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Protein ‘requirements’ beyond the RDA: implications for optimizing health

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Abstract

Substantial evidence supports the increased consumption of high quality protein to achieve optimal health outcomes. A growing body of research indicates that protein intakes well above the current Recommended Dietary Allowance (RDA) help to promote healthy aging, appetite regulation, weight management and goals aligned with athletic performance. Higher protein intakes may help prevent age-related sarcopenia, the loss of muscle mass and strength that predisposes older adults to frailty, disability and loss of autonomy. Higher protein diets also improve satiety, and lead to greater reductions in body weight and fat mass compared to standard protein diets, and may therefore serve as a successful strategy to help prevent and/or treat obesity. Athletes can also benefit from higher protein intakes to maximize athletic performance given the critical role protein plays in stimulating muscle protein remodeling after exercise. Protein quality, per meal dose and timing of ingestion are also important considerations. Despite persistent beliefs to the contrary we can find no evidence-based link between higher protein diets and renal disease or adverse bone health. This brief synopsis highlights recent learnings based on presentations at the 2015 Canadian Nutrition Society conference, *Advances in Protein Nutrition across the Lifespan*. Current evidence indicates intakes in the range of at least 1.2 to 1.6 g/kg/day of high quality protein is a more ideal target for achieving optimal health outcomes in adults.

Key Words

Protein

Protein recommendations

Protein quality

Sarcopenia

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Protein nutrition in the aging population

Maintaining an independent lifestyle at an advanced age largely defines quality of life. One major health challenge in the aging population is to slow the decline in muscle mass and strength, i.e. sarcopenia, to prevent functional impairments leading to gradual loss of autonomy. Among many other etiologic factors, low protein intake is thought to contribute to sarcopenia (Cruz-Jentof et al. 2010). In the Health, Aging, and Body Composition study including 2066 men and women of 70-79 years, the loss of total lean and appendicular muscle mass was less in the highest quintile of energy-adjusted protein intake of 1.2 g/kg/d than in the lowest quintile of 0.8 g/kg/d (Houston et al. 2008). Likewise, analysis of a subset of the Women's Health Initiative study (n=24,417 women, 65-79 years) determined a 32% lower risk of developing frailty over 3 years associated with a 20% increase in calibrated protein intake (as % of energy) (Beasley et al. 2010). These data from large cohort studies suggest health benefits from ingesting protein in greater amounts than the current RDA.

Protein requirements for older adults

The current harmonized USA-Canadian Recommended Dietary Allowance (RDA) for protein is 0.8 g/kg/d for all adults including older ones (Institute of Medicine 2005). The RDA represents the estimated average requirement plus 2 standard deviations, determined from selected nitrogen-balance studies of which very few were performed in older individuals (Rand et al. 2003). This approach, which determines the minimal protein intake required to avoid net nitrogen losses, is now considered inappropriate for establishing recommendations (Layman et al. 2015). This particularly applies to elderly persons experiencing muscle loss, reduced energy

intake and physical activity, and co-morbidities, that all affect nitrogen balance and protein anabolism.

Recent studies using the indicator amino acid oxidation technique, an independent tracer-based method that circumvents many nitrogen balance limitations, reported greater than current protein requirements in elderly women aged ≥ 65 years and specifically over 80. They estimated average requirements of 1.0-1.1 g/kg/d, and thus an RDA of 1.2-1.3 g/kg/d (Raffi et al. 2015; Tang et al. 2014). While these costly and labor-intensive studies are small in sample size, and would require confirmation in elderly men, they clearly indicate the need for more precise ways of determining minimal protein requirements. However, the emerging consensus goal is not only definition of minimal needs but also of levels to ensure optimal long-term health, including the prevention of sarcopenia (Bauer et al. 2013; Layman et al. 2015; Paddon-Jones et al. 2015; Volpi et al. 2013).

