibre intake for children.
- Recommendation 4 was assessed as *strong* because evidence for benefit was observed for a number of critical health outcomes across a wide range of intakes. The minimal value selected for dietary fibre intake was both associated with a significant benefit and an amount that many should be able to achieve. With the exception of increased risk of endometrial cancer with higher intakes of dietary fibre (*very low* certainty evidence), no undesirable effects were identified with dietary fibre intakes of at least 25 g per day, and no mitigating factors were identified that would argue against dietary fibre intake at this level.
- Recommendation 5 was assessed as *conditional* because, although the evidence observed for benefit in adults is robust and is expected to also be relevant for children and adolescents, the values were calculated based on extrapolation of adult values. Because the values are based both on extrapolated data and mean reference energy expenditures, a conservative approach was taken, leading to a *conditional* recommendation.

Remarks

- One of the original aims of updating the guidance on carbohydrate intake was to provide guidance on carbohydrate quality. Having considered the available evidence relating to food sources of carbohydrate and dietary fibre, starch digestibility and glycaemic response, as measured by glycaemic index and glycaemic load, the WHO NUGAG Subgroup on Diet and Health concluded that providing guidance on dietary fibre and food sources of carbohydrate with consistently demonstrated benefit in terms of important health outcomes was the most effective means of addressing carbohydrate quality.
- This guideline provides guidance on dietary fibre intake, and also updates the prior WHO recommendation on intakes of vegetables and fruits *(32)*. The scope of this guideline does not include an update to the previously published range of carbohydrate intake as a percentage of total energy intake, which was determined largely by the energy intake remaining after defining amounts of dietary fat and protein intake *(32)*. Consequently, this guideline does not include recommendations on the amount of carbohydrate that should be consumed, and carbohydrate intake should continue to be based on recommended levels of protein *(32)* and fat intake *(101)*. Results from a 2018 meta-analysis suggest that a range of total carbohydrate intake appears to be compatible with a healthy diet *(104)*. Intakes of approximately 40–70% of total energy intake as carbohydrate are associated with reduced risk of mortality compared with lower (<40%) or higher (>70%) intakes. This is largely consistent with the range of carbohydrate intakes resulting from current WHO guidance on protein intake *(32)* and updated guidance on total fat intake *(101)*.
- In addition to the benefits of dietary fibre from whole grains, vegetables, fruits and pulses, these foods may also contain other compounds that have been associated with health benefits *(105–107)*.
- The recommendations included in this guideline cover all types of whole grains, vegetables, fruits and pulses, with caveats relating to processing and preparation, as noted in the following remarks. A variety of such foods should be consumed, where possible.
- Although fresh vegetables and fruits are a good choice when and where they are available, in some settings they present a significant risk for foodborne illness. In areas where risk of foodborne illness is high, selecting vegetables and fruits with hard skins or peels that can be removed, thoroughly washing them with potable water, or consuming cooked or canned varieties can reduce the risk of illness *(108)*.

- The recommendations covering vegetable and fruit intake are not limited to fresh vegetables and fruits. Evidence from the systematic reviews suggests health benefits from a wide range of vegetables and fruits, including those that are fresh, cooked, frozen or canned. However, an increased risk of all-cause mortality and CVDs was observed for tinned fruits in a small number of studies. Specific evidence for dried fruits and fruit juices in the systematic reviews is very limited, and results are inconsistent; however, both can be significant sources of sugars, as can fruit concentrates and fruit sugars (i.e. sugars and syrups obtained from whole fruits). All should therefore be consumed in accordance with WHO recommendations on free sugars intake *(15)*. Similarly, although no specific evidence was identified for canned vegetables, some canned vegetables contain added sodium and should therefore be consumed in accordance with WHO recommendations on sodium intake *(99)*.
- The method of preparation and the level of processing should be considered when consuming whole grains, vegetables, fruits and pulses, and should be compatible with other WHO macronutrient recommendations. For example, frying and addition of sauces or condiments can significantly increase the amount of fat, sugars or salt. Therefore, fresh foods, or foods that are minimally processed or modified beyond the treatment necessary to ensure edibility, without added fat, sugars or salt, are preferred.
- Whole grains contain the naturally occurring components of the kernel (i.e. bran, germ and endosperm). Some processed foods are labelled whole grain if these three components of the grain are included, regardless of the extent to which the grains have been processed, and highly processed products labelled as whole grain are becoming increasingly available (e.g. products containing flour from milled whole grains with added fat, sugar or salt). Because there is evidence to suggest that the naturally occurring structure of intact whole grains contributes to its observed health effects *(109–111)*, minimal processing of whole grains beyond that necessary to ensure edibility is preferred.
- The source of dietary fibre in the prospective cohort studies included in the systematic reviews, upon which recommendations 4 and 5 are largely based, is fibre naturally occurring in foods and not extracted or synthetic fibre added to foods or consumed on its own (e.g. fibre supplements, capsules, powders). Although there was limited evidence for a reduction in total cholesterol with use of extracted or synthetic fibre, further research on disease outcomes associated with extracted or synthetic fibre is needed before conclusions on potential health benefits can be drawn. Therefore, the recommendations specifically cover dietary fibre that occurs naturally in foods.
- Plant-based foods – including whole grains, vegetables, fruits and pulses – contain some compounds that have been shown to inhibit absorption of certain nutrients, most notably minerals such as iron, zinc and calcium *(112)*. These "antinutrients" include lectins, oxalates, phytates, goitrogens, phytoestrogens, tannins, saponins and glucosinolates, and many of these have also been shown to have health benefits unrelated to their impact on nutrient absorption. The extent to which an impact on nutrient absorption occurs varies from person to person. The inhibitory effect is generally observed only at very high intakes and in individuals with existing nutritional deficiencies; in the context of adequate, diverse diets, it is generally not significant. In addition, some simple methods of preparation, including soaking and heating, and more advanced methods, including germination and fermentation, appear to reduce the inhibitory potential. Therefore, most people can generally consume whole grains, vegetables, fruits and pulses with little to no risk. Those with nutritional deficiencies or at high risk for nutritional deficiencies – particularly undernourished children and those who rely heavily on foods containing these compounds as staple foods without much additional diversity in the diet – may need to adopt behaviours that minimize the ability of these compounds to inhibit absorption of other nutrients.
- These recommendations do not cover children under 2 years of age. However, whole grains, vegetables, fruits and pulses can be healthy sources of carbohydrates in complementary foods consumed by children from 6 months to 2 years of age, and are strongly preferred to foods containing free sugars.[1]

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[1] WHO recommends that infants should be exclusively breastfed for the first 6 months of life to achieve optimal growth, development and health. Thereafter, to meet their evolving nutritional requirements, infants should receive nutritionally adequate and safe complementary foods, while continuing to breastfeed for up to 2 years or beyond *(113, 114)*.

Uptake of the guideline and future work

Dissemination

The guideline will be disseminated through:

the WHO e-Library of Evidence for Nutrition Actions (eLENA),[1] which is an online library of evidence-informed guidance for nutrition interventions that provides policy-makers, programme managers, health workers, partners, stakeholders and other interested actors with access to the latest nutrition guidelines and recommendations, as well as complementary documents, such as systematic reviews, and biological, behavioural and contextual rationales for the effectiveness of nutrition actions;

- relevant nutrition webpages on the WHO website, including a summary of the guideline in all six official WHO languages;
- the electronic mailing lists of the WHO Department of Nutrition and Food Safety, and the UN Standing Committee on Nutrition;
- the network of the six WHO regional offices and country offices; and
- the WHO collaborating centres.

The guideline will also be disseminated at various relevant WHO meetings, as well as at global and regional scientific meetings.

Translation and implementation

The recommendation in this guideline should be considered in conjunction with other WHO guidance on healthy diets – in particular, guidelines related to free sugars *(15)*, as well as sodium *(99)*, potassium *(100)*, total fat *(101)*, saturated fatty acids *(102)*, *trans*-fatty acids *(102)*, polyunsaturated fatty acids *(32)* [2] and non-sugar sweeteners *(103)* to guide effective policy actions and intervention programmes to promote healthy diets and nutrition, and prevent diet-related NCDs.

A detailed discussion of how the recommendations on carbohydrate intake might be implemented is beyond the scope of this guideline, however they can be considered by policymakers and programme managers when discussing possible measures, including:

- assessing current intakes of dietary fibre, vegetables and fruits in their populations relative to benchmarks;
- developing policy measures to increase intake of dietary fibre, whole grains, vegetables, fruits and pulses, where necessary, through a range of public health interventions, many of which are already being implemented by countries, including
  - nutrition labelling (i.e. mandatory nutrient declaration) and front-of-pack labelling systems
  - fiscal policies (i.e. subsidies) targeting foods containing dietary fibre, whole grains, vegetables, fruits and pulses
  - consumer education; and

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1 https://www.who.int/tools/elena
2 WHO guidance on polyunsaturated fatty acids is currently being updated.

- translating the recommendations into culturally and contextually specific food-based dietary guidelines that take into account locally available foods and dietary customs.

Providing overall dietary guidance is beyond the scope of this guideline because such guidance should be based on overall dietary goals that consider all required nutrients. However, it is feasible to achieve the recommendations in this guideline while respecting national dietary customs, because a wide variety of dietary fibre–containing wholegrains, fruits, vegetables and pulses are available in many countries.

Monitoring and evaluation

The impact of this guideline can be evaluated by assessing its adoption and adaptation across countries. Evaluation at the global level will be through the WHO Global database on the Implementation of Nutrition Action (GINA)[1] – a centralized platform developed by the WHO Department of Nutrition and Food Safety for sharing information on nutrition actions in public health practice implemented around the world. GINA currently contains information on thousands of policies (including laws and legislation), nutrition actions and programmes in more than 190 countries. GINA includes data and information from many sources, including the first and second WHO global nutrition policy reviews conducted in 2010–2011 and 2016–2017, respectively *(115, 116)*. By providing programmatic implementation details, specific country adaptations and lessons learned, GINA serves as a platform for monitoring and evaluating how nutrition-relevant WHO guidelines are being translated into policy actions and intervention programmes.

Research gaps and future initiatives

Based on the results of the systematic reviews and discussions with the NUGAG Subgroup on Diet and Health, a number of questions and gaps in the current evidence that should be addressed by future research were identified. Further research is needed to achieve a better understanding of:

- health effects resulting from intake of dietary fibre, whole grains, vegetables, fruits and pulses in children;
- potential health impacts of extracted or extrinsic dietary fibre, including fibre supplements and processed foods containing extracted fibre;
- the relationship between structure of naturally occurring fibre and health effects;
- which interventions are most effective in leading to behaviour change that results in increased intake of dietary fibre, whole grains, vegetables, fruits and pulses;
- impacts of structural changes to the food system, including agricultural production practices and elements of the supply chain;
- biological mechanisms mediating health effects observed with consuming dietary fibre, whole grains, vegetables, fruits and pulses, including the role that changes in body weight may play;
- possible differences in health effects resulting from intake of dietary fibre, whole grains, vegetables, fruits and pulses by age, ethnicity and socioeconomic status;
- possible differential health effects across different types of vegetables and fruits;
- the relationship between high dietary fibre intake and different cancer types; and
- possible differential health effects across different food sources of dietary fibre.

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[1] https://extranet.who.int/nutrition/gina/en

Updating the guideline

WHO regularly updates its guidelines and recommendations to reflect the latest scientific and medical knowledge. This guideline will therefore be updated as part of the ongoing efforts of WHO to update existing dietary goals and nutrition guidance for promoting healthy diets, nutrition and the prevention of NCDs. It is planned that the recommendations in this guideline will be reviewed when new data and information become available. At that time, any new evidence will be evaluated, and formal updates will be made, if necessary. The WHO Department of Nutrition and Food Safety, together with partners in other departments within the WHO Secretariat, will be responsible for coordinating the updating of the guideline, following the formal procedure described in the *WHO handbook for guideline development (33)*. At the time the guideline is due for review, WHO will welcome suggestions for additional questions that could be addressed in a potential update of the guideline.

