DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

NATIONAL DAIRY COUNCIL

Healthy Aging

America's older population is growing larger, becoming more diverse, and living longer. With aging, there is increased incidence of muscle and bone loss, which can increase the risk of sarcopenia and osteoporosis, respectively, and may contribute to loss of independence, risk of falls, and decreased quality of life. Nutrition, by promoting older adults' health and functionality, is a key component of successful aging. This report reviews the accumulating scientific evidence suggesting that, in addition to resistance exercise, moderately increasing the protein intake of older adults may lead to better muscle and bone health. Consuming a nutritionally balanced diet consistent with the 2010 Dietary Guidelines for Americans, including foods providing high-quality protein such as low-fat and fat-free milk, cheese, and yogurt, can help meet older adults' protein needs, as well as provide many other essential nutrients, such as calcium and vitamin D, that are important for healthy aging.

Scientific Status Report

Introduction

America's older population is growing larger, becoming more diverse, and living longer.[1] The population aged 65 years and older has increased from 35 million in 2000 to 40 million in 2010 (i.e., 13% of the total population) and is projected to grow to 72 million in 2030 (i.e., nearly 20% of the population).[1] Life expectancies at both age 65 and 85 have increased.[1] The 85+ population is expected to increase from 5.5 million in 2010 to 19 million by 2050.[1] Although Americans are living longer,[1] nearly half of older adults aged 65 and over have two or more chronic diseases.[2] Healthy People 2020's main goal for older adults is to improve their health, function, and quality of life.[3] Preventing chronic diseases and reducing associated complications is essential for keeping older adults healthy and independent.[4] Nutrition, by promoting older adults' health and functionality, is a key component of successful aging.[4]

Nutrient Needs & Nutritional Status

The increasing number of older adults and the occurrence of age-related diseases have heightened awareness of this population's nutrient needs and nutritional status.[4]

Nutrient Needs. The needs for several nutrients are unique for older adults compared to those of younger adults.[5,6] The Dietary Reference Intakes (DRIs) specify dietary recommendations for energy and several essential nutrients (e.g., calcium) and food components (e.g., dietary fiber) for adults aged 51 to 70 years and >70 years.[5,6] Older adults' nutrient needs are affected by numerous age-related changes in physiology, health, and lifestyle.[4]

The energy needs of persons 75 years of age and older may be somewhat lower than those of younger adults because of decreases in physical activity, reduced resting energy expenditure, and changes in body composition (i.e., loss of skeletal muscle and gain in body fat).[4,5] If overall energy intake is low, older adults must carefully select nutrient-dense foods to meet nutrient needs.[4]

The current Recommended Dietary Allowance (RDA) for protein is 0.8 g/kg body weight/day for adults aged 19 years and older – 56 g/day for men and 46 g/day for women using reference weights of 70 kg (154 lbs) and 57 kg (125 lbs), respectively, or 10% of total caloric intake when energy intake needs are ~ 2,000 to 2,200 kcal/day.[5] In contrast to the RDA for protein, which indicates the minimum amount of protein to prevent a deficiency, the Institute of Medicine has established an acceptable macronutrient distribution range (AMDR) for dietary protein of 10 to 35% of calories, which some have argued may be more in line with optimal intake for health.[5] Some experts are recommending that protein needs increase with advancing age and the protein recommendation for older adults should be greater than the current RDA.[7,8,9]

Dietary calcium and vitamin D recommendations are based on their need to support bone health.[6] Calcium RDAs are 1,000 mg/day for men aged 51 to 70 years and 1,200 mg/day for men >70 years and women 51 years of age and older.[6] The higher calcium RDA for older adults compared to their younger counterparts is due to an age-related increase in bone loss. The higher calcium RDA for women aged 51 to 70 years than for similar aged men is explained by the increased need for calcium to help overcome the effects of bone loss in women at the onset of menopause, which usually occurs around age 50 to 55 years.[6] Vitamin D recommendations are 600 IU/day for adults 51 to 70 and 800 IU/day for person >70 years.[6] The increased vitamin D recommendations for older adults (i.e., 800 IU/day) compared to adults aged 51 to 70 years (i.e., 600 IU/day) is explained by age-related physical (e.g., less efficient synthesis of vitamin D in the skin from vitamin D precursors, age-related decline in vitamin D absorption) and behavioral (limited exposure to sunlight) changes that increase the daily requirement for this nutrient.[6] Because older adults may malabsorb protein-bound vitamin B-12 (i.e., the

form occurring naturally in foods), synthetic vitamin B-12 from fortified foods or vitamin supplements is recommended for adults over age 50 to help meet their recommended intake for this vitamin.[5]