Surveys and large cohort studies in older adults report wide variations in protein intake with considerable proportions (10-35%) of individuals not even meeting the current RDA of 0.8 g/kg/d (USDA ARS 2014; Dumartheray et al. 2006). The Quebec Longitudinal Study on Nutrition as a Determinant of Successful Aging (NuAge), conducted in 1793 community-dwelling men and women of 68-82 years at baseline, in Quebec, Canada (Gaudreau et al. 2007), estimated an average protein intake ($\pm$ SD) of 1.0 ± 0.3 g/kg/d with a range of 0.4-3.0 g/kg/d. Thus, half of the cohort was consuming less than 1 g/kg/d, and 23% had intakes lower than the current RDA (unpublished data).

Protein distribution

Besides protein quantity, considerable interest currently focuses on patterns of protein intake throughout the day. The suggestion to distribute protein intake equally at each meal to favour protein anabolism stems from two main concepts (Paddon-Jones and Rasmussen 2009). First, because essential amino acids (EAA), leucine in particular, themselves stimulate muscle protein synthesis (Volpi et al. 2003), a threshold of high-quality protein intake must be reached at each meal. Second, excess dietary amino acids beyond the capacity to maximally stimulate protein synthesis are not stored but oxidized, and may therefore be considered “wasted”. These concepts warrant special attention when applied to the elderly population. In elderly versus young men, lower muscle protein synthesis was reported in response to a small dose of EAA (Katsanos et al. 2005), but was normal in response to greater EAA intake corresponding to 25–30 g of protein (Paddon-Jones et al. 2004). Similarly, the protein anabolic response to hyperinsulinemia was blunted in older participants (Chevalier et al. 2006), but normalized by supraphysiological insulin (Fujita et al. 2009) or postprandial hyperaminoacidemia (Chevalier et al. 2011). These findings led to the notion of anabolic resistance of aging, which, due to several possible factors such as insulin resistance, inflammation and inactivity, increases the threshold for postprandial protein anabolism (Borie 2013). This is supported by the recent retrospective calculation of more protein required to stimulate myofibrillar protein synthesis in older than in young men, equating to approximately 31 g of high-quality protein (whey and eggs) (Moore et al. 2015). As well, protein oxidation and synthesis processes are not mutually exclusive. While protein oxidation increases linearly with circulating amino acid increments, higher doses of protein are required to stimulate protein synthesis (Yang Y et al. 2012). Because higher protein intakes may also suppress protein breakdown, net protein anabolism (synthesis minus

breakdown) was shown to be linearly related to protein intake with no apparent plateau (Deutz and Wolfe 2013). Thus, amounts that may be considered excessive are not wasted and may have an important anabolic role, especially in older adults who have a higher threshold.

The usual protein intake distribution of US adults is typically skewed with a low intake at breakfast, not reaching the threshold of 25-30 g, and exceeding it at dinner (Paddon-Jones et al. 2015). The group of Paddon-Jones tested a redistribution of intake providing 30 g at each meal for 7 days in a cross-over design versus 11/16/63 g, in young adults (Mamerow et al. 2014). The even pattern resulted in greater 24-h muscle protein synthesis than with the skewed distribution. In contrast, Kim et al. (2015) found no effect of protein distribution at two levels of protein intakes (RDA vs. 2 x RDA) on whole-body balance and muscle protein synthesis in adults of 52-75 years, whereas intakes at twice the RDA improved these outcomes. Methodological differences and limitations aside, these short-term studies quantify acute effects on protein anabolism that remain to be translated into gains of lean mass or function. One longer-term study of 42 days was performed in malnourished hospitalized elderly persons consuming on average 1.3 g protein/kg/d either as a pulse feeding pattern, with >70% of protein provided at lunch, or spread into four meals (Bouillanne et al. 2013). Significant gains in body cell mass and lean mass, but not handgrip strength, were found only in the pulse-fed group. Because only two of the four meals in the spread pattern provided at least 30 g of protein, it may be that amounts were not sufficient at each eating occasion to reach an anabolic threshold that is, furthermore, likely elevated in these malnourished, inactive older patients. These findings point to probable differences in optimal protein intake in diseased versus healthy older adults and to the pressing need for more studies to elucidate this aspect.

