JIM Review-Key Symposium

doi: 10.1111/joim.13728

Diet strategies for promoting healthy aging and longevity: An epidemiological perspective

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Content List – This is an article from the symposium: "18th Key Symposium: Longevity and Healthy Ageing: What can we learn from Blue Zones?".

Abstract. Hu FB. Diet strategies for promoting healthy aging and longevity: An epidemiological perspective. *J Intern Med.* 2024;**295**:508–31.

In recent decades, global life expectancies have risen significantly, accompanied by a marked increase in chronic diseases and population aging. This narrative review aims to summarize recent findings on the dietary factors influencing chronic diseases and longevity, primarily from large cohort studies. First, maintaining a healthy weight throughout life is pivotal for healthy aging and longevity, mirroring the benefits of lifelong, moderate calorie restriction in today's obesogenic food environment. Second, the specific types or food sources of dietary fat, protein, and carbohydrates are more important in influencing chronic disease risk and mortality than their quantity. Third, some traditional diets (e.g., the Mediterranean, Nordic, and Okinawa) and contemporary dietary patterns, such as healthy plant-based diet index, the DASH (dietary approaches to stop hypertension) diet, and alternate healthy eating index, have been associated with lower mortality and healthy longevity. These patterns share many common components (e.g., a predominance of nutrient-rich plant foods; limited red and processed meats; culinary herbs and spices prevalent in global cuisines) while embracing distinct elements from different cultures. Fourth, combining a healthy diet with other lifestyle factors could extend disease-free life expectancies by 8–10 years. While adhering to core principles of healthy diets, it is crucial to adapt dietary recommendations to individual preferences and cultures as well as nutritional needs of aging populations. Public health strategies should aim to create a healthier food environment where nutritious options are readily accessible, especially in public institutions and care facilities for the elderly. Although further mechanistic studies and human trials are needed to better understand molecular effects of diet on aging, there is a pressing need to establish and maintain long-term cohorts studying diet and aging in culturally diverse populations.

Keywords: aging, cardiovascular risk factors, diet, epidemiology, physiology, nutrition

Introduction

In recent decades, life expectancy around the world has shown a remarkable increase, due to reduction in infant mortality and improvements in health care, nutrition, and public health measures [1]. However, longer life expectancies, along with declining birth rates, have led to a greater proportion of elderly individuals in many populations. In the meantime, there has been a rapid increase in the prevalence of chronic diseases, including diabetes, cardiovascular diseases (CVDs), cancer, dementia, and other age-related conditions [2]. Many of these diseases are related to suboptimal diet and lifestyles. Indeed, poor diet is recognized as a leading contributor to the global burden of diseases, including deaths and disability-adjusted life years (DALYs); it was estimated that worldwide, 11 million premature deaths and 255 million DALYs per year were attributable to unhealthy dietary factors including high sodium and trans fat, and low fruits, vegetables, nuts, and omega-3 fatty acids [3].

The concept of "healthy longevity" has garnered much attention in recent years because it is focused on not only increasing the overall life expectancy or life span of individuals but also on increasing the length of life free from major chronic diseases, often referred to as the "healthspan" [4]. The National Academy of Medicine defined healthy longevity as "years of good health approach the biological life span, with physical, cognitive, and social functioning that enable well-being" [5]. The definition underscores a preventive approach to health and well-being through diet and lifestyle modifications. This concept is also closely linked to healthy aging, which refers to maintenance of physical, mental, and cognitive health as individuals grow older [6], while preventing or delaying the onset of frailty in elderly individuals [7].

This narrative review aims to summarize recent findings on the dietary factors influencing chronic diseases and longevity, primarily from large cohort studies. Specifically, we highlight findings from two large cohort studies: the Nurses' Health Study (NHS) and Health Professionals' Follow-up Study (HPFS), which are among the largest and longest running cohort studies on diet and health in the world [8–10]. Besides large sample sizes, a long duration of follow-up spanning more than three decades, and high rates of follow-up (>90%), detailed data on diet and lifestyle factors have been collected every 2–4 years. The repeated measures of diet are particularly useful in reducing measurement errors stemming from self-reported diets and representing long-term dietary habits [9]. Because large randomized clinical trials (RCTs) of diet and longevity are typically not feasible due to lack of long-term adherence and cost considerations, observational data derived from high-quality cohorts—combined with insights from small RCTs in humans and experimental data from animal studies—can substantially enhance our understanding of the role of diet in preventing chronic diseases and reducing premature deaths, which can help to formulate evidence-based nutritional strategies to support healthy longevity in aging populations [11].

Calorie restriction and energy balance

Calorie restriction has been widely considered a promising approach to fostering long-term health and longevity [12]. In various organisms, from yeast to mammals, calorie restriction (with a significant reduction in food and caloric intake below ad libitum levels without causing malnutrition) has been found to be effective in increasing life span and delaying the onset of age-related diseases [13]. The molecular pathways underlying these benefits are complex and multifaceted, including reduced insulin and Insulin Growth Factor-1 (IGF-1) signaling, inhibiting the mechanistic target of rapamycin (mTOR) signaling, activation of AMP-activated protein kinase (AMPK) and sirtuins 1 (SIRT1), upregulation of the NAD+ pathway and autophagy, and reducing inflammation and oxidative stress [14, 15].

However, the effects of sustained calorie restriction over the long-term in humans are much more challenging to study, especially in the context of the obesogenic food environment [16]. In the longest caloric reduction trial among nonobese individuals, the Comprehensive Assessment of Long-term Effects of Reducing Intake of Energy (CALERIE) trial demonstrated that participants in the calorie restriction group achieved approximately 12% calorie reduction and a sustained 10% weight loss compared to the control group over 2 years, accompanied by significant improvement in blood lipids, blood pressure, insulin sensitivity, and pro-inflammatory cytokines [17]. Despite these promising findings, it is difficult to extrapolate the short-term cardiometabolic benefits to long-term chronic disease risk reduction and increased longevity due to the study's relatively short duration and small sample size.

A major challenge in the practical implementation of calorie restriction lies in the accurate tracking of daily caloric intake, energy expenditure, and long-term adherence to a calorie-restricted diet. In epidemiologic studies, body weight trajectories can be used as a marker of long-term energy balance across different stages of life. Using data from NHS and HPFS, we assessed body shape trajectories in early and middle life in relation to subsequent mortality risk [18]. Using a statistical modeling approach, five distinct trajectories of body shape from age 5 to 50 were identified: lean-stable, lean-moderate/increase, lean-marked/increase, medium-stable/increase, and heavy-stable/increase. To minimize confounding by smoking, the primary analyses were limited to never smokers. Compared to the lean-stable group, the multivariable-adjusted hazard ratio for death from any cause was 1.08 (95% confidence interval 1.02–1.14) for women and 0.95 (0.88–1.03) for men in the lean-moderate/increase group, 1.43 (1.33–1.54) for women and 1.11 (1.02–1.20) for men in the lean-marked/increase group, 1.04

(0.97–1.12) for women and 1.01 (0.94–1.09) for men in the medium-stable/increase group, and 1.64 (1.49–1.81) for women and 1.19 (1.08–1.32) for men in the heavy-stable/increase group. This study provides evidence to support the benefits on longevity of maintaining a stable-lean body shape throughout life. Similarly, women and men who maintained a lean body shape across different life stages had the lowest risk of type 2 diabetes and CVD, whereas those who had substantially increased body adiposity had the highest risk of developing these diseases [19].

In further analyses, even a modest amount of weight gain (e.g., 5 kg) during young and middle adulthood (18–55 years) was associated with a significantly elevated risk of developing type 2 diabetes (by 30%), hypertension (by 14%), CVD (by 8%), obesity-related cancer (by 6%), and premature death (by 5%) [20] (Fig. 1). This amount of weight gain was also associated with 17% lower likelihood of achieving healthy aging defined as being free of major chronic conditions and having no substantial cognitive, physical, or mental limitations after age 55. Moreover, individuals with the body mass index (BMI) range of 18.5–22.4, combined with higher levels of physical activity and healthy diets had the lowest mortality, suggesting that leanness induced by healthy diet and lifestyle is optimal to promote longevity [21].

