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Nutritional Interventions: Dietary Protein Needs and Influences on Skeletal Muscle of Older Adults

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Abstract

Background: This narrative review describes foundational and emerging evidence of how dietary protein intakes may influence muscle-related attributes of older adults.
Methods: PubMed was used to identify pertinent research.
Results: Among medically stable older adults, protein intakes below the recommended dietary allowance (RDA) (0.8 g/kg body weight [BW]/d) exacerbate age-related reductions in muscle size, quality, and function. Dietary patterns with total protein intakes at or moderately above the RDA, including one or preferably more meals containing sufficient dietary protein to maximize protein anabolism, promote muscle size and function. Some observational studies suggest protein intakes from 1.0 to 1.6 g/kg BW/d may promote greater muscle strength and function more so than muscle size. Experimental findings from randomized controlled feeding trials indicate protein intakes greater than the RDA (averaging ~1.3 g/kg BW/d) do not influence indices of lean body mass or muscle and physical functions with non-stressed conditions, but positively influence changes in lean body mass with purposeful catabolic (energy restriction) or anabolic (resistance exercise training) stressors. Among older adults with diagnosed medical conditions or acute illness, specialized protein or amino acid supplements that stimulate muscle protein synthesis and improve protein nutritional status may attenuate the loss of muscle mass and function and improve survival of malnourished patients. Observational studies favor animal versus plant protein sources for sarcopenia-related parameters.
Conclusions: Quantity, quality, and patterning of dietary protein consumed by older adults with varied metabolic states, and hormonal and health status influence the nutritional needs and therapeutic use of protein to support muscle size and function.

Keywords: Animal protein foods, Appendicular lean mass, Dietary protein distribution, Muscle protein synthesis, Physical function

Among adults, advancing age includes changes in skeletal muscle metabolism, physiology, morphology, and physical function. Broadly, the acute and chronic food and nutrient intakes affect these muscle attributes, which for older adults are usually compromised. The purpose of this short narrative review is to describe foundational and emerging evidence of how the quantity, quality (sources), and within-day distribution of dietary protein intakes influence muscle-related attributes.

What Are the Current Reference Designations and Recommendations for Dietary Protein Intake Among Healthy Older Adults?

The Dietary Reference Intakes for protein, set by the Institute of Medicine of the National Academies in the United States, include an estimated average requirement (EAR) of 0.66 g/kg body weight (BW)/d, and a recommended dietary allowance (RDA) of

0.80 g/kg BW/d (1). These quantitative estimates of daily total protein intake apply to apparently healthy adults, independent of sex or age; not adults with diagnosed medical conditions or acute illness. A "Requirement" is described as "the lowest continuing intake level of a nutrient that, for a specific indicator of adequacy, will maintain a defined level of nutriture in an individual" (1). The EAR is the "daily intake value that is estimated to meet the requirement in half of the apparently healthy individuals in a life stage or gender group," and the RDA is "the minimum daily average dietary intake level that meets the nutrient requirements of 97-98% of healthy individuals" (1). The EAR and RDA were estimated using classic nitrogen balance measurements, with subsequent research supporting the EAR is not different for healthy older adults than for younger adults and the RDA is sufficient for healthy older adults (2).

During the 2010s, total protein intake recommendations emerged for older adults to consume 125%–200% of the RDA. Examples include a recommendation for older adults to consume 1.2–1.6 g/kg BW/d, taking intake account potential anabolic resistance, to limit muscle mass loss (3); healthy older adults to consume 1.0–1.2 g/kg BW/d, with 1.2 g/kg BW/d recommended for exercisers (4,5); and 1.2–1.5 g/kg BW/d for older adults to reduce the risk of frailty (6).

Rationales for recommending protein intakes greater than the RDA with advancing age include, but are not limited to, protein anabolic resistance, insulin resistance, greater splanchnic extraction of amino acids, immobility, and chronic disease states (5). Regarding muscle-centric rationales for greater protein needs, it was hypothesized that older males need to consume more total protein at an eating occasion (~0.40 g/kg total protein), compared to young males (~0.24 g/kg total protein), to maximize the rate of myofibrillar synthesis (7). These differential protein intakes did not influence the apparent maximum rate of myofibrillar synthesis estimated for both young and older males.