Finally, data from the NuAge cohort indicate that protein intake pattern in older adults is not as skewed as in younger ones (Figure 1) (Farsijani et al. 2015). Breakfast is also the lowest protein-containing meal, whereas lunch and dinner provide more similar average amounts of protein, reaching the threshold of 30 g only by men, at dinner. Though promising and mechanistically sound, the available evidence is insufficient to recommend distributing protein intake evenly across meals in order to limit muscle mass and strength decline with age. Rather, reaching an optimal total protein intake should be the priority, which translates into increasing intakes for a large proportion of the older population. Still, given the limited appetite of most older adults, a pragmatic recommendation to ensure an optimal intake would be to include a high quality protein source at breakfast, the meal generally containing the least. Not only safe and feasible, this recommendation may also provide benefits on satiety and weight control.

Protein and weight management

Although the majority of North Americans are meeting the RDA of 0.8 g protein/kg/d to prevent protein-related deficiencies, emerging evidence illustrates beneficial effects on health-related outcomes when consuming protein at higher quantities (Fulgoni 2008; Leidy et al. 2015).

Specifically, increased dietary protein may serve as one dietary strategy to improve weight management by reducing body weight and fat mass while concomitantly preserving lean mass (Leidy et al. 2015). These improvements appear to occur as a result of key modulations in appetite control and satiety, leading to reductions in daily intake (Leidy et al. 2015). However, several key dietary factors exist which may directly influence these protein-related effects.

Notably, protein quantity, quality and timing of consumption may have effects on the practical outcomes and ingestive behavior mechanisms-of-action that influence weight management.

Protein quantity and weight loss

Over the past 4 years, there have been 6 meta-analyses performed to assess whether high-protein diets differentially impact weight loss and changes in body composition over the short- and longer-term [Wycherley et al. 2013; Dong et al. 2013; Santesso et al. 2012; Bueno et al. 2013; Schwingshackl and Hoffmann 2013; Clifton et al. 2014). In the tightly-controlled shorter-term studies of ≤ 1 year, the high-protein diets, ranging from 16-45% of daily intake as protein (i.e., ~ 1.2 - 1.6 g/kg/d) illustrated greater weight loss, fat mass loss, and/or preservation of lean mass compared to the normal-protein diets containing 5-23% of intake as protein (Wycherley et al. 2013; Dong et al. 2013; Santesso et al. 2012). In fact, two of the meta-analyses included studies that did not include energy restriction interventions and still reported more weight loss with the high-protein versions (Dong et al. 2013; Santesso et al. 2012). Regarding the longer-term studies (≥ 1 year), the high-protein diets within the meta-analyses again led to greater weight loss and fat mass losses compared to the normal-protein versions (Bueno et al. 2013; Clifton et al. 2014). It is important to note, though, that the greater preservation of lean mass detected in the shorter-term studies was not found with the longer-term studies. One potential reason for these conflicting findings might include the lack of dietary compliance to the longer term diets. In general, those that were prescribed a high-protein diet reduced their protein intake throughout the study, while the normal-protein diet groups increased their protein intake (Bueno et al. 2013; Schwingshackl and Hoffmann 2013; Clifton et al. 2014). Thus, it is

possible that the protein-related effects on weight and fat mass losses occur with a smaller increase in protein intake, whereas the preservation of lean mass requires a larger protein quantity.

Protein and appetite regulation

In terms of assessing the effects of increased protein consumption on the ingestive behavior mechanisms, the majority of data originate from tightly-controlled, single-meal, acute studies. The outcomes typically include subjective measures of postprandial appetite and satiety (i.e., hunger, desire to eat, and fullness) as well as the associated peripheral gut hormones that potentially modulate these sensations. The hormones include the hunger-stimulating hormone ghrelin and the satiety hormones PYY and GLP-1. A recent systematic review critically examined 23 studies that compared isocaloric high-protein meals (ranging from 20 – 207 g protein) vs. normal-protein meals (ranging from 3 – 66 g protein). The majority (71%) of the studies included within the review demonstrated improvements in at least one marker of appetite and satiety, typically that of increased postprandial fullness and PYY concentrations, following the consumption of high vs. normal-protein meals (Leidy et al. 2015). In addition, several of the studies that lacked satiety differences between meals included fairly low quantities of protein within the high-protein meals (i.e., <20 g protein), raising the question as to whether a specific protein threshold exists. A recent retrospective analysis of several previous studies in which 350 kcal meals were consumed that contained protein quantities ranging from 15 -30 g protein also supports this concept (Paddon-Jones and Leidy 2014). Within these studies, 2-h postprandial fullness responses were compared between meals. All meals led to an immediate rise in

