Fruits, Vegetables, and Human Health: Key Nutrients and Their Role in Chronic Diseases

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List of Abbreviations

RDA – Recommended Dietary Allowance

AI – Adequate Intake

RAE – Retinol Activity Equivalents

DNA – Deoxyribonucleic Acid

RNA – Ribonucleic Acid

DFE s – Dietary Folate Equivalents

LDL – Low-Density Lipoprotein

Gut – Gastrointestinal tract

CNDs – Chronic non-communicable diseases

UL – Upper Intake Level

CVDs – Cardiovascular diseases

DASH – Dietary Approaches to Stop Hypertension

COPD – Chronic obstructive pulmonary disease

NIH – National Institute for Health

Measurement Units

g – gram
mg – milligram
oz. – ounce (28.3 g)
mcg – microgram
kcal – kilocalories

Abstract

Global dietary guidelines consistently recommend a high daily intake of fresh fruits and vegetables due to their essential role in providing key nutrients, supporting overall health, and reducing the risk of chronic non-communicable diseases (CNDs). This review aims to (i) summarize the health benefits of the major nutrients present in fruits and vegetables, and (ii) demonstrate the role of diets rich in fruits and vegetables in the prevention and management of CNDs.

The initial sections of the review describe how fruits and vegetables constitute the primary source of vitamin C and provide substantial amounts of provitamin A, folate, vitamin K, diverse phytochemicals, minerals (including potassium and non-heme iron), and dietary fiber. Collectively, these nutrients exert multiple, well-documented positive impacts on human physiology and disease risk.

The subsequent sections outline the critical importance of fruit and vegetable consumption in reducing the incidence and aiding the management of major CNDs, including hypertension, obesity, diabetes, cardiovascular diseases, cancer (overall and site-specific), chronic respiratory diseases, gastrointestinal disorders, and mental disorders.

Overall, the evidence underscores the pivotal role of increased fruit and vegetable consumption as a cornerstone of strategies to prevent and manage CNDs and to promote overall health, physical fitness, and quality of life.

Key words: Fruits, Vegetables, Nutrients, Noncommunicable Diseases

INTRODUCTION

All leading health organizations and dietary guidelines worldwide recommend a high daily intake of fruits and vegetables in order to maintain good health, as well as to prevent and treat chronic non-communicable diseases (1). In modern society, the leading causes of illness and death are precisely chronic non-communicable diseases including cardiovascular diseases, diabetes, cancer, obesity, and chronic respiratory diseases (2,3). Adequate nutrition and a high daily intake of fruits and vegetables play a crucial role in the prevention and treatment of chronic non-communicable diseases, as well as in maintaining good health, physical fitness, and a high quality of life. For children, fruits and vegetables are also important for maintaining proper growth and development.

Vegetables and fruits recommended in human nutrition (4,5)

Vegetables

In human nutrition, vegetables are utilized in various forms, including fresh, frozen, and canned, and may be consumed raw, cooked, or processed**.** Based on their nutritional composition and functional role in the human diet, vegetables are categorized into the following groups:

- **Dark-Green Vegetables**: lettuce, broccoli, spinach, chard, collard greens, kale, mustard greens, poke greens, romaine lettuce, turnip greens, watercress, etc.
- **Red and Orange Vegetables**: carrots, red or orange bell peppers, tomatoes, sweet potatoes, winter squash, etc.
- **Beans, Peas, and Lentils**: dried beans (black beans, kidney beans, lima beans, pinto beans, etc.); dried peas, split peas, chickpeas, lentils, edamame, etc.
- **Starchy Vegetables:** potatoes, corn, breadfruit, burdock root, cassava, jicama, plantains, salsify, yams, yucca, etc.
- **Other Vegetables:** all other vegetables: cabbage, cucumber, cauliflower, asparagus, avocado, beets, bitter melon, Brussels sprouts, celery, eggplant, green beans, mushrooms, onions, radish, peas, zucchini, turnips, etc.

Fruits

In human nutrition, fruits are utilized in various forms, including fresh, frozen, canned, dried fruits, and 100% fruit juices. Some of the popular fruits are:

- **Citrus fruit:** oranges, grapefruit, lemons, limes, mandarins.
- **Berries:** blackberries, blueberries, currants, raspberries.
- **Melons:** cantaloupe, casaba, honeydew, watermelon.
- **Other Fruits:** apples, pears, bananas, cherries, dates, figs, grapes, mangoes, nectarines, papaya, peaches, pineapple, plums, pomegranates, raisins, etc.

THE OBJECTIVES OF THE REVIEW

The objectives of this review are:

1. To explain the health benefits of various nutrients found in fruits and vegetables.
2. To demonstrate the role of a diet rich in fruits and vegetables in the prevention and management of chronic non-communicable diseases, particularly:
    - Cardiovascular diseases;
    - Hypertension;
    - Obesity;
    - Diabetes;
    - Cancer (overall and site-specific);
    - Chronic respiratory diseases;
    - Gastrointestinal diseases; and
    - Mental disorders.

NUTRIENTS FROM FRUITS AND VEGETABLES — HEALTH BENEFITS

Fruits and vegetables are nutrient-dense foods, meaning they provide vitamins, minerals, and other health-promoting components, and have little to no added sugar, saturated fat, and sodium (4). Fruits and vegetables are complex mixtures of bioactive compounds, and are excellent sources of vitamins, phytochemicals, minerals, and fiber. Some vegetables are also a good source of protein. Fresh fruits and vegetables are naturally low in both fat and calories, making them a healthy dietary choice.

The recommended daily intake of vitamins, minerals, and other nutrients varies depending on an individual's specific age, gender, and nutritional or health needs. Recommended Dietary Allowance (RDA) represents the average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals. It is often used to plan nutritionally adequate diets for individuals. When evidence is insufficient to develop an RDA, an Adequate Intake (AI) is established and assumed to ensure nutritional adequacy (6).

Vitamins from fruits and vegetables

Vitamins are organic compounds that are essential in minute amounts for normal physiological function (i.e., maintenance, growth, development, and reproduction) and cause a specific deficiency syndrome by their absence or insufficiency. Vitamins cannot be synthesized endogenously by the human body and therefore must be obtained through the diet. Some vitamins are antioxidants that neutralize free radicals, reduce oxidative stress, and lower the risk of chronic diseases (7).

Fruits and vegetables are an excellent source of vitamin C, provitamin A, folate, vitamin K, and several other vitamins.

Vitamin C

Vitamin C is a water-soluble antioxidant that protects against the harmful effects of free radicals and contributes to the regeneration of other antioxidants in the body, such as vitamin E. Vitamin C is essential for the biosynthesis of collagen, which plays a critical role in wound healing and immune function. Additionally, it enhances the absorption of non-heme iron, and it is involved in the metabolism of protein (8,9).

The recommended dietary allowances (RDAs) for vitamin C are 75 mg for women and 90 mg for men. Individuals who smoke require 35 mg/day more vitamin C than non-smokers in order to compensate for the higher oxidative stress induced by tobacco (10). Fruits and vegetables represent the primary dietary sources of vitamin C, with particularly high concentrations found in citrus fruits, peppers, kiwifruit, tomatoes, broccoli, berries, etc. As noticed in Table 1, one portion of red pepper or an orange, meets the RDA for vitamin C, while other foods like grains, milk, meat, and butter are very low in vitamin C.

Table 1. Vitamin C Content per Serving of Selected Foods

High Vitamin C Food	mg per serving
Red pepper, raw, 100 g	142
Orange, 1 medium	70
Kiwifruit, 1 medium	64
Broccoli, cooked, ½ cup	51
Strawberries, sliced, ½ cup	49
Cabbage green row, 100 g	40
Potato, baked, 1 medium	17
Tomato, raw, 1 medium	17
Low Vitamin C Food	**mg per serving**
Bread, white, 1 slice	0
Milk, one cup	0
Chicken breast, 3 oz.	0
Cheese mozzarella, 1 oz.	0
Beef ground, 3 oz.	0
Butter, 1 spoon	0

Source: FoodData Central (11)

Provitamin A (carotenoids)

Carotenoids from fruits and vegetables are metabolized in the body into active metabolites of vitamin A. Vitamin A is a liposoluble vitamin that supports vision in darkness, corneal and conjunctiva development, cell growth and differentiation, bone and fetus development, and central nervous system (CNS) formation. In addition, vitamin A is essential for immune function, the integrity of surface linings of the respiratory tract, and is critical for vision (12,13).

The RDA for vitamin A, is 700 mcg Retinol Activity Equivalents (RAE) for women, and 900 mcg RAE for men (14). As evidenced in Table 2, vegetables constitute an excellent source of vitamin A.

Table 2. Vegetables and Fruits Rich in Vitamin A (Beta-Carotene)

Food	RAE* mcg per serving
Sweet potato, baked in skin, 1 whole	1403
Spinach, frozen, boiled, ½ cup	573
Carrots, raw, ½ cup	459
Cantaloupe, raw, ½ cup	135
Peppers, sweet, red, raw, ½ cup	117
Apricots, dried, 5 apricots	63
Broccoli, boiled, ½ cup	60

*RAE - retinol activity equivalents

Source: FoodData Central (11)

Folate

Folate is a water-soluble B vitamin that plays a fundamental role in the production and maintenance of new cells, a process particularly critical during periods of rapid growth such as infancy, adolescence, and pregnancy. It is essential for the synthesis of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), the molecular building blocks of cells. Additionally, adequate folate intake is necessary for both adults and children to support the formation of normal red blood cells and to prevent anemia (15,16).

