Lean Body Mass Loss With Age

Douglas Paddon-Jones, PhD

Sarcopenia is an age-related, multifactorial process characterized by the progressive loss of lean tissue mass. The onset of sarcopenia is insidious, but its progression may be accelerated by physical inactivity and poor nutrition. Research continues to focus on the mechanisms contributing to sarcopenia, including changes in protein metabolism and cell signaling, voluntary or imposed reductions in physical activity, malnutrition, and reduced anabolic efficiency to protein ingestion.

Elderly individuals are at increased risk of becoming physically incapacitated or placed on bed rest for an extended period. The loss of lean body mass is dramatically increased during inactivity and is driven by a chronic imbalance between muscle protein synthesis and breakdown and facilitated by decreased activation of nutrient signaling pathway.[1-3] In recent studies examining changes in protein synthesis and muscle mass in healthy adults subjected to bed rest, older subjects experienced an approximate three-fold greater loss of lean leg muscle mass compared to a cohort of younger individuals confined to bed for 28 days (Figs 1 and 2).[2,4]

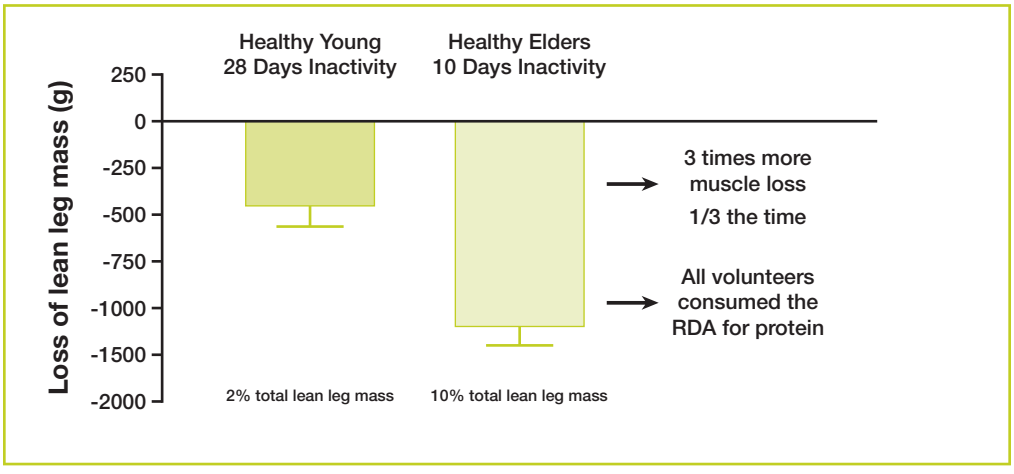

Fig 1. Inactivity and aging muscle. After 10 days of inactivity, older healthy subjects experienced an approximately three-fold greater loss of lean leg muscle mass than a cohort of younger individuals confined to bed for 28 days.[2,4] (1000 g=2.2 lb muscle loss)

Lean Body Mass Loss With Age

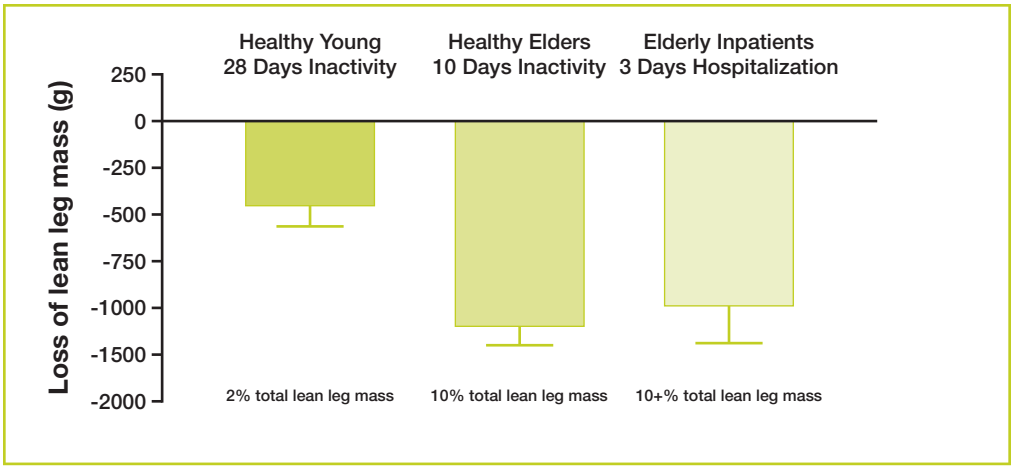

Fig 2. Muscle loss in hospitalized elders. After 3 days of hospitalization, elderly inpatients lost approximately the same amount of lean leg muscle mass as healthy older subjects experienced in 10 days of inactivity—approximately three-fold greater loss of lean leg muscle mass than a younger cohort confined to bed for 28 days.[2,4]