Nutritional Status. The nutritional status of the older population can be adversely affected by many factors that accompany the aging process.[4] These factors include medical/health status (e.g., use of medications, a decline in taste and smell, poor dentition), physical/functional status (e.g., surgery and chronic diseases, physical limitations, physical strength and endurance), cognition (depression, change in mental status), and environment (e.g., changes in living arrangements, poverty, access to food and food preparation, socialization).[4]

A decline in the nutrient intakes of many older adults can occur concomitant with an age-related decrease in the quantity of food consumed and energy intake.[4] Using data from the National Health and Nutrition Examination Survey (NHANES) 2003-2004, researchers identified the following shortfall nutrients for adults 70 years and older: calcium, vitamins D, E, and K, potassium, and fiber.[10] Although many Americans meet or exceed the current recommendation for protein, nationwide survey data indicate a trend toward decreased protein intake in later adult years.[11]

Older adults' food intake patterns contribute to their inadequate intake of nutrients. According to older adults' diet quality scores in 2001-02 and 2007-08, as measured by the *Healthy Eating Index* 2005, the diets of older adults need to be improved.[1,12] Specifically, increasing intakes of whole grains, dark green and orange vegetables and legumes, and milk products are needed to improve their diet quality[1,12] NHANES 2001-2004 data revealed that usual intake of food groups for a large percentage of older adults aged 51 to 70 years and those 71 years and older was below the recommended amounts.[13] For example, fewer than 10% of adults aged 71 years and older consumed minimum recommended servings of dairy foods.[13] The 2010 Dietary Guidelines for Americans recommends 3 cups of fat-free or low-fat milk and milk products (e.g., cheese, yogurt) as part of a healthful diet for Americans 9 years and older.[14] The dairy group – milk, cheese, yogurt – contributes many nutrients to the U.S. diet that are important for good health, including calcium, potassium, phosphorus, magnesium, zinc, protein, vitamin A, vitamin D, vitamin B-12, and riboflavin.[15] Consuming recommended servings of dairy foods is an important way to help healthy as well as frail older adults meet many shortfall nutrients.[16]

When the dietary patterns of more than 3,000 older adults were followed for over a 10-year period, researchers found that the older adults' nutritional status, quality of life, and survival were positively associated with a dietary pattern consistent with current dietary guidelines, that is, a diet containing relatively higher amounts of low-fat dairy products, vegetables, fruit, whole grains, poultry, and fish.[17]

Dietary Protein's Role in Healthy Aging

With aging, there is increased incidence of muscle and bone mass loss, which can increase the risk of sarcopenia and osteoporosis, respectively.[7] As the number of older people continues to grow, sarcopenia and osteoporosis are expected to become increasingly important public health concerns. Dietary protein is critical for the development and maintenance of muscle and bone, and scientific findings indicate that increasing dietary protein above the current RDA (0.8g/kg/day) may lead to better muscle and bone health in older adults.[7,8,9,18]

Optimizing muscle and reducing the risk of sarcopenia. Sarcopenia is defined as "the age-associated loss of skeletal muscle and function".[19] This condition is associated with reduced strength, physical function, and overall health and can lead to loss of independence, disability, hospitalization, and premature death.[19] Depending on the definition used, sarcopenia affects 5 to 13% of 60 to 70-year olds and 11 to 50% of adults >80 years.[20] Risk of sarcopenia is influenced by a complex interaction of genetic and environmental factors, including nutrition (e.g., protein intake) and physical activity.[19]