The RDA for folate for adults is 400 mcg of Dietary Folate Equivalents (DFEs), and 600 mcg DFEs for pregnant women (17). Vegetables are among some of the most significant sources of folate, as presented in Table 3.

Table 3. Folate Content per Serving of Selected Foods

Food	*DFEs mcg per serving
Spinach, boiled, ½ cup	131
Asparagus, boiled, 4 spears	89
Brussels sprouts, frozen, boiled, ½ cup	78
Lettuce, romaine, shredded, 1 cup	64
Avocado, raw, sliced, ½ cup 59	59
Kidney beans, canned, ½ cup	46
Banana, 1 medium	24

*DFEs - dietary folate equivalents

Source: FoodData Central (11)

Vitamin K

Vitamin K is necessary for the synthesis of proteins involved in hemostasis (blood coagulation), bone metabolism, and the regulation of various cellular functions. Vitamin K is a liposoluble vitamin needed to make clotting factors that help the blood to clot and prevent bleeding. Osteocalcin is a vitamin K dependent protein found in bone, potentially playing a role in bone mineralization and turnover. Another vitamin K–dependent protein, located in vascular smooth muscle, has become the subject of extensive scientific research due to its potential role in preventing abnormal calcification and cardiovascular disease (18,19).

Adequate Intake (AI) for vitamin K is 120 mcg for men, and 90 mcg for women (20). Vitamin K1, the main dietary form of vitamin K, is present in significant amounts in green leafy vegetables, as shown in Table 4.

Table 4. Vitamin K Content per Serving of Selected Vegetables

Food	mcg per serving
Collards, boiled, ½ cup	530
Turnip greens, boiled ½ cup	426
Spinach, raw, 1 cup	145
Kale, raw, 1 cup 113	113
Broccoli, chopped, boiled, ½ cup	110
Iceberg lettuce, raw, 1 cup	14
Blueberries, raw, ½ cup	14

Source: FoodData Central (11)

Other vitamins

Fruits and vegetables also contain significant amounts of other vitamins. For instance, potatoes and other starchy vegetables, as well as certain fruits like bananas, contain considerable amounts of **vitamin B6**, while green leafy vegetables contain **vitamin E** (11).

Phytochemicals from fruits and vegetables (21,22,23,24)

Phytochemicals are a diverse group of bioactive compounds produced by plants, primarily serving as part of their defense mechanisms against pathogens and environmental stressors. While not essential nutrients, these compounds are increasingly recognized for their contributions to the protective effects of plant-rich diets. Fruits and vegetables represent a primary dietary source of numerous phytochemicals.

Phytochemicals exhibit a broad spectrum of biological activities that underpin their health-promoting effects. Many phytochemicals serve as antioxidants, helping to neutralize free radicals, reduce oxidative stress, and lower the risk of chronic diseases. Additionally, phytochemicals may exhibit anti-inflammatory effects by modulating inflammatory pathways, potentially reducing the risk of diseases such as arthritis and cardiovascular disease. Certain phytochemicals have been shown to inhibit tumor growth and induce apoptosis in cancer cells (anticancer properties). By improving lipid profiles and vascular function, some phytochemicals help prevent atherosclerosis and hypertension. Other reported properties of phytochemicals include antimicrobial, antiviral, antiallergic, and immunomodulatory effects.

Major Classes of Phytochemicals in fruits and vegetables are:

Flavonoids constitute the largest family of polyphenolic phytochemicals, with over 6,000 identified structures. There has been much interest in the potential health benefits of flavonoids associated with fruit and vegetable-rich diets. The main dietary sources of flavonoids include tea, citrus fruit, berries, apples, legumes, and red wine. *Anthocyanins* are a subclass of flavonoids responsible for the red, blue, and purple pigmentation observed in berries, cherries, and red cabbage.

Carotenoids are yellow, orange, and red pigments synthesized by plants, many of which have important health benefits. Some carotenoids, such as *beta-carotene*, are classified as provitamin A carotenoids because the body can convert them into vitamin A. *Lycopene,* a non-provitamin A carotenoid, is found abundantly in tomatoes and tomato products, , watermelon, and red grapefruit. Another important carotenoid, *lutein*, is especially concentrated in dark green leafy vegetables like spinach and kale and is known for supporting eye health.

Glucosinolate is found in cruciferous vegetables, such as broccoli, Brussels sprouts, cabbage, cauliflower, kale, mustard, radish, rutabaga and turnips. Epidemiological studies link high cruciferous vegetable intake to lowered risks of lung, breast, and colorectal cancers.

Phytosterols, which are structurally similar to cholesterol, competitively inhibit intestinal cholesterol absorption, reducing LDL levels. Good food sources of phytosterols include unrefined vegetable oils, nuts, seeds, and legumes (exp. peas, kidney beans, lentils), and bananas.

Minerals from fruits and vegetables

Minerals constitute essential nutrients that the human organism is incapable of synthesizing endogenously and must therefore be obtained through dietary intake. Fruits and vegetables are rich sources of potassium, non-hem iron, magnesium and calcium.

Potassium

Potassium is an essential mineral and electrolyte. It helps maintain intracellular fluid balance and is necessary for nerve impulse conduction, muscle, and heart function. Results from numerous studies reported higher dietary potassium intakes to be associated with lower blood pressure and lower risks of stroke and cardiovascular disease (25,26).

Potassium is a "nutrient of public health concern" according to the 2020-2025 Dietary Guidelines for Americans, since it's under consumption in the US population is associated with adverse health effects, like - hypertension and cardiovascular diseases (4).

The adequate intake (AI) for potassium is 2,600 mg/day for women and 3,400 mg/day for men (27). Fruits and vegetables are rich sources of potassium as presented in Table 5.

Table 5. Vegetables and Fruits as Sources of Potassium

Food	mcg per serving
Potato, baked, 1 potato	610
White beans, canned, ½ cup	595
Tomato puree, ½ cup	549
Banana, 1 medium	422
Spinach, cooked, ½ cup	419
Peaches, dried, ¼ cup	398
Prunes, stewed, ½ cup	399
Orange, 1 medium	238

Non-heme iron

Iron is a vital element in hemoglobin, the protein in red blood cells responsible for transporting oxygen from the lungs to body tissues. It also plays a key role in myoglobin, a protein that supplies oxygen to muscles, thereby supporting muscle metabolism. Additionally, iron is essential for physical growth, brain development, and proper cellular function. Iron deficiency anemia is common in children, adolescent females, and women of childbearing age (28,29).

Iron exists in foods in two forms: heme iron and non-heme iron. Non-heme iron is more difficult for the body to absorb; however, these foods are still a meaningful source of iron. Sources of non-heme iron are dried beans and legumes (lima beans, soybeans, dried beans and peas, kidney beans), nuts (almonds, Brazil nuts), dried fruits (especially prunes, raisins, apricots), vegetables, and more specifically, green vegetables (broccoli, kale, collards, asparagus, dandelion greens). Foods rich in vitamin C enhance the absorption of non-heme iron and should be consumed at the same time as a non-heme iron-rich food or meal (28,29).

Other minerals

Calcium: The main food sources of calcium are milk and milk products. In addition to milk, a variety of foods contain calcium and can help children, teens, and adults get sufficient levels of calcium in their diets. For example, the calcium found in collard greens, kale, broccoli, mustard greens, turnip greens, and dried figs is as bioavailable as the calcium in milk. This is especially important for the large number of people who are lactose intolerant or avoid dairy products for other reasons (30).

Magnesium: Magnesium is a cofactor in hundreds of enzyme systems, contributing to energy production and DNA synthesis. Rich sources of magnesium include legumes, green leafy vegetables, nuts, beet greens, spinach, bananas, baked potatoes (with skin), many herbs, spices, and

Dietary fiber from fruits and vegetables

Dietary fiber is a diverse group of compounds, mainly complex carbohydrates, which cannot be digested by human enzymes in the small intestine, allowing them to arrive intact in the large intestine. Large prospective cohort studies consistently report inverse associations between consumption of diets rich in fiber and risks of cardiovascular disease and type 2 diabetes mellitus. Additionally, dietary fiber consumption is inversely associated with the risk of cancer of the esophagus, stomach, colon, pancreas, ovary, and breast (32).

Table 6. Fiber Content per Serving of Selected Foods

Legumes and vegetables	Fiber	Fruits	Fiber
Food	**g per serving**	**Food**	**g per serving**
Lima beans, cooked, 1 cup	13.2	Raspberries, 1 cup	8.0
Artichoke, cooked, 1 cup	9.2	Pear, 1 medium	5.5
Lentils, cooked, 1 cup	8.8	Kiwifruit, 1 cup	5.4
Brussels sprouts, cooked 1 cup	6.4	Apple, with skin 1 medium	4.8
Chickpeas, cooked, ½ cup	6.3	Figs, dried ¼ cup	3.7
Sweet potato, cooked 1 cup	6.2	Banana, 1 medium	3.2
Kidney beans, cooked, ½ cup	5.7	Strawberries, 1 cup	3.0
Broccoli, cooked 1 cup	5.2	Dates, ¼ cup	3.0

Source: FoodData Central (11)

Dietary fiber and gut health (32,33)

The human gastrointestinal tract (gut) hosts trillions of microorganisms collectively known as the gut microbiome, which plays vital roles in digestion, immune function, and overall health. Different types of fiber selectively promote the growth of different gut bacterial species, contributing to a diverse and balanced microbiome. By adding bulk to stool, dietary fiber improves bowel regularity and reduces transit time, which helps prevent constipation. Additionally, fiber may mitigate carcinoma risk by diluting potential gut carcinogens.