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Annexes

Annex 1

Members of the WHO Steering Group

Dr Ayoub Al-Jawaldeh,
Regional Adviser in Nutrition
WHO Regional Office for the Eastern Mediterranean
Egypt

Dr Anshu Banerjee
Director
Maternal, Newborn, Child & Adolescent Health & Ageing
WHO headquarters
Switzerland

Dr Hana Bekele
Nutrition Adviser
WHO Regional Office for Africa/Intercountry Support Team for East and Southern Africa
Congo

Dr Fabio Da Silva Gomes
Nutrition and Physical Activity Adviser
WHO Regional Office for the Americas
United States of America

Dr Padmini Angela De Silva
Regional Adviser in Nutrition
WHO Regional Office for South-East Asia
India

Dr Jason Montez
Scientist, Standards and Scientific Advice on Food and Nutrition
Department of Nutrition and Food Safety
WHO headquarters
Switzerland

Dr Chizuru Nishida
Unit Head, Safe, Healthy and Sustainable Diets
Department of Nutrition and Food Safety
WHO headquarters
Switzerland

Dr Gojka Roglic
Medical Officer, NCD Management – Screening, Diagnosis and Treatment
Department of Noncommunicable Diseases
WHO headquarters
Switzerland

Dr Juliawati Untoro
Regional Adviser in Nutrition
WHO Regional Office for the Western Pacific
Philippines

Dr Kremlin Wickramasinghe
Nutrition Adviser
WHO European Office for the Prevention and Control of NCDs
Russian Federation

Annex 2

Members of the guideline development group (NUGAG Subgroup on Diet and Health)

Professor Hayder Al-Domi
Division of Nutrition and Dietetics
Department of Nutrition and Food Technology
School of Agriculture
University of Jordan
Jordan
Areas of expertise: dietetics, human nutrition, diet and health, obesity biomarkers, diabetogenic dietary proteins

Professor John H Cummings (member until 2018)
Division of Cancer Research, Medical Research Institute
Ninewells Hospital & Medical School
University of Dundee
United Kingdom of Great Britain and Northern Ireland
Areas of expertise: carbohydrates, dietary fibre

Emeritus Professor Ibrahim Elmadfa
Department of Nutritional Sciences
Faculty of Life Sciences
University of Vienna
Austria
Areas of expertise: human nutrition, nutrient requirements, fats and fatty acids, diet and health, dietary diversity

Dr Lee Hooper
Norwich Medical School
University of East Anglia
United Kingdom of Great Britain and Northern Ireland
Areas of expertise: systematic review and research methods, dietetics, human nutrition, hydration, frail older adults and long-term care

Emeritus Professor Shiriki Kumanyika (Chairperson)
Perelman School of Medicine
University of Pennsylvania
United States of America
Areas of expertise: human nutrition, epidemiology, obesity, salt/sodium

Professor Mary L'Abbé
Department of Nutritional Sciences
Temerty Faculty of Medicine
University of Toronto
Canada
Areas of expertise: nutrition science, *trans*-fatty acids, sodium, risk assessment/risk management, food regulation, diet and health

Professor Pulani Lanerolle
Department of Biochemistry and Molecular Biology
Faculty of Medicine
University of Colombo
Sri Lanka
Areas of expertise: nutrition and health, body composition, nutrition education

Professor Duo Li
Institute of Nutrition & Health
Qingdao University
Department of Food Science and Nutrition
Zhejiang University
China
Areas of expertise: nutritional epidemiology, fats and fatty acids

Professor Jim Mann
Departments of Medicine and Human Nutrition
University of Otago
New Zealand
Areas of expertise: carbohydrates, sugars, diabetes, fats and fatty acids

Professor Joerg Meerpohl
Institute for Evidence in Medicine
Medical Center, University of Freiburg
Germany
Areas of expertise: systematic review methods, GRADE methodology, paediatrics, paediatric haematology and oncology

Professor Carlos Monteiro
Department of Nutrition, School of Public Health
University of Sao Paulo
Brazil
Areas of expertise: nutritional epidemiology, diet and all forms of malnutrition, obesity, food-based dietary guidelines

Dr Laetitia Ouedraogo Nikièma (member until 2020)
Institut de Recherche en Sciences de la Santé
Burkina Faso
Areas of expertise: nutritional epidemiology, maternal and child health and nutrition, all forms of malnutrition, diet-related noncommunicable diseases

Professor Harshpal Singh Sachdev
Sitaram Bhartia Institute of Science and Research
India
Areas of expertise: developmental origins of adult cardiometabolic disease, nutrition in children and mothers in low- and middle-income countries, childhood obesity, systematic review methods

Dr Barbara Schneeman
Departments of Nutrition/Food Science and Technology
University of California, Davis
United States of America
Areas of expertise: carbohydrates, dietary fibre, nutrition, diet and health, Codex Alimentarius, food regulation

Emeritus Professor Murray Skeaff
Department of Human Nutrition
University of Otago
New Zealand
Areas of expertise: fats and fatty acids, biomarkers, diet and health, human nutrition

Professor Bruno Fokas Sunguya
School of Public Health and Social Sciences
Muhimbili University of Health and Allied Sciences
United Republic of Tanzania
Areas of expertise: public health nutrition, research methods, systematic review methodology, human nutrition, nutrition epidemiology

Professor HH (Esté) Vorster (member until 2020)
Faculty of Health Sciences
North-West University
South Africa
Areas of expertise: nutrition physiology, public health nutrition, food-based dietary guidelines, nutrition transition in Africa

Annex 3
External peer review group

Dr Charlotte Evans
Associate Professor
School of Food Science and Nutrition
University of Leeds
United Kingdom of Great Britain and Northern Ireland

Professor Frank B Hu
Professor and Chair
Department of Nutrition
Harvard TH Chan School of Public Health
Harvard University
United States of America

Dr Amos Laar
Associate Professor of Public Health
Department of Population, Family & Reproductive Health, School of Public Health
University of Ghana
Ghana

Professor Reza Malekzadeh
Distinguished Professor of Medicine
Digestive Disease Research Institute
Tehran University of Medical Sciences
Iran (Islamic Republic of)

Professor Yang Yuexin
National Institute for Nutrition and Health
Chinese Center for Disease Control and Prevention
China

Annex 4

Summary and management of declarations of interests

Members of the guideline development group (NUGAG Subgroup on Diet and Health)

Interests declared or otherwise identified independently during the development of this guideline are summarized below.

Member	Interests declared/identified	Action taken
Mary L'Abbé	▶ Iodine Global Network: member, Board of Directors (2020–2021) ▶ WHO: Director, WHO Collaborating Centre on Nutrition Policy for NCD Prevention (2015–2021) ▶ Pan American Health Organization (PAHO): Chair, PAHO Technical Advisory Group to Mobilize Cardiovascular Disease Prevention through Dietary Salt/Sodium Control Policies and Interventions (2015–2021) ▶ PAHO: member/Chair of PAHO consultation meetings for setting sodium reduction targets, and other sodium-related work (2012–2021) ▶ Resolve to Save Lives, Vital Strategies: technical adviser on *trans*-fatty acids (2018–2019) ▶ Heart and Stroke Foundation of Canada: member, Council on Mission: Priorities, Advice, Science and Strategy Advisory Panel (CoMPASS) (2013–2021) ▶ World Obesity, World Federation of Public Health Associations: delegate representative to Codex Committee on Nutrition and Foods for Special Dietary Uses, and to Codex Committee on Food Labelling (2018–2021) ▶ National Nutrient Databank Conference: Steering Committee member (2017–2021) ▶ Nestle Nutrition: external peer reviewer for two research proposals; attended peer review meeting (2018) ▶ US *National Academies of Sciences, Engineering, and Medicine (NASEM)*: member, NASEM Panel on Global Harmonization of DRIs (2017–2018) ▶ World Obesity: member, Scientific and Technical Advisory Network (2014–2021) ▶ International Network for Food and Obesity/NCDs Research, Monitoring and Action Support (INFORMAS): member, International Network for Food and Obesity/NCD Research (2012–2021) ▶ Marketing to Kids Coalition: member and technical adviser, Health Canada discussion on policy options regarding marketing to children (2016–2021)	Each engagement was assessed in the context of the topic of this guideline. While meeting expenses were often covered by the relevant agencies listed, no income or honorariums were paid. The engagements have been on a variety of nutrition topics, none of which were determined to be directly relevant to the objective of this guideline, and were therefore not considered to represent a conflict of interest. The sources of research funds were not considered to represent a conflict of interest for this guideline. Nor were the topics covered by the research funds which focused primarily on assessing dietary quality, ways of promoting healthy diets (including sodium reduction strategies), and food labelling. Because none of the interests were directly relevant to the objective of this guideline, it was determined that they would not impact the ability of this expert to serve as a member of the NUGAG Subgroup

Member	Interests declared/identified	Action taken
	▸ Statistics Canada and Health Canada: technical adviser on analysis of dietary intake patterns for 2015 Canadian Community Health Survey (2015–2021) ▸ Health Canada: technical adviser on various projects – nutrient profiling for front-of-pack labelling, restricting marketing to children, updating Canada's Food Guide, developing a Canada Food Guide Adherence Tool on "what to eat" (2016–2021) ▸ Received research funding from various agencies: Canadian Institute of Health Research, Institute for the Advancement of Food and Nutrition Sciences, Alberta Innovates and Alberta Health Services, Health Canada, Sanofi-Pasteur – University of Toronto – Université Paris – Descartes International Collaborative Research Pilot and Feasibility Program, International Development Research Centre – NCD Prevention Program, Burroughs Wellcome Foundation, Fonds de recherche Société et culture Québec, Heart and Stroke Foundation of Canada (2012–2021)	on Diet and Health in an objective manner, and the expert was allowed to participate fully as a member of the NUGAG Subgroup on Diet and Health throughout the guideline development process.
Barbara Schneeman	▸ US Agency for International Development (USAID): employed as higher education coordinator from 2015 to 2016, where she worked with the higher education community to increase engagement with USAID ▸ US Food and Drug Administration (FDA): employed through 2012 (retired in 2013) ▸ Head of the US delegate to the Codex Committee on Nutrition and Foods for Special Dietary Uses, and Codex Committee on Food Labelling; she presented the positions of the United States in these Codex forums (up to 2012) ▸ Monsanto: member of advisory committee discussing role of agriculture in addressing climate change, and improving food and nutrition security (2014 –2017) ▸ McCormick Science Institute: member of advisory committee reviewing research proposals on spices and herbs (2014–2021) ▸ Ocean Spray: temporary adviser on health claim petitions that are submitted to US FDA related to cranberries (2014–2015) ▸ General Mills: temporary adviser on labelling requirements for nutrition declarations in the United States (2014–2016, and 2018) ▸ DSM: temporary adviser on Codex Alimentarius processes (2014–2015) ▸ Hampton Creek: temporary adviser on labelling standards for mayonnaise (2014–2015) ▸ Washington DC law firm: temporary adviser on labelling of genetically modified foods (2014–2015) ▸ NASEM: member of the National Academies and member/ Chair of the Dietary Guidelines Advisory Committee, involved in reviewing the evidence for developing the Dietary Guidelines for Americans	Each engagement was assessed in the context of the topic of this guideline. Meeting expenses and honorariums were paid in some instances. With the exception of membership on the US Dietary Guidelines Advisory Committee, the engagements have all been on topics unrelated to the objective of this guideline, primarily providing expert advice on US regulatory issues, such as food labelling (i.e. nutrient declarations, health claims, other types of labelling), or presenting the process for developing the dietary guidelines for the US, Dietary Guidelines for Americans. Regarding her membership on the US Dietary Guidelines Advisory Committee, although the nature of the work was similar to the work being carried out for this guideline, the work was done for a national authority

Member	Interests declared/identified	Action taken
	— Nominated to the Dietary Guidelines Advisory Committee of the USA by representatives from the North American Branch of the International Life Sciences Institute; American Beverage Association; American Bakers Association, Grain Chain; Grocery Manufacturers Association USA Dry Pea & Lentil Council, American Pulse Association — Received honorariums for presentations on the process to develop the Dietary Guidelines for Americans and policies for food labelling in the United States at various scientific meetings organized by PMK Associates (Institute of Food Technologists and American Oil Chemists' Society), McCormick Science Institute, Fibre Association Japan, and Mushroom Council ▶ International Food Information Council (IFIC): member, Board of Trustees, which ensures that IFIC upholds its responsibilities as a 501(c)*(3)* non-profit organization (2021) ▶ International Life Science Institute North America: government liaison, and evaluating research and organizing webinars on the microbiome (2018) ▶ International Dairy Foods Association: presented webinar on the work of the 2020 Dietary Guideline Advisory Committee, for which she received no remuneration (2020)	and therefore was not considered a conflict of interest. With respect to her nomination to the US Dietary Guidelines Advisory Committee by various industry groups, there is no relationship or affiliation between nominator and nominee. Because none of the interests were directly relevant to the objective of this guideline or were otherwise determined not to represent a conflict of interest, it was concluded that the interests would not impact the ability of this expert to serve as a member of the NUGAG Subgroup on Diet and Health in an objective manner. The expert was allowed to participate fully as a member of the NUGAG Subgroup on Diet and Health throughout the guideline development process.

