

# Successful aging through integrative nutrition: a four-pillar framework for deprescribing and resilience

Mikhail Kogan<sup>a,\*</sup>, Mehrshad Fahim Devin<sup>b,c</sup>, Frame A. Leigh<sup>c,d,e</sup>, Lindsey Gordon<sup>b,c</sup>, Zeynep Celikkol<sup>b,c</sup>, Ruhsen Ozcaglayan<sup>a</sup>

<sup>a</sup> Geriatrics and Palliative Medicine, The George Washington University School of Medicine and Health Sciences, Washington, DC, USA.

<sup>b</sup> Medical Doctor Program, The George Washington University School of Medicine and Health Sciences, Washington, DC, USA.

<sup>c</sup> The Frame-Corr Laboratory, Department of Clinical Research and Leadership, The George Washington University School of Medicine and Health Sciences, Washington, DC, USA.

<sup>d</sup> The Resiliency & Well-being Center, George Washington University, Washington, DC, USA.

<sup>e</sup> Department of Physician Assistant Studies, The George Washington University School of Medicine and Health Sciences, Washington, DC, USA.

## Abstract

Polypharmacy, micronutrient deficiencies, and gut dysbiosis frequently intersect in older adults to drive frailty, falls, cognitive decline, and loss of independence in late life. Using a representative case of an 81-year-old woman with recurrent falls and chronic polypharmacy, this commentary synthesizes some current evidence on integrative geriatric nutrition. We propose a four-pillar, nutrition-centered framework for guiding deprescribing and restoring resilience: food-based therapeutics for mild, self-limiting conditions that can safely substitute or reduce medications; nutrient density and targeted micronutrients including choline, creatine, C15:0, and vitamin D; the food matrix and anti-inflammatory dietary patterns to optimize nutrient bioavailability, metabolic signaling, and mitigation of cellular senescence; and gut microbiome-centered strategies that leverage fiber diversity, fermented foods, and synbiotics to support muscle, mood, cognition, and immune function. This framework incorporates evidence ranging from well-established interventions to emerging areas such as C15:0; therefore, findings should be applied with consideration of differing evidence maturity. Applied to the index case, this framework informs structured deprescribing, micronutrient repletion, diet-pattern shifts, and microbiome rehabilitation as low-risk pathways to reverse functional decline. Integrative geriatric nutrition, operationalized through these four pillars, offers clinicians a practical, scalable model to reduce medication burden while enhancing function, resilience, and quality of life in aging populations.

**Keywords:** Integrative geriatric nutrition, polypharmacy, deprescribing, gut microbiome, successful aging, frailty

## Introduction

In today's healthcare landscape, older adults frequently navigate a complex web of multiple medications, a.k.a.

polypharmacy. This overreliance on pharmaceuticals amplifies risks such as adverse drug interactions, reduced mobility, cognitive decline, and rising healthcare costs [1]. By contrast, nutrition offers a more foundational, integrative strategy—one that enhances resilience while curbing unnecessary medication use.

Dr. Kogan, along with his co-authors Julie Wendt and Colleen Considine, explore this paradigm in *Integrative Geriatric Nutrition: A Practitioner's Guide to Dietary Approaches for Older Adults* [2]. Building on this work and incorporating emerging evidence, the present commentary proposes a nutrition-centered framework for deprescribing in older adults. Specifically, we organize integrative geriatric nutrition around four interconnected pillars that

\* Corresponding author: Mikhail Kogan

Mailing address: Geriatrics and Palliative Medicine, The George Washington University School of Medicine and Health Sciences, Washington, DC, USA.

Email: mkogan@gwumc.com

Received: 21 January 2026 / Accepted: 02 February 2026

Published: 31 March 2026

provide clinicians with a practical approach to reducing medication burden, restoring function, resilience, and quality of life.

### Case study

An 81-year-old woman presents to a comprehensive integrative medicine clinic with progressively worsening symptoms: fatigue, generalized muscle weakness, and increasing forgetfulness. Though she has maintained relatively good health until recently, the onset of a series of falls has instilled a growing fear of walking. This functional decline is compounded by profound grief as her husband of over 50 years passed away approximately one year ago.