Given the impracticality of conducting long-term calorie restriction trials, to a certain extent, the analyses on life course body weight trajectories in relation to health outcomes resemble a natural experiment. Individuals who maintain a lifelong leanness through healthy diet and lifestyle practices tend to live longer and healthier lives, mimicking results one might expect from long-term calorie restriction studies. The fasting mimicking diet, designed to provide health benefits of fasting without total food abstinence, has demonstrated positive effects on weight loss and cardiometabolic risk factors in short-term trials [22, 23], though longer term data are needed.

Total and types of dietary fats

In many Asian populations, traditional diets often feature lower fat intake compared to typical Western diets. Previous cross-sectional and ecological studies suggested an inverse association between adherence to traditional Asian dietary patterns and lower rates of CVD, cancer, and mortality [24].

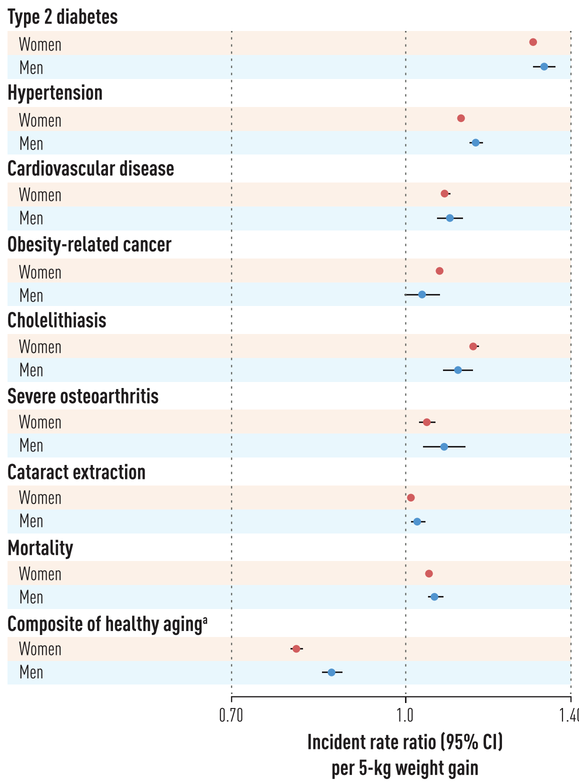

Fig. 1 *Associations of weight gain from early to middle adulthood with risk of individual health outcomes. After adjustment for age at cohort recruitment (continuous), height (continuous), race (non-White or White), pack-years of smoking (never smokers; past smoker with <5, 5–20, or >20 pack-years; and current smoker with <5, 5–20, or >20 pack-years), regular aspirin use (yes or no), status of menopause and hormone therapy (women only: premenopausal, postmenopausal and never use, postmenopausal and current use, or postmenopausal and past use), parity (women only: nulliparous, 1, 2, 3, or ≥4 children), physical activity, alcohol consumption dietary quality (alternative healthy eating index in quintiles), family history of respective diseases and weight at age of 18 years in women and at age of 21 years in men. Obesity-related cancer includes the esophagus (adenocarcinoma only), colon and rectum, pancreas, breast (after menopause, women only), endometrium (women only), ovaries (women only), prostate (advanced only, men only), kidney, liver, and gallbladder. [a]A composite healthy aging outcome was defined as being free of 11 chronic diseases and major cognitive or physical impairment. Expressed as odds ratio (95% CI) per 5-kg weight gain. Source: Reproduced with permission from Ref. [20]. Copyright (2017) American Medical Association. All rights reserved (superficially modified).*

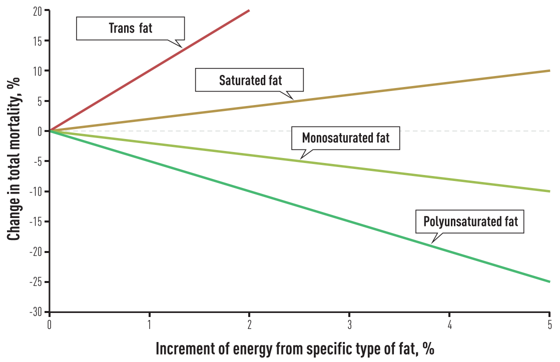

Fig. 2 *Change in total mortality risk associated with increments of calorie intake from specific types of fat in the Nurses' Health Study and Health Professionals Follow-Up Study. Multivariable HRs are shown for total mortality associated with replacing the percentage of energy from total carbohydrates with the same energy from specific types of fat (p-trend < 0.001 for all), adjusted for age, race, marital status, body mass index (BMI), physical activity, smoking status, alcohol consumption, multivitamin use, vitamin E supplement use, current aspirin use, family history of myocardial infarction, family history of diabetes, family history of cancer, history of hypertension, history of hypercholesterolemia, intakes of total energy and dietary cholesterol, percentage of energy intake from dietary protein, menopausal status and hormone use in women, and percentage of energy from the remaining specific types of fat. Source: The figure originally published in Hemler C, Hu F, "Plant-Based Diets for Personal, Population, and Planetary Health" Advances in Nutrition, 2019 Nov; 10(Suppl 4): S275–S283. https://advances.nutrition.org/. Reproduced with permission (superficially modified).*

However, these studies were strongly confounded by socioeconomic factors. Over the past several decades, a wealth of data from RCTs and large cohort studies has provided compelling evidence that different types of fats have different effects on various health outcomes. In the NHS and HPFS, types of fat were far more important than total amount of fat in determining the long-term risk of mortality [25]. Specifically, higher intakes of unsaturated fats (found predominantly in plant-based foods and marine fish) were associated with lower mortality risk, with linoleic acid exhibiting the strongest inverse association with mortality. On the other hand, higher intakes of trans fat and saturated fat were associated with increased mortality with the adverse effects of trans fat substantially stronger than those of saturated fat (Fig. 2). These associations were consistent when cause-specific mortality (including CVD mortality, cancer mortality, and mortality due to respiratory diseases or neurogenerative conditions) were analyzed separately. The benefits of polyunsaturated fats (PUFAs), especially linoleic acid, on CVD and total mortality were confirmed in systematic reviews and meta-analysis of cohort studies using biomarkers of linoleic acid intake [26, 27].

When interpreting these observed associations, it is important to consider substitution effects derived from isocaloric statistical modeling as such analyses emulate a dietary intervention study, while factoring in real-world dietary choices [28]. In the aforementioned study, replacing 5% of energy from saturated fat with the same amount of energy from monounsaturated fats (MUFAs) and PUFAs was associated with a 27% and 15% reduced risk of mortality, respectively [25]. In another study [29], replacing 5% of calories from saturated fat with PUFAs, MUFAs, or whole grains was associated with a 25%, 15%, and 9% lower risk of coronary heart disease (CHD), respectively. However, based on the substitution modeling, replacing saturated fat with carbohydrates from refined starches and added sugars did not alter CHD risk. The food source of fat (plant or animal) may also affect health outcomes, even when considering the same type of fat. For example, replacing 5% of energy intake from saturated fat, trans fat, and refined carbohydrates with MUFA intake from plant sources (e.g., vegetable oils, nuts, seeds, and avocados) was associated with lower risk of CHD, whereas the same substitution with MUFA from animal sources did not confer the same beneficial effects [30].

Types and food sources of protein

In model organisms, protein restriction or restriction of particular amino acids—such as methionine and tryptophan—has been shown to extend life and promote healthy longevity, independent of total caloric intake [31, 32]. One proposed mechanism of the underlying benefits of protein restriction lies its effects on IGF-1. Lower protein intake has been associated with decreased IGF-1 production and signaling, which is linked to reduced risk of cancer and slower aging [33].

Despite the strong experimental evidence, the extrapolation of this evidence to humans is complex due to differences in metabolism and physiology. Levine et al. [34] analyzed data from the National Health and Nutrition Examination Survey (NHANES) and found that the associations between protein intake and mortality varied by age groups and types of protein. Among individuals aged 50–65-year old, high protein intake was associated with a 75% increase in overall mortality and a fourfold increase in cancer and diabetes mortality during 18 years of follow up. The association was significant only for animal protein but not for plant protein. On the other hand, in individuals aged 65 or older, higher protein intake was associated with lower mortality. However, the interaction between protein intake and age on mortality has not been observed in other cohorts. In the NHS and HPFS, higher animal protein intake was positively associated with cardiovascular mortality, whereas higher plant protein intake was inversely associated with all-cause and cardiovascular mortality with no evidence of effect modification by age [35]. In the substitution analysis, replacing animal protein sources (especially red and processed meats) with plant protein sources was associated with significantly lower risk of all-cause mortality. In a separate analysis, plant protein sources were also associated with lower odds of cognitive decline when compared with animal protein sources, although adequate protein intake appears to be important in the maintenance of cognition in older individuals [36].