No other members of the NUGAG Subgroup on Diet and Health declared any interests (or the declared interests clearly did not represent a conflict of interest), nor were any interests independently identified (see **Annex 2** for the list of members of the NUGAG Subgroup on Diet and Health).

Members of the external peer review group

Member	Interests declared/identified	Action taken
Amos Laar	▶ International Development Research Center, Canada: research support to study the food environments of Ghanaian children to prevent obesity and NCDs (MEALS4NCDs)	Given the nature and topic of the research funding, it was not considered to represent a conflict of interest for serving as an external reviewer of this guideline.
Yang Yuexin	▶ President of the Chinese Nutrition Society	Given the nature of the engagement, it was not considered to represent a conflict of interest for serving as an external reviewer of this guideline.

No other members of the external peer review group declared any interests, nor were any interests independently identified (see **Annex 3** for the full list of external peer reviewers).

Members of the systematic review teams

No members of the systematic review teams declared any interests, nor were any interests independently identified.

Annex 5

Key questions in PICO format (population, intervention, comparator, outcome)

PICO questions

- What is the effect on prioritized health outcomes in adults and children of higher intake of dietary fibre compared with lower intake?
- What is the effect on prioritized health outcomes in adults and children of higher intake of high-quality carbohydrate compared with lower intake, assessed as
  - replacing rapidly digested starches with slowly digested starches (or higher compared with lower intake of slowly digested starches) as assessed by potential markers of digestibility

  and/or

  - consuming foods containing higher-quality carbohydrate compared with consuming foods containing lower-quality carbohydrate (i.e. higher consumption of foods containing higher-quality carbohydrate compared with lower consumption)?

Population	Apparently healthy adults and children in low-, middle- and high-income countries ▸ In each, consider population characteristics, such as age, gender, ethnicity, country/region (urban/rural), socioeconomic status, demographic factors, sanitation, health background and health status, including baseline risk of CVD
Intervention/ exposure	*Dietary fibre* Higher intake of either naturally occurring dietary fibre from foods (intrinsic) or extracted dietary fibre (extrinsic) through either experimental means (RCTs) or natural consumption in free-living populations in prospective cohort studies Possible subgroup analyses include: ▸ levels of intake ▸ intrinsic compared with extrinsic ▸ source of intrinsic dietary fibre (i.e. different food sources) *Carbohydrate quality* Intake of higher-quality carbohydrate, or foods containing higher quality carbohydrates through either experimental means (RCTs) or natural consumption in free-living populations in prospective cohort studies, assessed via: ▸ replacement of rapidly digested starches with slowly digested starches (or higher versus lower intake of slowly digested starches) as assessed by potential markers of digestibility and/or ▸ consumption of foods containing higher-quality carbohydrate compared with foods containing lower-quality carbohydrate (i.e. higher intake of foods containing higher-quality carbohydrate compared with lower intake)

	Possible subgroup analyses include: ▸ higher compared with lower glycaemic response ▸ refined carbohydrate compared with whole grain carbohydrate ▸ lower versus higher resistant starch intake ▸ lower versus higher pulse intake *Vegetables and fruits* Higher intake of vegetables and fruits
Comparator	*Dietary fibre* Lower, usual or no dietary fibre intake *Carbohydrate quality* Lower-quality carbohydrate or foods containing lower-quality carbohydrates, or different amounts of higher-quality carbohydrates *Vegetables and fruits* Lower or no intake of vegetables and fruits
Outcome	*Adults and children* ▸ CVDs, including markers of disease (e.g. blood lipids, blood pressure)[a] ▸ Prediabetes/type 2 diabetes, including markers of disease (e.g. markers of glycaemic control)[a] ▸ Overweight/obesity ▸ Colorectal cancer (adults only) ▸ Other cancers: oesophageal, breast, endometrium, prostate (adults only) ▸ Inflammatory bowel disease ▸ Oral health ▸ Quality of life ▸ Bowel habits ▸ Growth (children only) ▸ Bone density (children only) ▸ Anaemia (children only) ▸ Cognitive development (children only)

[a] For children, markers of disease only.

Annex 6

GRADE evidence profiles

GRADE evidence profile 1

Question: What is the effect of higher compared with lower intake of whole grains in adults?

Population: General adult population

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
All-cause mortality											
9	Observational	Not serious	Serious[1]	Not serious	Not serious	Dose–response	99 224 (13.8%)	717 331/10.7 + 1 nested case–control study	**RR 0.81** (0.72 to 0.90)	**26 fewer** (from 14 fewer to 39 fewer)	⨁⨁◯◯ Low
Coronary heart disease mortality											
2	Observational	Serious[2]	Not serious	Not serious	Not serious	Dose–response	1 588 (1.1%)	147 321/2.0	**RR 0.66** (0.56 to 0.77)	**4 fewer** (from 1 fewer to 5 fewer)	⨁⨁◯◯ Low
Coronary heart disease											
6	Observational	Not serious	Serious[3]	Not serious	Not serious	Dose–response	7 697 (3.3%)	232 886/2.8	**RR 0.80** (0.70 to 0.91)	**7 fewer** (from 3 fewer to 10 fewer)	⨁⨁◯◯ Low
Stroke mortality											
2	Observational	Serious[2]	Not serious	Not serious	Not serious	Dose–response	694 (0.5%)	147 321/2.0	**RR 0.74** (0.58 to 0.94)	**1 fewer** (from 0 fewer to 2 fewer)	⨁⨁◯◯ Low
Stroke											
3	Observational	Not serious	Not serious[4]	Not serious	Serious[5]	None	1 247 (1.4%)	91 393/1.1	**RR 0.86** (0.61 to 1.21)	**2 fewer** (from 3 more to 5 fewer)	⨁◯◯◯ Very low
Cardiovascular disease mortality											
6	Observational	Not serious	Serious[6]	Not serious	Not serious	Dose–response	19 985 (3.8%)	520 590/8.5	**RR 0.77** (0.69 to 0.86)	**9 fewer** (from 5 fewer to 12 fewer)	⨁⨁◯◯ Low

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
Cardiovascular diseases											
3	Observational	Not serious	Not serious	Not serious	Not serious	Dose–response	4 357 (6.4%)	68 488/0.9	**RR 0.89** (0.81 to 0.98)	**7 fewer** (from 1 fewer to 12 fewer)	⊕⊕⊕◯ Moderate
Cancer mortality											
5	Observational	Not serious	Serious[7]	Not serious	Not serious	Dose–response	32 727 (5.0%)	654 588/10.1	**RR 0.84** (0.76 to 0.92)	**8 fewer** (from 4 fewer to 12 fewer)	⊕⊕◯◯ Low
Type 2 diabetes											
8	Observational	Not serious	Serious[8]	Not serious	Not serious	Dose–response	14 686 (4.0%)	363 546/3.9	**RR 0.67** (0.58 to 0.78)	**13 fewer** (from 9 fewer to 17 fewer)	⊕⊕◯◯ Low
Colorectal cancer[9]											
7	Observational	Not serious	Not serious[10]	Not serious	Not serious	Dose–response	8 803 (1.2%)	710 363/6.8	**RR 0.87** (0.79 to 0.96)	**2 fewer** (from 0 fewer to 3 fewer)	⊕⊕⊕◯ Moderate
Prostate cancer											
3	Observational	Not serious	Not serious	Not serious	Not serious	None	7 010 (8.3%)	84 752/1.5	**RR 1.10** (1.02 to 1.19)	**8 more** (from 2 more to 16 more)	⊕⊕◯◯ Low
Body weight (kg)											
11	RCT	Not serious	Serious[11]	Not serious	Not serious	None	498[12]	421[13]	**MD –0.62** (–1.19 to –0.05)		⊕⊕⊕◯ Moderate

CI: confidence interval; IR: incidence rate; MD: mean difference; RCT: randomized controlled trial; RR, relative risk.

1 Initial heterogeneity as measured by I^2 was 97.4%. One study *(1)* strongly influenced the pooled result. Removal of this study did not change the direction or significance of the pooled effect size (0.78; 95% CI: 0.72 to 0.85); however, the heterogeneity remained high with an I^2 of 86.9%.

2 This is a pooled estimate from only two studies.

3 Initial heterogeneity as measured by I^2 was 79.1%. One study *(2)* strongly influenced the pooled result. Removal of this study did not change the direction or significance of the pooled effect size (0·77; 95% CI: 0.67 to 0.88); however, the heterogeneity remained high with an I^2 of 62.6%.

4 Initial heterogeneity as measured by I^2 was 65.2%. One study *(3)* strongly influenced the pooled result. Removal of this study did not change the direction or significance of the pooled result (0·71; 95% CI: 0.54 to 0.94), and the I^2 was reduced to 0%.

5 95% CIs are wide, from 0.61 to 1.21, indicating a high level of uncertainty around the effect estimate.

6 Heterogeneity as measured by I^2 of 72.0% was unexplained by sensitivity analyses.

7 Heterogeneity as measured by I^2 of 78.3% was unexplained by sensitivity analyses.

8 Initial heterogeneity as measured by I^2 was 82.4%. Data from one cohort (NHS I) of one study *(4)* strongly influenced the pooled result. Removal of these data did not change the direction or significance of the pooled result (0.70; 95% CI: 0.59 to 0.83); however, the heterogeneity remained high with an I^2 of 78.5%.

9 No studies were identified that assessed breast, endometrial or oesophageal cancer.

[10] Initial heterogeneity as measured by I^2 was 51.9%. One study *(5)* strongly influenced the pooled result. Removal of this study did not change the direction or significance of the pooled result (0.82; 95% CI: 0.75 to 0.90), and the I^2 was reduced to 20%.
[11] Evidence of significant heterogeneity; $I^2 > 50\%$.
[12] Higher whole grain intake.
[13] Lower whole grain intake.

GRADE evidence profile 2

Question: What is the effect of higher compared with lower intake of vegetables and fruits in adults?

Population: General adult population

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people	Relative (95% CI)	Absolute – per 1000 (95% CI)	
All-cause mortality											
22	Observational[1]	Not serious[2]	Serious[3]	Not serious	Not serious	Dose–response[4,5]	87 574 (8.5%)	1 035 556	**RR 0.82** (0.79 to 0.86)	**15 fewer** (from 12 fewer to 18 fewer)	⨁⨁◯◯ Low
Coronary heart disease											
16	Observational[6]	Not serious	Not serious[7]	Not serious	Not serious	Dose–response[5,8]	18 516 (2.3%)	792 197	**RR 0.87** (0.83 to 0.91)	**3 fewer** (from 2 fewer to 4 fewer)	⨁⨁⨁◯ Moderate
Stroke[9]											
8	Observational[10]	Not serious	Not serious[11]	Not serious	Not serious	Dose–response[5,12]	10 560 (4.7%)	226 910	**RR 0.79** (0.71 to 0.88)	**10 fewer** (from 6 fewer to 13 fewer)	⨁⨁⨁◯ Moderate
Cardiovascular diseases[13]											
16	Observational[14]	Not serious[2]	Serious[15]	Not serious	Not serious	Dose–response[16]	27 842 (2.9%)	963 240	**RR 0.84** (0.79 to 0.90)	**5 fewer** (from 3 fewer to 6 fewer)	⨁⨁◯◯ Low
Cancer[13]											
13	Observational[17]	Not serious	Not serious[18]	Not serious	Not serious	Dose–response[19]	54 123 (6.0%)	904 300	**RR 0.93** (0.87 to 0.98)	**4 fewer** (from 1 fewer to 8 fewer)	⨁⨁⨁◯ Moderate
Body weight (kg)											
8	RCT	Not serious	Serious[20]	Not serious	Serious[21]	Publication bias[22]	287[23]	249[24]	**MD −0.54** (−1.05 to −0.04)		⨁◯◯◯ Very low

CI: confidence interval; IR: incidence rate; MD: mean difference; RCT: randomized controlled trial; RR: relative risk.