Although age-related sarcopenia has been suggested to result from a negative protein balance due to a disproportionate decrease in the basal or fasted rate of skeletal muscle protein synthesis and/or an increase in fasted skeletal muscle protein breakdown, current evidence indicates that basal rates of muscle protein synthesis and breakdown do not differ substantially between the young and the elderly.[21] Rather, some researchers suggest that a blunted responsiveness of muscle protein synthesis to anabolic stimuli such as dietary protein/essential amino acids and/or resistance exercise may be responsible for the age-related decline in skeletal muscle mass.[21] That is, the increase in muscle protein synthesis in response to meals containing a smaller amount of protein (i.e., < 20 g) appears to be less in older adults compared to that in younger adults, which may lead to an overall reduction in muscle protein balance and loss of muscle mass.[9,21] However, scientific research indicates that this age-related "anabolic resistance" may be counteracted by increased intake of high-quality dietary protein/essential amino acids and/or resistance exercise.[21,22,23]

The amount, distribution, and source of protein consumed influence the increase in blood levels of essential amino acids, which in turn can affect muscle protein synthesis.[21,23,24] Although the optimal intake of protein that may reduce the risk of or minimize sarcopenia has yet to be conclusively established, protein intakes of 1.0 to 1.6 g/kg per day (i.e., 70 to 112 g/day for a person weighing 70 kg or 154 pounds) have been suggested to result in better muscle health in older adults.[4,7]

In addition to the total daily intake of protein, the amount of protein consumed at individual meals could be important. Emerging findings from studies examining intact protein and essential amino acids and protein synthesis in the elderly suggest that consuming approximately 20 to 30 g of high-quality protein (~ 10 g essential amino acids) at each meal throughout the day (breakfast, lunch, and dinner), rather than the current practice of consuming the majority of daily protein intake at the dinner meal, may maximally stimulate muscle protein synthesis per meal.[9,21,25] Furthermore, some experts suggest consuming this amount of protein at each meal may help preserve muscle with aging.[9]

High quality protein providing essential amino acids may be important in helping older adults maintain their muscle mass.[21] Animal foods such as dairy, meat, and eggs are sources of high-quality protein, meaning that they contain all the essential amino acids that humans cannot make on their own and that the protein is highly digestible.[5] Milk-based proteins - casein (80% of milk protein) and whey (20% of milk protein) - are high-quality proteins that have been shown to increase muscle protein synthesis.[24] However, whey protein leads to a greater acute rise in muscle protein synthesis than a dose-matched intake of casein both at rest and after resistance exercise in healthy adults.[24,26,27] Researchers found that intake of 20 g whey protein, a rapidly digested protein, increased rates of muscle protein synthesis, specifically myofibrillar (contractile) muscle protein fraction, more than an equal amount of casein, a slowly digested protein, both at rest and after resistance exercise in healthy elderly men.[26] Likewise, a study in 48 healthy older men who were randomly assigned to consume 20 g of whey, casein, or casein hydrolysate protein found that whey protein was more effective in stimulating postprandial muscle protein synthesis than casein or casein hydrolysate.[24] Researchers suggest that the greater stimulation of muscle protein synthesis with whey protein than casein in short-term studies may be explained by whey protein's faster digestion than casein.[24,26] Longer-term studies have demonstrated the beneficial effects of milk protein concentrate (whey and casein) on muscle protein synthesis. A long-term (24 weeks) clinical trial in frail elderly adults showed that an increase in milk protein concentrate (15 g twice daily or an increase in daily protein intake from 1.0 to 1.4 g/kg/day) combined with resistance exercise significantly increased skeletal muscle mass.[28] Another 24-week trial by the same researchers indicated that increasing milk protein concentrate by 30 g a day without exercise did not increase skeletal muscle mass, but significantly improved frail elderly adults' physical performance (e.g., balance, gait speed) compared with those who received a placebo drink.[29] The researchers state that their findings "point toward the application of dietary protein supplementation in frail elderly people as a

promising nutritional strategy to improve physical performance, attenuate the progression of frailty, and delay the onset of disability."[29]