fullness; however, the 30 g protein meal elicited a larger (and more sustained) increase in postprandial fullness compared to the 15, 20, and 25 g versions. In addition, no differences in postprandial fullness were observed between the other protein quantities. Thus, these data lend support for a specific within-meal, protein-satiety threshold of approximately 30 g protein per eating occasion.

In addition to the appetitive and hormonal responses, several studies have identified the effects of increased protein consumption on the neural signals that modulate central food cravings and reward-driven eating behavior. The consumption of high-protein meals containing at least 30 g of protein led to greater reductions in select cortico-limbic neural responses to food stimuli compared to the consumption of normal-protein meals containing between 15-18 g protein (Leidy et al. 2011a; Leidy et al. 2013). The brain regions identified (i.e., insula, hippocampus, parahippocampus) are those regions associated with food cravings and food reward (Van Vugt 2010).

Collectively, these data support the consumption of higher protein diets (~ 1.2 - 1.6 g/kg/d), including ~ 30 g protein per eating occasion, to improve appetite control, satiety, and weight management.

Timing of protein consumption

Most North Americans are meeting the proposed 30 g per meal protein-satiety threshold at lunch and are generally consuming more protein at dinner (Rains et al. 2013). However, the average consumption of protein at breakfast is well under this quantity (Rains et al. 2013), and as many as 60% of certain age groups skip breakfast altogether (Deshmukh-Taskar et al. 2010;

ADAF 2010; Food Dive 2013). Since the dietary habit of skipping breakfast is strongly associated with weight gain and obesity (Brown et al. 2013), it is critical to explore the combined effects of breakfast and increased dietary protein for improvements in weight management. A study that assessed the satiating effects of protein when provided at different meal occasions further supports the concept of consuming more protein at breakfast (Leidy et al. 2009). The consumption of a high-protein breakfast led to greater fullness which extended throughout the day and into the evening hours compared to a high-protein lunch or dinner. These data suggest that the timing of protein consumption directly influences satiety, with breakfast eliciting unique effects.

Several acute studies have examined the addition of normal-protein vs. high-protein breakfasts on appetite control, satiety, and food cravings/reward in individuals who habitually skip breakfast (Leidy et al. 2013; Leidy and Racki 2010; Leidy et al. 2011b; Hoertel et al. 2014). When compared to skipping breakfast, the consumption of breakfast (in general) led to reductions in appetite, increases in fullness, reductions in food cravings, and reductions in the neural signals controlling reward-driven eating behavior (Leidy et al. 2013; Leidy and Racki 2010; Leidy et al. 2011b; Hoertel et al. 2014). However, the consumption of the high-protein breakfast led to greater modulations in these responses compared to the normal-protein breakfasts. These improvements were accompanied by voluntary reductions in high fat and high sugar evening snacking behavior (Leidy et al. 2013; Hoertel et al. 2014)]. These findings were recently extended to determine whether a 12-wk breakfast intervention, alone, would beneficially alter weight management in those who habitually skip breakfast (Leidy et al. In press). Although no differences in weight loss were observed between groups, the high-protein breakfast prevented

the gain in fat mass (-0.4 ± 0.5 kg) compared to continuing to skip breakfast ($+1.6 \pm 0.9$ kg, $p < 0.03$), whereas the normal-protein breakfast did not prevent fat mass gain ($+0.3 \pm 0.5$ kg). Collectively, these data suggest a unique benefit of including ~ 30 g of protein at the morning meal for longer-term improvements in weight management.