Her current medication regimen includes omeprazole for chronic gastroesophageal reflux disease, hydrochlorothiazide for hypertension, atorvastatin for hypercholesterolemia, nightly low-dose lorazepam for sleep and anxiety, and sertraline to address ongoing low mood. Laboratory investigations reveal hyponatremia, hypomagnesemia, and deficiencies in 25-hydroxyvitamin D and vitamin B12, along with elevated homocysteine levels. Other parameters are within normal limits.

This case exemplifies a common and complex clinical scenario in older adults—polypharmacy, compounded nutritional deficiencies, sarcopenia, increased fall risk, mood disturbance, and functional decline—intersecting to foster a trajectory toward frailty, deconditioning, and possibly irreversible morbidity and mortality [1, 3].

### The four-pillar framework

#### Food-based therapeutics for mild, self-limiting conditions

This first pillar focuses on accessible, food-based interventions that older adults can use to manage everyday symptoms without escalating medication reliance. When faced with mild, self-resolving symptoms—such as a common cold or mild reflux—older adults can often rely on the healing power of foods instead of immediately turning to medications. For instance, in gastroesophageal reflux disease (GERD), the current mainstay treatments are PPIs and histamine-2 receptor antagonists.

Chronic omeprazole use in older adults carries risks such as hypomagnesemia and increased fracture risk [4]. When there is no ongoing indication for proton pump inhibitor (PPI) therapy, a structured deprescribing approach is recommended [5]. Complementary integrative measures—such as elevating the head of the bed by 6–8 inches, avoiding reflux-triggering foods (spicy, acidic, or fatty meals), limiting caffeine and late-night eating, and incorporating stress-reduction techniques like gentle yoga or breathing exercises—can further support symptom control [2, 5]. Herbal and supplement options, including aloe vera juice (1/4 cup diluted, 1–3 times daily), deglycyrrhizinated licorice (DGL) chewables before meals, and ginger

tea, may soothe the gastric lining and ease reflux discomfort [2]. Monitoring should include vigilance for acid rebound—where short-term antacid use can be helpful—as well as periodic checks of serum magnesium and B12 if deficiency is suspected, with GI symptoms reassessed after 4–6 weeks [5].

#### Nutrient density & targeted micronutrients

Beyond symptom-focused applications, integrative geriatric nutrition also emphasizes targeted micronutrients that address underlying physiological vulnerabilities in aging.

##### Choline

Choline is a widely under-consumed essential nutrient that plays a vital role in human health. Its biological functions are vast. It serves as a precursor to acetylcholine, a fundamental neurotransmitter for cognition, muscle activation, and autonomic nervous system regulation [6]. Despite its physiological importance, the mean choline intake for both men and women remains significantly below the Adequate Intake set by the Institute of Medicine [6]. The Adequate Intake for adult men is 550 mg/day and 425 mg/day for adult women [6]. Choline deficiency is also associated with several liver pathologies, such as non-alcoholic fatty liver disease (NAFLD), cirrhosis, and liver carcinoma, reflecting choline's essential role in maintaining liver health [6].

A study investigating the cognitive effects of choline found that a 12-week supplementation of 500 mg per day of citicoline (CDP-choline) improved episodic memory and composite memory scores in participants aged 50–85 compared to placebo [7].

##### Creatine

Creatine is an emerging supplement with antioxidant properties that is being used to help prevent sarcopenia in older adults. A randomized control trial combining creatine with resistance training in older adults showed a significant increase in glutathione peroxidase compared to older adults who only did resistance training and compared to older adults in the control group [8]. Glutathione peroxidase is an enzyme involved in the antioxidation of reactive oxygen species (ROS). Increased levels of this enzyme with creatine supplementation provide hopeful mechanisms to not only combat age-related sarcopenia from increased ROS but also to prevent other diseases linked to oxidative stress, including cancer and cardiovascular disease [8].

##### C15:0

C15:0 is an odd-chain saturated fatty acid that is emerging as a key nutrient involved in human longevity, cardiometabolic, immune, and liver health. C15:0 directly targets multiple hallmarks of aging (mitochondrial dysfunction, cellular senescence, impaired cellular signaling, inflammation), playing a direct role in cellular pathways with demonstrated anti-inflammatory, antifibrotic, and anticancer activities (activation: AMPK, PPAR- $\alpha/\delta$ ; inhibition: mTOR, JAK-STAT, HDAC-6) [9].

