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Nutrition and Longevity in Aging: Dietary Strategies for Healthy Lifespan Extension

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ABSTRACT

Aging involves progressive physiological decline, increasing susceptibility to chronic disease and functional loss. Nutrition is a key modifiable determinant of healthspan, influencing oxidative stress, mitochondrial function, proteostasis, and nutrient-sensing pathways such as Mechanistic Target of Rapamycin (mTOR), Adenosine Monophosphate-Activated Protein Kinase (AMPK), Insulin-Like Growth Factor-1 (IGF-1), and sirtuins. Adequate protein preserves muscle mass, while high-quality fats especially omega-3s support cardiovascular, metabolic, and cognitive health. Low-glycemic, fiber-rich carbohydrates enhance insulin sensitivity and promote a diverse gut microbiome that generates short-chain fatty acids with anti-inflammatory effects. Dietary patterns like the Mediterranean diet, Blue Zone diets, and the Longevity Diet are linked to lower cardiometabolic risk and slower biological aging. Caloric restriction, intermittent fasting, and fasting-mimicking diets activate autophagy and mitochondrial efficiency. Effective implementation requires considering multimorbidity, polypharmacy, psychosocial factors, and food access. Advances in nutrigenomics, microbiome science, and digital health enable personalized nutrition, while sustainable plant-forward diets support both healthspan and environmental goals. Integrating nutrition into clinical care and public health can extend healthy lifespan and improve quality of life in older adults.

Keyswords: Nutrition, Aging, Longevity, Dietary Patterns, Healthspan.

INTRODUCTION

Aging is shaped by genetic, environmental, and lifestyle factors, and is accompanied by a progressive decline in physiological capacity and increased vulnerability to chronic diseases. Among the modifiable determinants of healthy aging, nutrition is one of the most powerful, directly influencing healthspan, defined as the years lived free from chronic disease and functional dependence. Growing scientific evidence demonstrates strong links between dietary habits and biological aging processes, including oxidative stress, mitochondrial dysfunction, chronic low-grade inflammation, and dysregulation of nutrient-sensing pathways such as Mechanistic Target of Rapamycin (mTOR), Adenosine Monophosphate-Activated Protein Kinase (AMPK), Insulin-Like Growth Factor-1 (IGF-1), and sirtuins. Understanding how nutrition interacts with these mechanisms is essential for mitigating age-related deterioration. Both macronutrient quality and micronutrient adequacy play critical roles in aging biology. Diets rich in omega-3 fatty acids help reduce inflammation and support cardiovascular function, while adequate and well-distributed protein intake is necessary to counteract sarcopenia and maintain muscle strength in older adults. Micronutrient deficiencies particularly in vitamins D, B12, folate, and key minerals can further impair immune competence, bone health, and cognitive function. Beyond individual nutrients, dietary patterns exert substantial influence on longevity. The Mediterranean diet, characterized by high intake of plant-based foods and healthy fats, is consistently associated with reduced incidence of age-related diseases and improved functional status. Such patterns also promote a diverse gut microbiome, supporting metabolic flexibility and immune balance.

This review examines how dietary strategies can modulate aging biology and identifies practical nutrition approaches to enhance healthspan in older adults.

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Biological Mechanisms of Aging and the Role of Nutrition

Hallmarks of Aging

The nine hallmarks of aging genomic instability, telomere attrition, epigenetic alterations, loss of proteostasis, deregulated nutrient sensing, mitochondrial dysfunction, cellular senescence, stem-cell exhaustion, and impaired intercellular communication offer a comprehensive framework for understanding biological aging. Nutrition modulates these hallmarks primarily through nutrient-sensing pathways such as mTOR, AMPK, IGF-1, and sirtuins, which translate dietary inputs into cellular aging responses (8). Methionine and Branched-Chain Amino Acids (BCAA) restriction suppress mTORC1 and enhance autophagy, while polyphenols and omega-3 fatty acids lower oxidative stress and inflammaging, supporting genomic stability and healthy signaling (9).