Protein quality and weight management

It is important to note that the meal and/or diet recommendations for increased protein consumption are based upon studies that include high quality, animal-based protein sources. The practical significance for including animal proteins stems from the high protein density accompanied by the lower energy content of these foods in comparison to plant-based proteins (Table 1). Thus, when attempting to adhere to specific energy and macronutrient quantities, lean animal sources allow for the greatest protein content with fewer calories. In addition, although the data are still somewhat limited, increasing evidence suggests that animal proteins, particularly whey protein, promote gains in lean mass through increased skeletal muscle protein synthesis and improve appetite control and satiety more so than plant proteins, such as soy protein (Hector et al. 2015; Volek et al. 2013; Veldhorst et al. 2009).

Optimizing adaptations to exercise

The joint statement from the WHO/FAO/UNU committee on dietary protein (2011) states the following, "...the protein requirement of adults can be defined as the minimum intake that will allow nitrogen equilibrium (zero nitrogen balance), at an *appropriate body composition during energy balance* [italics added] and at *moderate physical activity* [italics added]. In practice, the nitrogen balance studies... involve studies on healthy adults assumed to be in energy balance,

usually on the basis of weight maintenance and of an ‘appropriate’ body composition, *but without specific measurement to ensure that this was the case* [italics added].” It is important to understand just how different the current recommendations for protein intake are from what many athletes are engaging in as part of their normal training on a regular basis. Athletes are not always in energy balance, maintaining weight, and their body compositions can fluctuate substantially, depending on their sport, to what would be considered far from ‘appropriate’. Thus, as opposed to a minimal level of protein to maintain nitrogen balance, athletes are seeking protein intakes to optimize adaptations to their training and achieve peak competition in performance (Phillips 2012). To this end, a more appropriate target than achieving nitrogen balance would be for an athlete to have an optimally functioning musculoskeletal system (bone, muscle, and connective tissues), cardiovascular system, immune system, and, for all intents and purposes, an optimal physiological function (Phillips 2012). Insofar as muscle is concerned, there is evidence that we may be able to begin to define a more ‘optimal’ level of protein intake (Phillips 2012; Phillips and van Loon 2011) rather than a minimal level that offsets deficiency. A conceptual framework is provided here to help practitioners understand how athletes might plan their dietary protein intake to achieve an optimal muscle mass, which is a contributor to performance (Phillips 2012; Phillips and van Loon 2011).

Optimal protein intakes for athletes

Fluctuations in muscle protein synthesis (MPS) and muscle protein breakdown (MPB) occur with ingestion of protein and are amplified, at least in the case of MPS, by muscle contractions;

for a review of this framework the reader is referred to several recent reviews (Churchward-Venne et al. 2012a; McGlory and Phillips 2014). Changes in MPS are several-fold greater than changes in MPB (Churchward-Venne et al. 2012b) in healthy persons and thus a focus of research has been on this variable as the primary determinant of changes in muscle mass (Phillips 2012). Several studies have now defined the dose-response nature of MPS both at rest and after resistance exercise (Moore et al. 2009; Witard et al. 2014) and have shown that the level of protein intake at which MPS is maximally stimulated is a per meal (dose) protein intake of ~ 0.25 g/kg/meal in young men (Moore et al. 2015). The level for younger women has not been experimentally determined, but given that young men and women respond very similarly to hyperaminoacidemia and hyperinsulinemia (Smith et al. 2009) and loading (West et al. 2012), it is proposed that there would not likely be much difference in that estimate of protein intake to maximize the stimulation of MPS in young women. Adding two standard deviations to the estimated average intake 0.25 g/kg/meal (Moore et al. 2015) gives an estimated intake of 0.4 g/kg/meal, which would provide for some margin for inter-individual error and the fact that the per meal estimates derived from this work were for isolated proteins. When consumed as a mixed meal, protein digestion would be, relative to isolated proteins, delayed (Bos et al. 1999) and the ensuing aminoacidemia (Burke et al. 2012) would definitely affect MPS (Bos et al. 2003).