Increasing dietary C15:0 effectively raises RBC mem-

brane concentrations, which independently predict raised, healthier hemoglobin concentrations in long-lived mammals. In a 12-week animal study, daily supplementation significantly raised hemoglobin, hematocrit, and red blood cell counts [10].

#### Vitamin D

Vitamin D plays an essential role in musculoskeletal integrity, neuromuscular function, immune regulation, and mood stability—domains that are particularly vulnerable in older adults [11–14]. Despite its importance, vitamin D insufficiency is highly prevalent in aging populations, driven by reduced dermal synthesis, limited outdoor exposure, renal conversion decline, and medication-induced disruptions (including PPIs, glucocorticoids, and certain anticonvulsants).

Active vitamin D (1,25-dihydroxyvitamin D) modulates adaptive and innate immunity by enhancing antimicrobial peptide production to improve mucosal defense against infections, suppressing pro-inflammatory, and promoting T-regulatory cell populations to maintain immune tolerance and reduce auto-inflammatory activity [13].

Vitamin D deficiency contributes to muscle weakness, impaired balance, falls, fractures, and secondary hyperparathyroidism. Observational evidence also links low vitamin D with cognitive decline and depressed mood, underscoring its broader neuromodulatory influence [11, 12, 14]. Importantly, serum concentrations adequate for bone health may not fully support immune function. While  $\geq 30$  ng/mL is typically associated with musculoskeletal benefits, studies suggest that immunomodulatory effects likely require concentrations closer to 40–60 ng/mL [13, 15].

Cholecalciferol (vitamin D<sub>3</sub>) remains the preferred form for repletion, which should be taken daily with a meal containing some form of fat to maximize absorption and in tandem with magnesium repletion [15, 16].

#### The food matrix & dietary patterns

##### Dietary patterns & anti-inflammatory eating

Almost half of all deaths in the United States in 2022 were due to heart disease and cancer (21.4%, 18.5%) [17]. Nutrition is essential to prevent disease-related morbidity and mortality. Inflammatory processes drive chronic disease; thus, dietary interventions should mitigate inflammation. Foods rich in antioxidants and phytonutrients may help reverse the oxidative damage associated with aging. In addition to eating foods high in vitamins and minerals, it is also important to consider how nutrient-dense foods are broken down. Previously, the diet-health relationship was viewed in terms of the number of nutrients in a food, but more recent research shows that a more holistic approach that considers the complexity of the food matrix is a better measure of a healthy diet [18].

A food matrix is made up of the composition of nutrients, bioactive constituents, other compounds, and how they are packaged and compartmentalized. An example of how form and structure play a role in the food matrix: healthy participants were fed test meals with intact, disrupted, or fiber-free apples. Postprandial plasma glucose increased

to similar concentrations in all three treatments, but serum insulin rose the least in the intact apples [18].

##### Nutrient density and senescence

Senescence is characterized by a gradual decline in physiological reserve and increased vulnerability to cellular stressors, a process that can be exacerbated by nutrient insufficiency and metabolic dysregulation. Nutrient density—the concentration of essential vitamins, minerals, amino acids, and bioactive compounds per calorie—is critically important, as energy intake often declines. Diets low in processed foods and rich in nutrient-dense whole foods provide the micronutrients necessary for physiological and cellular maintenance.

For example, organ meats (liver, heart, and kidney) are among the most nutrient-dense foods, delivering bioavailable B vitamins, heme iron, zinc, selenium, vitamin A, choline, and other cofactors that support cellular resilience in aging. By minimizing processing and prioritizing nutrient density, the diet may more effectively counteract cellular senescence. Literature increasingly points to the role of nutritional inputs in modulating pathways of cellular senescence and aging. For instance, a review outlines how micronutrients, antioxidants, and bioactives may influence senescence-associated phenotypes, enhancing mitochondrial health, reducing reactive oxygen species, and modulating inflammatory signaling [19].