AMPK activation via energy deficit, exercise, or polyphenols improves mitochondrial biogenesis and metabolic flexibility. Sirtuin activity, dependent on Nicotinamide Adenine Dinucleotide (NAD+), is strengthened by fasting and physical activity, linking diet to chromatin remodeling, deoxyribonucleic acid (DNA) repair, and stress resilience. Adequate micronutrients (vitamins D, B12, folate, magnesium, zinc) further support mitochondrial and redox homeostasis, reducing epigenetic drift and neurodegenerative risk (4). Diet also shapes the gut microbiome, where fiber diversity and fermented foods increase Short-Chain Fatty Acids (SCFA) production, modulating immune tone and nutrient sensing. Collectively, optimized macro- and micronutrient intake can rebalance nutrient signaling, preserve genomic and mitochondrial integrity, and slow cellular senescence (10, 11).

Caloric Restriction and Intermittent Fasting

Caloric restriction (CR) a 20–40% reduction in intake without malnutrition is the most robustly validated dietary strategy for extending lifespan and healthspan. In humans, CR improves insulin sensitivity, lowers Low-Density Lipoprotein Cholesterol (LDL-C) and blood pressure, reduces oxidative stress, and modulates IGF-1, mTOR, AMPK, and sirtuin pathways, enhancing autophagy, mitochondrial efficiency, and metabolic flexibility (12).

Intermittent fasting (IF) approaches including alternate-day fasting, 5:2, and time-restricted feeding (TRF) activate similar mechanisms, improving insulin sensitivity, lowering inflammation, and strengthening circadian rhythms (13). In older adults, these interventions must be adapted to preserve lean mass through adequate protein intake (1.0–1.2 g/kg/day), nutrient sufficiency, hydration, and careful medication monitoring (14). Early-day TRF shows particular benefits for glycemic and circadian regulation, while fasting-mimicking diets may replicate CR's effects with greater adherence. Overall, CR, IF, and TRF converge on reduced mTOR/IGF-1 signaling and increased AMPK/sirtuin activity, offering meaningful metabolic, cognitive, and functional benefits in aging populations (15, 16).

Nutritional Principles for Healthy Aging

Energy Requirements, Body Composition and Macro-micro Nutrient

Aging is characterized by declines in basal metabolic rate and physical activity, which reduce total energy requirements; however, excessive caloric restriction can accelerate loss of fat-free mass and worsen sarcopenia, ultimately impairing mobility and physiological resilience (17). Therefore, maintaining energy balance with nutrient-dense, protein-rich foods is essential to support muscle anabolism while limiting visceral adiposity, a key driver of insulin resistance and chronic low-grade inflammation. Effective strategies include evenly distributing energy across meals centered on high-quality protein and fiber, emphasizing low–energy-dense foods such as vegetables, legumes, whole grains, and fruits to meet micronutrient needs, and coordinating nutrient intake with resistance and balance training to optimize lean mass preservation (Table 1) (18).

Regular body-composition assessment using Dual-Energy X-ray Absorptiometry (DXA) or bioimpedance can guide individualized adjustments aimed at maintaining skeletal muscle and bone while reducing central fat. In older adults at risk for undernutrition, oral nutrition supplements or fortified foods may be necessary to prevent protein–energy malnutrition without promoting excess adiposity (19). Overall, balanced energy intake, adequate protein, and structured exercise form the foundation for protecting muscle health and metabolic function during aging.