The period of time during which athletes would be in negative protein balance would be overnight, when no periodic feeding takes place (Groen et al. 2012; Res et al. 2012). One study has provided evidence, however, that pre-sleep ingestion of protein (at a dose of ~ 0.55 g/kg) resulted in a greater overnight MPS (Res et al. 2012). While impractical for athletes, it has also

been shown that intra-gastric protein infusion while sleeping stimulated MPS in elderly men (Groen et al. 2012). The acute results from these studies have been shown to have some relevance in a recently published study from Snijders et al. (2015) in which it was reported that habitual consumption of a pre-sleep supplement that provided 27.5 g protein (~ 0.36 g/kg) and 15 g carbohydrate versus a non-caloric placebo resulted in greater hypertrophy in the supplemented group. The conclusion that it was the pre-sleep timing of the protein beverage in that study requires further study, however, since the control group was not supplemented with protein and thus the supplemented group had a higher total protein intake of ~ 0.6 g/kg/d.

Protein quality and muscle protein synthesis

The quality of protein has, in some circumstances, been shown to be a factor in determining the MPS response after exercise [for review see (Phillips 2014)]. In general, it appears that proteins that are higher in leucine content, which are quite rapidly digested, provide a good stimulus for MPS (Phillips 2014). Thus, targeting a leucine content on a per meal basis has been suggested as a variable beyond simply protein content as being an important consideration for stimulating MPS (Layman et al. 2015). There is also the suggestion that more slowly digested proteins such as casein or egg may allow for the prolongation of the MPS response by maintaining hyperaminoacidemia (Reitelseder et al. 2010). Thus, protein blends containing milk proteins (whey and casein) or milk proteins combined with soy proteins (Reidy et al. 2013) for example would be expected to be more effective. A claim for superiority of such blends is not possible based on the evidence to date, however, which shows that (on a leucine-matched basis) there is an equivalent MPS response with isolated versus blended proteins (Reidy et al. 2013).

Meal planning for athletes

With a per meal dose of protein defined a meal plan can be formulated. Table 2 gives a protein per meal plan that targets protein intakes at levels designed to maximally stimulate MPS. While the optimal timing between the meals throughout the day is not completely clear at this time there is evidence supporting a 3-4 h refractory period, rather than shorter or longer periods of time. What is also unknown is how many times a person could consume a meal on a daily basis to elicit this optimal pattern of stimulating MPS. However, it is proposed that it would be unlikely that more than 3-4 meals per day would be optimal and, admittedly, that less meal feedings may also be able to provide an adequate stimulus for MPS. Nonetheless, there are considerations for other macronutrients (in particular carbohydrates), workout timing, fuelling, and hydration that would have to be considered for athletes so pragmatic rules may trump optimal recommendations. Considering a breakfast, lunch, dinner, pre-bed pattern Table 2 provides some guidance for protein intakes in athletes to optimize their MPS response.

Health Impacts

The most often-cited/held beliefs regarding higher protein are that higher protein intakes lead to renal failure and/or results in reduced bone health. Evidence-based analyses of these beliefs shows, however, that neither has a foundation. The response to an increase in dietary protein intake in those with normal renal function is actually an increase in glomerular filtration rate (Schwingshackl and Hoffman, 2014). In the most recent round of discussions in setting the Dietary Reference Intakes, the Institute of Medicine concluded, "Correlation of creatinine clearance with protein intake showed a [positive] linear relationship... suggesting that the low

protein intake itself decreased renal function. These factors point to the conclusion that the protein content of the diet is not responsible for the progressive decline in kidney function with age. (p. 842)” (Institute of Medicine, 2005). In addition, From the WHO/FAO report on protein requirements, the following summarizes the views from that expert consultation “... symptomatic renal failure does not result from the physiological decrease in glomerular filtration rate that occurs with age, because symptoms do not occur until the glomerular filtration rate has decreased much more than occurs with ageing. Moreover, protein restriction lowers glomerular filtration rate, suggesting that the decline of glomerular filtration rate with age is a natural consequence of the decline in protein intake as age progresses, and is unrelated to deterioration of renal function. (p. 224)” (WHO Technical Report Series 935, 2011). Thus, statements linking a decline in renal function to consumption of a higher protein diet are belief- and not evidence-based.