##### The gut microbiome as a central integrator

The gut microbiome is a dynamic, metabolically active ecosystem that plays a central role in health across the lifespan. In aging, disruptions to this ecosystem have been associated with sarcopenia, frailty, neurocognitive decline, mood disorders, metabolic dysfunction, and heightened inflammatory burden [20–22]. Polypharmacy further compounds these effects. Medications commonly prescribed to older adults have been shown to reduce microbial diversity and alter the abundance of key functional taxa [23].

Dysbiosis as a driver of inflammaging, frailty, and cognitive decline

The gut microbiome is a primary regulator of the microbiota-gut-brain-immune axis, influencing cognitive resilience, neuroinflammation, and emotional health through production of neuromodulatory short-chain fatty acids (SCFAs) and other metabolites [23]. SCFA depletion has been associated with diminished hippocampal function, worse executive function scores, and increased risk of mild cognitive impairment and Alzheimer's disease [21, 23]. Dysbiosis also promotes increased intestinal permeability, enabling lipopolysaccharide (LPS) translocation into systemic circulation—a recognized mechanism of neuroinflammation and mood disturbance [22].

Nutrition, microbial diversity, and healthy longevity

Diet remains the strongest modifiable determinant of gut microbiome composition [23, 24]. For our 81-year-old patient, low dietary variety, low magnesium status, and chronic PPI use may jointly inhibit microbial resilience and nutrient bioavailability. Foundational food-as-medi-

cine strategies include high-diversity dietary fiber, prebiotic fibers, fermented foods, and Polyphenol-rich foods. These food-based strategies align closely with deprescribing goals by reducing reflux symptoms, improving bowel regularity, and enhancing mood and cognition.

#### Precision supplementation to restore microbial function

Targeted supplementation may be warranted in older adults experiencing dysbiosis or malabsorption, especially when medication regimens can further impair nutrient uptake. Clinical options include:

- Multispecies probiotics: prioritizing strains with geriatric evidence shown to reduce constipation, improve mood, and support immune responses to vaccines [22, 25].
- Postbiotics and microbial metabolites: including SCFA-enhancing substrates, gaining attention for restoring epithelial barrier integrity and reducing inflammaging [25].
- Synbiotics: combinations of prebiotic and probiotic components (and their metabolites) designed to confer microbiome-mediated health benefits, with growing interest in their potential role in supporting resilience in older adults [25].

Emerging microbiome-supportive nutrients discussed elsewhere in this paper (C15:0, creatine, choline) may exert synergistic benefits through mitochondrial health, methylation support, and inflammatory modulation.

#### Clinical integration: a gut-centered approach to deprescribing

An integrative model places gut health at the center of deprescribing strategies. As PPIs are tapered appropriately, nutritional support helps prevent symptom rebound while rebuilding microbial and mucosal resilience. Regular monitoring for constipation, unintentional weight loss, and mood changes ensures early detection of microbiome-linked frailty trajectories. Gut microbiome optimization in older adults is not merely a digestive intervention. It is foundational to preserving muscle, memory, mood, mobility, and meaning—the five essential domains of successful aging.

## Conclusions

In the case of this 81-year-old woman, low 25-hydroxyvitamin D status likely contributes to her muscle weakness, balance impairment, falls, depressed mood, and increased infection vulnerability. Chronic PPI therapy further reduces vitamin D and magnesium absorption, worsening neuromuscular function and bone health. Correcting her deficiency to 30+ ng/mL for musculoskeletal benefits (ideally 40–60 ng/mL to support immune modulation) would be a high-yield intervention that strengthens mobility, restores confidence in ambulation, and may reduce healthcare encounters associated with fall-related injuries and preventable infections. Ensuring adequate magnesium intake and repletion concurrently would support both vitamin D metabolism and improved physical performance, accelerating the reversal of her functional decline. Food-based therapeutics, such as aloe vera, DGL licorice, ginger tea,