1 Subgroup analyses for all-cause mortality indicated inverse associations with apples/pears, berries, citrus fruits, fruit juice, cooked vegetables, cruciferous vegetables, potatoes and green leafy vegetables/salads. There was a positive association with tinned fruit. As with all foods, the cooking method could attenuate or remove any observed health benefit.

2 Egger's test suggested a risk of publication bias; however, trim and fill analysis did not appreciably change the point estimate of the pooled result.

3 Initial I^2 was 62.3%; heterogeneity was unexplained by any sensitivity analyses.

4 Consistent benefits were seen with non-linear dose–response analysis with a difference in vegetable and fruit intake from 50 g each day (RR 0.96; 95% CI: 0.95 to 0.97) to 830 g each day (RR 0.69; 95% CI: 0.66 to 0.73).

5 A recent systematic review of potato intake *(6)* did not observe an association between total potato intake and all-cause mortality, coronary heart disease, stroke or colorectal cancer. Updating their analysis with a new cohort study published following the release of the systematic review removed the significance of the association between total potato intake and type 2 diabetes incidence. Fried potato intake was associated with increased risk of type 2 diabetes and hypertension.

[6] Subgroup analyses for coronary heart disease mortality indicated inverse associations with apples/pears, citrus fruits, fruit juices, green leafy vegetables, beta carotene–rich vegetables and fruits, and vitamin C–rich vegetables and fruits. As with all foods, the cooking method could attenuate or remove any observed health benefit.

[7] I^2 was 0%.

[8] Consistent benefits were seen with non-linear dose–response analysis with a difference in vegetable and fruit intake from 100 g each day (RR 0.97; 95% CI: 0.96 to 0.98) to 900 g each day (RR 0.73; 95% CI: 0.71 to 0.76).

[9] The systematic review pooled incidence and mortality together. Evidence from the per 200 g increase analyses indicated that there was a greater effect size for stroke mortality (RR 0.75; 95% CI: 0.63 to 0.89) than for stroke incidence (RR 0.85; 95% CI: 0.77 to 0.94) when considered separately.

[10] For stroke mortality, there were inverse associations with apples/pears, citrus fruits, fruit juice, green leafy vegetables and pickled vegetables. As with all foods, the cooking method could attenuate or remove any observed health benefit.

[11] I^2 was 37.6%.

[12] Consistent benefits were seen with non-linear dose–response analysis with a difference in vegetable and fruit intake from 50 g each day (RR 0.98; 95% CI: 0.97 to 0.99) to 900 g each day (RR 0.66; 95% CI: 0.58 to 0.74).

[13] The systematic review pooled incidence and mortality together for the higher versus lower analyses. Evidence from the per 200 g increase analyses indicated that there was no difference between incidence and mortality for this outcome when considered separately.

[14] Subgroup analyses for CVD mortality indicated inverse associations with apples/pears, berries, citrus fruits, carrots and non-cruciferous vegetables. There was a positive association with tinned fruit. As with all foods, the cooking method could attenuate or remove any observed health benefit.

[15] Initial I^2 was 53.5%; heterogeneity was unexplained by any sensitivity analyses.

[16] Consistent benefits were seen with non-linear dose–response analysis with a difference in vegetable and fruit intake from 50 g each day (RR 0.99; 95% CI: 0.98 to 0.99) to 900 g each day (RR 0.70; 95% CI: 0.66 to 0.75).

[17] Subgroup analyses for total cancer mortality indicated inverse associations with cruciferous vegetables and green–yellow vegetables. As with all foods, the cooking method could attenuate or remove any observed health benefit.

[18] I^2 was 41.2%.

[19] Consistent benefits were seen with non-linear dose–response analysis with a difference in vegetable and fruit intake from 100 g each day (RR 0.98; 95% CI: 0.97 to 0.98) to 900 g each day (RR 0.86; 95% CI: 0.84 to 0.88).

[20] High unexplained heterogeneity, with an initial I^2 of 73%.

[21] Confidence intervals are wide and include both a benign effect and a strong effect.

[22] Egger's *P* for possible publication bias of 0.012 indicated risk of publication bias. Trim and fill analysis removed the significance of the association.

[23] Higher vegetable and fruit intake.

[24] Lower vegetable and fruit intake.

GRADE evidence profile 3

Question: What is the effect of higher compared with lower intake of pulses in adults?

Population: General adult population

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people	Relative (95% CI)	Absolute – per 1000 (95% CI)	
Coronary heart disease											
10	Observational	Not serious	Not serious	Not serious	Not serious	Dose–response	7 451 (2.4%)	313 414	**RR 0.90** (0.84 to 0.97)	**2 fewer** (from 1 fewer to 4 fewer)	⊕⊕⊕◯ Moderate
Stroke											
6	Observational	Not serious	Not serious	Not serious	Not serious	None	6 336 (2.4%)	266 241	**RR 1.01** (0.89 to 1.14)	**0 fewer** (from 3 fewer to 3 more)	⊕⊕◯◯ Low
Cardiovascular diseases											
5	Observational	Not serious	Not serious	Not serious	Not serious	None	18 475 (14.2%)	129 692	**RR 0.90** (0.84 to 0.97)	**14 fewer** (from 4 fewer to 23 fewer)	⊕⊕◯◯ Low
Type 2 diabetes											
2	Observational	Serious[1]	Not serious	Not serious	Not serious	None	2 746 (2.7%)	100 179	**RR 0.79** (0.71 to 0.87)	**6 fewer** (from 4 fewer to 23 fewer)	⊕◯◯◯ Very low
Body weight (kg)											
3	RCT	Not serious	Not serious	Not serious	Not serious	None	178[2]	178[3]	**MD −0.18** (−0.52 to 0.16)		⊕⊕⊕⊕ High

CI: confidence interval; IR: incidence rate; MD: mean difference; RCT: randomized controlled trial; RR: relative risk.

[1] This is a pooled estimate from only two studies.

[2] Higher intake of pulses.

[3] Lower intake of pulses.

GRADE evidence profile 4

Question: What is the effect of higher compared with lower intake of dietary fibre in adults?

Population: General adult population

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
All-cause mortality											
10	Observational	Not serious	Not serious[1]	Not serious	Not serious	Dose–response	80 139 (8.5%)	947 111/12.3	**RR 0.85** (0.79 to 0.91)	**13 fewer** (from 8 fewer to 18 fewer)	⊕⊕⊕◯ Moderate
Coronary heart disease mortality											
10	Observational	Not serious	Not serious	Not serious	Not serious	Publication bias;[2] dose–response	7 243 (1.2%)	596 887/6.9	**RR 0.69** (0.60 to 0.80)	**4 fewer** (from 2 fewer to 5 fewer)	⊕⊕⊕◯ Moderate
Coronary heart disease											
9	Observational	Not serious	Not serious	Not serious	Not serious	Dose–response	7 155 (2.4%)	299 386/2.7	**RR 0.76** (0.69 to 0.83)	**6 fewer** (from 4 fewer to 7 fewer)	⊕⊕⊕◯ Moderate
Stroke mortality											
2	Observational	Serious[3]	Not serious	Not serious	Serious[4]	None	1 113 (1.2%)	89 761/1.3	**RR 0.80** (0.56 to 1.14)	**2 fewer** (from 2 more to 5 fewer)	⊕◯◯◯ Very low
Stroke											
9	Observational	Not serious	Not serious	Not serious	Not serious	Dose–response	13 134 (3.6%)	364 204/4.6	**RR 0.82** (0.75 to 0.90)	**6 fewer** (from 4 fewer to 9 fewer)	⊕⊕⊕◯ Moderate
Cardiovascular disease mortality											
7	Observational	Not serious	Not serious	Not serious	Not serious	Dose–response	15 433 (1.6%)	947 870/ 10.7	**RR 0.77** (0.71 to 0.83)	**4 fewer** (from 3 fewer to 53 fewer)	⊕⊕⊕◯ Moderate
Cardiovascular diseases											
8	Observational	Not serious	Not serious[5]	Not serious	Not serious	Dose–response	12 423 (6.2%)	200 143/ 2.1	**RR 0.76** (0.68 to 0.85)	**15 fewer** (from 9 fewer to 20 fewer)	⊕⊕⊕◯ Moderate
Cancer mortality											
5	Observational	Not serious[6]	Not serious	Not serious	Not serious	Dose–response	29 593 (3.5%)	844 225/11.2	**RR 0.87** (0.79 to 0.95)	**5 fewer** (from 2 fewer to 7 fewer)	⊕⊕⊕◯ Moderate

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
Type 2 diabetes											
17	Observational	Not serious	Not serious[7]	Not serious	Not serious	Dose–response	48 468 (7.6%)	640 656/6.9	**RR 0.84** (0.78 to 0.90)	**12 fewer** (from 8 fewer to 17 fewer)	⊕⊕⊕◯ Moderate
Breast cancer											
18	Observational	Not serious	Not serious	Not serious	Not serious	Dose–response	37 194 (2.9%)	1 283 089/12.1 + 2 nested case controls	**RR 0.93** (0.90 to 0.97)	**2 fewer** (from 1 fewer to 3 fewer)	⊕⊕⊕◯ Moderate
Colorectal cancer incidence											
22	Observational	Not serious	Not serious	Not serious	Not serious	Dose–response	22 920 (1.5%)	1 560 045/16.9	**RR 0.84** (0.78 to 0.89)	**2 fewer** (from 2 fewer to 3 fewer)	⊕⊕⊕◯ Moderate
Endometrial cancer											
4	Observational	Not serious	Not serious	Not serious	Serious[8]	None	1 982 (0.5%)	417 031/3.8	**RR 1.16** (1.01 to 1.33)	**1 more** (from 0 fewer to 2 more)	⊕◯◯◯ Very low
Oesophageal cancer incidence											
1	Observational	Serious[9]	Not serious	Not serious	Serious[10]	Dose–response	169 (0.5%)	34 351/0.5	**RR 0.57** (0.36 to 0.92)	**2 fewer** (from 0 fewer to 3 fewer)	⊕◯◯◯ Very low
Prostate cancer incidence											
5	Observational	Not serious	Serious[11]	Not serious	Not serious	None	9 640 (3.9%)	247 400/2.9	**RR 1.02** (0.89 to 1.17)	**1 more** (from 4 fewer to 7 more)	⊕◯◯◯ Very low
Body weight (kg)											
27	RCT	Not serious	Not serious	Not serious	Not serious	None	1 294[12]	1 201[13]	**MD –0.37** (–0.63 to –0.11)		⊕⊕⊕⊕ High
BMI (kg/m²)											
9	RCT	Not serious	Serious[14]	Not serious	Not serious	None	608[12]	614[13]	**MD –0.17** (–0.33 to –0.01)		⊕⊕⊕◯ Moderate
Fasting glucose (mmol/L)											
39	RCT	Not serious	Serious[14]	Serious[15]	Not serious	None	1 716[12]	1 547[13]	**MD –0.09** (–0.15 to –0.02)		⊕⊕◯◯ Low

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
LDL cholesterol (mmol/L)											
34	RCT	Not serious	Serious[14]	Not serious	Not serious	None	1 801[12]	1 640[13]	**MD –0.09** (–0.15 to –0.04)		⊕⊕⊕◯ Moderate
Systolic blood pressure (mmHg)											
15	RCT	Not serious	Serious[14]	Not serious	Not serious	None	1 064[12]	988[13]	**MD –1.27** (–2.50 to –0.04)		⊕⊕⊕◯ Moderate
Diastolic blood pressure (mmHg)											
15	RCT	Not serious	Not serious	Not serious	Not serious	None	1 064[12]	988[13]	**MD –1.34** (–2.96 to 0.27)		⊕⊕⊕⊕ High

BMI: body mass index; CI: confidence interval; IR: incidence rate; LDL: low-density lipoprotein; MD: mean difference; RCT: randomized controlled trial; RR: relative risk.