General consensus exists that a moderate-to-large serving of protein or amino acids increases muscle protein synthesis similarly in both young and elderly.[4-12] Unlike earlier *proof of concept* studies using free-form amino acid supplements, several recent studies have adopted a more practical approach and sought to examine the ability of protein-rich foods (eg, milk and beef) to stimulate protein anabolism. These studies are important as they more closely reflect responses to actual dietary practices and provide information on how meal choices may influence accrual of muscle mass and ultimately functional capacity. In one study directly comparing young and elderly, Symons et al[13] reported that a moderate 113 g (≈4 oz) serving of an intact protein (ie, lean beef) contains sufficient essential amino acids (EAAs) (30 g total; ≈12 g EAAs) to increase mixed-muscle protein synthesis by 50% in both young and elderly men and women (Fig 3).

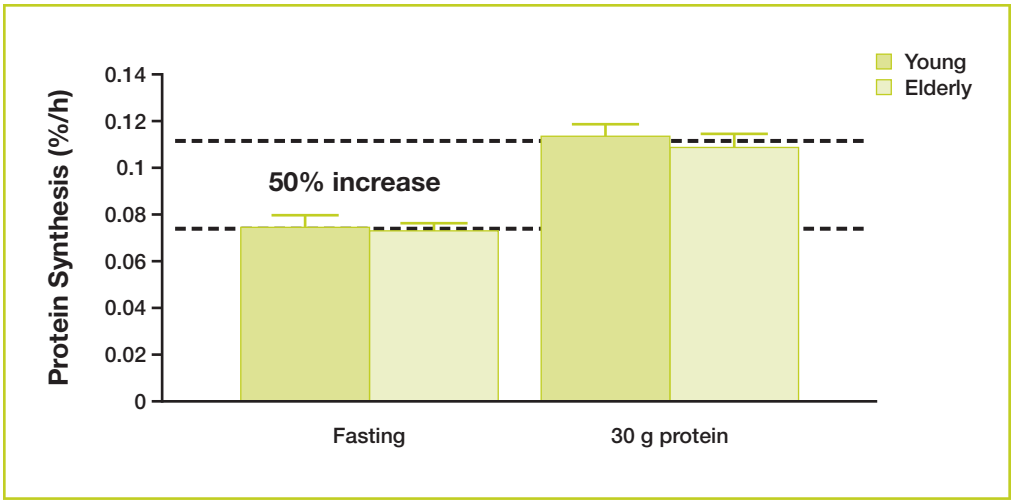

Fig 3. Aging does not impair the ability to increase muscle protein synthesis following ingestion of 113 g of lean beef (30 g protein). h=hour

The adequacy of the recommended dietary allowance (RDA) for protein has recently been the subject of renewed debate.[14-19] The current recommendation for protein intake for adults is 0.8 g/kg^{-1}/day^{-1}. While a modest increase in protein intake beyond 0.8 g/kg^{-1}/day^{-1} is likely to be beneficial for many elders, there is a greater need to specifically examine the dose and distribution of protein across each meal. For a 75 kg individual, the RDA represents 60 g protein/day, or if distributed evenly across three meals, 20 g protein/meal. A 20-g serving of most protein contains 5–8 g of EAAs, which are primarily responsible for stimulating muscle protein synthesis.[10] This is important because aging appears to be associated with an inability of skeletal muscle to respond to low doses of protein (<20 g) or EAAs (<8 g), whereas higher doses (protein >25 g; EAAs 10–15 g) are capable of stimulating muscle protein synthesis in older adults to a similar extent as in the young (Fig 4).[7,20]