Importantly, the EAR and RDA are not based on metabolic, physiological, morphological, or physical functional outcomes, for which accepted biomarkers or criteria of adequate or preferred intake are not established. In addition, recommendations for adults to consume higher amounts of total protein (eg, greater than 1.0 g/kg BW/d) based only on skeletal muscle-centric outcomes may be problematic for many older adults. For example, low-protein diets containing 0.6–0.8 g/kg BW/d total protein help retard chronic kidney disease progression (8). Forty-six percent of adults aged 70 years and older live with chronic kidney disease and 9 out of 10 of these individuals may not know it (9). Also importantly, experimental research in very old adults (>85 years) is limited. Unknowns in this age group include dietary protein requirement, postprandial muscle protein synthesis response to protein ingestion, and metabolic and physical function adaptability of skeletal muscle to higher chronic protein intake (10).

How Much Protein Should Healthy Older Adults Consume?

Older adults who chronically consume insufficient total protein experience adverse accommodation responses, including reduced muscle size, strength, and function. For example, weight-stable postmenopausal females who consumed 0.45 versus 0.92 g/kg BW/d total protein (56 vs 115% of the RDA) for 10 weeks (randomized, controlled trial, with all foods provided) experienced negative whole body nitrogen balance, and decreased lean body mass, total body muscle mass, type 1 muscle fiber area, and muscle strength (11,12). The females who consumed 0.92 g/kg BW/d total protein remained in whole body nitrogen equilibrium and did not experience any of these adverse accommodation responses. Results from a 3-year prospective observational study with 2 066 females and males, age range 70–79 years, indicated that "participants in the highest quintile of protein intake [1.1 g/kg BW/d, 18.2% of energy intake] lost 40% less [lean mass] and [appendicular lean mass] than did those in the lowest quintile of protein intake [0.7 g/kg BW/d, 11.2% of energy intake]" (13). The participants in the lowest 2 quintiles consumed less than the RDA for protein, which is considered inadequate protein intake. Thus, these results support consuming less than the RDA is associated with accelerated reductions in total and appendicular lean masses among older adults, compared to consuming at (quintile 3) or greater than (quintiles 4 and 5) the RDA for protein. Also noted, the group of participants with the highest protein intake (quintile 5) consumed 1.1 g/kg BW/d total protein, which is near the lower limit or less than contemporary recommendations ranging from 1.0 to 1.6 g/kg BW/d (3–6) to promote muscle retention and anabolism. Retrospective analyses demonstrated that energy imbalances influenced relationships between total protein intake and changes in appendicular lean mass. Participants who lost weight after 3 years experienced greater appendicular lean mass losses, especially when protein intakes were less than the RDA (quintiles 1 and 2). In contrast, participants who gained weight after 3 years while consuming the most protein (quintile 5) differentially gained more appendicular lean mass. Collectively, these results show that total protein intakes below the RDA adversely affect skeletal muscle size and function and changes in lean body mass among healthy older adults, and intakes above the RDA may positively impact lean body mass and function (11–13).

The adverse effects of advancing adult age on skeletal muscle size and strength typically start in middle age. Among a cohort of 1 209 males and 1 208 females aged 40–59 years, 15.6% of males and 13.4% of females had low appendicular lean mass and 3.5% of males and 2.3% of females exhibited skeletal muscle weakness (14). Regarding dietary protein intake, cross-sectional data showed that protein intakes (g/kg BW/d) were positively associated with appendicular lean mass and maximal handgrip strength (each expressed relative to body mass index), among both males and females (14). Categorically, compared with the moderate protein group (≥0.8 to <1.2 g/kg BW/d daily protein intakes), males and females in the high protein group (≥1.2 g/kg BW/d) had higher maximum handgrip strength, and the low protein group (<0.8 g/kg BW/d) had lower maximum handgrip strength. The low protein group had a lower appendicular lean mass (significant for females; trend for males) and had a higher odds ratio for low lean mass (males) compared with the moderate protein group. Compared to the moderate protein group, males and females in the higher protein group did not have higher appendicular lean mass. These results support the importance of dietary protein intake for skeletal muscle size and strength among middle-aged adults; the relevancy of recommendations to consume at or moderately above the RDA of 0.8 g/kg BW/d total protein; and the potential benefit of protein intakes ≥1.2 g/kg BW/d to promote greater muscle strength. The observed potential benefit of higher total protein intake on muscle strength is consistent with cross-sectional and prospective observational research with older adults (15,16)