Higher fiber intake is associated with reduced risk of irritable bowel syndrome, inflammatory bowel disease, diverticular disease, hemorrhoids, and colorectal cancer.

The AI for fiber is 38 g for men, and 25 g for women (34). Most high-income countries recommend a daily intake of dietary fiber of 25–35 g for adults and less for children and older adults, depending on age (35).

Good sources of dietary fiber include legumes, nuts, whole grains, bran products, fruit, and non-starchy vegetables.

Proteins

Proteins are the primary structural component of all human cells and play numerous essential physiological roles. Proteins are composed of 20 amino acids, nine of which are essential and must be obtained through dietary intake, as they cannot be synthesized by the human body.

High-quality (complete) proteins are predominantly found in animal-derived foods. However, plant-based sources such as legumes, soy, cereals, nuts, green peas, and potatoes also provide significant amounts of protein. Although most plant proteins are incomplete—lacking one or more essential amino acids—strategic dietary combinations (e.g., legumes with cereals or with nuts) can ensure a complete amino acid profile and meet physiological requirements (36).

Beans, peas, and lentils are excellent plant-based sources of protein and are also rich in dietary fiber, vitamins, and minerals, while being low in fat. The protein content in legumes depends on the type and cultivation method (37).

As demonstrated in Table 8, certain vegetables also serve as sources of dietary protein.

Table 7. Dry Legumes as a Source of Protein

Legumes (dry)	g protein per 100 g
Kidney bean	17–27
Navy bean	19–27
Black bean	22–23
Chickpea	19–27
Lentil	23–31
Pea	14–31
Lupin	32–55
Soybeans	32–43

Adapted from (37) Zhang W, Boateng ID, Xu J, Zhang Y. Proteins from Legumes, Cereals, and Pseudo-Cereals: Composition, Modification, Bioactivities, and Applications. Foods. 2024 Jun 22;13(13):1974.

Table 8. Vegetables as a Source of Protein

Vegetable	g per serving
Green peas, 1 cup cooked	8 .1
Brussels sprouts, 1 cup cooked	5.6
Potato, 1 medium, baked	4.3
Avocado, 1 medium	4.0

Source: FoodData Central (12)

Low energy density (38,39)

Energy density refers to the amount of kilocalories released per gram of food. Foods with high energy density are typically characterized by a higher fat content and lower water content, such as oils, snacks, and chocolate. They may also contain higher amounts of added sugars and/or sodium. In contrast, low-energy-density foods provide fewer kilocalories per gram and are considered beneficial in the prevention and management of obesity and metabolic disorders. Fruits and vegetables are examples of foods with the lowest energy density.

Vegetables, fruits, and cooked legumes are low in fat and high in water and fiber content, contributing to lower energy intake while promoting satiety. For this reason, a high daily intake of fruits and vegetables is strongly recommended in both the prevention and treatment of weight-related conditions like overweight and obesity and obesity-related conditions.

Table 9. Comparison of Low- and High-Energy-Density Foods

Low-energy-density food	kcal/100 g	High-energy-density food	kcal/100 g
Cucumber	15	Butter	720
Cabbage	23	Croissant	410
Red pepper	26	Sausage	360
Carrot	41	Mozzarella cheese	310
Cooked beans	125	Chips	570
Apple	52	Peanuts roasted	580
Strawberries	32	Milk chocolate	540
Banana	98	Cookies	480

Source: FoodData Central (12)

FRUITS, VEGETABLES, AND CHRONIC NON-COMMUNICABLE DISEASES

Introduction to chronic non-communicable diseases (CNDs)

Chronic non-communicable diseases (CNDs) represent a major global health challenge, responsible for the majority of illness, disability, and deaths worldwide. CNDs account for around 75% of all deaths globally, while millions of people live with CNDs and experience a reduced quality of life. The main types of CNDs are: cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes, and they account for 80% of all premature CND deaths (2,3,40).

Chronic diseases constitute the primary contributors to mortality and disability in the United States and represent major determinants of annual health care expenditures. Six in 10 Americans have at least one chronic disease, and four in 10 have two or more, (41) and younger Americans will likely face a greater risk of mortality than previous generations (related to obesity) (42).

In the European region, 89% of all deaths are contributed to CNDs. One in five men and one in ten women die before 70 years of age because of CNDs (43).

The major characteristics of CND are summarized in Table 10.

Table 10. Chronic Non-Communicable Diseases – Major Characteristics (2,40,41)

Leading CNDs	Cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases
Transmission	Cannot be transmitted from one person to another
Causative agents	Genetics, behavioral, and environmental factors
Leading causes	Smoking, unhealthy diet, physical inactivity and harmful use of alcohol
Metabolic risk factors	Hypertension, obesity, high blood glucose, abnormal blood lipids
Progression	Generally slow progression over time, tend to be of longer duration
Consequences	Long-term health consequences often require long-term treatment and care which can be costly

Modifiable behavioral risk factors that increase the risk of chronic non-communicable diseases are: smoking, unhealthy diet, physical inactivity, and the harmful use of alcohol. Addressing those behavioral factors is essential in both the prevention and treatment of CNDs.

Eating habits that increase the risk of CNDs are:

- Low intake of: vegetables, fruits, fiber, vitamins, and minerals;
- Excess intake of: sodium, added sugar, trans fatty acids, and saturated fats (44,45).

New behavior patterns have promoted a decrease in home cooking along with increases in convenience foods and eating outside of the home. All of these changes are accompanied by the increased consumption of processed, less nutrient-dense food, decreased intake of whole fruits and vegetables, and increased consumption of high added sugar containing foods and beverages. Such dietary habits lead to an increase in chronic non-communicable diseases (46).

Environmental factors contributing to CNDs include air pollution – indoor and outdoor, environmental toxins exposure, noise, climate changes, etc. (47).

The social determinants of CNDs encompass the conditions in which individuals are born, grow, live, work, and age. These include factors such as socioeconomic status, education, employment, social support, and access to essential resources like nutritious food and safe housing. Poverty, inadequate access to healthcare, low educational attainment, and limited availability of healthy food options significantly increase the risk of developing CNDs. Effectively addressing these determinants is essential for advancing health equity and reducing disparities in chronic disease outcomes (40,48).

Fruits, vegetables, and inflammation

Numerous studies have indicated that prolonged inflammation is a key factor in the pathogenesis of chronic diseases. Immune response characterized by an increased ratio of proinflammatory to anti-inflammatory cytokines leads to chronic inflammation and CNDs (49).

A growing concern is that this inflammatory process may begin in utero, triggered by the maternal inflammatory environment, potentially programming the fetus for an increased risk of chronic disease throughout life (50).

Nutrition and lifestyle are modulators of sustained inflammation. For example, an adequate intake of fruits and vegetables provides essential micronutrients and phytochemicals with the potential to modulate inflammatory processes. As mentioned earlier, many phytochemicals from fruits and vegetables serve as antioxidants, helping to neutralize free radicals and reduce oxidative stress that causes inflammation. Additionally, phytochemicals and micronutrients may exhibit anti-inflammatory effects by modulating inflammatory pathways, improving lipid profiles and vascular function, and providing protection from toxin exposure (21-24).

Vitamin C is another powerful antioxidant that protects against the harmful effects of free radicals and contributes to the regeneration of other antioxidants in the body, such as vitamin E (8,9). Fruits and vegetables are a major source of both vitamin C and phytochemicals.

Lack of dietary vegetable and fruit micronutrient and phytochemical intake have been shown to increase inflammation. When the antioxidant and flavonoid status is inadequate to protect cells and tissues, accelerated damage occurs, promoting degeneration, inflammation, and CNDs (51).

Metabolic risk factors

Key metabolic risk factors that increase the risk of CNDs are:

- Raised blood pressure and hypertension;
- Overweight and obesity;
- High blood glucose levels and diabetes; and
- Abnormal blood lipids. (2,42,40).

Hypertension

Hypertension is a common public health problem. An estimated 1.28 billion adults aged 30-79 years worldwide (52), and 47.7 % of the US adult population have hypertension (53).

Untreated hypertension leads to atherosclerosis and many degenerative diseases (54):

- Cardiovascular diseases – angina pectoris, left ventricular hypertrophy, myocardial infarction, heart failure, arrhythmia, etc.;
- Renal diseases – renal failure and end-stage renal disease;
- Cerebrovascular diseases – stroke, carotid stenosis, etc.;
- Peripheral vascular disease;
- Retinopathy.

The relationship between blood pressure and risk of CVD events is continuous and independent of other risk factors. The higher the blood pressure, the greater the chance of target organ damage (54,55).

Hypertension is a leading risk factor for early death and poor health globally (3). It is often called a "silent killer" because people with hypertension can be asymptomatic for years and then have a fatal stroke or heart attack (56).