and honey-based remedies, offer safe alternatives to medications she is currently over-relying on, particularly PPIs and sedating agents that exacerbate fatigue, micronutrient depletion, and fall risk. Targeted micronutrient repletion (choline for elevated homocysteine and cognitive symptoms, creatine to counter sarcopenia and improve muscle strength, C15:0 for cellular resilience) provides low-risk options for restoring physiological reserve. Transitioning from processed, low-fiber foods toward nutrient-dense, matrix-intact whole foods can improve satiety, stabilize glucose responses, and enhance micronutrient absorption—essential in older adults with reduced appetite and functional limitations. Finally, her chronic PPI use, benzodiazepine exposure, low dietary diversity, and micronutrient deficiencies suggest significant gut dysbiosis, which may perpetuate systemic inflammation, mood disturbances, and frailty. Introducing fermented foods, prebiotic fibers, polyphenol-rich plants, and, when appropriate, geriatric-focused probiotics/synbiotics can help restore microbial diversity and SCFA production. Applying all four pillars described provides a comprehensive, low-risk pathway to reduce polypharmacy, improve functional capacity, and rebuild the resilience necessary for successful aging. Nutrition, when used as medicine, not only adds years to life but life to years.

By integrating food-based therapeutics for mild conditions, targeted micronutrient repletion, dietary patterns that honor the food matrix, and microbiome-centered strategies, providers can shift care from reactive disease management to proactive restoration of resilience. Applied thoughtfully, these tools not only reduce medication burden but also reestablish the physiological, cognitive, and emotional foundations that allow older adults to thrive rather than merely survive.

## Declarations

**Authors' contributions:** Mikhail Kogan led the conceptualization of the manuscript, provided the overarching framework for content inclusion, and critically reviewed and edited all sections. Mehrshad Fahim Devin performed manuscript refinement, developed and articulated the four-pillar framework, and coordinated drafting, revisions, and submission among co-authors. Leigh A. Frame contributed subject-matter expertise and authored major sections on vitamin D and the gut microbiome, in addition to substantially editing and refining the integrative nutrition framework. Lindsey Gordon, Zeynep Celikkol, and Ruhsen Ozcaglayan each contributed to writing specific sections, literature review, and critical revision of the manuscript for important intellectual content. All authors reviewed and approved the final version of the manuscript.

**Financial support and sponsorship:** None.

**Conflicts of interest:** All authors declared that there are no conflicts of interest.

**Ethical approval and consent to participate:** Not applicable.

**Copyright:** Authors retain copyright of their works through a Creative Commons Attribution 4.0 International License that clearly states how readers can copy, distribute, and use their attributed research, free of charge.