1 The initial heterogeneity as measured by I^2 was 75.8%. One study was found to strongly influence the pooled result *(7)*. Removal of this study did not change the direction or significance of the pooled result (0.87; 95% CI: 0.82 to 0.94); however, the heterogeneity as measured by I^2 remained high at 53.3%. Further removal of the one study with low case numbers *(8)* reduced the heterogeneity as measured by I^2 to less than 50% without changing the direction or significance of the pooled result (0.86; 95% CI: 0.79 to 0.92).

2 Egger's test for bias $P = 0.004$. Trim and fill analysis did not change the direction or significance of the pooled estimate.

3 This is a pooled estimate from only two studies.

4 95% CIs are wide, from 0.56 to 1.14, indicating a high level of uncertainty around the effect estimate.

5 The initial I^2 value was 62.2%. Influence analysis indicated that one study *(9)* strongly influenced the pooled estimate. The pooled effect size without this study was 0.73 (95% CI: 0.66 to 0.81), and the heterogeneity as measured by I^2 decreased to 38.7%.

6 The dose–response estimate was generated by only one study of 5.2 million person-years.

7 The initial heterogeneity when measured by I^2 was 71.2%. One study *(10)* strongly influenced the pooled estimate. Removing this study did not change the direction or significance of results. Removal of low-quality studies (Newcastle–Ottawa Scale <6) further reduced heterogeneity as measured by I^2 to 49.7% without changing the direction or significance of the pooled effect size.

8 95% CIs are wide, from 1.01 to 1.33, indicating a high level of uncertainty around the effect estimate.

9 This effect size estimate is from only one study.

10 95% CIs are wide, from 0.36 to 0.92, indicating a high level of uncertainty around the effect estimate.

11 Heterogeneity as measured by I^2 of 59.1% was unexplained by sensitivity analysis.

12 Higher dietary fibre intake.

13 Lower dietary fibre intake.

14 Evidence of significant heterogeneity; $I^2 > 50\%$.

15 Outcome is an indirect marker of cardiometabolic risk.

GRADE evidence profile 5

Question: What is the effect of diets with lower compared with higher glycaemic index in adults?

Population: General adult population

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
All-cause mortality											
3	Observational	Not serious	Serious[1]	Not serious	Serious[2]	None	7 698 (11.3%)	68 185/0.6	**RR 0·89** (0.70 to 1.13)	**12 fewer** (from 15 more to 34 fewer)	⊕◯◯◯ Very low
Coronary heart disease mortality											
1	Observational	Serious[3]	Not serious	Not serious	Serious[4]	None	Incidence not stated	0.04 million	**RR 1.10** (0.69 to 1.75)	Not calculated	⊕◯◯◯ Very low
Coronary heart disease											
10	Observational	Not serious	Not serious	Not serious	Not serious	None	8 456 (3.1%)	274 085 + 1 cohort where incidence was not stated/2.4 + 1 nested case–control study	**RR 0.93** (0.83 to 1.04)	**2 fewer** (from 1 more to 5 fewer)	⊕⊕◯◯ Low
Stroke mortality											
3	Observational	Not serious	Not serious	Not serious	Not serious	None	951 (1.0%)	95 087/1.2	**RR 0.63** (0.52 to 0.77)	**4 fewer** (from 2 fewer to 5 fewer)	⊕⊕◯◯ Low
Stroke											
5	Observational	Not serious	Serious[5]	Not serious	Not serious	None	5 527 (2.3%)	243 276/3.0	**RR 0.84** (0.72 to 0.99)	**4 fewer** (from 0 fewer to 6 fewer)	⊕◯◯◯ Very low
Cardiovascular disease mortality											
2	Observational	Serious[6]	Not serious	Not serious	Serious[7]	None	2 469 (3.8%)	64 602/0.6	**RR 0.81** (0.70 to 0.94)	**7 fewer** (from 14 fewer to 23 more)	⊕◯◯◯ Very low
Cardiovascular diseases											
2	Observational	Serious[6]	Serious[8]	Not serious	Serious[9]	None	928 (2.8%)	33 138/0.3	**RR 0.95** (0.50 to 1.82)	**1 fewer** (from 14 fewer to 23 more)	⊕◯◯◯ Very low

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
Cancer mortality											
1	Observational	Serious[3]	Not serious	Not serious	Serious[10]	None	1 401 (4.9%)	28 356/0.4	**RR 1.11** (0.90 to 1.38)	**5 more** (from 5 fewer to 19 more)	⊕◯◯◯ Very low
Type 2 diabetes											
14	Observational	Not serious	Serious[11]	Not serious	Not serious	None	36 908 (7.2%)	499 989/6.5	**RR 0.89** (0.82 to 0.97)	**8 fewer** (from 2 fewer to 13 fewer)	⊕◯◯◯ Very low
Breast cancer											
11	Observational	Not serious	Not serious	Not serious	Not serious	None	26 394 (3.3%)	807 741/9.0	**RR 0.95** (0.91 to 0.99)	**2 fewer** (from 0 fewer to 3 fewer)	⊕⊕◯◯ Low
Colorectal cancer											
10	Observational	Not serious	Serious[12]	Not serious	Not serious	None	11 245 (1.2%)	941 652/8.8	**RR 0.91** (0.82 to 1.01)	**1 fewer** (from 0 fewer to 2 fewer)	⊕◯◯◯ Very low
Endometrial cancer											
6	Observational	Not serious	Not serious	Not serious	Not serious	None	3 586 (0.6%)	627 030/5.3	**RR 1.02** (0.92 to 1.14)	**0 fewer** (from 0 fewer to 1 more)	⊕⊕◯◯ Low
Oesophageal cancer											
1	Observational	Serious[3]	Not serious	Not serious	Serious[13]	Dose–response	501 (0.1%)	446 177/3.1	**RR 0.68** (0.51 to 0.91)	**0 fewer** (from 0 fewer to 1 fewer)	⊕◯◯◯ Very low
Prostate cancer incidence											
4	Observational	Not serious	Not serious	Not serious	Not serious	None	23 654 (6.9%)	344 551/3.1	**RR 1.02** (0.97 to 1.07)	**1 more** (from 1 fewer to 5 more)	⊕⊕◯◯ Low
Body weight (kg)											
8	RCT	Not serious	Not serious	Not serious	Not serious	None	464	355	**MD –0.29** (–0.62 to 0.03)		⊕⊕⊕⊕ High
BMI (kg/m²)											
3	RCT	Not serious	Not serious	Not serious	Serious[14]	None	75	70	**MD –0.28** (–0.50 to –0.06)		⊕⊕⊕◯ Moderate
Fasting glucose (mmol/L)											
11	RCT	Not serious	Not serious	Serious[15]	Not serious	None	609	475	**MD 0.00** (–0.08 to 0.07)		⊕⊕◯◯ Low

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
LDL cholesterol (mmol/L)											
8	RCT	Not serious	Serious[16]	Not serious	Not serious	None	605	478	**MD 0.05** (–0.13 to 0.22)		⊕⊕⊕◯ Moderate
Systolic blood pressure (mmHg)											
4	RCT	Not serious	Not serious	Not serious	Not serious	None	519	397	**MD –0.17** (–1.03 to 0.69)		⊕⊕⊕◯ Moderate
Diastolic blood pressure (mmHg)											
4	RCT	Not serious	Not serious	Not serious	Not serious	None	519	397	**MD –0.13** (–0.46 to 0.72)		⊕⊕⊕⊕ High

BMI: body mass index; CI: confidence interval; IR: incidence rate; LDL: low-density lipoprotein; MD: mean difference; RCT: randomized controlled trial; RR: relative risk.

[1] Initial heterogeneity as measured by I^2 was 83.8%. The three studies report such different effect sizes that one study *(11)* strongly influenced the pooled result in one direction, while another *(12)* strongly influenced the pooled result in the opposite direction. Removal of one study with less than 200 cases *(13)* did not change the non- significance of the pooled result, and the heterogeneity as measured by I^2 from the two remaining studies was high at 82.4%.

[2] 95% CIs are wide, from 0.70 to 1.13, indicating a high level of uncertainty around the effect estimate.

[3] This is an effect size estimate from only one study.

[4] 95% CIs are wide, from 0.69 to 1.75, indicating a high level of uncertainty around the effect estimate.

[5] Initial heterogeneity as measured by I^2 was 63.7%. One study *(14)* strongly influenced the pooled result. Removal of this study changed the significance of the pooled effect size (0.90; 95% CI: 0.79 to 1.03) while reducing the heterogeneity as measured by I^2 to 12.3%.

[6] This is a pooled estimate from only two studies.

[7] 95% CIs are wide, from 1.06 to 1.41, indicating a high level of uncertainty around the effect estimate.

[8] The heterogeneity when combining these two studies as measured by I^2 is 85.5%.

[9] 95% CIs are wide, from 0.50 to 1.82, indicating a high level of uncertainty around the effect estimate.

[10] 95% CIs are wide, from 0.90 to 1.38, indicating a high level of uncertainty around the effect estimate.

[11] Initial heterogeneity as measured by I^2 was 74.3%. Data from one cohort (NHS I) of one study *(15)* strongly influenced the pooled result. Removal of these data removed the significance of the pooled result (0.92; 95% CI: 0.84 to 1.00); however, heterogeneity remained high with an I^2 of 58.1%. Removal of a further two studies with a Newcastle–Ottawa Scale <6 also resulted in a non-significant pooled effect (0.95; 95% CI: 0.87 to 1.04), and the heterogeneity as measured by I^2 remained high at 53.9%.

[12] Heterogeneity as measured by I^2 was 55.2%; this was unexplained by sensitivity analyses.

[13] 95% CIs are wide, from 0.51 to 0.91, indicating a high level of uncertainty around the effect estimate.

[14] Evidence of serious imprecision in the effect size estimate.

[15] Indirect measure of cardiometabolic risk.

[16] Evidence of significant heterogeneity.

GRADE evidence profile 6

Question: What is the effect of diets with lower compared with higher glycaemic load in adults?

Population: General adult population

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
All-cause mortality											
3	Observational	Not serious	Serious[1]	Not serious	Serious[2]	None	7 698 (11.3%)	68 185/0.6	**RR 1.13** (0.96 to 1.31)	**15 more** (from 5 fewer to 35 more)	⊕◯◯◯ Very low
Coronary heart disease mortality											
1	Observational	Serious[3]	Not serious	Not serious	Serious[4]	None	162 (0.8%)	20 275/0.2 + 1 nested case–control study	**RR 0.79** (0.49 to 1.30)	**2 fewer** (from 2 more to 4 fewer)	⊕◯◯◯ Very low
Coronary heart disease											
10	Observational	Not serious	Not serious[5]	Not serious	Not serious	Dose–response	9 235 (2.6%)	353 914/2.6	**RR 0.85** (0.76 to 0.95)	**4 fewer** (from 1 fewer to 6 fewer)	⊕⊕⊕◯ Moderate
Stroke mortality											
2	Observational	Serious[6]	Serious[7]	Not serious	Serious[8]	Dose–response	856 (0.9%)	92 190/1.1	**RR 0.70** (0.46 to 1.06)	**3 fewer** (from 1 more to 5 fewer)	⊕◯◯◯ Very low
Stroke											
5	Observational	Not serious	Serious[9]	Not serious	Not serious	None	5 527 (2.3%)	243 276/3.0	**RR 0.84** (0.72 to 0.98)	**4 fewer** (from 0 fewer to 6 fewer)	⊕◯◯◯ Very low
Cardiovascular disease mortality											
2	Observational	Serious[6]	Not serious	Not serious	Serious[10]	None	2 469 (3.8%)	64 602/0.6	**RR 1.02** (0.88 to 1.18)	**1 more** (from 5 fewer to 7 more)	⊕◯◯◯ Very low
Cardiovascular diseases											
1	Observational	Serious[3]	Not serious	Not serious	Serious[11]	None	799 (5.1%)	15 714/ 0.1	**RR 0·83** (0.68 to 1.02)	**9 fewer** (from 1 more to 16 fewer)	⊕◯◯◯ Very low
Cancer mortality											
1	Observational	Serious[3]	Not serious	Not serious	Serious[12]	None	1 401 (4.9%)	28 356/0.4	**RR 1.30** (1.01 to 1.67)	**15 more** (from 0 fewer to 33 fewer)	⊕◯◯◯ Very low