Risk factors for hypertension (58,52)

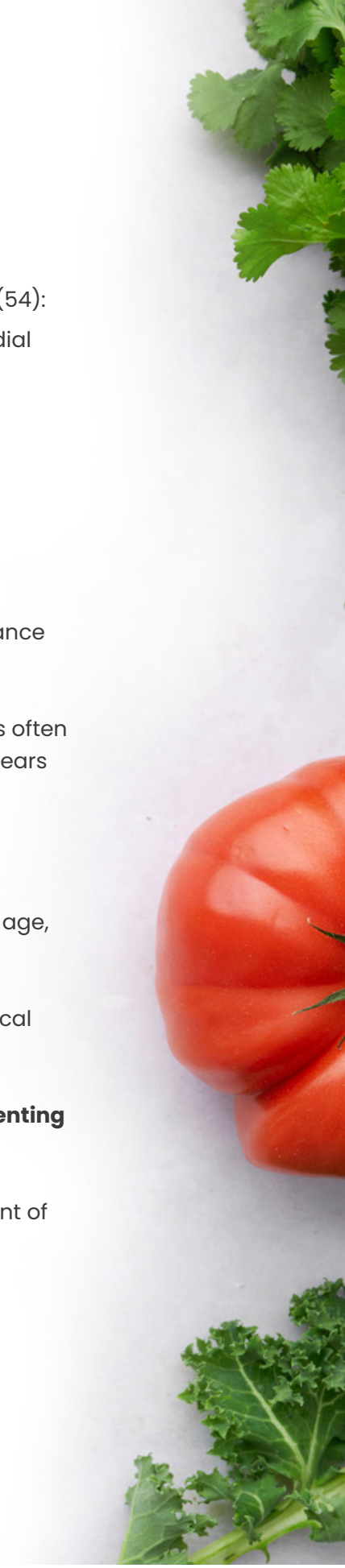
Major non-modifiable risk factors for hypertension are genetic predisposition, older age, and race.

Major modifiable risk factors (lifestyle factors) are poor diet, smoking, obesity, physical inactivity, alcohol consumption and stress.

Understanding and managing the modifiable risk factors **is essential for both preventing and controlling hypertension**.

Adhering to dietary recommendations is crucial for the prevention and management of hypertension, particularly those emphasizing:

- Reduced intake of sodium, saturated and trans fats; and
- Increased intake of potassium, dietary fiber, and fruits and vegetables.



Fruits, vegetables, and hypertension

Numerous studies, as well as dietary recommendations, emphasize the importance of greater long-term intake and increased consumption of fruits and vegetables in the prevention and treatment of hypertension (58-60,4,1).

Fruits and vegetables contribute meaningfully to the prevention and management of hypertension through several well-established mechanisms:

- **Low sodium content:** Naturally low in sodium—typically containing only 5 to 10 mg per serving—fruits and vegetables help reduce overall dietary sodium intake. This is particularly relevant given that the recommended dietary allowance (RDA) for sodium in adults is 1,500 mg per day, with a Tolerable Upper Intake Level (UL) of 2,300 mg per day (61,62). Using fresh herbs like parsley, basil, rosemary, and oregano is an excellent way to add complex flavor and aroma to dishes, allowing to reduce or eliminate the need for sodium.
- **High potassium content:** Fruits and vegetables serve as excellent sources of potassium; a nutrient known to mitigate the hypertensive effects of sodium and promote vasodilation (27,62).
- **High fiber content:** Dietary fiber, abundantly present in legumes, fruits, and vegetables, is associated with improved endothelial function, enhanced lipid profiles, and favorable blood pressure modulation (63,32).
- **Low fat content:** Most fresh fruits and vegetables are inherently low in total fat and virtually devoid of saturated fatty acids (11). This characteristic contributes to a reduced risk of endothelial dysfunction, arterial stiffness, and elevated blood pressure.

DASH diet – Dietary Approaches to Stop Hypertension

The DASH (Dietary Approaches to Stop Hypertension) diet was developed by the United States National Institutes of Health (NIH) to address high blood pressure. The diet recommends: eating plenty of vegetables, fruits, and whole grains; adding fat-free or low-fat dairy products, fish, poultry, beans, nuts, and vegetable oils; limiting salt; limiting foods that are high in saturated fat, such as fatty meats, full-fat dairy products, and tropical oils; and limiting sweets and sugary beverages (64).

The most significant nutritional profile characteristics of the DASH diet are (65):

- Low content of sodium, saturated fatty acids, and trans fatty acids;
- High content of potassium, fiber, calcium, vitamins, and phytochemicals.

Table 11 presents the DASH diet plan based on a 2,000-kcal daily intake.

Table 11. DASH Diet Plan for 2,000-kcal Daily Intake

Food Group	Servings per Day	What Counts as a Serving
Vegetables	4 – 5	1 cup leafy veg, ½ cup cut-up raw or cooked veg
Fruits	4 – 5	1 medium fruit, 1/2 cup fresh, frozen, or canned
Grains (whole grains)	6 – 8	1 slice of bread, 1/2 cup cooked rice/pasta/cereal
Low-fat dairy products	2 – 3	1 cup milk/yogurt, 1.5 oz. cheese
Lean meats, poultry, fish, egg	6 or less	1 oz. cooked meats, fish, or poultry; 1 egg
Fats and oils	2 – 3	1 tsp. soft margarine, 1 tsp. vegetable oil
Nuts, Seeds, Legumes	4 – 5 per week	1/3 cup nuts, 2 tbsp. peanut butter, 1/2 cup beans
Sodium	**Up to** 2,300 mg	Preferably up to 1,500 mg

Adapted from the National Heart, Lung, and Blood Institute. DASH Eating Plan (66).

The large number of fruits and vegetables recommended in the DASH diet makes it easy to meet the dietary potassium recommendations, approximately 4.7 g/d (27,62). To achieve the 8 to 10 servings, two to three fruits and vegetables should be consumed at each meal (66).

Over the years, a substantial body of evidence has demonstrated the effectiveness of the DASH diet in the prevention and management of hypertension, as well as in reducing the risk of cardiovascular diseases, diabetes, and promoting overall health and well-being (64,67-71). The DASH dietary pattern was also associated with significantly lower all-cause mortality (72).

The National Institute for Health (NIH) supported the DASH diet, named "Best Heart-Healthy Diet" and "Best Diet for High Blood Pressure" in the 2025 Best Diets **report from U.S. News & World Report** (73).

Overweight and obesity

Overweight and obesity are among the key metabolic risk factors for the development and progression of chronic non-communicable diseases (CNDs), with obesity itself being associated with more than 200 distinct conditions. For example, a substantial proportion of diabetes and cardiovascular disease cases are attributable to obesity (74,75).

The global obesity epidemic represents one of the most significant public health challenges of modern society. In 2022, approximately 18% of the global population was living with obesity, while an estimated 43% were classified as overweight (76).

The prevalence of overweight (including obesity) among children and adolescents aged 5 to 19 years has increased markedly, from 8% in 1990 to 20% in 2022 (76). Related to obesity, it is presumed that young people will likely face a greater risk of mortality throughout their lifespan than previous generations (49).

In both the prevention and management of obesity, lifestyle modifications—particularly changes in dietary habits and physical activity—occupy a central role. Despite significant advances in obesity pharmacotherapy (e.g., with GLP-1 receptor agonists) and advances in surgical treatment of obesity, nutritional interventions remain fundamental for optimal outcomes (77,78).

One of the most common nutritional interventions, relevant to both prevention and treatment of obesity, is an increased intake of fruits and vegetables (77,79,4).

Fruits, vegetables, and obesity

Fruits and vegetables play an important role in the prevention and treatment of obesity due to the following characteristics:

- **Low energy density:** fruits and vegetables provide relatively few calories per gram. For instance, 300 grams of cucumber have approximately the same caloric value as only 10 grams of chocolate or 5 grams (one teaspoon) of butter (11).
- **Low in fat:** most fruits and vegetables are naturally low in fat, usually containing less than 0.5 grams of fat per 100 grams of produce (11).
- **High in fiber:** as discussed in part III 4. fruits and vegetables are a good source of dietary fiber, which enhances satiety.
- **High content of essential micronutrients:** fruits and vegetables are an excellent source of numerous vitamins, minerals, and phytochemicals, as discussed in part III 1., 2., and 3.

Fruits and vegetables are high in water and low in fat, contributing to low energy density and reduced calorie intake while promoting satiety (38,39). Additionally, a high intake of dietary fiber and essential micronutrients from fruits and vegetables can promote the feeling of fullness and reduce the intake of energy-dense foods, resulting in a decreased risk of overweight and obesity (80,81).

From a preventive standpoint, a high daily intake of fruits and vegetables is recommended. For adults with a daily caloric requirement of approximately 2000 kcal, the guideline is to consume at least two and a half servings of vegetables and two servings of fruit per day, with one serving generally corresponding to one cup (4). In the context of obesity treatment, even greater quantities of vegetables are frequently advised to aid in weight management and support satiety and nutritional adequacy.

General recommendations for patients with obesity most commonly include the

following (82,83):

- Increase the amount of vegetables in appetizers, sandwiches, and main dishes to enhance meal volume without significantly increasing caloric content.
- Consume a variety of salads as frequently as possible but avoid adding high-fat dressings. Whole, fresh fruits are particularly effective when displacing more energy-dense foods
- Add fresh fruit to desserts to improve nutritional quality and increase dietary fiber without excessive caloric intake.
- Add legumes such as beans, lentils, and chickpeas to soups, stews, and salads to increase fiber and protein intake while maintaining satiety.

Diabetes

Diabetes mellitus is a group of metabolic diseases characterized by prolonged high blood glucose concentrations (hyperglycemia). Approximately one in nine adults worldwide (84) and one in ten adults in the United States (85) are living with diabetes. Over the past three decades, the prevalence of type 2 diabetes has increased dramatically across countries of all income levels, and this trend is projected to continue (86).