## References

- Xue L, Boudreau R, Donohue J, Zgibor J, Marcum Z, Costacou T, et al. Persistent polypharmacy and fall injury risk: the health, aging and body composition study. *BMC Geriatr*, 2021, 21(1): 710-723. [Crossref]
- Wendt J, Considine C, & Kogan M (2021). Integrative geriatric nutrition: a practitioner's guide to dietary approaches for older adults.
- Ofori-Asenso R, Chin K, Mazidi M, Zomer E, Ilomaki J, Zullo A, et al. Global incidence of frailty and prefrailty among community-dwelling older adults: a systematic review and meta-analysis. *JAMA Netw Open*, 2019, 2(8): e198398. [Crossref]
- Condur L, Chirila S, Alexandrescu L, Iancu M, Neculau A, Berariu F, et al. Proton pump inhibitor use in older adult patients with multiple chronic conditions: clinical risks and best practices. *J Clin Med*, 2025, 14(15): 5318-5329. [Crossref]
- Bucan J, Braut T, Krsek A, Sotosek V, & Baticic L. Updates in gastroesophageal reflux disease management: from proton pump inhibitors to dietary and lifestyle modifications. *Gastrointestinal Disorders*, 2025, 7(2): 33-46.
- Zeisel S, & da Costa K. Choline: an essential nutrient for public health. *Nutr Rev*, 2009, 67(11): 615-623. [Crossref]
- Nakazaki E, Mah E, Sanoshy K, Citrolo D, & Watanabe F. Citicoline and memory function in healthy older adults: a randomized, double-blind, placebo-controlled clinical trial. *J Nutr*, 2021, 151(8): 2153-2160. [Crossref]
- Amiri E, & Sheikholeslami-Vatani D. The role of resistance training and creatine supplementation on oxidative stress, antioxidant defense, muscle strength, and quality of life in older adults. *Front Public Health*, 2023, 11: 1062832. [Crossref]
- Venn-Watson S, & Schork N. Pentadecanoic acid (C15:0), an essential fatty acid, shares clinically relevant cell-based activities with leading longevity-enhancing compounds. *Nutrients*, 2023, 15(21): 4607-4620. [Crossref]
- Venn-Watson S, Lumpkin R, & Dennis E. Efficacy of dietary odd-chain saturated fatty acid pentadecanoic acid parallels broad associated health benefits in humans: could it be essential? *Sci Rep*, 2020, 10(1): 8161-8173. [Crossref]
- Bischoff-Ferrari H, Willett W, Wong J, Giovannucci E, Dietrich T, & Dawson-Hughes B. Fracture prevention with vitamin D supplementation: a meta-analysis of randomized controlled trials. *JAMA*, 2005, 293(18): 2257-2264. [Crossref]
- Bigman G. Vitamin D metabolites, D<sub>3</sub> and D<sub>2</sub>, and their independent associations with depression symptoms among adults in the United States. *Nutr Neurosci*, 2022, 25(4): 648-656. [Crossref]
- Ismailova A, & White J. Vitamin D, infections and immunity. *Rev Endocr Metab Disord*, 2022, 23(2): 265-277. [Crossref]
- Fu Q, DeJager J, & Gardner E. Supplementation and mitigating cognitive decline in older adults with or without mild cognitive impairment or dementia: a systematic review. *Nutrients*, 2024, 16(20): 3567-3578. [Crossref]
- Khan Q, & Fabian C. How I treat vitamin D deficiency. *J Oncol Pract*, 2010, 6(2): 97-101. [Crossref]
- Dai Q, Zhu X, Manson J, Song Y, Li X, Franke A, et al. Magnesium status and supplementation influence vitamin D status and metabolism: results from a randomized trial. *Am J Clin Nutr*, 2018, 108(6): 1249-1258. [Crossref]
- Curtin S, Betzaida & Bastian B (2024). Deaths: Leading Causes for 2022. S. National Center for Health. Hyattsville, MD. 73.
- Fardet A. Ultra-processing should be understood as a holistic issue, from food matrix, to dietary patterns, food scoring, and food systems. *J Food Sci*, 2024, 89(7): 4563-4573. [Crossref]
- Diwan B, & Sharma R. Nutritional components as mitigators of cellular senescence in organismal aging: a comprehensive review. *Food Sci Biotechnol*, 2022, 31(9): 1089-1109. [Crossref]
- Mayer M, Woldemariam S, Gisinger C, & Dorner T. Association of gut microbiome with muscle mass, muscle strength, and muscle performance in older adults: a systematic review. *Int J Environ Res Public Health*, 2024, 21(9): 1246-1258. [Crossref]
- Jemimah S, Chabib C, Hadjileontiadis L, & AlShehhi A. Gut microbiome dysbiosis in Alzheimer's disease and mild cognitive impairment: a systematic review and meta-analysis. *PLoS One*, 2023, 18(5): e0285346. [Crossref]
- Alli S, Gorbovskaia I, Liu J, Kolla N, Brown L, & Müller D. The gut microbiome in depression and potential benefit of prebiotics, probiotics and synbiotics: a systematic review. *Int J Mol Sci*, 2022, 23(9): 4494-4502. [Crossref]
- Frame L, Costa E, & Jackson S. Current explorations of nutrition and the gut microbiome: a comprehensive evaluation of the review literature. *Nutr Rev*, 2020, 78(10): 798-812. [Crossref]
- Bolte L, Vich Vila A, Imhann F, Collij V, Gacesa R, Peters V, et al. Long-term dietary patterns are associated with pro-inflammatory and anti-inflammatory features of the gut microbiome. *Gut*, 2021, 70(7): 1287-1298. [Crossref]
- Swanson K, Gibson G, Hutkins R, Reimer R, Reid G, Verbeke K, et al. The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of synbiotics. *Nat Rev Gastroenterol Hepatol*, 2020, 17(11): 687-701. [Crossref]

**Cite this article as:** Kogan M, Devin MF, Frame LA, Gordon L, Celikkol Z, & Ozcaglayan R. Successful aging through integrative nutrition: a four-pillar framework for deprescribing and resilience. *Aging Pathobiol Ther*, 2026, 8(1): 88-92. doi: 10.31491/APT.2026.03.209