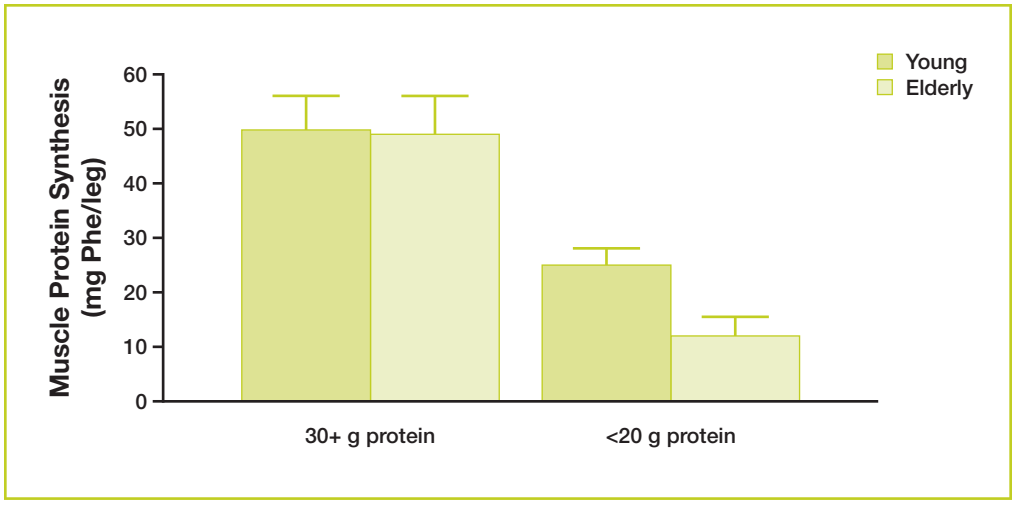

Fig 4. Older adults exhibit a blunted anabolic response to a lower "subthreshold" dose of amino acids or protein measured by the uptake of phenylalanine (mg Phe) per leg (adapted from Katsanos et al[20]).

To examine the effect of protein dose on muscle protein synthesis using a high-quality, protein-rich food, we demonstrated that a large single 340-g (≈12 oz) serving of lean beef (90 g protein) does not elicit a greater anabolic response in healthy young and elderly people than a serving one third the size.[21] This suggests that, despite the additional protein and energy content, ingestion of more than 30 g of protein in a single meal may be an energetically inefficient means of stimulating muscle protein synthesis. If we accept that 25–30 g of high-quality protein (≈10 g EAAs) are necessary to maximally stimulate skeletal muscle protein synthesis, then it seems reasonable to suggest that ingestion of this amount of high-quality protein at each meal could be a useful strategy to maintain muscle mass in the elderly (Fig 5).

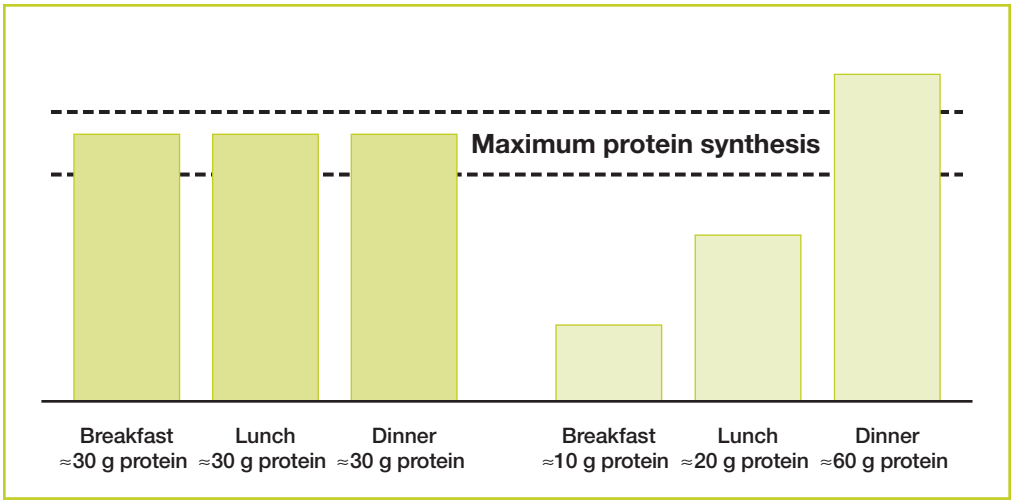

Fig 5. Ingestion of 90 g of protein, distributed evenly over three meals is more likely to provide a greater 24-hour protein anabolic response than an unequal protein distribution.

Thus, research indicates that ingestion of protein, consumed in adequate amounts over the course of a day, can ameliorate the effects of sarcopenia in older adults.