Diabetes contributes to a considerable increase in morbidity and mortality, which can be reduced by early diagnosis and treatment. Chronic, untreated hyperglycemia typically leads to vascular complications and progressive organ damage, including coronary heart disease, peripheral vascular disease, cerebrovascular disease, diabetic retinopathy, diabetic nephropathy, and diabetic neuropathy (87).

Diabetes, along with its associated kidney complications, was responsible for over two million deaths globally in 2021. Additionally, elevated blood glucose levels contributed to approximately 11% of all cardiovascular-related deaths (86).

Non-modifiable risk factors for diabetes include older age, family history of diabetes, ethnicity, and history of gestational diabetes (88).

Modifiable risk factors for diabetes include overweight and obesity, unhealthy dietary patterns, physical inactivity, smoking, and elevated blood pressure. For both the prevention of type 2 diabetes and the mitigation of its complications, it is essential to address those modifiable risk factors (88,89).

Fruits, vegetables, and diabetes

Vegetables and fruit have been shown in numerous studies to exert a protective effect against diabetes. This protective effect is most attributed to the high content of dietary fiber, phytonutrients, and antioxidants found in vegetables and fruit (90-92).

As discussed in Part III, fruits and vegetables represent an important source of dietary fiber. Diets rich in dietary fiber play a crucial role in diabetes prevention and management, leading to notable improvements in glycemic control, lipid profiles, body weight regulation, and inflammatory markers. Dietary fiber helps delay the absorption of carbohydrates, which in turn reduces postprandial blood glucose levels. It also supports improved insulin sensitivity and promotes more effective insulin secretion, helping to counteract insulin resistance. Dietary fiber contributes significantly to the control of several markers, such as HbA1c, blood glucose, triglycerides, LDL, and body weight. Additionally, increased fiber intake has been linked to a lower risk of premature mortality in individuals with diabetes (93-95).

Fruits and vegetables also contain all various phytochemicals, including polyphenols, flavonoids, and antioxidants that may improve insulin sensitivity and could further decrease the risk of type 2 diabetes. In the context of diabetes prevention, particular attention has been given to specific types of fruits and vegetables due to their bioactive compounds. Berries, for example, are rich in anthocyanins, green leafy and yellow vegetables are notable sources of carotenoids, while cruciferous vegetables contain substantial amounts of glucosinolates and other phytochemicals with potential antioxidant and anti-diabetic properties (96,97).

Dietary patterns rich in fruits and vegetables are also critically important for the prevention and management of obesity and hypertension, which are major risk factors associated with diabetes. As previously discussed, fruits and vegetables play a vital role in both the prevention and treatment of overweight and obesity, primarily due to their low energy density, high micronutrient content, and abundance of dietary fiber, which enhances satiety (77,79-81). Fruits and vegetables are also widely recommended for the prevention and treatment of hypertension—another risk factor associated with diabetes—as they are naturally low in sodium and rich in potassium, dietary fiber, and essential micronutrients that contribute to blood pressure regulation and overall cardiovascular health (1,4,58-60).

Individuals with diabetes should be encouraged to consume an adequate amount of dietary fiber as part of their overall dietary management. Key sources of dietary fiber include vegetables, pulses (such as beans, lentils, and chickpeas), whole fruits, and whole grains. These foods not only provide substantial amounts of fiber but are also rich in essential micronutrients and bioactive compounds that contribute to overall metabolic health. Integrating these fiber-rich foods into daily dietary patterns is a practical and evidence-based strategy for supporting long-term diabetes management and reducing the risk of comorbid conditions (93,94).

As part of diabetes management, the American Diabetes Association recommends filling half of the plate with non-starchy vegetables at each meal to support glycemic control, weight management, and overall metabolic health (98).

Cardiovascular diseases

Cardiovascular diseases (CVDs) are a group of diseases that include atherosclerosis, hypertension, ischemic heart disease (angina, myocardial infarction), peripheral vascular disease, heart failure, and cerebrovascular disease (stroke).

Cardiovascular diseases are the leading cause of death in both developed and developing nations. The Central Europe, Eastern Europe, and Central Asia regions experience the highest cardiovascular disease mortality rates in the world. The second highest cardiovascular disease mortality rates occurred in the North Africa and Middle East region. In most regions of the world, the leading cause of cardiovascular disease mortality is ischemic heart disease, followed by stroke (3).

It is estimated that one in three adult Americans has one or more types of cardiovascular diseases, and one in every three deaths is attributed to CVD. Heart disease is the number one cause of death and disability in the United States (3,99).

Behavioral risk factors

Behavioral risk factors for cardiovascular diseases (CVDs) are of critical importance, as they can be influenced through targeted strategies, including lifestyle modifications and evidence-based medical interventions. Implementing such strategies provides individuals with a substantial opportunity to reduce their risk of developing CVDs or experiencing associated complications. For individuals already diagnosed with CVD, managing modifiable risk factors is essential for controlling the disease, preventing complications, and improving quality of life.

Major behavioral risk factors for cardiovascular diseases are unhealthy diet, physical inactivity, smoking, and harmful use of alcohol. These factors often lead to metabolic risk factors, including elevated blood pressure, increased blood glucose and lipid levels, and obesity, which further increase the risk of cardiovascular diseases (100,101).

Diet is one of the key modifiable risk factors. According to strong evidence from a systematic review conducted by the 2025 Dietary Guidelines Advisory Committee, a lower risk of CVDs is associated with higher intakes of vegetables, fruits, legumes, nuts, whole grains, and unsaturated fats relative to saturated fats, as well as lower intake of sodium, red and processed meats, refined grains, and sugar-sweetened foods and beverages. These findings were consistent across diverse racial/ethnic groups and socioeconomic positions (102).

Fruits, vegetables, and CVDs

For several decades, findings from both observational and intervention studies from all regions in the world have consistently demonstrated that diets rich in fruits and vegetables are associated with a reduced risk of cardiovascular disease (102-109).

As mentioned earlier, key metabolic risk factors for CVDs are hypertension, overweight and obesity, diabetes, and abnormal blood lipids. Dietary patterns rich in fruits and vegetables are critically important for the prevention and management of several major risk factors associated with cardiovascular diseases (CVDs):

- **Hypertension:** The consumption of fruits and vegetables is strongly recommended in the prevention and treatment of hypertension, primarily due to their low sodium content and high levels of potassium and dietary fiber, and other vasculoprotective nutrients (27,61-63).
- **Obesity:** Owing to their low energy density and high content of water, fiber, and essential micronutrients, fruits and vegetables contribute to energy balance and satiety and are therefore widely recommended in both the prevention and treatment of obesity (4,11, 77,79).
- **Diabetes:** Diets abundant in fruits and vegetables support glycemic control and insulin sensitivity through their fiber content, antioxidant compounds, and low glycemic load, making them a key component in diabetes prevention and management (93-97).
- **Abnormal blood lipids:** Regular intake of fruits and vegetables, characterized by low levels of total and saturated fats and high fiber content (11), has been shown to reduce serum cholesterol and low-density lipoprotein (LDL) concentrations—major contributors to the development of atherosclerosis.
- **Inflammation:** Fruits and vegetables are rich in bioactive compounds such as vitamin C, polyphenols, and other antioxidants, which exert anti-inflammatory effects. These properties are particularly relevant given the central role of chronic inflammation in the pathogenesis of CVDs (21-24).

All forms of fruits and vegetables (fresh, frozen, canned, and dried) can be incorporated into heart-healthy dietary patterns. Fruits and vegetables may be consumed raw or processed in various ways, while types with added salt and sugar should be limited (110). Vegetables can be included in a wide range of mixed dishes, including soups, stews, pasta and rice dishes, casseroles, omelets, sandwiches, etc. Fruits are most commonly consumed in nutrient-dense forms, such as fresh fruit, although they are also frequently included in desserts and fresh fruit juices. (4).

Most people would benefit from increasing their intake of fruit and vegetables. Incorporating a diverse range of fresh fruits and vegetables into the daily diet plays a crucial role in ensuring adequate intake of essential nutrients, such as vitamins, minerals, and dietary fiber, as well as a wide array of health-promoting phytochemicals. This comprehensive nutritional profile contributes significantly to the establishment and maintenance of heart-healthy dietary patterns, which are associated with a reduced risk of cardiovascular diseases (111).

Mediterranean diet

The Mediterranean diet is one of the most extensively studied and widely recognized dietary patterns worldwide, based on the traditional eating habits of populations in

countries bordering the Mediterranean Sea. Historically, this dietary pattern has been associated with low rates of chronic diseases and greater longevity among adults (112). The Mediterranean diet promotes plant-based foods, including a wide variety of vegetables, whole grains, legumes, and the use of fruits as desserts. Olive oil serves as the primary source of fat, while fish, poultry, and dairy are consumed in moderation, and red meat is limited to occasional intake (113).

Since the 1950s, strong evidence from numerous observational and interventional studies has demonstrated the benefits of the Mediterranean diet in preventing cardiovascular diseases and supporting overall health and life expectancy. In many studies, higher adherence to the Mediterranean diet was also associated with reduced risk of chronic diseases, myocardial infarction, overall cancer incidence, neurodegenerative diseases, dementia, and diabetes (112-118).

Table 12. presents the Mediterranean diet plan based on a 2,000-kcal daily intake (4).