The importance of protein sources is further underscored by food-based analysis. In the NHS and HPFS, an increase in 1 serving of processed and unprocessed red meat per day was linked to a 13% and 20% increased risk of mortality, respectively [37]. Replacing 1 serving of red meat per day with other foods, such as fish, poultry, legumes, nuts, low-fat dairy, or whole grains, was associated with a 7%–19% lower risk of premature death. Based on the estimates from statistical modeling, if all study participants in the cohorts had consumed less than a half serving of red meat (42 g) per day, 9.3% of deaths in men and 7.6% in women could have been prevented. Several systematic reviews and meta-analyses have consistently found that higher consumption of red and processed meats was significantly associated with increased risk of developing type 2 diabetes, CVD, and some cancers, especially colorectal cancer [38–41]. Moreover, habitual consumption of unprocessed and processed red meat was associated with a moderately higher risk of frailty (defined as having ≥3 of the following five criteria from the FRAIL scale: fatigue, low strength, reduced aerobic capacity, having ≥5 illnesses and weight loss ≥5%) [42]. Replacement of red meat by plant protein sources was associated with lower risk of frailty.

Nuts—rich in plant protein and healthy fat—have been studied extensively for their benefits on reducing risk of chronic diseases and mortality. Numerous short-term RCTs have shown that incorporating nuts into regular diets significantly reduced total and LDL cholesterol levels [43]. Large cohort studies have shown that regular consumption of nuts was associated with significantly lower risk of type 2 diabetes [44], CVD [45], some cancers [46], and mortality [47]. Peanuts, although botanically legumes, appear to confer similar health benefits as tree nuts [48]. In the NHS and HPFS, compared to participants who seldom ate nuts, those who consumed nuts at least once daily had a 20% lower death rate [49]. The inverse associations were similar for peanuts and tree nuts. In addition, habitual consumption of nuts was associated with significantly lower risk of frailty [50] and increased likelihood of healthy aging [51], suggesting that nuts can be included in a dietary pattern for the preservation of health and well-being in older adults.

Carbohydrate quantity and quality

Low-carbohydrate or ketogenic diets have been extensively studied in animal models and humans for their impact on metabolic health outcomes and longevity. Ketogenic diets are extreme low-carbohydrate diets that induce a state of ketosis, in which the body relies primarily on ketone bodies for energy [52]. Animal studies suggest that a ketogenic diet may enhance longevity and health span through influencing multiple metabolic and aging pathways, including reducing mTOR signaling, AMPK and SIRT1 activation, improving insulin sensitivity, and inhibiting chronic inflammation [53, 54].

In short-term RCTs, low-carbohydrate or ketogenic diets have been shown to be more effective in promoting weight loss compared to conventional low-fat high-carbohydrate diets [55]. In addition, carbohydrate restriction lowers blood glucose levels, reduces postprandial glucose spikes, and improves insulin sensitivity in glycemic control among individuals with type 2 diabetes [56, 57]. However, long-term adherence to very low-carbohydrate or ketogenic diets is often challenging due to their restrictive nature. In addition, very low-carbohydrate intake leads to reduced intake of fiber, vitamins, and minerals, which could have negative health consequences. Although low-carbohydrate diets often decrease triglyceride levels and increase HDL levels, such diets have been associated with increased LDL cholesterol levels [52].

The long-term health effects of low-carbohydrate diets appear to depend on the type of fat and protein in the diets [58]. During up to 20–26 years of follow-up in NHS and HPFS, the overall low-carbohydrate diet score was only weakly associated with all-cause mortality. However, a higher animal low-carbohydrate diet score was associated with higher all-cause and cancer mortality, whereas a higher vegetable low-carbohydrate score (emphasizing plant sources of protein and fat) was associated with lower mortality, particularly CVD mortality. Similarly, among individuals with type 2 diabetes, greater adherence to low-carbohydrate diet patterns that emphasize plant sources of fat and protein was significantly associated with lower total, cardiovascular, and cancer mortality [59]. It should be noted that in real-world epidemiologic studies, the amount of carbohydrates in the low-carbohydrate diet pattern was much higher than that used in controlled intervention studies of ketogenic or very low-carbohydrate diets.

Numerous epidemiologic studies have investigated the role of both quantity and quality of carbohydrates in long-term health outcomes and mortality. Carbohydrate quality is typically defined according to its nutritional value and health effects, including the degree of processing, fiber content, and glycemic index and glycemic load [56]. Overall evidence suggests that carbohydrate quality plays a more important role in chronic disease outcomes than carbohydrate amount. A series of systematic reviews and meta-analyses of data from large cohort studies have shown that high glycemic index or glycemic load diets (often containing higher amounts of refined grains, such as white rice and white bread, starchy foods such as potatoes, and sugar-sweetened beverages [SSBs]), are consistently associated with increased risk of weight gain, obesity, diabetes, CVD, some cancers, and mortality [60–64], whereas minimally processed grains, legumes, whole fruits, and non-starchy vegetables are protective against these conditions [65–68]. In a recent longitudinal analysis of changes in carbohydrate intake and long-term weight gain in the NHS and HPFS, increasing dietary glycemic index, glycemic load, and amounts of starch, added sugars, refined grains, and starchy vegetables was associated with greater midlife weight gain. In contrast, increasing amounts of fiber, whole grains, fruit, and non-starchy vegetables was associated with less weight gain [69].

SSBs are a primary source of added sugars in many diets and have been consistently associated with increased risk of chronic diseases and mortality [70]. In the NHS and HPFS, each serving per day increment in SSBs was associated with a 7% higher risk of total mortality (HR: 1.07; 95% CI: 1.05, 1.09), a 10% higher risk of CVD death (HR: 1.10; 95% CI: 1.06, 1.14), and a 5% higher risk of cancer death (HR 1.05, 95% CI 1.02–1.08) [71]. The association between higher consumption of artificially sweetened beverages (ASBs) and risk of mortality was less clear. Higher consumption of SSBs and ASBs was associated with a significantly increased risk of frailty [72].

SSBs promote weight gain and, consequently, elevate the risk of chronic diseases through multiple mechanisms [70]. These include the body's incomplete compensation for liquid calorie intake by not sufficiently reducing food intake at subsequent meals, hyperinsulinemia resulting from rapid absorption of large amounts of sugar, increased chronic inflammation, and potential neural pathways linked to food addiction. Although high consumption of these beverages increases type 2 diabetes and cardiometabolic risk primarily through weight gain, it also has direct impact. Specifically, the high amount of glycemic load and fructose in SSBs can lead to accumulation of visceral adipose tissue and ectopic lipid deposition and increased risk of gout and nonalcoholic fatty liver disease [70].

Polyphenol-rich plant foods

Polyphenols are a diverse group of naturally occurring compounds found in plant-based foods, such as fruits, vegetables, whole grains, nuts, and legumes—including soy products, coffee, tea, cocoa, red wine, herbs, and spices [73, 74]. There are thousands of different polyphenols, which can be categorized into subclasses, including flavonoids (found in fruits, vegetables, tea, coffee, cocoa, and soy), lignans (found in seeds, grains, and vegetables), phenolic acids (found in coffee, nuts, and fruits), and resveratrol (found in grapes and wine). Because of their antioxidant, anti-inflammatory, and anticarcinogenic properties, polyphenol-rich foods are considered an important component of healthy dietary patterns that promote overall health and well-being. In addition to their cardiometabolic benefits, such as improved blood lipid profiles and reduced blood pressure, polyphenols have the potential to improve cognitive function and lower the risk of neurodegenerative diseases [75, 76]. Furthermore, they act as prebiotics, promoting the growth of beneficial gut bacteria and maintaining a healthy gut microbiome [74]. Experimental studies indicate that polyphenols exhibit antiaging properties by influencing various hallmarks of aging, including inflammation, oxidative stress, epigenetic alterations, and protein homeostasis [77]. Below we highlight epidemiologic and clinical trial evidence on the health benefits of several polyphenol-rich foods, such as coffee, tea, extra-virgin olive oil, blueberries, avocados, and culinary herbs and spices, as an exhaustive review of all major foods high in polyphenols is beyond the scope of this paper. It is worth noting that foods rich in polyphenols also contain other beneficial nutrients and compounds, such as minerals, vitamins, and carotenoids. Carotenoids, which are phytochemicals with antioxidant effects that give plant foods their vibrant colors, have been associated with lower risk of chronic diseases [78, 79]. Therefore, the health benefits of these foods may result from a combination of many components, not just polyphenols alone.