Table 1. Summary of Macronutrient and Micronutrient Priorities for Healthy Aging

Macronutrient and Micronutrient	Key Focus	Short Summary
Protein Requirements	Higher protein needs in aging	Older adults require **1.0–1.2 g/kg/day** (up to **1.5 g/kg/day** with illness/sarcopenia). Distributing **25–30 g protein/meal** maximizes MPS. High-quality or leucine-rich proteins and supplements may support low appetite or rehab needs(20-22).
Fat Quality	Omega-3 and healthy fats	Fat quality is crucial: **EPA/DHA** reduce inflammation and support cardiometabolic and cognitive health. Replacing saturated fats with **MUFA/PUFA** (olive oil, nuts, seeds) improves lipid profiles. Avoid trans fats and ultra-processed oils (23-26).
Carbohydrates & Fiber	Glycemic control & SCFAs	Choose low-glycemic, minimally processed carbohydrates. **Soluble/fermentable fibers** increase SCFAs, improving gut integrity and inflammation. Target **25–35 g/day** while limiting refined grains and sugars(26-29).
Micronutrients & Phytochemicals	Key vitamins, minerals, polyphenols	Vitamin **D, B12**, magnesium, zinc, and selenium are essential and often insufficient in aging. Polyphenols reduce oxidative stress and support longevity pathways. A food-first approach with variety and fortification ensures adequacy (30-31).

Abbreviations; DHA: Docosahexaenoic Acid, EPA: Eicosapentaenoic Acid, MUFA: Monounsaturated Fatty Acid, MPS: Muscle Protein Synthesis, PUFA: Polyunsaturated Fatty Acid, SCFAs: Short-Chain Fatty Acids.

Dietary Models Promoting Longevity

The Mediterranean Diet

The Mediterranean diet (MedDiet) centers on fruits, vegetables, legumes, whole grains, extra-virgin olive oil, nuts, seeds, moderate fish and fermented dairy, and minimal red meat and added sugars. High adherence is consistently linked to lower all-cause and cardiovascular mortality, reduced risks of type 2 diabetes and neurodegenerative diseases, and lower frailty incidence in older adults (32). Mechanistically, polyphenols and monounsaturated fats reduce oxidative stress and modulate Nuclear Factor kappa B/Nuclear Factor Erythroid 2–Related Factor 2 (NF-κB/Nrf2) pathways, while omega-3–rich fish improves lipid metabolism and endothelial function. Diverse plant fibers enhance gut microbiome richness and short-chain fatty acid production, reducing systemic inflammation (33). Cohort data associate MedDiet adherence with longer telomeres and favorable epigenetic aging profiles. The Prevención con Dieta Mediterránea (PREDIMED) trial's 30% reduction in major cardiovascular events emphasizes the added benefit of high-quality fats such as olive oil and nuts (34). For older adults, tailoring energy and protein intake, supporting practical meal preparation, and managing medication–nutrient interactions optimize adherence and safety (35).

Blue Zone Dietary Patterns

Blue Zone regions (Okinawa, Sardinia, Nicoya, Ikaria, Loma Linda) exhibit exceptional longevity supported by plant-forward diets rich in legumes, whole grains, vegetables, fruits, and nuts, with minimal ultra-processed foods (36, 37). These patterns provide low-to-moderate animal protein, high fiber and resistant starch, and cardioprotective unsaturated fats, improving microbiome diversity, glycemic control, and insulin sensitivity (38). Lifestyle factors natural movement, strong social networks, low stress, adequate sleep further reinforce benefits (39, 40).

The Longevity Diet (Longo Model)

The Longevity Diet combines plant-based eating with periodic fasting-mimicking diet (FMD) cycles, downregulating mTOR/IGF-1 and activating AMPK and sirtuins to enhance autophagy and mitochondrial efficiency (7, 41). Adequate intake of vitamin D, B12, folate, magnesium, and zinc, along with structured refeeding, helps preserve lean mass. In older adults, sufficient protein on non-FMD days, pairing meals with resistance exercise, and careful medication monitoring are essential (42, 43).

Malnutrition and Sarcopenia

Malnutrition is often underrecognized in older adults despite its association with frailty, functional decline, and higher healthcare use (44, 45). Screening tools such as Mini Nutritional Assessment (MNA) and Sarcopenia Screening Questionnaire (SARC-F) should be followed by evaluation of diet, weight trends, body composition, inflammation, oral health, and dysphagia (45–47). Management emphasizes adequate energy and protein, leucine or essential amino acids, vitamin D optimization, and structured resistance and balance training, with supplements useful for low appetite (47, 48).