Table 12. Mediterranean-Style Dietary Pattern for 2,000 kcal daily intake

Food Group	Servings per day	What Counts as a Serving
Vegetables	2.5	1 cup raw or cooked vegetables; 2 cups leafy salad greens
Fruits	2.5	1 cup raw fruit; 1 cup fruit juice; ½ cup dried fruit
Grains (whole grains)	6	1 ounce slice of bread, 1/2 cup cooked rice/pasta/cereal
Low-fat dairy products	2	1 cup milk/yogurt, 1.5 oz. cheese
Protein food	6.5	1 oz. cooked fish, or poultry, or meat; 1 egg; ½ oz. nuts or seeds
Olive oil	27 g	

Adapted from Dietary guidelines for Americans, 2020–2025 (4)

Year after year, the Mediterranean diet ranks among the best in the U.S. News & World Report's annual list of top diets (119). Also, many health organizations and dietitians consider it one of the healthiest diets in the world.

Cancer

Cancer is a generic term for a large group of diseases that can affect any part of the body. Other terms used are malignant tumors and neoplasms. In 2022, cancer accounted for approximately 20 million new cases and nearly 10 million deaths globally, making it the second leading cause of death worldwide. The global burden of cancer is projected to grow, with incidence and mortality rates set to rise by 40% and 50%, respectively, by 2040. In the United States, with more than 2,3 million new cases in 2022, cancer ranked as the second leading cause of death, accounting for approximately one in every six deaths (120).

In Europe, cancer was responsible for 4.5 million new cases and nearly 2 million deaths, making it the second leading cause of death in 2022 (121). Risk of developing cancer before the age of 75 years was higher in the U.S. than in Europe, 34.3% and 27%, respectively (120).

Globally, and in both the U.S. and Europe, the most common cancer among males is prostate cancer, while among females, it is breast cancer. Lung cancer is the second most common cancer in both sexes (globally, in the U.S., and among males in Europe), followed by colorectal cancer as the third most common globally and in the U.S., and as the second most common among women in Europe (120).

Approximately 10.9% of cancer cases among women and 4.8% among men in the United States were linked to overweight or obesity, making it the second leading preventable cause of cancer after cigarette smoking. For certain cancer types, the proportion attributed to excess body fat is particularly high: obesity was responsible for 60.3% of corpus uteri cancers and over 30% of cases of gallbladder, liver, kidney/renal pelvis cancers, and esophageal adenocarcinomas (122,123).

Adopting effective prevention strategies is a key approach to addressing the growing incidence of various cancers. Central to these strategies are healthy lifestyle choices, including maintaining a healthy weight, following a balanced diet, engaging in regular physical activity, avoiding smoking, limiting alcohol consumption and sun exposure, and ensuring adequate vitamin D intake. These modifiable risk factors significantly influence cancer development, progression, and severity, especially in the three most frequent cancers: breast, colorectal, and prostate cancers (124-126).

Adherence to a prudent dietary pattern has been linked to reduced all-cause mortality across various types of cancer. This dietary pattern is characterized by higher intake of vegetables, whole fruits, whole grains, legumes, nuts, omega-3 fatty acids, and polyunsaturated fats, along with limited consumption of sugar-sweetened beverages, red and processed meats, sodium, trans fats, and moderate alcohol use (127).

Fruits, vegetables, and cancer

Several studies have shown that diets high in vegetables, fruits, and their associated compounds—such as fiber and antioxidants—are associated with a reduced risk of cancer (128). The Mediterranean diet is considered one of the most effective dietary patterns and may be regarded as a recommended therapeutic dietary strategy (123,129). The anti-carcinogenic potential of fruits and vegetables is attributed to a combination of bioactive compounds and nutritional components that work through multiple biological mechanisms:

- Fruits and vegetables are abundant in antioxidants such as vitamin C, carotenoids, and flavonoids, which help neutralize free radicals and reduce oxidative DNA damage—a known contributor to cancer development (8,9).

- Many fruits and vegetables contain naturally occurring phytochemicals such as glucosinolates, polyphenols, and indoles that modulate inflammatory pathways and may inhibit tumor initiation and progression (21-24).
- Dietary fiber, particularly from whole fruits, vegetables, and legumes, is associated with a reduced risk of colorectal and other gastrointestinal cancers. Fiber promotes regular bowel movements, reduces transit time, and may dilute carcinogens in the gut (130).
- Fruits and vegetables are generally low in calories and fat, supporting a healthy body weight—an important factor in cancer prevention, particularly for hormone-related cancers such as breast, endometrial, and prostate cancers (125).

Table 13. Major Anti-Cancer Phytochemicals, their Sources, and the Related Benefits

Anticancer phytochemicals	Sources	Benefits	Reference
Flavones	Red and yellow fruits and vegetables (watermelons, bell peppers, etc.)	- Reduced risk of coronary heart diseases, cancers, chronic inflammation, osteoporosis, and other age-related diseases. - Lowering estrogen levels can help inhibit breast tumor growth and reduce the risk of recurrence.	(131)
Isoflavones	Sour cherries, tomatoes, broccoli, carrots	- Inhibition of cancer cell growth, suppression of metastasis, and induction of apoptosis. - Inhibits the proliferation of breast cancer cells by inducing cell cycle arrest.	(132)
Prenylated flavonoids	Morus alba, artocarpus heterophyllus, glycine max, and ficus carica	- Anti-cancer, anti-inflammatory, neuroprotective, anti-diabetic, anti-obesity, cardioprotective effects, and anti-osteoclastogenic activities. - Induced apoptosis suppresses cytotoxicity against human breast cancer cells.	(133)
Lignans	Potatoes, broccoli, berries	- Resolves immunodeficiency, cancer, inflammation, hypertension, and hyperlipidemia. - Reduced risks of postmenopausal breast cancer.	(134)
Sitosterol	Fat-rich vegetables (avocados)	- Reduces immunomodulatory, antimicrobial, anticancer, anti – inflammatory, and lipid-lowering effect. - Inhibits breast cancer cell growth and induces apoptosis.	(135)

Source: Kim M, Lee M, Sa J, 2025 (136)

Despite progress in cancer diagnosis and treatment leading to improved clinical outcomes, many patients struggle to maintain adequate nutritional status due to cancer-related symptoms and treatment side effects—factors that can adversely affect overall health outcomes. It means that beyond prevention, the type of food consumed

also plays a significant role in the treatment of cancer (137). Guidelines were developed by the American Cancer Society, which include evidence-based recommendations for both cancer prevention and treatment. These recommendations include achieve and maintain a healthy weight; be physically active; avoid alcohol; and follow a healthy eating pattern at all ages (123,138).

A healthy eating pattern is defined as:

- Foods that are high in nutrients in amounts that help patients achieve and maintain a healthy body weight;
- A variety of vegetables – dark green, red, and orange, fiber-rich legumes (beans and peas), and others;
- Fruits, especially whole fruits in a variety of colors; and
- Whole grains.

In addition to what is recommended to consume, a healthy eating pattern limits red and processed meats, sugar-sweetened beverages, highly processed foods, and refined grain products (123,138).

The guidelines include a comprehensive table summarizing the relationship between key lifestyle factors and specific cancer types (123,138). Selected dietary recommendations that include fruits and vegetables are presented in Table 14.

Table 14. Dietary Recommendations for Cancer Patients and Survivors

Cancer site	Dietary recommendations
Breast	• Dietary patterns rich in plant foods and low in anumal products and refined carbohydrates lower risk • The Mediterranean diet patter lowers risk • Consumption of non-starchy vegetables and/or vegetables rich in carotenoids may lower the risk for estrogen receptor-negative breast tumors
Colorectal	• A healthy eating pattern with whole grains, higher fiber, and less added sugar lowers risk • Consuming non-starchy vegetables and whole fruits probably lowers risk
Lung	• Consuming non-starchy vegetables and whole fruits, including those high in vitamin C (especially for smokers), probably lowers risk
Stomach/gastric	• Intake of non-starchy vegetables and whole fruits, especially citrus fruits, probably lowers risk
Upper aerodigestive	• Consumption of non-starchy vegetables and whole fruits probably lowers risk

Chronic respiratory diseases

Chronic respiratory diseases are long-term conditions that affect the lungs and airways. Common types include chronic obstructive pulmonary disease (COPD), asthma, occupational lung diseases, and pulmonary hypertension.