Among polyphenol-rich foods, coffee stands out as a major source of polyphenols in many populations. Chlorogenic acids are the most abundant polyphenols in coffee, possessing strong anti-inflammatory and antioxidant properties. Numerous epidemiologic studies have examined the associations between coffee consumption and risk of chronic diseases [80]. Consistent evidence has shown that moderate coffee consumption (3–5 standard cups per day) is associated with reduced risk of developing type 2 diabetes, CVD, and some cancers, such as liver, endometrial, and colorectal cancer. Moderate coffee consumption is also associated with lower risk of premature death in diverse populations [81, 82]. In addition, coffee consumption has been associated with a reduced risk of cognitive disorders [83] and Parkinson's disease [84]. Moreover, there is consistent evidence that coffee consumption is associated with a reduced risk of depression [85] and suicide [86]. The health benefits of coffee are likely due to various bioactive compounds including polyphenols, although caffeine—a central nervous system stimulant—also plays a role in improving cognitive function and reducing risk of neurodegenerative diseases. It should be noted that individuals' response to coffee can vary depending on genetics, and social and behavioral factors [80].

Regular consumption of tea has been associated with myriad health benefits, including lower risk of type 2 diabetes, CVD, and mortality [87, 88], although the overall evidence is less consistent and robust compared to that for coffee. Green tea has received a great deal of attention because of its high contents of catechins and other polyphenols with potent antioxidant effects. Green tea polyphenols—particularly epigallocatechin gallate—have been shown to improve blood lipid profiles, reduce blood pressure, and enhance vascular function [89, 90]. These polyphenols have also been associated with improved cognitive function and lower risk of neurodegenerative diseases [91].

Extra virgin olive oil (EVOO) is obtained from the mechanical pressing of olives without the use of heat or chemicals. Compared to regular olive oil, EVOO contains higher amounts of polyphenols such as oleuropein and hydroxytyrosol, which contribute to its color and flavor as well as potential health benefits [92, 93]. High olive oil consumption is a hallmark of the traditional Mediterranean diet (MedDiet), which has been consistently associated with lower risk of chronic diseases and mortality [94]. In the PREDIMED trial, participants who followed a MedDiet supplemented with EVOO or mixed nuts had significantly reduced risk of CVD including strokes, heart attacks, and cardiovascular deaths compared to the control group [95]. The intervention group supplemented with EVOO also had significantly reduced risk of type 2 diabetes [96] and breast cancer [97]. Despite relatively low consumption of olive oil compared to Spanish or other European populations, participants in the NHS and HPFS who consumed four or more tablespoons of olive oil per week had significantly lower risk of developing type 2 diabetes [98], CVD [99], and mortality [100].

In a subsample of the PREDIMED trial, the participants assigned to the MedDiet group supplemented with either EVOO or mixed nuts experienced significantly improved cognitive function compared to the control group [101]. These benefits are likely due to both the antioxidant and anti-inflammatory effects of polyphenols in the intervention diets as well as the indirect effects through improved vascular function by the interventions with their healthy fats.

Blueberries are rich in polyphenols, especially anthocyanins. Prospective analyses using data from NHS and HPFS have shown that higher consumption of anthocyanins or blueberries was associated with lower risk of type 2 diabetes [102], CVD [103, 104], and all-cause mortality [105]. In the longest duration RCT to date among participants with metabolic syndrome, 1 cup [150 g] of blueberries/d for 6 months led to clinically significant improvements in endothelial function, systemic arterial stiffness, and HDL-cholesterol levels, compared to the control group [106].

In animal studies, supplementation with blueberries led to improvements in cognitive and motor behaviors as well as in learning and memory [107]. Small RCTs in humans have shown that blueberry supplementation improves cognitive performance in children and older adults [108]. In the NHS and HPFS, higher consumption of total flavonoids and subclasses, including flavones, flavanones, and anthocyanins, was associated with lower odds of subjective cognitive decline [SCD] [109]. In this study, many flavonoid-rich foods, including berries, oranges, grapefruits, citrus juices, apples/pears, celery, peppers, and bananas, were significantly associated with lower likelihood of SCD.

Avocados are a nutrient-rich fruit that contain a variety of beneficial components, such as fiber, monounsaturated fat, potassium, and magnesium, and bioactive compounds including polyphenols, especially flavonoids [110]. Small RCTs have shown that diets that incorporated avocados significantly decreased LDL cholesterol levels [111]. In the NHS and HPFS, [112] higher avocado intake ($\geq$2 servings/week) was associated with a 16% lower risk of CVD (HR, 0.84; 95% CI, 0.75–0.95) and a 21% lower risk of CHD (HR, 0.79; 95% CI, 0.68–0.91). No significant associations were observed for stroke. In substitution analyses, replacing half a serving/day of margarine, butter, egg, yogurt, cheese, or processed meats with the equivalent amount of avocado was associated with a 16% to 22% lower risk of CVD.

Herbs and spices are widely used in global cuisines, contributing not only to diversity of flavor but also potential health benefits due to their rich content of bioactive compounds, including polyphenols [113]. Notable examples include turmeric in Indian dishes; basil, rosemary, and oregano in Mediterranean cuisine; and ginger, garlic, and cloves in East Asian cuisines. Experimental studies have indicated that many herbs and spices have antimicrobial, antioxidant, and antitumorigenic properties [113]. Beyond its culinary use, turmeric has historically been used in Chinese and Indian traditional medicine for treating various diseases and conditions. Curcumin—a polyphenol and the active component of turmeric—has been extensively studied in recent decades, demonstrating its potential antioxidant, anti-inflammatory, anti-diabetes, and anticancer effects [114]. A systematic review and meta-analysis of 64 RCTs found that turmeric/curcumin supplementation was effective in improving blood levels of TC, TG, LDL-c, and HDL-c [115]. Turmeric/curcumin supplementation has also been shown to improve markers of liver function [116]. Moreover, curcumin supplementation significantly increased serum brain-derived neurotrophic factor levels [117], which might have positive effects on cognitive function, learning, and memory. Despite these encouraging results, the quality of these RCTs is generally low due to limited sample sizes, short durations, and varied supplement preparations. Recently, a randomized, crossover, controlled feeding study found that the addition of a relatively high dosage of mixed herbs and spices to a standard US-style diet significantly improved 24-h blood pressure but did not affect other cardiometabolic risk factors after four weeks, compared with lower dosages among adults at elevated risk of cardiometabolic diseases [118]. In epidemiologic studies, the low consumption levels of herbs and spices and lack of specific biomarkers of their intakes make it challenging to examine their associations with long-term outcomes. Nevertheless, incorporating turmeric and other herbs and spices into diets can offer promising approaches for enhancing health. Going forward, more rigorous research is needed to standardize spice and herb extracts and preparations, obtain more accurate information about the chemical profiles or active ingredients, develop specific biomarkers for these compounds, and better understand underlying molecular pathways [113].

Taken together, the health benefits of polyphenol-rich foods, including coffee, tea, EVOO, blueberries, and avocados, are well supported by the convergence of evidence from observational cohort studies, small-scale RCTs, and mechanistic studies. In addition, emerging evidence suggests potential health benefits associated with culinary herbs and spices prevalent in global cuisines. Although further research is needed to understand the biological mechanisms underlying these effects, these findings highlight the importance of including a variety of polyphenol-rich foods in a healthy dietary pattern to promote healthy aging and longevity.