Population-based dietary protein intake recommendations, such as the U.S. Dietary Reference Intakes (1), apply to apparently healthy groups of people in non-stressed states and were mostly based on nitrogen balance studies performed in young adult males. There have been considerable limitations of studies in older adults investigating intake greater than the RDA for protein including short trial duration, lack of energy intake controls, variability in participant adherence, and recruitment of participants who do not consume less than the RDA for protein or have physical functional limitations. The OPTIMEN study aimed to address these issues by conducting a 6-month quasi-feeding study with community-living males aged 65 years and older living with moderate physical function limitations and total protein intakes ≤RDA (17). Quasi-feeding is a term used to denote the provision of custom-prepared meals, snacks, and supplements to each participant at their home on a weekly basis (with food exchanges for discretionary foods and meals eaten out) such that energy and protein intakes were reasonably determined and kept constant over a longer time than is feasible in a completely controlled feeding trial. During the 6-month intervention period, participants were provided diets with 0.8 g/kg BW/d of protein plus placebo, 1.3 g/kg BW/d of protein plus placebo, 0.8 g/kg BW/d of protein plus testosterone enanthate (100 mg weekly), or 1.3 g/kg BW/d of protein plus testosterone. Adherence to meals and supplements was consistently over 80% throughout the study and no difference was determined between intervention and control groups. While the effects of higher protein intake on indexes of appetite were not assessed in the OPTIMEN study, mechanistic (18) and experimental (19) research indicates moderately higher protein intake does not suppress appetite among older adults. The primary aims of this trial were to determine whether increasing protein intake in older males whose usual protein intake was ≤RDA would result in gains in whole body and appendicular lean masses, and indices of muscle performance and physical function. The secondary aims were to determine whether gains in lean body mass, muscle performance, and physical function during testosterone administration were augmented when more protein was consumed. The authors abstracted that "The changes from baseline in [lean body mass] (0.31 kg; 95% CI, −0.46 to 1.08 kg; $p = .43$) and appendicular (0.04 kg; 95% CI, −0.48 to 0.55 kg; $p = .89$) and trunk (0.24 kg; 95% CI, −0.17 to 0.66 kg; $p = .24$) lean mass, as well as muscle strength and power, walking speed and stair-climbing power, health-related quality of life, fatigue, and well-being, did not differ between males assigned to 0.8 vs 1.3 g/kg BW/d of protein regardless of whether they received testosterone or placebo" (17). It seems that the RDA for protein is sufficient to maintain lean body mass in these older males, and a protein intake 63% greater than the RDA does not promote lean mass accretion or augment the effects of testosterone. Interestingly, higher protein intake did favorably improve body composition by reducing visceral body fat, but there was no change in metabolic risk factors, suggesting that perhaps an even longer trial is needed to accrue benefit in metabolic outcomes. The trial did not include prescribed physical activity or resistance exercise training in addition to higher protein intake and (or) testosterone therapy. It may be that a combination of all 3 anabolism-promoting interventions is needed to increase muscle mass and function in older males with moderate physical function limitations.

How Much Protein Should Older Adults With a Disease Consume?

The Dietary Reference Intakes for protein do not apply to people with diagnosed medical conditions or acute illness that involve non-purposeful catabolic stress. Patients that are admitted to the hospital usually already have consumed a lower amount of protein in relation to their malnutrition state and benefit substantially from increasing protein and energy intakes. For instance the NOURISH (20,21) and EFFORT (22) trials showed that increasing protein to 1.0–1.5 g/kg BW/d in malnourished older adults admitted to a hospital improved survival of these patients.

There is also a growing interest in determining the effectiveness of specialized nutritional supplements that may help attenuate loss of muscle function and mass (23). Several different interventions including amino acid supplements, whey protein isolate or hydrolysate, creatine in combination with exercise or β-hydroxy β-methylbutyrate supplementation positively affected muscle mass. Also, non-protein/amino acid supplements, such as fish oil, are shown to increase muscle protein synthesis during a hyperaminoacidemic hyperinsulinemic clamp in healthy older adults (24), and to improve anabolism after protein intake and reduce fasting net protein breakdown in chronic obstructive pulmonary disease patients (25).