Certainty assessment							No. of participants		Effect		Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases (IR)	No. of people/ person-years (millions)	Relative (95% CI)	Absolute – per 1000 (95% CI)	
Type 2 diabetes											
15	Observational	Not serious	Serious[13]	Not serious	Not serious	None	45 495 (7.9%)	575 501/7.6	**RR 0.99** (0.90 to 1.09)	**1 fewer** (from 7 more to 8 fewer)	⊕○○○ Very low
Breast cancer											
11	Observational	Not serious	Not serious	Not serious	Not serious	None	26 394 (3.3%)	807 741/9.0	**RR 1.00** (0.95 to 1.06)	**0 fewer** (from 2 fewer to 2 more)	⊕⊕○○ Low
Colorectal cancer											
12	Observational	Not serious	Not serious	Not serious	Not serious	None	12 907 (1.1%)	1 181 780/11.2	**RR 1.08** (0.99 to 1.17)	**1 more** (from 0 fewer to 2 more)	⊕⊕○○ Low
Endometrial cancer											
7	Observational	Not serious	Serious[14]	Not serious	Serious[15]	None	4 255 (0.6%)	695 100/6.6	**RR 0.89** (0.75 to 1.07)	**1 fewer** (from 0 fewer to 2 fewer)	⊕○○○ Very low
Oesophageal cancer											
1	Observational	Serious[3]	Not serious	Not serious	Serious[16]	None	501 (0.1%)	446 177/3.1	**RR 1.30** (0.79 to 2.13)	**0 fewer** (from 0 fewer to 1 more)	⊕○○○ Very low
Prostate cancer											
4	Observational	Not serious	Not serious	Not serious	Not serious	None	23 654 (6.9%)	344 551/3.1	**RR 1.05** (0.97 to 1.14)	**3 more** (from 2 fewer to 10 more)	⊕⊕○○ Low

CI: confidence interval; IR: incidence rate; MD: mean difference; RR: relative risk.

1 Initial heterogeneity as measured by I^2 was 56.2%. Removal of one study with less than 200 cases *(13)* changed the significance of the pooled effect (1.16; 95% CI: 1.07 to 1.26) and reduced the heterogeneity as measured by I^2 to 0%; however, this estimate is at high risk of bias because it is based on only two studies.

2 95% CIs are wide, from 0.96 to 1.31, indicating a high level of uncertainty around the effect estimate.

3 This is an effect size estimate from only one study.

4 95% CIs are wide, from 0.49 to 1.30, indicating a high level of uncertainty around the effect estimate.

5 Initial heterogeneity as measured by I^2 was 49.9%, and P for heterogeneity was 0.036. One study *(16)* strongly influenced the pooled result. Removal of this study did not change the significance or direction of the pooled result (0.82; 95% CI: 0.73 to 0.92); heterogeneity as measured by I^2 decreased to 35%, and P for heterogeneity was 0.138.

6 This is a pooled estimate from only two studies.

7 The heterogeneity when combining these two studies as measured by I^2 was 73.0%.

8 95% CIs are wide, from 0.46 to 1.06, indicating a high level of uncertainty around the effect estimate.

9 Initial heterogeneity as measured by I^2 was 62.5%. One study *(14)* strongly influenced the pooled result. Removal of this study changed the significance of the pooled result (0.92; 95% CI: 0.81 to 1.04), reducing the heterogeneity as measured by I^2 to 20.0%.

[10] 95% CIs are wide, from 0.88 to 1.18, indicating a high level of uncertainty around the effect estimate.
[11] 95% CIs are wide, from 0.68 to 1.02, indicating a high level of uncertainty around the effect estimate.
[12] 95% CIs are wide, from 1.01 to 1.67, indicating a high level of uncertainty around the effect estimate.
[13] Initial heterogeneity as measured by I^2 was 80.5%. Removal of two low-quality studies (Newcastle–Ottawa Scale <6) did not affect the direction or non-significance of the pooled result (1.01; 95% CI: 0.89 to 1.15), and heterogeneity remained high with an I^2 of 80.6.
[14] Initial heterogeneity as measured by I^2 was 65.8%. Removal of one low-quality study (Newcastle–Ottawa Scale <6) did not affect the direction or non-significance of the pooled result (0.91; 95% CI: 0.74 to 1.12), and heterogeneity remained high with an I^2 of 69.4%.
[15] 95% CIs are wide, from 0.75 to 1.07, indicating a high level of uncertainty around the effect estimate.
[16] 95% CIs are wide, from 0.79 to 2.13, indicating a high level of uncertainty around the effect estimate.

GRADE evidence profile 7

Question: What is the effect of higher compared with lower intake of dietary fibre in children?

Population: General child population

Certainty assessment							No. of participants/ person-years	Observed effect	Direction of relationship	Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Body weight										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	1 817/4 495	**Change in weight (kg/y)** β (95% CI) **2.14 (–10.4 to 14.7)**	NS	⊕○○○ Very low
								Weight gain from 8 months to 2 years β (*P* value) **0.034 (0.032)**	Positive	
Total cholesterol										
3	Observational	Not serious	Serious[2]	Not serious[3]	Serious[2]	None	1 453/6 081	**Between baseline diet and follow-up** Spearman correlation (*P* value) F **0.05 (0.53)** Spearman correlation (*P* value) M **0.08 (0.27)**	NS	⊕○○○ Very low
								Per 1 g increase in fibre per day β (*P* value) **–0.0074 (0.012)**	Inverse	
								Per 1 g increase in fibre per day β (*P* value) **–0.14 (< 0.05)**	Inverse	
LDL cholesterol										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	934/4 006	**Between baseline diet and follow-up** Spearman correlation (*P* value) W **0.01 (0.91)** Spearman correlation (*P* value) M **0.07 (0.42)**	NS	⊕○○○ Very low
								Per 1 g increase in fibre per day β (*P* value) **–0.005 (0.13)**	NS	

Certainty assessment							No. of participants/ person-years	Observed effect	Direction of relationship	Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Triglycerides										
4	Observational	Not serious	Serious[2]	Not serious[3]	Serious[2]	None	2 708/21 283	**Per 1 g increase in fibre per day** β (*P* value) **−0.0008 (0.76)**	NS	⊕○○○ Very low
								Per 1 g increase in fibre per day β (*P* value) **−0.07 (NS)**	NS	
								Change per g/1000 kcal Ratio of geometric mean (95% CI) **1.00 (0.97 to 1.03)**	NS	
								Change per 1 g increase in fibre SDS (95% CI) **−0.018 (−0.036 to −0.002)**	Inverse	
HbA1c										
1	Observational	Serious[1]	Serious	Not serious[3]	Serious[2]	None	368/8 832	**Change per g/1000 kcal** Coefficient (95% CI) **−0.01 (−0.03 to 0.01)**	NS	⊕○○○ Very low
Systolic blood pressure										
1	Observational	Not serious	Serious[2]	Not serious[3]	Serious[2]	None	2 758/19 443	**Per 10 g increase in fibre per day** β (95% CI) **−0.03 (−0.12 to 0.04)**	NS	⊕○○○ Very low
								Change per g/1000 kcal Coefficient (95% CI) **0.05 (−0.37 to 0.47)**	NS	
								Change per 1 g increase in fibre SDS (95% CI) **−0.009 (−0.023 to 0.050)**	NS	
								Change per 1 g increase in fibre SDS (95% CI) **−0.003 (−0.017 to 0.011)**	NS	
Bowel habits										
1	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	8 899/2 966	**Frequent experience of hard stools by tertile of fibre intake** OR (95% CI) 1.87 (1.61 to 2.16)	Inverse	⊕○○○ Very low

CI: confidence interval; HbA1c: haemoglobin A1c; LDL: low-density lipoprotein; NOS: Newcastle–Ottawa Scale; NS: non-significant; OR: odds ratio; SDS: standard deviation score.

[1] Effect size estimates from two or fewer studies.

[2] Study results were not amenable to meta-analyses; therefore, inconsistency and imprecision could not be assessed. Downgraded once across both domains.

[3] This study was conducted in the population of interest, all comparisons were made directly with an appropriate control group, and outcome is a priority outcome that was decided on before initiating the review.

GRADE evidence profile 8

Question: What is the effect of higher compared with lower intake of vegetables in children?

Population: General child population

Certainty assessment							No. of participants/ person-years	Observed effect	Direction of relationship	Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Body weight										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	6 025/26 587	**Per 100 g of daily intake** g (significance) **–100 g (*P* < 0.01)**	Inverse	⊕◯◯◯ Very low
								Change in weight kg/year β (*P* value) **0.09 (0.02)**	Positive	
Cholesterol (total, HDL, total to HDL ratio)										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	1 038/15 602	**Total cholesterol** **>3 serves (ref) vs. <3 serves a day** β (95% CI) –0.17 **(–0.33 to –0.01)**	Inverse	⊕◯◯◯ Very low
								HDL cholesterol **>3 serves (ref) vs. <3 serves a day** β (95% CI) **–0.007 (–0.06 to 0.08)**	NS	
								Total to HDL ratio per 1 SD increase β (95% CI) **–0.63 (–0.110 to –0.016)**	Inverse	
HbA1c										
1	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	665/6 650	**>3 serves (ref) vs. <3 serves a day** β (95% CI) **0.18 (–0.75 to 1.12)**	NS	⊕◯◯◯ Very low
Metabolic syndrome										
3	Observational	Not serious	Serious[2]	Not serious[3]	Serious[2]	None	2 976/60 509	**Per point on the HEI** OR (95% CI) **0.95 (0.85 to 1.04)**	NS	⊕◯◯◯ Very low
								Highest quartile OR (95% CI) **0.35 (0.13 to 0.95)**	Inverse	
								Per 1 SD increase OR (95% CI) **0.86 (0.77 to 0.96)**	Inverse	

Certainty assessment							No. of participants/ person-years	Observed effect	Direction of relationship	Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Systolic blood pressure										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	1 271/7 862	**SBP >3 serves (ref) vs. <3 serves a day** β (95% CI) **–0.003 (–1.64 to 1.63)**	NS	⊕◯◯◯ Very low
								SBP g per day β (95% CI) **F 0.002 (–0.003 to 0.007)** β (95% CI) **M –0.0004 (–0.005 to 0.004)**	NS	
Cognition										
1	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	2 868/28 680	**Vocabulary test** β (95% CI) **0.12 (–0.05 to 0.29)**	NS	⊕◯◯◯ Very low
								Coloured progressive matrix test β (95% CI) **0.18 (–0.20 to 0.55)**	NS	

CI: confidence interval; F: female; HbA1c: haemoglobin A1c; HDL: high-density lipoprotein; HEI: Healthy Eating Index; M: male; NS: non-significant; OR: odds ratio; SBP: systolic blood pressure; SD: standard deviation.

1 Effect size estimates from two or fewer studies.

2 Study results were not amenable to meta-analyses; therefore, inconsistency and imprecision could not be assessed. Downgraded once across both domains.

3 This study was conducted in the population of interest, all comparisons were made directly with an appropriate control group, and outcome is a priority outcome that was decided on before initiating the review.

GRADE evidence profile 9

Question: What is the effect of higher compared with lower intake of fruit in children?