Healthy dietary patterns

Because individual foods or nutrients are not typically consumed in isolation, it is important to understand health effects of overall dietary patterns, which can provide a more comprehensive view of overall diet, reflecting real-world eating habits [119]. Moreover, evaluating overall dietary patterns can help capture the synergistic or antagonistic effects of different food components consumed concurrently and reduce confounding from intercorrelated dietary components. Moreover, dietary patterns can take into account cultural and regional variations in diet, making dietary recommendations more adaptable and relevant for diverse global populations.

The Mediterranean diet (MedDiet). The traditional MedDiet is widely considered a model for healthy eating. The main features of the MedDiet include an abundance of plant foods, such as fruits, vegetables, whole grains, nuts, and legumes; olive oil as the main source of dietary fat; fish and poultry consumed in low-to-moderate amounts; relatively low consumption of red meat; and moderate consumption of wine, typically in conjunction with meals [94]. A recent comprehensive review [120] conducted by Guasch-Ferre and Willett summarized the extensive body of evidence from both observational studies and clinical trials on the relationships between adherence to the Mediterranean dietary patterns and a wide spectrum of health outcomes. Overall, there is compelling evidence that greater adherence to the MedDiet is associated with reduced risk of obesity, type 2 diabetes, hypertension, dyslipidemia, CHD, stroke, and heart failure. In prospective cohort studies, adherence to the Mediterranean dietary pattern is associated with reduced mortality, especially cardiovascular mortality, thus contributing to increased longevity. In addition, the MedDiet has been associated with slower progression of age-related cognitive decline [121] and lower risk of neurodegenerative disorders such as dementia and Alzheimer's disease [122]. The MIND diet (Mediterranean-DASH Intervention for Neurodegenerative Delay)—a hybrid of the MedDiet and the DASH (Dietary Approaches to Stop Hypertension) diet—has been consistently associated with a decreased risk of cognitive decline and dementia in large cohort studies [123]. However, a recent RCT did not find significant effects of the MIND diet intervention on changes in cognition over three years [124]. The relatively short duration of the intervention and similar weight loss between the intervention and control groups might have contributed to the null findings.

The Nordic diet. Similar to the MedDiet, the Nordic diet focuses on plant-based and locally sourced foods that are typically found in the Nordic countries, such as Sweden, Denmark, Norway, Iceland, and Finland [125]. One notable difference between the MedDiet and the Nordic diet is the type of oil used. The MedDiet mainly uses EVOO, whereas in the Nordic diet rapeseed oil is commonly used. Although olive oil is high in oleic acid, rapeseed oil is rich in oleic acid, linoleic acid, and alpha-linolenic acid. The types of whole grains in the Nordic regions are mostly rye, barley, and oats. Among various fruits, berries are featured more prominently in the Nordic diet.

Compared to the MedDiet, the extent of research available regarding health benefits of the Nordic diet is more limited and more recent. A systematic review and meta-analysis summarized data on Nordic dietary patterns and cardiometabolic outcomes from 15 prospective cohort studies [126] and 6 RCTs. In cohort studies, adherence to the Nordic dietary pattern was associated with a small reduction in risk of CVD (7%) and type 2 diabetes (9%). Small RCTs showed that the Nordic dietary pattern led to a modest reduction in LDL-cholesterol, ApoB, body weight, insulin, and SBP, compared to a control diet. Several cohort studies suggested that adherence to the MedDiet was more strongly associated with total mortality than adherence to the Nordic diet [125]. While the landmark PREDIMED trial has demonstrated the benefits of the MedDiet supplemented with EVOO or mixed nuts on CVD and other clinical end points, no such trial has been conducted to investigate long-term effects of the Nordic diet.

The Okinawa diet. The traditional Okinawa diet has been linked to high concentrations of centenarians on the island of Okinawa [127, 128]. This dietary pattern resembles a vegetarian diet, characterized by its emphasis on root vegetables (mainly purple sweet potatoes), green and yellow vegetables, soybean-based foods, seaweeds and algae, tea, and a variety of medicinal plants (e.g.

bitter melon) and spices such as turmeric. Animal food consumption is often limited except for marine fish in coastal regions of the island. In addition to its food composition, a unique feature of the Okinawan diet is the practice of stopping eating when one is 80% full, known as Hara Hachi Bu [129]. This practice is akin to a natural form of mild caloric restriction.

Okinawa is one of the five "Blue Zones," a concept introduced by Buettner [130]. In addition to Okinawa, the other Blue Zones include Sardinia in Italy, Nicoya Peninsula in Costa Rica, Ikaria in Greece, and Loma Linda in California, USA. These regions were recognized for their residents' longevity and high numbers of centenarians. The diets of the Blue Zones are believed to play a crucial role in the exceptional longevity observed in these regions. However, the lifestyles in the Blue Zones also encompass shared features, such as plant-based eating, moderation in consumption, being physically active, and strong familial and social connections. Therefore, it is not possible to attribute the longevity observed in these regions solely to their diets.

Although the traditional diets in the Blue Zones have garnered much attention for their potential influence on longevity and health, it is worth noting that not all these diets and their health effects have been rigorously studied. In particular, while the Seventh-day Adventists Study based in Loma Linda is a well-established cohort to examine long-term effects of diet on health outcomes and longevity spanning decades [131], the diets in other Blue Zone regions and their health implications have been less well described. Moreover, the diets in the Blue Zones have evolved over time and thus differ substantially from traditional practices due to shifts in social-economic and cultural factors. For instance, the Okinawa diet has undergone considerable Westernization in recent years, which might have contributed to the rise of chronic diseases and decreased life expectancy on the island [132].

Vegetarian and other plant-based diets. Plant-based diets consist of a diverse spectrum of dietary patterns, generally defined by limited consumption of animal foods. Vegetarian diets are a major category of plant-based diets ranging from partial to complete exclusion of animal products, such as vegan diets [133]. Small RCTs have shown that compared to participants' usual diets, vegetarian diets significantly reduced blood pressure, total and LDL cholesterol levels, body weight, HbA1c, and other cardiometabolic risk factors [134]. Large cohort studies have shown that vegetarians tended to have lower risk of obesity, type 2 diabetes, and CHD than nonvegetarians [134]. In the Seventh-day Adventist Health Study, participants who followed vegetarian or vegan diets had reduced mortality and longer life expectancies compared to the general population [135]. In addition, participants following vegetarian diets had lower rates of certain cancers—particularly colon, breast, and prostate cancers [134]. Moreover, vegetarian diets were associated with better cognitive function and a lower risk of cognitive decline among Adventists [136]. Although the Seventh-day Adventist Health Study has provided valuable insights into the health benefits of vegetarian diets, caution is warranted when applying these findings to the broader population because the participants' other lifestyle practices and religious benefits might have contributed to some of the observed health outcomes. In addition, it is important to pay attention to nutritional adequacy (vitamins B12 and D, iron, calcium, zinc, and long-chain omega-3 fatty acids) of vegetarian diets, particularly vegan diets that entirely exclude animal foods.