References

1. Dreyer HC, Glynn EL, Lujan HL, et al: Chronic paraplegia-induced muscle atrophy downregulates the mTOR/S6K1 signaling pathway. *J Appl Physiol* 2008; 104:27-33.
2. Kortebein P, Ferrando A, Lombeida J, et al: Effect of 10 days of bed rest on skeletal muscle in healthy older adults. *JAMA* 2007;297:1772-1774.
3. Paddon-Jones D, Sheffield-Moore M, Cree MG, et al: Atrophy and impaired muscle protein synthesis during prolonged inactivity and stress. *J Clin Endocrinol Metab* 2006;91:4836-4841.
4. Paddon-Jones D, Sheffield-Moore M, Urban RJ, et al: Essential amino acid and carbohydrate supplementation ameliorates muscle protein loss in humans during 28 days bedrest. *J Clin Endocrinol Metab* 2004;89:4351-4358.
5. Paddon-Jones D, Sheffield-Moore M, Aarsland A, et al: Exogenous amino acids stimulate human muscle anabolism without interfering with the response to mixed meal ingestion. *Am J Physiol Endocrinol Metab* 2005;288:E761-E767.

6. Paddon-Jones D, Sheffield-Moore M, Katsanos CS, et al: Differential stimulation of muscle protein synthesis in elderly humans following isocaloric ingestion of amino acids or whey protein. *Exp Gerontol* 2006;41:215-219.
7. Paddon-Jones D, Sheffield-Moore M, Zhang XJ, et al: Amino acid ingestion improves muscle protein synthesis in the young and elderly. *Am J Physiol Endocrinol Metab* 2004;286:E321-E328.
8. Paddon-Jones D, Wolfe RR, Ferrando AA: Amino acid supplementation for reversing bed rest and steroid myopathies. *J Nutr* 2005;135:1809S-1812S.
9. Volpi E, Ferrando AA, Yeckel CW, et al: Exogenous amino acids stimulate net muscle protein synthesis in the elderly. *J Clin Invest* 1998;101:2000-2007.
10. Volpi E, Kobayashi H, Sheffield-Moore M, et al: Essential amino acids are primarily responsible for the amino acid stimulation of muscle protein anabolism in healthy elderly adults. *Am J Clin Nutr* 2003;78:250-258.
11. Volpi E, Lucidi P, Cruciani G, et al: Contribution of amino acids and insulin to protein anabolism during meal absorption. *Diabetes* 1996;45:1245-1252.
12. Volpi E, Mittendorfer B, Wolf SE, Wolfe RR: Oral amino acids stimulate muscle protein anabolism in the elderly despite higher first-pass splanchnic extraction. *Am J Physiol Endocrinol* 1999;277:E513-E520.
13. Symons TB, Schutzler SE, Cocke TL, et al: Aging does not impair the anabolic response to a protein-rich meal. *Am J Clin Nutr* 2007;86:451-456.
14. Campbell WW, Trappe TA, Wolfe RR, Evans WJ: The recommended dietary allowance for protein may not be adequate for older people to maintain skeletal muscle. *J Gerontol A Biol Sci Med Sci* 2001;56:M373-M380.
15. Wolfe RR: The underappreciated role of muscle in health and disease. *Am J Clin Nutr* 2006;84:475-482.
16. Wolfe RR, Miller SL: The recommended dietary allowance of protein: A misunderstood concept. *JAMA* 2008;299:2891-2893.
17. Leidy HJ, Carnell NS, Mattes RD, Campbell WW: Higher protein intake preserves lean mass and satiety with weight loss in pre-obese and obese women. *Obesity* (Silver Spring) 2007;15:421-429.
18. Thalacker-Mercer AE, Fleet JC, Craig BA, et al: Inadequate protein intake affects skeletal muscle transcript profiles in older humans. *Am J Clin Nutr* 2007; 85:1344-1352.
19. Millward DJ, Layman DK, Tomé D, Schaafsma G: Protein quality assessment: Impact of expanding understanding of protein and amino acid needs for optimal health. *Am J Clin Nutr* 2008;87:1576S-1581S.
20. Katsanos CS, Kobayashi H, Sheffield-Moore M, et al: Aging is associated with diminished accretion of muscle proteins after the ingestion of a small bolus of essential amino acids. *Am J Clin Nutr* 2005;82:1065-1073.
21. Symons TB, Sheffield-Moore M, Wolfe RR, Paddon-Jones D: A moderate serving of high-quality protein maximally stimulates skeletal muscle protein synthesis in young and elderly subjects. *J Am Diet Assoc* 2009;109:1582-1586.