Researchers indicate that the capacity of whey versus casein protein in stimulating muscle protein synthesis is attributed to whey protein's higher content of the branched-chain amino acid leucine, which stimulates muscle protein synthesis, and leucine's rapid rate of absorption and digestion.[21,24,26] Increasing intake of leucine or leucine-rich proteins (i.e., whey protein) may help overcome resistance to the anabolic effects of protein/essential amino acids in older adults.[21,23,30,31] Supplementation of each of three daily meals with 4 g leucine (12 g/day) consumed for two weeks by older adults who habitually consumed an amount of protein close to the RDA for protein increased muscle protein synthesis.[31] Analyses of muscle biopsy samples indicated that leucine supplementation altered aging muscle to become more sensitive to the stimulatory effects of amino acids. However, no change in muscle mass was observed in this short-term study.[31] A recent review of nutritional interventions and resistance exercise on aging muscle mass and strength calls for additional research to determine if leucine has the potential to reverse or prevent sarcopenia.[32]

A study in 33 healthy elderly men assigned to consume 10, 20 or 35 g whey protein found that consumption of 35 g whey protein, when compared with 10 or 20 g, resulted in greater absorption of leucine and greater stimulation of muscle protein synthesis.[23] Also, whole body net protein balance was highest and lowest after consumption of 35 and 10 g of whey protein, respectively.[23] According to the authors, these results imply that the blunted response of skeletal muscle to food intake in older adults "can, at least partly, be compensated for by ingesting a greater amount of whey protein".[23]

Resistance exercise increases muscle protein synthesis, although this effect is generally impaired in older adults compared with younger adults.[21] However, increased intake of protein in conjunction with resistance exercise may overcome this impaired effect in older adults.[33] A recent study suggests that older adults may need twice as much protein as young adults (i.e., 40 g vs. 20 g) to maximize the anabolic potential of prior resistance exercise.[33] This randomized controlled trial conducted among 37 healthy elderly men who consumed 0, 10, 20, or 40 g of whey protein as a beverage found that post-exercise rates of muscle protein synthesis increased in a stepwise manner with increasing amounts of whey protein, with the greatest increase in muscle protein synthesis seen with 40 g of whey protein.[33] This is double the amount of high-quality protein previously shown to maximally stimulate muscle protein synthesis after resistance exercise in young adults.[33,34] These data suggest that, in contrast to younger adults in whom some studies indicate that post-exercise rates of muscle protein synthesis may be saturated with 20 g of protein, exercised muscles of older adults respond to higher protein doses.[33] In a recent review, the researchers suggest that "protein ingestion at doses of at least 20 g and perhaps as high 30-40 g, in close proximity to, and at intervals over 24 h after resistance exercise, may be able to elicit an anabolic response in the elderly".[21]

Optimizing bone health and reducing the risk of osteoporosis. Older adults are at risk of bone loss, which can lead to osteoporosis (porous bones), a disease characterized by reduced bone mass and structural deterioration of bone tissue, increasing the risk for fractures.[7,35] In addition to calcium and vitamin D, which are critical for bone health,[6] accumulating scientific evidence supports a beneficial role for protein in bone health and suggests that optimal protein intake for bone health in older adults is likely higher than the RDA for this nutrient.[7,8,36] Protein makes up approximately 50% of bone's volume and one-third of its mass.[36] Several mechanisms may contribute to protein's beneficial effect on bone health. Protein provides amino acids, which are substrates for building bone matrix, stimulates the production of insulin-like growth factor -1 (IGF-1), a key mediator of bone growth, increases calcium absorption, and increases muscle strength and mass when combined with exercise.[7,8,36,37,38] Bone health is a musculoskeletal issue, not just a skeletal issue.[36]

Low protein intake has been shown to be associated with loss of bone mineral density, while increased protein intake has been demonstrated to be positively associated with bone health in older adults.[36,38,39,40,41] When the relationship between protein intake and a 4-year change in bone mineral density was examined in 615 older adults, the group in the lowest quartile of protein (0.21-0.71 g/kg/day) had the greatest loss of bone mineral density, whereas the lowest loss in bone density was found in the group consuming the highest quartile of protein (1.24 – 2.78 g/kg/day).[40] A study of 862 older women found that after 5 years, bone mineral content was greater in those consuming the highest amount of protein (>87 g/day) than a moderate (66-87 g/day) or low (<66 g/day) protein diet.[41] However, protein's effect on bone mineral content disappeared after adjusting for lean body mass, indicating a beneficial role of muscle mass.[41] Whole body muscle mass was higher in the women consuming the highest dietary protein than in those consuming moderate or low intakes of protein.[41] The researchers suggest that protein's beneficial effect on bone may be partly mediated by its effects on muscle. Some epidemiological studies also suggest that increased dietary protein may be associated with reduced risk of fractures in older adults, however, further study is needed to confirm this observation.[42,43]