Traditionally, plant-based diets are quantified by the reduced amount and frequency of animal-based food consumption, often overlooking the quality of the plant-based foods consumed. However, there is large heterogeneity among plant foods in terms of their nutritional value and health effects. Therefore, we examined two distinct variations of plant-based dietary patterns [133]: A healthful plant-based index (hPDI) that favors high-quality nutrient-dense plant-based foods (whole grains, fruits, vegetables, nuts, and legumes) and minimizes less healthy plant foods (refined grains, potatoes, SSBs) and animal products; and an unhealthful plant-based index (uPDI) that is comprised mostly of less healthy plant foods (sugar and refined carbohydrates) and with less intake of healthy plant foods. In the NHS and HPFS, there were divergent associations for healthy versus unhealthy plant-based diet indices and risk of type 2 diabetes [137], CHD [138], and stroke [139]. For instance, an overall plant-based diet index was modestly inversely associated with incident CHD (HR comparing extreme deciles: 0.92; 95% CI: 0.83–1.01; p-trend = 0.003). This inverse association was substantially stronger

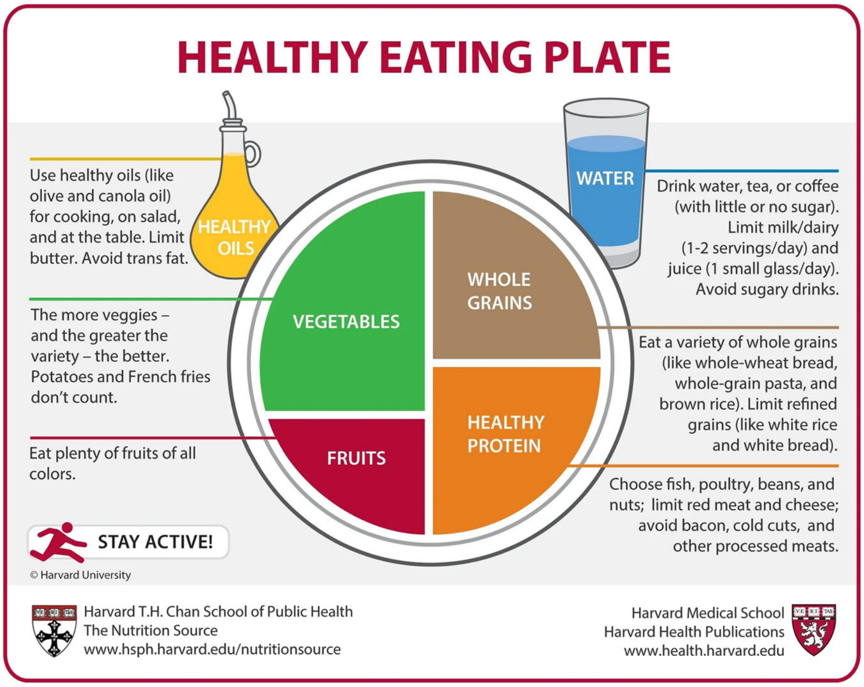

Fig. 3 *Healthy eating plate: The Nutrition Source. Copyright 2011 Harvard University. For more information about The Healthy Eating Plate, see The Nutrition Source, Department of Nutrition, Harvard T.H. Chan School of Public Health, http://www.thenutritionsource.org and Harvard Health Publications, health.harvard.edu.*

for hPDI (HR comparing extreme deciles: 0.75; 95% CI: 0.68–0.83; *p*-trend $<$ 0.001). However, the association was positive for uPDI (HR comparing extreme deciles: 1.32; 95% CI: 1.20–1.46; *p*-trend $<$ 0.001). Adherence to a healthful plant-based diet was associated with improvements in both physical and mental dimensions of health-related quality of life [140]. In the VA Million Veteran Program [141], hPDI was inversely associated with total mortality (HR comparing extreme deciles = 0.64, 95% CI: 0.61–0.68), whereas uPDI was positively associated with total mortality (HR comparing extreme deciles = 1.41, 95% CI: 1.33–1.49). The associations between the plant-based diet indices and total mortality were consistent among African and European American participants.

Besides the healthful plant-based diets defined by hPDI, there are a variety of healthy plant-based dietary patterns defined by other dietary indices, such as the Healthy Eating Index 2015 (HEI-2015) based on Dietary Guidelines for Americans [142], Alternate Healthy Eating Index (AHEI) based on Harvard's Healthy Eating Plate [143] (Fig. 3), the DASH score [144, 145], the Portfolio diet score [146, 147], empirical dietary inflammatory pattern score [148, 149], and the planetary health diet index [150] (see Table 1).

We recently conducted a comparative analysis of four healthy dietary patterns (HEI-2015, AHEI, hPDI, and aMED) in relation to mortality risk in the NHS and HPFS [151]. When comparing the highest with the lowest quintiles, the pooled multivariable-adjusted HRs of total mortality were 0.81 (95%CI, 0.79–0.84) for HEI-2015, 0.82 (95%CI, 0.79–0.84) for aMED score, 0.86 [95%CI, 0.83–0.89] for hPDI, and 0.80 [95%CI, 0.77–0.82] for AHEI [$p < .001$ for trend for all]. All dietary scores were significantly inversely associated with death from CVD, cancer, and respiratory disease. The aMED score and AHEI were inversely associated with mortality from neurodegenerative disease. The inverse associations between these scores and risk of mortality were consistent in different racial and ethnic groups, including Hispanic, non-Hispanic Black, and non-Hispanic White individuals. These findings support that multiple healthy eating patterns can be adapted to individual food preferences and cultural traditions.

Table 1. *Healthy plant-based dietary patterns associated with healthy aging and longevity.*

Mediterranean dietary pattern: Based on observational cohort studies and clinical trials demonstrating health benefits	• Principal source of culinary fat is olive oil • Abundant plant-based foods (such as fresh fruit, vegetables, nuts, legumes, and whole grains) • Moderate fish, poultry, and dairy products (mostly yogurt and cheese) • Low red/processed meats and sweets • Wine with meals in moderation
Nordic dietary pattern: Based on observational cohort studies and small clinical trials demonstrating health benefits on cardiometabolic risk	• Locally sourced and seasonal foods • Rapeseed oil is widely used as a main source of culinary fat • Abundant fruits (especially berries), vegetables (cabbage, leafy vegetables, and root vegetables) • Rye, barley, and oats as main types of whole grains • High consumption of fish like salmon, herring, and mackerel • Moderate consumption of dairy products • Low red/processed meats, sweets, and highly processed foods
Traditional Asian diets: Based on small intervention studies on cardiovascular risk factors and ecological and cross-cultural analyses on various Asian dietary patterns and chronic diseases and mortality	• Vary significantly based on the region, culture, and local ingredients • Low-fat high-carbohydrate diets with rice and noodles as staple foods • High intake of a variety of vegetables • Beans, lentils, and soy foods as main sources of protein • High intakes of nuts/peanuts and seeds • Generous use of phytochemical-rich herbs and spices • Healthy beverages such as green/red tea • Fermented vegetables rich in probiotics (e.g., miso, tempeh, and kimchi) • Low intake of red meat and high-fat dairy products
Traditional Okinawa diet: Based on cross-cultural and epidemiological analyses of diet and longevity in Okinawa	• Largely a calorie-restricted diet (i.e., stopping eating when one is 80% full, known as Hara Hachi Bu) • Abundant green/orange/yellow vegetables (bitter melon is commonly consumed) • Purple sweet potatoes as staple carbohydrates • High amounts of soy foods, seafood, Jasmine tea, spices like turmeric • Low consumption of red meat, eggs, and dairy • Limited consumption of highly processed foods

(*Continued*)

Table 1. *(Continued)*

Healthy vegetarian diet: Adapted from dietary intervention trials on vegetarian diets and cardiometabolic disease risk factors and observational cohort studies	• High consumption of healthy plant foods, such as fruits, vegetables, legumes, nuts, seeds, and whole grains • Higher consumption of soy (tofu and other processed soy products) • No meat, fish/seafood or poultry • Moderate dairy and eggs • Can be adapted to be vegan by replacing dairy products with plant-based dairy substitutes
Healthy plant-based diet index (hPDI): Based on associations between quality or specific types of plant foods and chronic disease outcomes in large cohorts	• Emphasizes high-quality plant foods, including whole grains, fruits, vegetables, nuts, legumes, vegetable oils, tea, and coffee • Limits low-quality plant foods, such as fruit juices, refined grains, potatoes, sugar-sweetened beverages, and sweets/desserts • Contains low amounts of all animal foods
Planetary health diet: Designed by the EAT-Lancet Commission to improve human and planetary health	• Abundant vegetables, fruits, whole grains, legumes, nuts, and unsaturated oils • Moderate seafood, poultry, and dairy • Limits red meat, processed meat, added sugar, refined grains, starchy vegetables, and highly processed foods
Healthy U.S.-style: Based on recommendations from the USDA Dietary Guidelines for Americans	• Abundant fruits (especially whole fruits) and vegetables from all subgroups (dark green, red/orange, legumes, starchy, and other) • Moderate dairy, mostly low-fat, or fat-free • At least half of grains are whole grains • Protein sources include seafood, lean meats, poultry, eggs, soy products, nuts, and seeds • Limits saturated fats, sodium, and added sugar
Alternate healthy eating index (AHEI): Based on Harvard's Healthy Eating Plate	• Higher intakes of fruits, vegetables, whole grains, nuts, and legumes • Frequent consumption of fish and seafood • Use olive oil or other vegetable oils high in unsaturated fats • Drink unsweetened coffee and tea or plain water instead of sugar-sweetened beverages or fruit juices • Limit consumption of red and processed meats • Limit sodium • Moderate consumption of alcohol