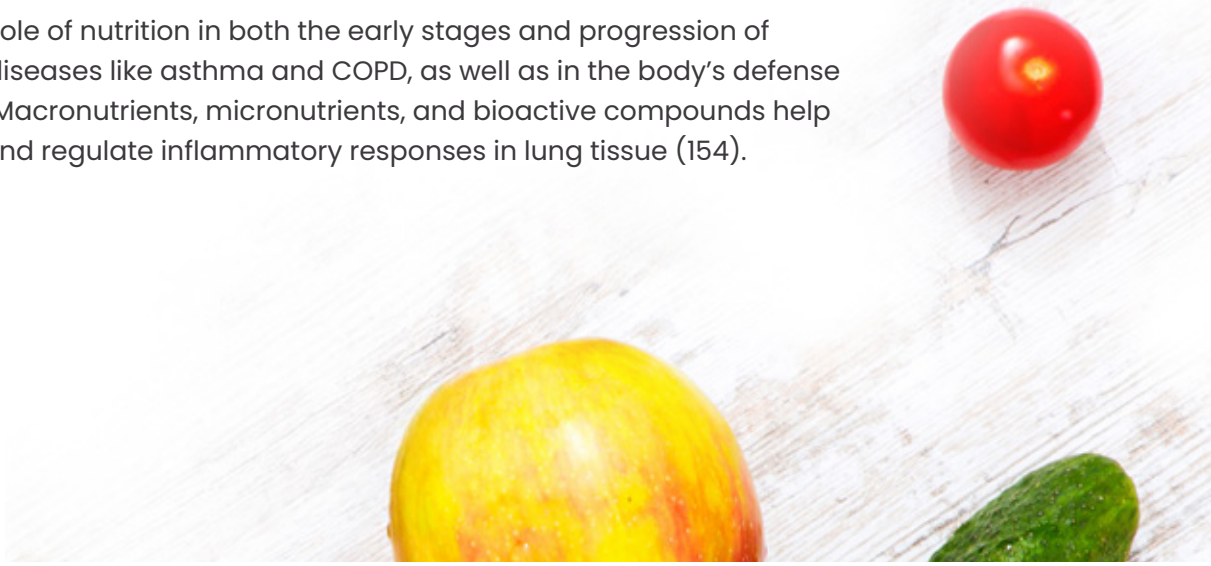
Chronic obstructive pulmonary disease is a progressive respiratory disorder characterized by airflow limitation that is not fully reversible. It is the eighth leading cause of poor health worldwide and the fourth leading cause of death worldwide, responsible for 3.5 million deaths in 2021, accounting for approximately 5% of all global deaths (139). In the U.S., COPD caused 54.3 deaths per 100,000 population in women and 47.6 per 100,000 population in men in 2021 (140).

Asthma affected an estimated 262 million people in 2019 and caused 460,000 deaths (141). In the U.S., around 27 million people are living with asthma (8.2% of the U.S. population), with 10.6 deaths per million population reported in 2021 (142). Across Europe, the prevalence of asthma ranges from 5.1% to 8.2% in adults, causing between 0.15 and 2.39 deaths per 100,000 population (143, 144).

Chronic respiratory diseases are often linked to smoking, but other risk factors include air pollution, exposure to workplace chemicals and dust, and repeated lower respiratory infections in childhood (139, 145).

Diet and nutrition are modifiable factors that influence the development and progression of chronic lung diseases and infections (146-150). Various nutrients—including vitamins A, C, D, and E; minerals like zinc, selenium, iron, and magnesium; as well as flavonoids and fatty acids—help reduce the risk of chronic lung diseases and viral infections (151). Oxidative stress, driven by chronic airway inflammation, plays a key role in asthma (152). Antioxidant-rich foods like fruits and vegetables can counteract this by neutralizing reactive oxygen species and reducing inflammation, while low-antioxidant diets may worsen oxidative stress and increase the risk of allergic diseases (153).

Evidence highlights the role of nutrition in both the early stages and progression of obstructive pulmonary diseases like asthma and COPD, as well as in the body's defense against lung infections. Macronutrients, micronutrients, and bioactive compounds help maintain homeostasis and regulate inflammatory responses in lung tissue (154).



Fruits, vegetables, and chronic respiratory diseases

High fruit consumption is linked to a lower risk of COPD, with specific fruits like apples, pears, and bananas showing the strongest associations. Current smokers consuming less than one serving of fruits and vegetables per day had a 38-fold higher risk of COPD compared to never smokers who consumed three or more servings daily. Similarly, ex-smokers with low fruit intake faced a 13-fold higher risk than never smokers with high consumption (155). A three-year randomized controlled trial demonstrated that increasing fruit and vegetable intake can lead to significant improvements in lung function among patients with COPD (156).

Antioxidants found in fruits and vegetables—such as vitamin C, vitamin E, carotenoids, and polyphenols—play a critical role in neutralizing reactive oxygen species generated by smoking and environmental pollutants. By mitigating oxidative damage and inflammation in the airways, these nutrients may slow disease progression and reduce susceptibility (157).

Fruits and vegetables support asthma management by providing key nutrients: vitamin A boosts lung health via immune regulation, vitamin E reduces symptoms and inflammation, magnesium improves breathing through bronchodilation, and selenium protects airways from oxidative damage. Flavonoids reduce inflammation and airway sensitivity, while fiber enhances lung immunity by promoting gut health (151).

Gastrointestinal health

The gastrointestinal tract is a complex organ system responsible not only for digestion, absorption, and nutrient processing, but also for immune defense, hormone production, and communication with the brain via the gut-brain axis (158-161). It plays a central role in maintaining fluid and electrolyte balance, supporting the gut microbiome, and eliminating undigested material (162). Proper gastrointestinal function and motility are essential for overall health, metabolism, and disease prevention (163).

It is estimated that the global prevalence of constipation is 14% (164). Chronic constipation imposes a significant economic burden on both patients and healthcare systems, as evidenced by multiple studies conducted in the United States and Europe**.** In the U.S., the total annual cost was estimated at $235 million, while a 2010 analysis reported constipation-related healthcare expenses reaching up to $11,991 per individual annually**,** nearly half of which were attributed to outpatient services (165-168).

Maintaining a healthy gut begins with the foods, and fruits and vegetables offer some of the most effective components for gut support. The World Gastroenterology Association recommends increasing fiber intake through dietary modification for constipation treatment (169). In the United Kingdom, professional guidelines for healthcare providers also emphasize the inclusion of fruits—particularly those high in sorbitol, such as apricots,

peaches, and plums, as part of dietary strategies to support gastrointestinal health (170). Apricots are also rich in fiber, as are grapes and kiwifruit (171-173). According to the Dietary Guidelines for Americans, 2020–2025, adults should aim to consume between 22 and 34 grams of fiber daily, with specific needs varying by age and sex (4).

The gut microbiota, a complex ecosystem of bacteria, fungi, and viruses, regulates immune responses and supports intestinal integrity. Fruits and vegetables modulate the gut microbiome, enhance short-chain fatty acid production, and support gastrointestinal immunity. Fruits, rich in dietary fiber, polyphenols, vitamins, and antioxidants, not only enhance immune function but also reduce gastrointestinal inflammation and increase microbial diversity (20-22,173,174,175). The apple, grape, and berries have a significant role in maintaining gastrointestinal microbiota (176-178). Vegetable fiber and plant compounds promote beneficial gut bacteria and overall metabolic balance (175).

In addition, fresh fruits and vegetables contain fiber, phytonutrients, and natural sugars that trigger the release of gut hormones like:

- **GLP-1** – improves insulin secretion, reduces appetite;
- **PYY** – promotes satiety (feeling full);
- **Serotonin (5-HT)** – regulates mood and gut movement;
- **GIP** – helps regulate blood sugar.

These hormones are crucial for metabolic and emotional balance**.** High-fiber meals increase GLP-1 and PYY levels, regulate ghrelin (hunger hormone), and support satiety (161, 163, 179).

Dietary fiber, especially from whole fruits, vegetables, and legumes, is linked to a lower risk of colorectal and other gastrointestinal cancers. It supports regular bowel movements, shortens transit time, and may dilute carcinogens in the digestive tract. Consuming non-starchy vegetables and whole fruits likely contributes to further risk reduction due to their protective nutrients and health-promoting properties (130,138,180).

Mental health

WHO defines mental health as a state of mental well-being that enables people to cope with the stresses of life, to realize their abilities, to learn well and work well, and to contribute to their communities. Mental health is not just the mere absence of mental illness; it is an intrinsic part of our health and well-being, and it is crucial to personal, community and socio-economic development (181).

Mental health conditions encompass mental disorders, psychosocial disabilities, and other mental states that involve significant distress, functional impairment, or an increased risk of self-harm (181). According to the Global burden of disease study, in 2023, about 1 in 7 people worldwide—roughly 1.2 billion individuals—were living with a mental

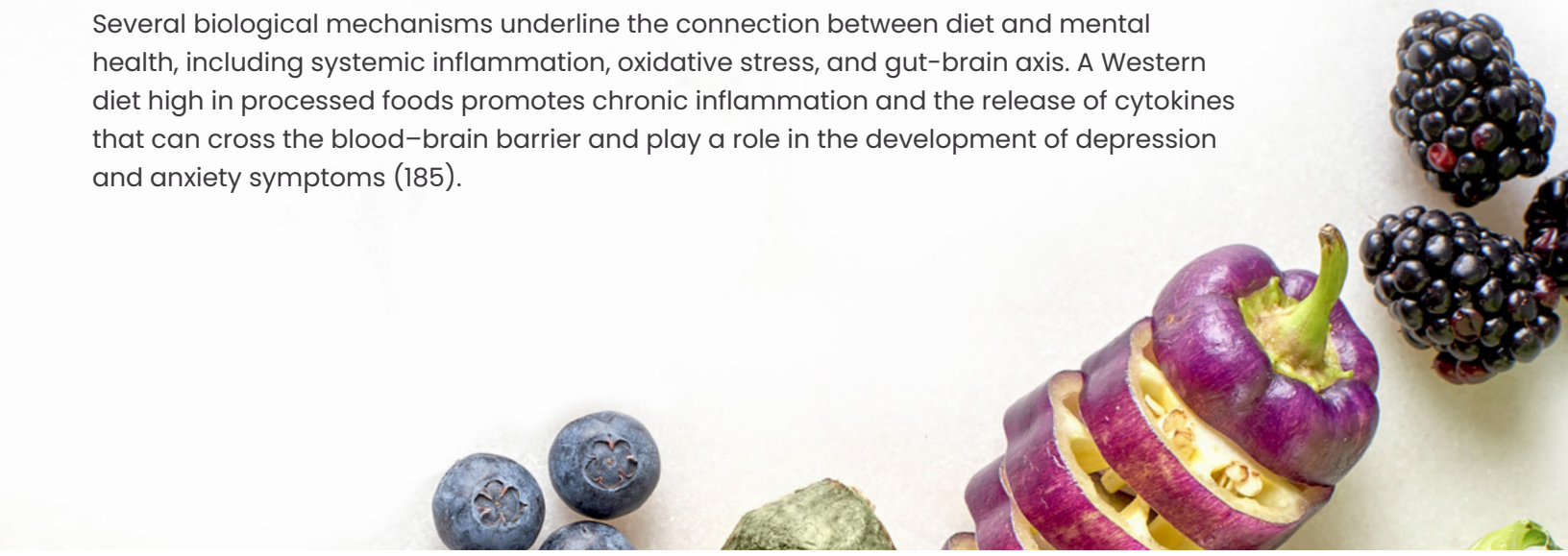
disorder, with anxiety and depression being the most prevalent (3). In the U.S., mental health conditions are among the most common health issues, with 31.9% of adolescents and 22.8% of adults receiving mental health treatment in 2022 (182).