Population: General child population

Certainty assessment							No. of participants/ person-years	Observed effect	Direction of relationship	Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Body weight										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	6 025/26 587	**Per 100 g of daily intake** g (*P* value) **15 g (NS)**	NS	⊕○○○ Very low
								Change in weight kg/year β (*P* value) **0.04 (0.17)**	NS	
Cholesterol (total, HDL, total to HDL ratio)										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	1 038/15 602	**Total cholesterol** **>2 serves (ref) vs. <2 serves a day** β (95% CI) **−0.004 (−0.16 to 0.16)**	NS	⊕○○○ Very low
								HDL cholesterol **>2 serves (ref) vs. <2 serves a day** β (95% CI) **−0.05 (−0.12 to 0.02)**	NS	
								Total to HDL ratio per 1 SD increase β (95% CI) **0.054 (0.014 to 0.094)**	Positive	
HbA1c										
1	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	665/6 650	**>2 serves (ref) vs. <2 serves a day** β (95% CI) **−0.16 (−1.11 to 0.79)**	NS	⊕○○○ Very low
Metabolic syndrome										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	2 552/58 982	**Per point on the HEI** OR (95% CI) 0.88 (0.79 to 0.98)	Inverse	⊕○○○ Very low
								Per 1 SD increase OR (95% CI) 0.88 (0.79 to 0.99)	Inverse	

Certainty assessment							No. of participants/ person-years	Observed effect	Direction of relationship	Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Systolic blood pressure										
3	Observational	Not serious	Serious[2]	Not serious[3]	Serious[2]	None	1 556/8 717	**SBP >2 serves (ref) vs. <2 a day** β (95% CI) **0.66 (–0.97 to 2.30)**	NS	⊕◯◯◯ Very low
								SBP g per day β (95% CI) **F –0.004 (–0.001 to 0.002)** β (95% CI) **M 0.0004 (–0.005 to 0.006)**	NS	
								Baseline intake with SBP at follow-up R (significance) **–0.031 (NS)**	NS	
Cognition										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	5 736/60 228	**Vocabulary test** β (95% CI) **0.21 (0.03 to 0.39)**	Positive	⊕◯◯◯ Very low
								Coloured progressive matrix test β (95% CI) **0.39 (–0.04 to 0.76)**	NS	
								Baseline intake with maths at follow-up β (95% CI) **1.47 (0.27 to 2.67)**	Positive	
								Baseline intake with reading at follow-up β (95% CI) **1.46 (0.52 to 2.41)**	Positive	
								Baseline intake with writing at follow-up β (95% CI) **1.74 (0.14 to 3.34)**	Positive	
								Baseline intake with spelling at follow-up β (95% CI) **1.57 (0.11 to 3.02)**	Positive	

CI: confidence interval; F: female; HDL: high-density lipoprotein; HEI: Healthy Eating Index; M: male; NS: non-significant; OR: odds ratio; SBP: systolic blood pressure; SD: standard deviation.

[1] Effect size estimates from two or fewer studies.

[2] Study results were not amenable to meta-analyses; therefore, inconsistency and imprecision could not be assessed. Downgraded once across both domains.

[3] This study was conducted in the population of interest, all comparisons were made directly with an appropriate control group, and outcome is a priority outcome that was decided on before initiating the review.

GRADE evidence profile 10

Question: What is the effect of higher compared with lower intake of whole grains in children?

Population: General child population

Certainty assessment							No. of participants/ person-years	Observed effect	Direction of relationship	Certainty
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Body weight										
1	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	4 646/34 845	**Weight gain per 100 g increase** g (significance) **WG –380 (*P* < 0.001)** g (significance) **RG 145 (*P* < 0.001)**	Inverse for whole grain; positive for refined grain	⊕◯◯◯ Very low
Blood lipids (total, LDL, HDL, non-HDL, total to HDL ratio, triglycerides)										
2	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	1 873/23 952	**Total cholesterol by tertile of intake** *P* for trend **WG 0.484**	NS	⊕◯◯◯ Very low
								HDL cholesterol by tertile of intake *P* for trend **WG 0.683**	NS	
								Non-HDL cholesterol by tertile of intake *P* for trend **WG 0.390**	NS	
								LDL cholesterol by tertile of intake *P* for trend **WG 0.498**	NS	
								Triglycerides by tertile of intake *P* for trend **WG 0.098**	NS	
								Total to HDL ratio at baseline β (95% CI) **WG –0.025 (–0.075 to 0.025)**	NS	
Metabolic syndrome										
1	Observational	Serious[1]	Serious[2]	Not serious[3]	Serious[2]	None	424/1 526	**Per point on the HEI** OR (95% CI) **WG 0.95 (085 to 1.07)**	NS	⊕◯◯◯ Very low

CI: confidence interval; HDL: high-density lipoprotein; HEI: Healthy Eating Index; LDL: low-density lipoprotein; OR: odds ratio; RG: refined grain; WG: whole grain.

[1] Effect size estimates from two or fewer studies.

[2] Study results were not amenable to meta-analyses; therefore, inconsistency and imprecision could not be assessed. Downgraded once across both domains.

[3] This study was conducted in the population of interest, all comparisons were made directly with an appropriate control group, and outcome is a priority outcome that was decided on before initiating the review.

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Annex 7

Evidence to recommendations table

Background

Intervention: higher intake of dietary fibre, whole grains, vegetables, fruits, pulses
Comparison: usual diet or lower intake of dietary fibre, whole grains, vegetables, fruits, pulses
Main outcomes: CVDs, type 2 diabetes, cancer, all-cause mortality
Setting: healthy individuals; prospective cohort studies, RCTs

Assessment

	Judgement	Research evidence	Additional considerations
Problem	**Is the problem a priority?** **Dietary fibre, whole grains, vegetables, fruits, pulses** ☐ No ☐ Probably no ☐ Probably yes ■ **Yes** ☐ Varies ☐ Don't know	NCDs are the world's leading cause of death, responsible for an estimated 41 million of the 55 million deaths in 2019 *(1)*. Nearly half of these deaths were premature (i.e. in people under the age of 70 years) and occurred in LMICs. Obesity is a risk factor for diet-related NCDs and itself is responsible for millions of deaths globally *(2, 3)*. In 2016, more than 1.9 billion adults aged 18 years and older were overweight *(4)*. The spotlight on prevention and management of NCDs and obesity has intensified recently as a result of the COVID-19 pandemic, as there is increasing recognition that those with obesity or certain NCDs are at increased risk for adverse outcomes associated with COVID-19 (5-9). Modifiable risk factors such as unhealthy diets, physical inactivity, tobacco use and harmful use of alcohol are major risk factors for NCDs and obesity. The quality of carbohydrates in the diet has been extensively explored as a potential modulator of NCD and obesity risk.	NCDs are growing rapidly in LMICs.
Desirable effects	**How substantial are the desirable anticipated effects?** **Dietary fibre** ☐ Trivial ☐ Small ☐ Moderate ■ **Large** ☐ Varies ☐ Don't know **Whole grains, vegetables, fruits, pulses** ☐ Trivial ☐ Small ■ **Moderate** ■ **Large** ☐ Varies ☐ Don't know	Effects observed in RCTs for all exposures and outcomes were considered to be trivial to small. Because evidence for children was extrapolated from evidence for adults in all cases, the assessment of the magnitude of desirable effects come from adult data. **Dietary fibre** Associations were observed between higher dietary fibre intake and reduced risk of all disease outcomes assessed in prospective cohort studies, except for stroke mortality and incidence of the following cancer types: endometrial, oesophageal and prostate. The largest observed association was a 31% reduction in risk of coronary heart disease mortality with higher dietary fibre intake (RR 0.69; 95% CI: 0.60 to 0.80). Other reductions in risk varied from 7% to 24%. Overall, the desirable anticipated effects of higher dietary fibre intake were considered to be large. **Whole grains, vegetables, fruits, pulses** Across all four foods (whole grains, vegetables, fruits and pulses) and health outcomes, the desirable anticipated effects of higher intake were considered to be moderate to large.	See GRADE evidence profiles for magnitude of all outcomes (**Annex 6**).

<table>
<tr><th></th><th>Judgement</th><th>Research evidence</th><th>Additional considerations</th></tr>
<tr><td>Desirable effects</td><td></td><td>Whole grains

Associations were observed between higher intake of whole grains and reduced risk of all disease outcomes assessed in prospective cohort studies, except for incidence of stroke and prostate cancer. The largest observed associations were a 34% reduction in risk of coronary heart disease mortality (RR 0.66; 95% CI: 0.56 to 0.77) and a 33% reduction in type 2 diabetes (RR 0.67; 95% CI: 0.58 to 0.78) with higher dietary fibre intake. Other reductions in risk varied from 11% to 26%.

Overall, the desirable anticipated effects of higher intake of whole grains were considered to be large.

Vegetables and fruits

Associations were observed between higher intake of vegetables and fruits and reduced risk of all disease outcomes assessed in prospective cohort studies. The largest observed association was a 21% reduction in risk of stroke incidence or mortality (RR 0.79; 95% CI: 0.71 to 0.88) with higher intake of vegetables and fruits. Other reductions in risk varied from 7% to 18%.

Overall, the desirable anticipated effects of higher intake of vegetables and fruits were considered to be moderate.

Pulses

Associations were observed between higher intake of pulses and reduced risk of CVD, coronary heart disease and type 2 diabetes, but not between higher intake of pulses and stroke incidence or mortality. Risk of CVDs or coronary heart disease was reduced by 10% with higher intake of pulses, and risk of type 2 diabetes was reduced by 21%.

Overall, the desirable anticipated effects of higher intake of pulses were considered to be moderate.</td><td></td></tr>
<tr><td>Undesirable effects</td><td>How substantial are the undesirable anticipated effects?

Dietary fibre

☐ Trivial
☐ Small
■ Moderate
☐ Large
☐ Varies
☐ Don’t know

Whole grains, vegetables, fruits, pulses

☐ Trivial
■ Small (whole grains only)
☐ Moderate
☐ Large
☐ Varies
☐ Don’t know</td><td>There were no adverse effects on any outcome assessed in RCTs, but an increased risk of endometrial cancer with higher dietary fibre intake (RR 1.16; 95% CI: 1.01 to 1.33) and an increased risk of prostate cancer with higher whole grain intake (RR 1.10; 95% CI: 1.02 to 1.19) were observed in prospective cohort studies. The certainty in the evidence for these two outcomes was assessed as very low and low, respectively, and there are no clear biological mechanisms that would explain these potential relationships.

With respect to magnitude of the effects alone, the undesirable anticipated effects of higher intake of dietary fibre were considered to be moderate, and those of whole grains to be small.</td><td></td></tr>
</table>

	Judgement	Research evidence	Additional considerations
Certainty of evidence	**What is the overall certainty in the evidence of effects?** **See adjacent column** ☐ Very low ☐ Low ☐ Moderate ☐ High ☐ No included ☐ studies	Because evidence for children was extrapolated from evidence from adults in all cases, the overall certainties in the evidence reported below come from adult data. **Dietary fibre** The overall certainty in the available evidence for desirable effects of higher compared with lower dietary fibre intake was assessed as *moderate*. **Whole grains, vegetables, fruits, pulses** Across all four foods (whole grains, vegetables, fruits and pulses) and health outcomes, the overall certainty in the available evidence for desirable effects of higher compared with lower intake was assessed as *moderate*.	See GRADE evidence profiles for certainty of evidence for all outcomes (**Annex 6**).
Values	**Is there important uncertainty about, or variability in, how much people value the main outcomes?** **Dietary fibre, whole grains, vegetables, fruits, pulses** ☐ Important uncertainty or variability ☐ Possibly important uncertainty or variability ■ **Probably no important uncertainty or variability** ☐ No important uncertainty or variability	These recommendations address several NCDs, all-cause mortality, and overweight and obesity. NCDs are the world's leading cause of death *(1)*, and therefore interventions and programmes targeting reduction in risk of NCDs are valuable in all contexts and a high priority for many countries. Despite the global burden of NCDs, the priority placed on this problem by authorities at different levels may vary, depending on the real or perceived magnitude of the problem within a particular country or region. The recommendations in this guideline place a high value on reducing risk of mortality, NCDs and obesity; however, although individuals almost universally value the prevention of premature mortality, those affected by the recommendations may place a different value on the benefit of reducing risk of NCDs and obesity, based on personal preferences, beliefs and customs. For example, because CVD is a high-profile public health topic, including in many LMICs where these diseases represent a growing threat *(10)*, it is expected that most individuals would value efforts to reduce risk. However, in real-world settings, perception of the risk varies considerably *(11–15)*, and outreach and communication efforts may be needed to improve understanding. Similarly, although many people in LMICs are increasingly aware of negative health effects associated with being overweight or obese, some cultures still consider overweight to be a desirable or positive attribute *(16–18)*; others believe body weight to be hereditary and therefore not amenable to management via lifestyle changes *(15, 19)*; and many, regardless of personal beliefs, incorrectly perceive their own body weight in the context of overweight and obesity (i.e. they believe they are at a healthy body weight when in fact they are overweight or obese according to accepted standards for assessing body weight outcomes) *(15, 19, 20)*.	