(*Continued*)

Table 1. *(Continued)*

Dietary Approaches to Stop Hypertension (DASH): Based on clinical trials showing DASH diets reduced blood pressure and cohort studies showing that the DASH score was associated with lower risk of CVD and mortality	• Abundant fruits, vegetables • Increase whole grains, nuts, and seeds • Increase fat-free/low-fat dairy and reduce full-fat dairy products • Poultry and fish in place of red and processed meats • Limit sodium • Reduce sugar-sweetened foods and beverages
Anti-inflammatory diet: Based on small clinical trials and epidemiologic studies showing benefits of such a dietary pattern reduces inflammatory cytokines and chronic disease risk	• Abundant green leafy and dark yellow vegetables, whole fruits • High in whole grains, nuts/seeds, and legumes • Healthy beverages especially coffee and green tea • Fatty fish • Extra-virgin olive oil • Moderate consumption of wine • Low in red meat, processed meat, sugary beverages, refined carbohydrates, fried food
Portfolio diet: Based on clinical trials showing that the Portfolio diet reduces total and LDL cholesterol and epidemiological studies showing Portfolio diet index was associated lower risk of diabetes and heart disease	• Increased consumption of soy protein and tree nuts • Increased consumption of soluble viscous fiber from oatmeal, barley, beans, lentils, and chickpeas • Increased consumption of plant sterols from vegetable oils, some vegetables, and certain margarines • High consumption of fruits and vegetables • Reduced consumption of foods high in saturated fat and cholesterol like red and processed meats, eggs, and high-fat-dairy products

Abbreviation: CVD, cardiovascular disease.

The combined effects of diet and lifestyle on healthy longevity

Healthy longevity is influenced not only by diet but also various lifestyle factors, including smoking, physical activity, alcohol consumption, and body weight. Given the interconnected nature of these factors, it is useful to examine the combined effects of diet and lifestyle factors on longevity. Using data from NHS and HPFS [152], we defined five low-risk lifestyle factors as fulfilling either: never smoking, maintaining normal weight (BMI 18.5–24.9 kg/m^2), 30+ minutes/day moderate to vigorous physical activity, moderate alcohol intake (no more than one drink per day for women and no more than two for men), and a high-quality diet as indicated by the AHEI in the upper 40%. The multivariable-adjusted HRs for mortality in adults with five low-risk factors compared with those with none were 0.26 (95% CI: 0.22–0.31) for all-cause mortality, 0.35 (95% CI: 0.27–0.45) for cancer mortality, and 0.18 (95% CI: 0.12–0.26) for CVD mortality. We estimated that the life expectancy at age 50 was 29.0 years (95% CI: 28.3–29.8) for females and 25.5 years (95% CI: 24.7–26.2) for males who adopted zero low-risk lifestyle factors and 43.1 years (95% CI: 41.3–44.9) for females and 37.6 years (95% CI: 35.8–39.4) for males who adopted five low-risk lifestyle factors (Fig. 4). Consequently, adhering to all five low-risk factors could potentially prolong life expectancy at age 50 by

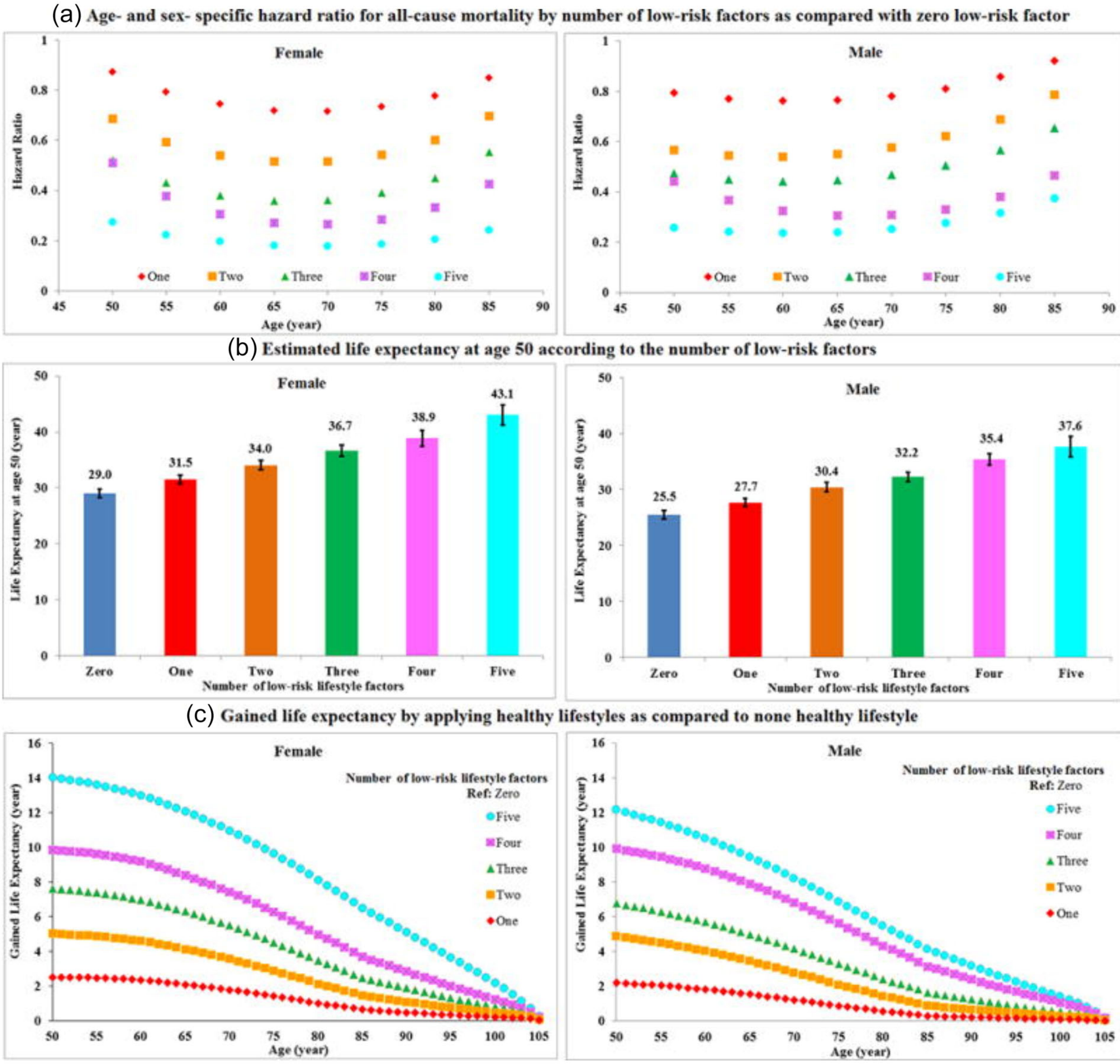

Fig. 4 *Life expectancy estimated based on overall mortality rate of Americans (CDC report), the prevalence of lifestyle factors using National Health and Nutrition Examination Survey (NHANES) data 2013–2014 and age- and sex-specific hazard ratios (a: hazard ratio; b: life expectancy at age 50; c: life expectancy by age). Low-risk lifestyle factors included cigarette smoking (never smoking), physically active (≥3.5 h/week moderate to vigorous intensity activity), high diet quality (upper 40% of alternative healthy eating index (AHEI), moderate alcohol intake of 5–15 g/day (female) or 5–30 g/day (male), and normal weight (body mass index < 25 kg/m^2). The estimates of cumulative survival from 50 years of age onward among the five lifestyle risk factor groups were calculated by applying: (1) all-cause and cause-specific mortality rates were obtained from the US CDC WONDER database; (2) distribution of different numbers of low-risk lifestyles was based on the US National Health and Nutrition Examination Survey (NHANES) 2013–2014; (3) multivariate-adjusted hazard ratios (sex- and age-specific) for all-cause mortality associated with the five low-risk lifestyles as compared to those without any low-risk lifestyle factors, adjusted for ethnicity, current multivitamin use, current aspirin use, family history of diabetes mellitus, myocardial infarction, or cancer, and menopausal status and hormone use (females only), were based on data from the Nurses' Health Study (NHS) and Health Professionals' Follow-up Study (HPFS). Source: The figure originally published in Ref. [152]. Reproduced with permission.*

14.0 years for females and 12.2 years for males, in comparison to those adopting none.