How Much Protein Should Older Adults Consume When Purposefully Inducing Non-Steady States?

Currently, the dietary reference intakes for protein do not apply to groups of people purposefully inducing either a catabolic stress or an anabolic stress. Moderate dietary energy restriction to reduce BW and alter body composition, and resistance exercise training to induce skeletal muscle anabolism are examples of purposeful catabolic and anabolic stressors, respectively, which are practiced by or recommended for older adults. In both instances, higher protein intakes are recommended to augment desired changes in lean body mass, which includes skeletal muscle. When addressing the question of "does higher protein intake promote the retention of lean mass during dietary energy restriction and promote gains in lean mass during resistance exercise training," an initial question is: higher than what? Self-chosen, habitual protein intakes? The RDA, 0.8 g/kg BW/d of protein? A 2020 systematic review and meta-analysis focused on the RDA, with the investigators asking the question: what effect does consuming >0.8 g/kg BW/d, specifically compared to 0.8 g/kg BW/d, have on changes in lean mass in adults (26). Among 19 randomized controlled trials, representing 22 comparisons, total protein intakes averaged ~0.8 and ~1.3 g/kg BW/d for the RDA and >RDA groups, respectively. The authors abstracted that "among all comparisons, protein intakes greater than the RDA benefitted changes in lean mass relative to consuming the RDA [weighted mean difference (95% CI): 0.32 (0.01, 0.64) kg, $n = 22$ comparisons]. In the subgroup analyses, protein intakes greater than the RDA attenuated lean mass loss after [energy restriction] [0.36 (0.06, 0.67) kg, $n = 14$], increased lean mass after resistance training [0.77 (0.23, 1.31) kg, $n = 3$], but did not differentially affect changes in lean mass [0.08 (−0.59, 0.75) kg, $n = 7$] under non-stressed conditions [no energy restriction or resistance training]. Protein intakes greater than the RDA beneficially influenced changes in lean mass when adults were purposefully stressed by the catabolic stressor of dietary [energy restriction] with and without the anabolic stressor of [resistance training]. The RDA for protein is adequate to support lean mass in adults during non-stressed states" (26).

Does the Source of Dietary Protein Influence Skeletal Muscle-Related Outcomes?

The 2020–2025 Dietary Guidelines for Americans (27) encourages older adults to consume a healthy dietary pattern containing a variety of nutrient-dense foods, including animal- and plant-based protein foods. Animal-based protein foods may include lean or low-fat red meats and poultry, eggs, seafood, and dairy. Plant-based protein foods may include unsalted nuts, seeds, soy products, and fortified soy alternatives to dairy. Based on 2020–2025 Dietary Guidelines for Americans recommendations, about 30% of males and 50% of females aged 71 years and older under-consume protein foods (27). A NHANES survey of 1 768 adults aged 51+ years showed that animal sources provide about 60% of total protein intake among older adults, with percent protein from animal sources predicting total protein intake and the odds of meeting the RDA (28).

Rationales for why animal- versus plant-based protein sources might differentially affect muscle anabolism include varied protein quality (essential and branch chain amino acids and leucine), bioaccessibility, and bioactivity (6,29). Observational studies on the relationship between animal versus plant protein intakes and sarcopenia-related parameters are inconsistent but may favor animal protein. A 2020 review (6) described research showing that higher animal protein intakes were positively associated with muscle mass, muscle mass index, less muscle mass loss, reduced risk of frailty, and reduced loss of handgrip strength. However, higher animal protein intakes were also negatively associated with fast-paced walking speed. Higher plant protein intakes were positively associated with muscle mass, fast-paced walking speed, and with lower "pre-frailty or frailty" incidence with higher vegetable protein intake. However, higher plant protein intakes were associated with lower muscle mass index in older females, and not associated with muscle mass index or changes in muscle mass among groups of females and males combined. Importantly, these results from observational research are not suitable to assess or infer cause and effect relationships between protein sources or individual protein-rich foods on these muscle size, strength, and function-related outcomes. Older adults who consume a variety of high-quality, protein-rich foods as part of a healthy dietary pattern have a lower risk of physical performance decline and possibly developing sarcopenia (30).

Does the Within-Day Pattern of Protein Intake Matter for Older Adults?