Simply stated, the acid-ash hypothesis posits that diets with higher protein and grain foods, with a low potassium intake, produce a greater dietary acid load (Fenton et al, 2009). The increase in net urinary acid excretion, increases urinary calcium excretion, and subsequent release of calcium from the skeleton. As Fenton et al (2009) have pointed out, the linear association between changes in calcium excretion in response to experimental changes in net acid excretion is not evidence that the source of the excreted calcium is bone or that this calciuria contributes to the development of osteoporosis. Evidence-based analysis using the application of Hill’s criteria for causality showed clearly that, “A causal association between dietary acid load and osteoporotic bone disease is not supported by evidence...” (Fenton et al, 2011). It has in fact been suggested that dietary protein is a nutrient that is supportive of bone

health due, but this is only the case when calcium intakes are adequate (Mangano et al, 2014). Thus, we propose, as reviewed in several recent publications recommending greater protein intakes (≥ 1.2 g/kg/day) for older persons (Bauer et al, 2013; Deutz et al, 2014), there is no evidence supportive of higher protein intakes leading to renal failure and/or poor bone health.

Conclusion

Substantial evidence indicates that protein intakes higher than the current RDA can be an important strategy to help promote healthy aging, weight management, and athletic performance. Protein quality, per meal dose and timing are also important considerations in practice. Current evidence suggests that intakes of high quality protein in the range of 1.2-1.6 g/kg/day is a more ideal target to achieve optimal health outcomes in adults.

Take-home points:

- Because of anabolic resistance, sedentary lifestyles and common illnesses, older adults need higher protein intakes (≥ 1.2 g/kg/d) to help prevent age-related sarcopenia.
- Including a high quality protein source at breakfast, the meal generally containing the least protein, is a simple and pragmatic approach to increase intakes in older adults, and has also been shown to reduce unhealthy snacking behavior in younger individuals.
- The consumption of higher protein diets (~ 1.2 - 1.6 g/kg/d), including ~ 30 g protein per eating occasion, improves appetite control, satiety, and weight management.

- Athletes appear to benefit from protein intakes as much as 2x the RDA, with a per meal dose of about 0.4 g/kg/meal consumed 3 to 4 times per day. Meal planning should be centred around post-exercise protein provision to amplify the protein synthetic response.
- High quality protein from animal-based sources (e.g. milk, meat, poultry, and eggs) provide a concentrated source of essential amino acids, including leucine, to maximize muscle protein synthesis, with relatively few calories compared to plant-based protein sources.

Draft

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Table 1. Protein Quantity of Common Consumed Protein Foods

Foods & USDA Standard Servings	Protein (g)	Energy (kcal)
1 ‘scoop’ Whey Protein (Shake)	24-26	113
3 oz Cooked Skinless Chicken Breast	26	130
3 oz Cooked 95% Lean Ground Beef	22	140
6 oz Greek Yogurt Plain	17	100
2 Large Eggs	12	144
½ cup Tofu	10	95
½ cup Beans	8	110
2 Tbsp Peanut Butter	8	190
1 oz Almonds	6	165
1 cup Cooked Oatmeal	6	165
½ cup Cooked Quinoa	4	110

USDA National Nutrient Database for Standard Reference: <http://ndb.nal.usda.gov/>

Table 2. Protein intakes in an athlete (80 kg male swimmer, 1.9 m) consuming the recommended dietary allowance (RDA) for protein in a typical 'skewed' fashion versus an 'optimal' protein intake in a 'balanced' fashion.

	Minimal (RDA) in skewed Fashion	Optimal balanced intake
Requirement	64 g	Not applicable
Breakfast	8 g	$0.4 \times 80 = 32 \text{ g}$
Lunch	15 g	32 g
Dinner	35 g	32 g
Pre-sleep	6 g	$0.4\text{-}0.6 \times 80 = 32\text{-}48 \text{ g}^*$
Total daily protein intake (g/kg)	0.8	1.6 - 1.8
% of total E	7.6	17.2

This swimmer, based on weekly total volume of 30 km (training 6 d/wk), would have an estimated daily energy expenditure of ~14 MJ/d. * Based on available data from Groen et al. (2012) and Snijders et al. (2015).

Figure 1. Distribution of protein intake in men and women from the NuAge study. Values are means $\pm$ SD. Data from Farsijani et al. (2015). * $p < 0.001$ vs. breakfast and dinner, ** $p < 0.001$ vs. breakfast and lunch from Kruskal -Wallis test.

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