Dietary protein stimulates IGF-1, a recognized bone-promoting factor.[8] A recent two-year randomized controlled trial in 219 older women aged 70 to 80 years whose baseline average protein intake was relatively high (1.1 g/kg/day or 76 g/day) found that those who received a skim milk drink supplemented with 30 g of whey protein and 600 mg calcium a day had significantly higher blood levels of IGF-1 at one and two years than women who received a lower protein drink containing 2 g whey protein and 600 mg calcium a day.[44] However, there was no change in bone density or strength over two years as a result of the extra protein intake (30 g/day). The researchers suggest that the lack of an increase in bone density or strength could be explained by the women's relatively high usual protein intake.[44] This study also showed that the high protein intake did not have a detrimental effect on bone health.[44]

Higher protein diets have been suspected of having an adverse effect on bone health because of dietary protein's ability to increase urinary calcium excretion and contribute to endogenous acid production, creating an environment favorable for demineralization of bone.[8,38,39] However, studies indicate that the increase in urinary calcium excretion is not of bone origin, but rather due to improved calcium absorption.[7,38] Also, researchers suggest that it is improbable that bone acts as a buffer for protein-induced metabolic acid load.[8] Higher protein diets have not been found to have a negative effect on calcium balance and bone health, especially when calcium intake is adequate.[7,8,36,38,44,45,46]

Increasing protein intake in older adults

Some data indicates that a protein intake equal to or less than the RDA of 0.8g/kg/day may be insufficient to support optimal muscular and bone health in older adults.[7,8] Although emerging research suggests that doubling the protein RDA from 0.8 g/kg/day to 1.6 g/kg/day may help promote optimal muscle and bone health, researchers suggest a moderate increase in the RDA of protein to 1.0 to 1.2 g/kg/day for older adults.[7] This more conservative recommendation for dietary protein for older adults takes into consideration gaps in knowledge and concerns related to high protein diets (e.g., risk of renal damage) for older adults.[7] Long-term clinical trials are needed before public health recommendations for dietary protein for healthy older adults can be made.[8]

Consuming nutritionally balanced diets including foods providing high-quality protein can help meet older adults' protein needs. Low-fat and fat-free milk, cheese, and yogurt are good sources of high-quality protein, as well as other essential nutrients important for older adults' muscle mass and bone health.[15,47] In addition, dairy foods are an economical source of nutrients,[48] which may be an important consideration for many older adults. An analysis that ranked foods according to their nutrient content

and USDA food price data found that milk and milk products were the lowest cost source of dietary calcium and among the lowest cost sources of riboflavin and vitamin B-12.[48]

Conclusion

Nutrition plays a key role in healthy aging.[4] Age-related changes in physiology, lifestyle, and health can increase older adults' needs for several nutrients such as calcium and vitamin D compared to younger adults. Also, the nutritional status of older adults can be adversely affected by many factors that accompany the aging process.

With aging, there is increased incidence of muscle and bone loss, which can increase the risk of sarcopenia and osteoporosis, respectively, leading to loss of independence, risk of falls, and decreased quality of life.[7,8] Accumulating scientific evidence suggests that, in addition to resistance exercise, moderately increasing protein intake above the RDA of 0.8 g/kg/day to 1.0 to 1.2 g/kg/day may lead to better muscle and bone health in older adults.[7] High-quality dairy proteins such as whey protein, which is a rich source of the amino acid leucine, has been shown to stimulate muscle protein synthesis in older adults.[24,26,27] Consuming 25 to 30 g of high quality protein at each meal throughout the day – breakfast, lunch, and dinner – is suggested by some experts to build a higher protein diet and optimize muscle protein synthesis, which may slow age-related muscle loss.[9,21]