Unlike glycogen for glucose and triglycerides for fatty acids, protein and amino acids do not have an inactive reservoir (31). Therefore, the protein and amino acids taken with each meal must be incorporated into functional proteins or be oxidized. Skeletal muscle is the tissue that serves as the major active protein reservoir by incorporating dietary amino acids after the meals and releasing amino acids during fasting and stress. Thus, an adequate anabolic response to each meal is needed for the maximal uptake of dietary amino acids. Due to the anabolic resistance of aging (32), the amount of protein consumed at each individual meal has been proposed to be more important than the total daily protein amount to promote skeletal muscle retention in older adults (33). Broadly, these strategies may focus on pulse protein feeding (34) or amino acid supplementation of meals (35), varied diurnal patterns (eg, even amounts of protein at each meal versus skewed meal distributions, protein supplementation before bed, between meal protein supplementation), or protein intake in conjunction with exercise. While research on the acute effect of these strategies favor the higher protein/amino acid intakes per meal, results from long-term interventions on body composition and functional outcomes are less clear. A 2020 review (36) summarized historical and recent evidence from observational and experimental studies, including acute and chronic feeding trials, on the effects of dietary protein distribution on body composition and muscle-related outcomes. "Because typical protein distribution patterns are skewed towards the dinner meal, encouraging adults, especially older adults with marginal or inadequate protein intakes (<0.8 g/kg BW/d), to better balance their daily protein intake, by consuming more protein at breakfast and lunch meals, may be a practical way to achieve a moderately higher total protein diet and promote skeletal muscle health. However, recommending individuals who consume a low-protein diet to balance protein distribution without increasing their total protein intake to become adequate is ill-advised. Among individuals who consume adequate total protein (0.8 to 1.3 g/kg BW/d), the preponderance of evidence suggests that consuming at least one high-protein meal per day may be sufficient to support skeletal muscle-related outcomes even if the distribution is unbalanced" (36). Among older adults, especially those at risk for or living with sarcopenia and moderate muscle dysfunction, the strategic use of high-quality protein/amino acid supplements, coupled with consuming protein-rich foods and being physically active may promote muscle anabolism and physical function abilities.

Conclusion

Older adults progressively experience adverse changes in skeletal muscle. Among medically stable older adults, research supports protein consumption below the RDA exacerbates age-related reductions in muscle size, quality, and function. Observational and acute feeding studies support recommendations for older adults to consume 1.0–1.6 g/kg BW/d protein, including one and preferably more meals/d with sufficient protein to maximally stimulate muscle protein synthesis and promote greater muscle strength and function. Experimental research conducted with older adults in varied states of metabolic, physiological, hormonal, and physical functional health provides inconsistent evidence on relationships between dietary protein and skeletal muscle. Protein intakes of about 1.3 g/kg BW/d more consistently promote appendicular lean mass retention or anabolism with purposeful catabolic (weight loss) or anabolic (resistance exercise training) stressors. Among older adults with diagnosed medical conditions or acute illness, specialized protein or amino acid supplements that stimulate muscle protein synthesis and improve protein nutritional status may attenuate muscle mass and function losses, along with lengthening survival of malnourished patients. Observational studies on the relationship between animal versus plant protein intakes and sarcopenia-related parameters are inconsistent but may favor animal protein sources. Muscle-centric recommendations for older adults to consume greater amounts of protein should only be made after considering potential non-muscle effects on health. Collectively, relationships between protein intake and muscle strength and function in older persons are complex and modulated by amounts and types of protein, timing of protein intake, hormonal status and metabolic state.

More targeted research is needed considering these variables to determine precise protein needs of older adults. Importantly, there is a paucity of, and need for high-quality longitudinal randomized controlled trials designed (a priori) to assess the effects protein quantity, quality (source), and ingestion timing on indexes of skeletal muscle size and strength, along with physical functional outcomes in adults at high risk for or living with sarcopenia or frailty. Examples of relevant research include (i) the relative effectiveness of varied animal and plant protein-rich foods and products; (ii) considerations of protein amount and source within the context of overall dietary quality (eg, unhealthy vs healthy dietary patterns); (iii) assessing the importance of timing protein intake when total protein intake is "optimal"; (iv) the feasibility and practicality of protein timing for older adults needing assistance care; and (v) the use of dietary protein as a "tool" to augment other therapies (eg, medications, exercise, etc.).

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Conflict of Interest

None declared

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