In further analyses, adherence to the low-risk lifestyle was associated with a longer life expectancy at age 50 free of major chronic diseases (cancer, CVD, and diabetes) of approximately 7.6 years in men and 10 years in women compared with participants with no low-risk lifestyle factors [153]. These findings suggest that most of the extended life expectancies resulting from a healthy diet and lifestyle are free from major chronic diseases. In other words, following a healthy diet and lifestyle not only enhances overall life span but also extends health span, contributing to a longer period of disease-free life expectancy. Adherence to these lifestyle factors was also strongly associated with lower risk of frailty in older women [154].

Summary and public health implications

This review provides an overview of dietary factors related to longevity and healthy aging, primarily based on findings from large cohort studies. First, maintaining a healthy weight across various life stages is crucial for achieving longevity and healthy aging. This approach—reminiscent of the “80% full” principle found in the traditional Okinawan diet—mimics the positive effects of lifelong, moderate calorie restriction, especially within today’s obesogenic food environment.

Second, the specific food sources or types of dietary fat, protein, and carbohydrates appear to be more important in influencing the risk of chronic diseases and mortality than their quantity. The debate on the superiority of low-fat versus low-carbohydrate diets is not meaningful unless the food sources of fats or carbohydrates are clearly defined. For example, the specific food sources of macronutrients can alter the relationship between carbohydrate intake and mortality risk. A low-carbohydrate diet dominated by animal-derived fat or protein was associated with higher mortality, but a low-carbohydrate diet rich in plant-based fat and protein was associated with lower mortality.

Third, although there is no one-size-fits-all diet for everyone, some traditional diets such as the MedDiet, Nordic, and Asian and contemporary dietary patterns such as HEI-2015, the AHEI, and the DASH diet share many common components while embracing distinct elements from diverse cultures. These dietary patterns typically emphasize minimally processed plant foods and healthy fats, coupled with reduced consumption of red and processed meats and added sugars. The existence of multiple healthy eating patterns across diverse cultures offers the flexibility of combining beneficial elements of various dietary patterns to create personalized diets that enhance long-term enjoyment and adherence.

Fourth, a healthy diet often includes a variety of plant foods rich in polyphenols and other phytonutrients with antioxidant and anti-inflammatory properties. Higher consumption of polyphenols has been associated with beneficial effects on the gut microbiome [155] and small-molecule metabolites [156], contributing to better physical and mental health. Polyphenol-rich foods drawn from diverse cultures and regions of the world, such as coffee, tea, a variety of fruits and vegetables, cocoa, EVOO, avocados, nuts, and seeds, can be tailored to fit individuals’ own food preferences and cultures.

Fifth, adopting a healthy diet along with other lifestyle factors (not smoking, engaging in regular physical activity, maintaining a healthy weight, and consuming alcohol in moderation [if any]) can potentially add approximately 8 to 10 years of disease-free life expectancy. Beyond physical health and longevity, a healthy diet and lifestyle can help to promote mental well-being and mitigate age-related cognitive decline, reducing the risk of dementia and enhancing the overall quality of life.

Lastly, healthy dietary patterns’ emphasis on plant-based foods and sustainable practices aligns with concerns about the environmental impact of the global food system. They are widely recognized to not only reduce risk of chronic diseases and mortality but also contribute to lower greenhouse gas emissions, resulting in lower environmental impact [157, 158].

These findings hold important clinical and public health implications. Health professionals should encourage and support individuals to maintain a healthy weight and prevent excess weight gain across all life stages. Balancing dietary choices and physical activity levels, coupled with regular weight monitoring, are practical strategies in countering age-related weight gain. For older adults, it is critical to address concerns related to sarcopenia and unintentional weight loss and frailty due to chronic conditions through appropriate dietary strategies including maintaining adequate protein intake and taking vitamin or mineral supplements when necessary. Recent RCTs have suggested that daily multivitamin supplements moderately improved memory and other cognitive functions in older adults [159, 160], though further confirmation of these findings is needed. Moreover, clinicians should promote a holistic approach to healthy aging by emphasizing not only dietary habits but also other lifestyle factors, including regular exercise, avoidance of smoking and excess alcohol drinking, ensuring sufficient sleep, and fostering meaningful social connections.

From the public health point of view, policies and initiatives should aim to create a healthier food environment where nutritious options are not only accessible but also the default [161]. This extends to homes, health care facilities, and nursing care facilities for older adults. Public health measures, such as soda taxes, front-of-package labeling, and restricting unhealthy food marketing, can shift societal norms and guide individuals toward healthier eating behaviors. In addition, public health strategies must address the pervasive consumption of ultra-processed foods of low nutritional value, which have been linked to increased obesity and chronic diseases [162, 163]. Reducing consumption of these foods not only improves physical health but also positively impacts mental well-being. Finally, by focusing on both human health and planetary health, public health strategies should encourage the adoption of healthy plant-based foods while minimizing the environmental footprint of dietary choices [164, 165]. This requires incorporating environmental sustainability into dietary guidelines for healthy aging as well as broader agricultural and food policies.

Future research directions

Given that the majority of studies on diet and healthy aging have been conducted in US and European populations, there is an urgent need to conduct long-term cohort studies in diverse populations with varied cultural traditions and eating patterns. Even though the diets from the Blue Zones are considered models for healthy aging, more rigorous investigations are required to better understand nutritional profiles and the health consequences of these diets. To achieve this goal, it is vital to develop better dietary assessment tools that are suitable for culturally diverse populations. Although traditional self-reported instruments, such as food frequency questionnaires, 24-h recalls, and food records, will likely remain as the mainstay for large-scale population-based studies, it is crucial to develop objective biomarkers to improve the assessment of various dietary patterns and their components. Although high-throughput metabolomics have shown promise in identifying biomarkers of specific food intakes and dietary patterns, it is imperative to validate these biomarkers across diverse populations [166, 167].

Recognizing that various eating patterns have overlapping components but also unique features, it is useful to conduct intervention studies to test the effects of combining multiple beneficial elements of different eating patterns on health outcomes. A recent 18-month RCT conducted in Israel demonstrated that compared to a control diet, a diet rich in polyphenols achieved by integrating the components of MedDiet with walnuts, green tea, and Mankai (a specific duckweed strain) shake led to a significant reduction in visceral adiposity [168] and age-related brain atrophy [169]. This “fusion diet” approach not only amplifies the benefits of dietary strategies to reduce chronic diseases and promote healthy aging but also enhances acceptability by broader populations.

There is an increasing need to identify reliable biomarkers that reflect the effects of diet on healthy aging outcomes. Such biomarkers can provide insights into mechanisms by which diet influences aging and offer potential end points for assessing the efficacy of dietary interventions. Although epigenetic clocks and telomere lengths are emerging as promising biomarkers for aging research, their broad applications in clinical settings require further research and validation [170, 171]. This underscores the need for a deeper understanding of the biological mechanisms underlying diet and healthy aging. Emerging evidence suggests that certain dietary patterns, such as the MedDiet and its components, could influence multiple molecular pathways related to healthy aging [172]. These include reduction of chronic inflammation and oxidative stress, decreased rates of telomere shortening and epigenetic aging, amelioration of mitochondrial dysfunction, maintenance of protein homeostasis, and regulation of nutrient-sensing pathways. Given our limited understanding of these mechanisms, more in-depth mechanistic studies and human trials are needed to better elucidate the molecular pathways, which can help develop biomarkers that better characterize the effects of diet on the aging process.

Acknowledgments

Dr. Hu's research is supported by National Institutes of Health grants (DK129670, HL118264, and DK127601). The author thanks Walter Willett, Meir Stampfer, Brett Otis, and Fenglei Wang for their comments.

Conflict of interest statement

The author declares no conflict of interest.

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