Low protein intake is associated with loss of bone mineral density, whereas increased protein intake has been positively associated with bone health in older adults.[8] Little evidence indicates that higher protein intake increases bone loss, especially when calcium intake is adequate.[8,38,39] Consuming a nutritionally balanced diet consistent with the 2010 Dietary Guidelines for Americans,[14] including foods providing high-quality protein such as low-fat and fat-free milk, cheese, and yogurt, can help meet older adults' protein needs, as well as provide many other essential nutrients important for healthy aging.[16]

References

1. Federal Interagency Forum on Aging-Related Statistics. *Older Americans 2012: Key Indicators of Well-Being.* Federal Interagency Forum on Aging-Related Statistics. Washington, DC: U.S. Government Printing Office, June 2012. http://www.agingstats.gov. Accessed August 18, 2012.

2. Fried, V.M., A.B. Bernstein, and M.A. Bush. Multiple chronic conditions among adults aged 45 and older: Trends over the past 10 years. NCHS data brief, no. 100. Hyattsville, MD: National Center for Health Statistics, 2012. http://www.cdc.gov/nchs/data/databriefs/db100.htm. Accessed August 2, 2012.

3. U.S. Department of Health and Human Services. *Healthy People 2020.* Older Adults. http://www.healthypeople.gov/2020/topicsobjectives2020/overview.aspx?topicid=31. Accessed July 12, 2012.

4. Academy of Nutrition and Dietetics. Position of the Academy of Nutrition and Dietetics: Food and Nutrition for Older Adults: Promoting Health and Wellness. J. Acad. Nutr. Diet. 112: 1255-1277, 2012.

5. Otten, J.J., J.P. Hellwig, and L.D. Meyers (Eds). *Dietary Reference Intakes. The Essential Guide to Nutrient Requirements.* Washington, DC: The National Academies Press, 2006. http://www.nap.edu/catalog.php?record_id=11537.

6. Institute of Medicine of the National Academies, Committee to Review Dietary Reference Intakes for Vitamin D and Calcium. *Dietary Reference Intakes for Calcium and Vitamin D.* Washington, DC: The National Academies Press, 2011.

7. Gaffney-Stomberg, E., K.L. Insogna, N.R. Rodriguez, et al. Increasing dietary protein requirements in elderly people for optimal muscle and bone health. J. Am. Geriatr. Soc. 57: 1073-1079, 2009.

8. Surdykowski, A.K., A.M. Kenney, K.L. Insogna, et al. Optimizing bone health in older adults: the importance of dietary protein. Aging Health 6: 345-357, 2010.

9. Paddon-Jones, D., and B.B. Rasmussen. Dietary protein recommendations and the prevention of sarcopenia. Curr. Opin. Nutr. Metab. Care 12: 86-90, 2009.

10. Lichtenstein, A.H., H. Rasmussen, Y. Winifred, et al. Modified MyPyramid for older adults. J. Nutr. 138: 5-11, 2008.

11. Fulgoni, V.L. III. Current protein intake in America: Analysis of the National Health and Nutrition Examination Survey 2003-2004. Am. J. Clin. Nutr. 87: 1554s-1557s, 2008.

12. Juan, W.Y., P.M. Guenther and P.S. Kott. *Quality of Diets of Older Americans in 1994-96 and 2001-02 as measured by the Healthy Eating Index 2005.* Nutrition Insight 41, November 2008. http://www.cnpp.usda.gov/Publications/NutritionInsights/Insight41.pdf. Accessed June 17, 2012.

13. Krebs-Smith, S.M., P.M. Guenther, A.F. Subar, et al. Americans do not meet federal dietary recommendations. J. Nutr. 140: 1832-1838, 2010.

14. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans, 2010.* 7th Edition. Washington, DC: U.S. Government Printing Office, December 2010.

15. Dairy Research Institute, NHANES (2003-2006). Data Source: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, [2003-2004; 2005-2006]. http://www.cdc.gov/nchs/nhanes.htm.

16. Van Staveren, W.A., and L.P.G.M deGroot. Evidence-based dietary guidance and the role of dairy products for appropriate nutrition in the elderly. J. Am. Coll. Nutr. 30: 429s-437s, 2011.