	Judgement	Research evidence	Additional considerations
Balance of effects	**Does the balance between desirable and undesirable effects favour the interventions or the comparisons?** **Dietary fibre, whole grains, vegetables, fruits, pulses** ■ **Favours interventions** ☐ Probably favours interventions ☐ Does not favour either ☐ Probably favours comparisons ☐ Favours comparisons ☐ Varies ☐ Don't know	Weighed against the strong benefit observed for a large number of NCD outcomes – including significant reductions in mortality – with higher intakes of dietary fibre, whole grains, vegetables, fruits and pulses, the robust desirable effects of the recommended dietary goals were considered to strongly outweigh any potential undesirable effects as observed in the prospective cohort studies.	
Resources required	**How large are the resource requirements of the interventions?** **Dietary fibre, whole grains, vegetables, fruits, pulses** ☐ Large costs ☐ Moderate costs ☐ Negligible costs and savings ☐ Moderate savings ☐ Large savings ■ **Varies** ☐ Don't know	Absolute costs of translating the recommendations in this guideline into policies and actions will vary widely, depending on which approaches are taken. It should be possible to incorporate the recommendations into existing and planned activities to promote healthy diets, such as food-based dietary guidelines and fiscal policies, which might limit the resources required to implement the recommendations. Implementation of the recommendations will likely require consumer education and public health communications, some or all of which can be incorporated into existing public health nutrition education campaigns and other existing nutrition programmes at the global, regional, national and subnational levels. Several modelling studies have estimated the potential savings in health-care costs of increasing intakes of dietary fibre, whole grains, vegetables, fruits or pulses, independent of how the increase is achieved (most studies of vegetables and fruits assess specific interventions). Results of these modelling studies, all of which were simulated in populations in high-income countries, suggest that increasing intake of dietary fibre, whole grains, vegetables, fruits or pulses would result in cost savings in terms of lower health-care costs *(21–30)*.	An assessment of the costs of all possible ways of implementing the recommendations is beyond the scope of this guideline.

	Judgement	Research evidence	Additional considerations
Certainty of evidence of required resources	**What is the certainty of the evidence of resource requirements (costs)?** **Dietary fibre, whole grains, vegetables, fruits, pulses** ☐ Very low ☐ Low ☐ Moderate ☐ High ■ **Don't know**	Because the costs will vary widely depending on which approaches are taken, and detailed discussion of all possible approaches is beyond the scope of this guideline, it is not possible to assign a certainty to the evidence of resource requirements.	
Cost-effectiveness	**Does the cost-effectiveness of the intervention favour the intervention or the comparison?** **Dietary fibre, whole grains, vegetables, fruits, pulses** ☐ Favours the intervention ☐ Probably favours the intervention ☐ Does not favour either ☐ Probably favours the comparison ☐ Favours the comparison ■ **Varies** ☐ Don't know	The cost-effectiveness of the recommended interventions cannot be determined because published cost-effectiveness analyses relate to specific policies or interventions. A large number of such studies have assessed the cost-effectiveness of a variety of policies and interventions, finding that cost-effectiveness varies. A detailed assessment of cost-effectiveness for all possible policies and interventions is beyond the scope of this guideline.	This question cannot be answered with certainty because it requires an assessment of the different, individual modes of implementing the recommendations, which is beyond the scope of this guideline.

<table>
<tr><th></th><th>Judgement</th><th>Research evidence</th><th>Additional considerations</th></tr>
<tr><td>Equity</td><td>What would be the impact on health inequity?

Dietary fibre, whole grains, vegetables, fruits, pulses

☐ Reduced
■ Probably reduced
☐ Probably no impact
☐ Probably increased
☐ Increased
■ Varies
☐ Don't know</td><td>The recommendations in this guideline have the potential to reduce health inequity by improving the health of people of lower socioeconomic status, who are generally disproportionately affected by overweight, obesity and NCDs (31–35); however, in some LMIC settings, people of higher socioeconomic status may be more at risk than those of lower socioeconomic status and may benefit more from relevant interventions (36, 37). Regardless, results of several modelling studies (primarily targeting vegetable and fruit intake) suggest that the effect on equity and human rights would likely be affected by how the recommendations are translated into policies and actions (e.g. fiscal policies, reformulation); some interventions are likely to reduce health inequity, whereas others might increase it (38–42). A small number of studies suggest that fiscal policies targeting foods and beverages, front-of-pack labelling and restrictions on marketing unhealthy foods may increase health equity (43); however, if measures affect all individuals in a population equally, relevant inequalities may not be addressed (44). The impact of interventions on the pricing of manufactured foods would require careful consideration, as any increase in costs borne by manufacturers might be passed on to the consumer; this would likely disproportionately affect people of lower socioeconomic status.

Overall health inequities would likely be reduced, but this would vary depending on the specific policy or action and the specific population.</td><td>Limited published evidence is available from which to make a judgement.</td></tr>
<tr><td>Acceptability</td><td>Is the intervention acceptable to key stakeholders?

Dietary fibre, whole grains, vegetables, fruits, pulses

☐ No
☐ Probably no
■ Probably yes
☐ Yes
☐ Varies
☐ Don't know</td><td>The recommendations in this guideline are already in line with existing national guidance in some countries. However, institutional acceptability may vary across different countries and cultural contexts.

Acceptability may be influenced by:
• how the recommendations are translated into policies and actions – some means of implementation may be more acceptable than others;
• levels of awareness of the potential health problems associated with inadequate or low intake of dietary fibre, whole grains, vegetables, fruits and pulses – interventions may be less acceptable in settings where awareness is low;
• potential impact on national economies; and
• compatibility with existing policies.

At an individual level, acceptability of increasing intake of dietary fibre, whole grains, vegetables, fruits and pulses varies widely within and across countries (see Feasibility, below). Acceptability of the recommendations can be improved with appropriate public health messaging on the health benefits of dietary fibre, whole grains, vegetables, fruits and pulses, and more broadly on an overall healthy diet, including the message that whole fruits can provide a healthy source of sweetness in the diet.</td><td></td></tr>
</table>

	Judgement	Research evidence	Additional considerations
Feasibility	**Is the intervention feasible to implement?** **Dietary fibre, whole grains, vegetables, fruits, pulses** ☐ No ☐ Probably no ■ **Probably yes** ☐ Yes ☐ Varies ☐ Don't know	Large-scale achievement of the dietary goals in this guideline is possible. However, current intakes of dietary fibre, whole grains, vegetables, fruits and pulses, while variable (see *Acceptability*, above), are generally low at the global level relative to recommended intakes in this guideline and other national reference values *(45–52)*. Low vegetable and fruit intakes in LMICs are of particular concern: recent estimates suggest that less than 20–30% of individuals in many LMICs meet WHO recommendations for vegetable and fruit intake *(53, 54)*. Although the reasons underlying the variability in intakes of dietary fibre, whole grains, vegetables, fruits and pulses are complex and varied across different settings, common issues are supply, access and availability, and individual behaviours and preferences. Detailed discussion of these themes is beyond the scope of this guideline; however, they are summarized below. *Supply.* For most or all individuals to achieve the dietary goals in this guideline, stable and consistent supply of whole grains, vegetables, fruits and pulses will be necessary. Supply issues currently exist in some settings, particularly for fresh vegetables and fruits *(55, 56)*, which are generally more perishable than grains and pulses, and are thus subject to spoilage and waste during storage and transport. *Access and availability.* Even if sufficient quantities of whole grains, vegetables, fruits and pulses are produced, large-scale achievement of the dietary goals in this guideline will be difficult if individuals cannot afford them or otherwise cannot obtain them. Access to, and availability of, vegetables and fruits, in particular, have long posed a problem for people in LMICs and more generally people of lower socioeconomic status, regardless of country or region of the world *(57–60)*. Those of lower socioeconomic status generally need to spend a significant percentage of their household income when purchasing vegetables and fruits, leading to lower consumption *(51, 56)*. Data suggest that there is greater access to pulses and whole grains in many settings, particularly where these foods traditionally form part of the staple diet *(47, 49, 61)*. Global prices of pulses fluctuate; although prices have generally increased during the past several years, pulses remain affordable to many *(49, 61, 62)*. Foods prepared with whole grains have historically been more expensive than refined grain counterparts, but costs are decreasing as public interest in whole grains increases. *Individual behaviour and preferences.* Ultimately, achieving the dietary goals will require most individuals to consume more dietary fibre, whole grains, vegetables, fruits and pulses, which may require significant modifications to diets. Willingness to modify the diet will vary significantly across populations and from individual to individual, and will be based on numerous considerations, including personal preferences and tastes, as well as cultural customs and traditions. For example, pulses, whole grains and staple foods rich in dietary fibre are already traditionally consumed in many settings (e.g. India, Scandinavian countries, parts of Africa, South-East Asia, South America), whereas, in others, pulses are not consumed regularly and/or refined grains are more commonly consumed than whole grains *(47, 49, 61, 62)*.	

	Judgement	Research evidence	Additional considerations
Feasibility		In many settings, fibre-containing foods such as pulses and whole grains are perceived as expensive, bland or unpleasant tasting, and difficult to prepare *(46, 63)*. In some settings experiencing rapid economic growth, pulses and whole grains are associated with cultural stigma because they are viewed as something that people of lower socioeconomic status eat *(49)*. Even where there is awareness of the health benefits of these foods, there may be confusion about what whole grains and pulses are, and more generally which foods are good sources of dietary fibre *(46, 63)*. As noted elsewhere in the guideline, achieving the dietary goals can be achieved in numerous ways, including through behaviour change interventions, fiscal policies, regulation of marketing of foods and beverages, product labelling schemes, and reformulation of manufactured products. Feasibility varies depending on the approach used. Regardless of specific modes of implementation, the recommendations can be incorporated into existing activities designed to promote healthy diets. Although assessment of the feasibility of all possible policies and interventions is beyond the scope of this guideline, recent evidence suggests that a variety of interventions can be effective. Effectiveness is increased when multiple interventions are implemented together in multifaceted strategies, involving multiple stakeholders, across multiple aspects of the food system *(46, 56, 64–67)*.	

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Annex 8
Calculation of values for children

Recommended levels of intake of dietary fibre, and vegetables and fruits for children were extrapolated from adult values by scaling down (or up, in the case of 10-year-olds) daily total energy expenditure (dTEE) estimates for children that considered a range of different body sizes and physical activity levels for both girls and boys. Calculations were made using information from the 2001 Joint FAO/WHO/United Nations University Expert Consultation on Human Energy Requirements *(1)*. Separate dTEE values for boys and girls were averaged, yielding a single value for each age. Using an average adult intake of 2000 kcal/day, and 25 g of dietary fibre and 400 g of vegetables and fruits per day yields 0.0125 g of fibre and 0.2 g of vegetables and fruits per 1 kcal. Values are averaged across the age brackets used in the recommendations (i.e. 2–5 years, 6–9 years) and rounded to whole numbers. Because average energy expenditure in children and adolescents becomes greater than the value used for adults beginning at 10 years of age, values were not extrapolated beyond 10 years of age. Recommended intakes for children 10 years and older are therefore the same as for adults.

Age (years)	dTEE (kcal)	Fibre intake (g/day)	Average (g/day)	Vegetable + fruit intake (g/day)	Average (g/day)
2	1076	13.5	2–5 years: **15**	215	2–5 years: **250**
3	1193	14.9		239	
4	1290	16.1		258	
5	1388	17.4		278	
6	1488	18.6	6–9 years: **21**	298	6–9 years: **350**
7	1608	20.1		322	
8	1746	21.8		349	
9	1895	23.7		379	
10	2055	25.7	**25**	411	**400**

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For more information, please contact:

Department of Nutrition and Food Safety
World Health Organization
Avenue Appia 20
1211 Geneva 27
Switzerland

Email: nutrition@who.int
https://www.who.int/teams/nutrition-and-food-safety

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