United Nations Rev. 4 Political declaration of the General Assembly on the prevention and control of noncommunicable diseases and the promotion of mental health and well-being emphasize that noncommunicable diseases and mental health and well-being are closely intertwined with brain health and neurological conditions. Mental health conditions and neurological conditions contribute to the global incidence and impact of noncommunicable diseases, and people living with mental health conditions and neurological conditions also have an increased risk of other noncommunicable diseases and therefore have higher rates of morbidity and mortality (183).

Risk factors for mental health conditions include abuse and violence, bullying, sudden loss of a loved one, unemployment, genetic factors, substance abuse, unhealthy diet, chronic disease, climate crisis, conflict and forced displacement, poor access to services, discrimination, etc. (181).

The potential protective effects of healthy lifestyles, including healthy diet, on both mental and brain health, has become a research focus over the past decade. In numerous studies, adherence to a high-quality diet, like Mediterranean diet or a diet that contains higher consumption of vegetables, fruits and fish were associated with lower anxiety and depression scores (184,185). In contrast, Western dietary patterns rich in processed foods, refined carbohydrates, and pro-inflammatory foods have been linked to a higher prevalence of depression and anxiety symptoms (185,186). Dietary recommendations for the prevention of depression include adherence to traditional dietary patterns, such as the Mediterranean, Norwegian, or Japanese diet, increased consumption of fruits, vegetables, legumes, whole grains, nuts, and seeds, high intake of foods rich in omega-3 polyunsaturated fatty acids, substitution of unhealthy food items with nutrient-dense, wholesome alternatives, and the limitation of processed foods, fast foods, commercial baked products, and sweets (187).

Several biological mechanisms underline the connection between diet and mental health, including systemic inflammation, oxidative stress, and gut-brain axis. A Western diet high in processed foods promotes chronic inflammation and the release of cytokines that can cross the blood–brain barrier and play a role in the development of depression and anxiety symptoms (185).



Fruits, vegetables, and mental health

A systematic review of 61 observational studies found that higher fruit and vegetable intake is linked to better mental health outcomes, particularly reduced depressive symptoms and improved well-being. Specific subgroups such as berries, citrus, and leafy greens showed the strongest benefits, including greater optimism, self-efficacy, and lower psychological distress. Although methodological diversity across studies limited comparability, the consistent positive associations support recommendations of at least five portions of fruits and vegetables daily for mental health benefits (188).

The Mediterranean diet rich in fruits, vegetables, polyphenols, fiber and olive oil, is associated with a reduced risk of recurrent depression (189), as well as significant improvements in mood and reduced anxiety in adults with major depression (190).

Several mechanisms have been proposed to explain the positive effects of healthy dietary patterns and increased intake of fruits and vegetables rich in vitamins, minerals, phytochemicals, and fiber on mental health. It is estimated that diets abundant in anti-inflammatory compounds, antioxidants, and essential nutrients enhance neurotransmitter function, lower systemic inflammation, and foster a healthy gut microbiota, all of which may contribute to better mood regulation and stress resilience (191,192).

In addition, chronic non-communicable diseases are significant risk factors for mental disorders, and as demonstrated in Part IV, diets rich in fruits and vegetables contribute significantly to the prevention and management of CNDs, including cardiovascular disease, diabetes, obesity and cancer.

The Mediterranean-DASH Intervention for Neurodegenerative Delay ("MIND") diet combines the principles of the Mediterranean and DASH diets and was designed to improve nervous system function and delay the progression of neurodegenerative diseases. This diet emphasizes a high intake of vegetables, fruits, nuts, whole grain cereal products, olive oil, fish, and seafood. The MIND diet is beneficial for cognitive decline during aging, as well as for the prevention and progression of neurodegenerative diseases, including Alzheimer's disease (193,194).

Studies on children have also demonstrated that children who ate regular, balanced meals, especially those consuming more fruits and vegetables, had significantly higher mental well-being scores than children who consumed poor-quality options or skipped meals (195).

CONCLUSIONS

Fruits and vegetables are nutrient-dense foods, meaning they provide vitamins, minerals, and other health-promoting components, and have no added sugar, saturated fat, and sodium.

Fruits and vegetables are rich dietary sources of several essential ***vitamins***, including vitamin C, a powerful antioxidant; provitamin A, which supports visual processes; folate, necessary for DNA synthesis; and vitamin K, important for blood coagulation. In addition, fruits and vegetables are a primary dietary source of numerous ***phytochemicals*** that exhibit antioxidant, anti-inflammatory, anticancer, and cardioprotective properties. Furthermore, fruits and vegetables are rich in several ***minerals***, including non-heme iron and potassium, which play an important role in the prevention of hypertension.

Fruits and non-starchy vegetables are a good source of ***dietary fiber***, while legumes, green peas, and green leafy vegetables are a good source of plant-based ***proteins***. Additionally, fruits and vegetables are foods with the ***lowest energy density*** and are therefore strongly recommended for both the prevention and treatment of obesity and obesity-related conditions.

Numerous studies, as well as dietary recommendations, emphasize the importance of greater long-term intake of fruits and vegetables in the prevention and treatment of ***chronic non-communicable diseases***, which are responsible for most illnesses, disabilities, and deaths worldwide. Key metabolic risk factors that increase the risk of CNDs are hypertension, obesity and diabetes.

Hypertension is a leading risk factor for early death and poor health worldwide. Because fruits and vegetables are high in potassium and fiber and low in sodium and fat, diets rich in fruits and vegetables—such as the DASH diet—are strongly recommended for the prevention and management of hypertension.

The global ***obesity*** epidemic represents one of the most significant public health challenges of modern society. Fruits and vegetables play an important role in the prevention and treatment of obesity due to the following characteristics: low energy density, low fat content, high fiber content that enhances satiety, and a high content of vitamins and minerals.

Diabetes contributes to a considerable increase in morbidity and mortality. Numerous studies have shown that fruits and vegetables exert a protective effect against diabetes primarily due to their high content of dietary fiber, phytonutrients, and antioxidants. Dietary fiber helps delay the absorption of carbohydrates, reducing postprandial blood glucose levels and improving insulin sensitivity.

Cardiovascular diseases are the leading cause of death in both developed and developing nations. For several decades, findings from both observational and intervention studies from all regions in the world have consistently demonstrated that diets rich in fruits and vegetables are associated with a reduced risk of cardiovascular disease. Additionally, dietary patterns rich in fruits and vegetables, such as the Mediterranean diet, are critically important for the prevention and management of several major risk factors associated with cardiovascular diseases, including hypertension, obesity, diabetes, abnormal blood lipids, and inflammation.

In the United States and Europe, ***cancer*** ranks as the second leading cause of death. Several studies have shown that diets high in vegetables, fruits, and their associated compounds—such as fiber and antioxidants—are associated with a reduced risk of cancer. The anti-carcinogenic potential of fruits and vegetables is attributed to a combination of bioactive compounds and nutritional components, including antioxidants such as vitamin C and vitamin E, phytochemicals, dietary fiber, and the promotion of a healthy body weight.

Diet and nutrition are modifiable factors that influence the development and progression of ***chronic respiratory diseases*** and infections. Antioxidants found in fruits and vegetables—such as vitamin C, vitamin E, carotenoids, and polyphenols—play a critical role in neutralizing reactive oxygen species generated by smoking and environmental pollutants, thereby mitigating oxidative damage and inflammation in the airways, slowing progression of chronic respiratory diseases, and reducing susceptibility.

Fruits and vegetables offer some of the most effective components to support ***gastrointestinal health***. Fresh produce helps modulate the gut microbiome and enhance gastrointestinal immunity. Dietary fiber, especially from whole fruits, vegetables, and legumes, promotes regular bowel movements and is associated with a lower risk of colorectal and other gastrointestinal cancers.

Mental health is a vital component of overall well-being that enables individuals to cope with life's challenges, realize their potential, and contribute meaningfully to society. Evidence shows that healthy dietary patterns, especially those rich in fruits, vegetables, and whole foods like those included in the Mediterranean and MIND diets, are associated with better mental health outcomes, including reduced depression and anxiety.

In this review it was explained how adequate nutrition and a high daily intake of fruits and vegetables play a crucial role in the prevention and treatment of chronic non-communicable diseases, as well as in maintaining good health and a high quality of life. Consequently, all leading health organizations and dietary guidelines worldwide recommend a high daily intake of fruits and vegetables.

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