17. Anderson, A.L., T.B. Harris, F.A. Tylavsky, et al. Dietary patterns and survival of older adults. J. Am. Diet. Assoc. 111: 84-91, 2011.

18. Paddon-Jones, D., K.R. Short, W.W. Campbell, et al. Role of dietary protein in the sarcopenia of aging. Am. J. Clin. Nutr. 87: 1562s-1566s, 2008.

19. International Working Group on Sarcopenia. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology and consequences. J. Am. Med. Dir. Assoc. 12: 249-256, 2011.

20. Cruz-Jentoft, A.J., J.P. Baeyens, J.M. Bauer, et al. Sarcopenia: European consensus on definition and diagnosis. Age and Ageing 39: 412-423, 2010.

21. Breen L., and S.M. Phillips. Skeletal muscle protein metabolism in the elderly: Interventions to counteract the anabolic resistance of ageing. Nutr. Metab. 8: 68-78, 2011.

22. Pennings, B., R. Koopman, M. Beelen, et al. Exercise before protein intake allows for greater use of dietary protein-derived amino acids for de novo muscle protein synthesis in both young and elderly men. Am. J. Clin. Nutr. 93: 322-331, 2011.

23. Pennings, B., B.B. Groen, A. de Lange, et al. Amino acid absorption and subsequent muscle protein accretion following graded intakes of whey protein in elderly men. Am. J. Physiol. Endocrinol. Metab. 302(8): E992-999, 2012.

24. Pennings, B., Y. Boirie, J.M. Senden, et al. Whey protein stimulates postprandial muscle protein accretion more effectively than do casein and casein hydrolysate in older men. Am. J. Clin. Nutr. 93: 997-1005, 2011.

25. Symons, T.B., M. Sheffield-Moore, R.R. Wolfe, et al. A moderate serving of high-quality protein maximally stimulates skeletal muscle protein in young and elderly subjects. J. Am. Diet. Assoc. 109: 1582-1586, 2009.

26. Burd, N.A., Y. Yang, D.R. Moore, et al. Greater stimulation of myofibrillar protein synthesis with ingestion of whey protein isolate v. micellar casein at rest and after resistance exercise in elderly men. Br. J. Nutr. 108: 958-962, 2012.

27. Tang, J.E., D.R. Moore, G.W. Kujbida, et al. Ingestion of whey hydrolysate, casein, or soy protein isolate: effects on mixed muscle protein synthesis at rest and following resistance exercise in young men. J. Appl. Physiol. 107: 987-992, 2009.

28. Tieland, M., M.L. Dirks, N. van der Zwaluw, et al. Protein supplementation increases muscle mass gain during prolonged resistance-type exercise training in frail elderly people: a randomized, double-blind, placebo-controlled trial. J. Am. Med. Dir. Assoc. 13: 713-719, 2012.

29. Tieland, M., O. van de Rest, M.L. Dirks, et al. Protein supplementation improves physical performance in frail elderly people: a randomized, double-blind, placebo-controlled trial. J. Am. Med. Dir. Assoc. 13: 720-726, 2012.

30. Katsanos, C.S., H. Kobayashi, M. Sheffield-Moore, et al. A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly. Am. J. Physiol. Endocrinol. Metab. 291: E381-E387, 2006.

31. Casperson, S.L., M. Sheffield-Moore, S.J. Hewlings, et al. Leucine supplementation chronically improves muscle protein synthesis in older adults consuming the RDA for protein. Clin. Nutr. 31: 512-519, 2012.

32. Candow, D.G., S.C. Forbes, J.P. Little, et al. Effect of nutritional interventions and resistance exercise on aging muscle mass and strength. Biogerontology 13: 345-358, 2012.

33. Yang, Y.L. Breen, N.A. Burd, et al. Resistance exercise enhances myofibrillar protein synthesis with graded intakes of whey protein in older men. Br. J. Nutr. 108: 1780-1788, 2012.

34. Moore, D.R., M. J. Robinson, J.L. Fry, et al. Ingested protein dose response of muscle and albumin protein synthesis after resistance exercise in young men. Am. J. Clin. Nutr. 89: 161-168, 2009.