Multimorbidity and Dietary Adaptation

Nutrition care must be individualized to multimorbidity, polypharmacy, and functional capacity. In diabetes, low-glycemic carbohydrates and unsaturated fats improve control while avoiding excess lean mass loss, with medication adjustments needed for fasting routines. In Chronic Kidney Disease (CKD), protein needs vary by stage moderate in non-dialysis CKD and higher in dialysis (49). Conditions such as heart failure, osteoporosis, and cognitive decline require tailored sodium/fluid, calcium–vitamin D, protein intake, and easy-to-prepare meals. Drug–nutrient interactions, oral health issues, and taste changes necessitate ongoing reassessment (50, 51).

Psychosocial and Accessibility Factors

Diet quality in later life is shaped by economic constraints, food access, mobility, cooking skills, and social engagement. Social isolation and bereavement often reduce appetite and worsen dietary patterns (52, 53). Effective strategies include culturally tailored meals, congregate dining, mobile markets, produce prescription programs, and home-delivered meals (54–56). Skills training in simple, budget-friendly cooking and safe storage improves confidence and adherence (57). Assistive devices and texture-modified diets aid those with swallowing or functional impairments. Public health approaches that connect screening with community resources, transportation, and digital tools for food access can reduce inequities, while policies supporting nutrient-dense foods enhance dietary resilience population-wide.

Future Research Directions

Nutrigenomics and Nutriepigenetics

Future studies should clarify how diet interacts with longevity genes Forkhead box-O transcription factors3 (FOXO3), Sirtuin-1 (SIRT1), IGF-1 and shapes epigenomic remodeling across aging tissues. Multi-omics approaches can identify responders to dietary interventions and define nutrient thresholds influencing DNA repair, autophagy, and stress resilience.

Microbiome Research

Research is needed to determine how fibers, resistant starch, fermented foods, and targeted probiotics/postbiotics modify microbiome composition and metabolites affecting inflammation, metabolism, and cognition. Stratified trials should map dose–response effects and connect microbial pathways to nutrient sensing and gut barrier integrity.

Precision Nutrition and Digital Health

Wearables, continuous glucose monitoring (CGM) and artificial intelligence (AI) tools can deliver real-time personalized dietary guidance based on circadian rhythms, activity, and medications. Studies should test their impact on adherence and outcomes in older adults and develop secure datasets for scalable predictive models.

Sustainability and Implementation Science

Plant-forward diets that support healthy aging must also minimize environmental impact. Research should compare sustainable dietary models and evaluate policies such as subsidies and procurement standards, ensuring equitable access for underserved older adults.

CONCLUSION

Nutrition is a key driver of healthy longevity, influencing inflammation, oxidative stress, mitochondrial function, and nutrient-sensing pathways such as mTOR, AMPK, IGF-1, and sirtuins. Dietary patterns emphasizing moderate caloric intake, adequate and well-distributed protein, high-quality unsaturated fats, and fiber-rich, low-glycemic carbohydrates exemplified by the Mediterranean diet, Blue Zone traditions, and the Longevity Diet are consistently linked to lower cardiometabolic risk, improved function, and slower biological aging. These benefits partly arise from supporting a diverse gut microbiome and greater short-chain fatty acid production.

Effective translation into real-world practice requires attention to nutrient density, functional maintenance, and cultural feasibility in older adults. Personalized plans should reflect medical conditions, medications, cognitive and functional status, and socioeconomic context, alongside regular screening for malnutrition and sarcopenia. Practical implementation pairs dietary guidance with resistance training, optimal protein timing, and strategies that enhance access and social connectedness, including community meal programs, produce prescriptions, and home-delivered services. Policies that reduce the cost of nutrient-dense foods and integrate nutrition into primary care can extend benefits at scale.

Advances in precision nutrition, supported by multi-omics, digital tools, and AI, will further tailor dietary recommendations and improve adherence. Robust trials and implementation research in diverse aging populations are needed to close evidence–practice gaps. Integrating nutrition into geriatric care and public health systems offers a powerful means to extend healthspan, reduce morbidity, and improve quality of life as populations age.

DESCRIPTIONS

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