35. National Osteoporosis Foundation Fast Facts. www.nof.org/node/40/. Accessed August 9, 2012.

36. Heaney, R.P., and D.K. Layman. Amount and type of protein influences bone health. Am. J. Clin. Nutr. 87(suppl): 1567s-1570s, 2008.

37. Heaney, R.P. Dairy and bone health. J. Am. Coll. Nutr. 28: 82s-90s, 2009.

38. Calvez, J., N. Poupin, C. Chesneau, et al. Protein intake, calcium balance and health consequences. Eur. J. Clin. Nutr. 66: 281-295, 2012.

39. Thorpe, M.P., and E.M. Evans. Dietary protein and bone health: harmonizing conflicting theories. Nutr. Rev. 69(4): 215-230, 2011.

40. Hannan, M.T., K.L. Tucker, B. Dawson-Hughes, et al. Effect of dietary protein on bone loss in elderly men and women: the Framingham Osteoporosis Study. J. Bone Miner. Res. 15: 2504-2512, 2000.

41. Meng, X., K. Zhu, A. Devine, et al. A 5-year cohort study of the effects of high protein intake on lean mass and BMC in elderly postmenopausal women. J. Bone. Miner. Res. 24: 1827-1834, 2009.

42. Munger, R.G., J.R. Cerhan, and B.C. Chiu. Prospective study of dietary protein intake and risk of hip fracture in postmenopausal women. Am. J. Clin. Nutr. 69: 147-152, 1999.

43. Misra, D., S.D. Berry, K.E. Broe, et al. Does dietary protein reduce hip fracture risk in elders? The Framingham Osteoporosis Study. Osteoporos. Int. 22: 345-349, 2011.

44. Zhu, K., X. Meng, D.A. Kerr, et al. The effects of a two-year randomized controlled trial of whey protein supplementation on bone structure, 1GF-1, and urinary calcium accretion in older postmenopausal women. J. Bone Miner Res. 26: 2298-2306, 2011.

45. Cao, J.J., L.K. Johnson, and J.R. Hunt. A diet high in meat protein and potential renal acid load increases fractional calcium absorption and urinary calcium excretion without affecting markers of bone resorption or formation in postmenopausal women. J. Nutr. 141: 391-397, 2011.

46. Dawson-Hughes, B., and S.S. Harris. Calcium intake influences the association of protein intake with rates of bone loss in elderly men and women. Am. J. Clin. Nutr. 75: 773-779, 2002.

47. U.S. Department of Agriculture, Agricultural Research Service. 2012. *USDA National Nutrient Database for Standard Reference, Release 25*. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov.gov/ba/bhnrc/ndl.

48. Drewnowski, A. The contribution of milk and milk products to micronutrient density and affordability of the U.S. diet. J. Am. Coll. Nutr. 30 (5 suppl.1): 422s-428s, 2011.

Dairy Research Institute® *was established under the leadership of America's dairy farmers with a commitment to nutrition, product and sustainability research. The Dairy Research Institute is a 501(c)(3) non-profit organization created to strengthen the dairy industry's access to and investment in the technical research required to drive innovation and demand for dairy products and ingredients globally. The Institute works with and through industry, academic, government and commercial partners to drive pre-competitive research in nutrition, products and sustainability on behalf of the Innovation Center for U.S. Dairy®, National Dairy Council® and other partners. The Dairy Research Institute is primarily funded by the national dairy checkoff program managed by Dairy Management Inc.*

About National Dairy Council
National Dairy Council® (NDC), the non-profit organization funded by the national dairy checkoff program, is committed to nutrition education and research-based communications. NDC provides science-based nutrition information to, and in collaboration with, a variety of stakeholders committed to fostering a healthier nation, including health professionals, educators, school nutrition directors, academia, industry, consumers and media. Established in 1915, NDC comprises a staff of registered dietitians and nutrition research and communications experts across the country. NDC has taken a leadership role in promoting child health and wellness through programs such as Fuel Up to Play 60. Developed by NDC and the National Football League (NFL), Fuel Up to Play 60 encourages youth to consume nutrient-rich foods and achieve at least 60 minutes of physical activity every day. For more information, visit www.NationalDairyCouncil.org.