

Nutrient Needs of the Older Adult

Chair: Professor Cornel Sieber



Satellite Symposium Proceedings
32nd ESPEN Congress

6 September 2010
Nice, France

Nutrient Needs of the Older Adult

The elderly population is diverse – from healthy, chronologically aged adults living independently, to frail individuals with multiple health issues housed in assisted care facilities or nursing homes. Meeting the nutrient needs of older individuals is critical to ensuring their overall health. Nutritional needs of individuals are known to vary with functional and nutritional status, physical activity and lifestyle of the individual, and may potentially be higher in frail and ill elderly.

A Nestlé Nutrition Institute-sponsored satellite symposium, held in conjunction with the 32nd European Society for Clinical Nutrition and Metabolism (ESPEN) Congress in Nice, France, on 6 September 2010, focused on the nutrient needs of older adults. A faculty of renowned experts in the field of nutrition presented on the differing nutritional needs of the elderly and the impact of nutrition on the functionality of the elderly person, with a particular focus on Vitamin D and protein needs.

Nutrient needs of the older adult: Are they really different?



Dr Dorothee Volkert
Institute for Biomedicine of Aging
University of Erlangen-Nürnberg, Germany

Age-related physiological changes, together with a reduction in lean body mass, basal metabolic rate and overall physical activity that occur with aging, all contribute to an overall reduction in the energy needs and energy intake in older adults compared with younger people. The decrease in energy intake with age was confirmed in the German Nationwide Food Consumption Study II, which reported a median decline in intake of approximately 450 kcal in men and 220 kcal in women between the age groups of 25–34 years and 65–80 years.¹ This is a cause for concern as with decreased energy intake there is a subsequent decrease in intake of other nutrients leading to nutrient deficiencies which may aggravate functional decline and contribute to further deterioration of health in this vulnerable age group.

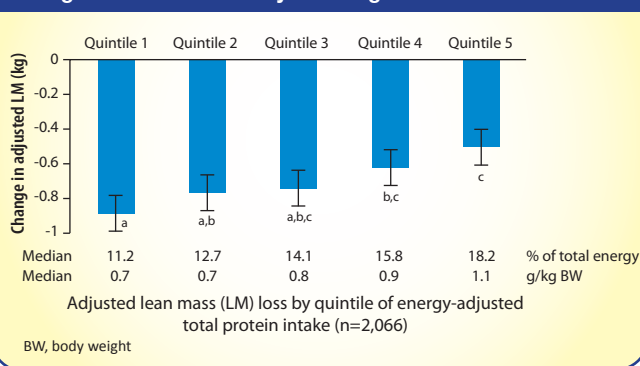
Protein needs and intake in older adults

The current recommendations for protein intake by a joint World Health Organization/Food and Agriculture Organization of the United Nations/United Nations University (WHO/FAO/UNU) expert consultation are a Recommended Dietary Allowance (RDA) of 0.8 g/kg.² However, this recommended protein intake may be insufficient to cover the needs of all elderly, as evidenced from nitrogen balance studies (traditionally used to determine protein requirements) which suggest that not all elderly can achieve nitrogen balance with 0.8 g/kg of protein intake. The optimal protein intake to meet the requirements of maintaining nitrogen balance, preservation of muscle mass and health, and prevention of sarcopenia, remains to be ascertained, but many experts suggest between 1.2 – 1.5 g/kg/d.

Although the median protein intake in German elderly remained well above the German RDA, it has been documented that approximately 15% in the age group of 65–80 years did not achieve this recommended intake level.¹

Protein intake is an important determinant of muscle mass and function as demonstrated in a study by Castaneda and co-workers, in which the muscle mass and strength of a group of healthy elderly women consuming 0.45 g/kg body weight/day decreased over a period of 9 weeks. In a parallel group with approximately twice the amount of protein intake (0.92 g/kg body weight/day), muscle mass remained stable and muscle strength improved.³ Furthermore, recent epidemiological evidence from the Health, Aging and Body Composition Study of 2,066 elderly participants, with median protein intake ranging between 0.7 g/kg in the lowest quintile and 1.1 g/kg in the

Figure 1: Dietary protein intake is associated with lean mass change in older community-dwelling adults⁴



highest quintile, reported a loss in lean mass of 0.85 kg in the quintile with lowest protein intake versus a loss of 0.45 kg in the quintile with the highest protein intake. This translates into a 40% less decrease in lean mass over 3 years in participants in the highest quintile of protein intake compared with the lowest quintile, establishing a clear linkage between dietary protein intake and lean mass change in older adults [Figure 1].⁴

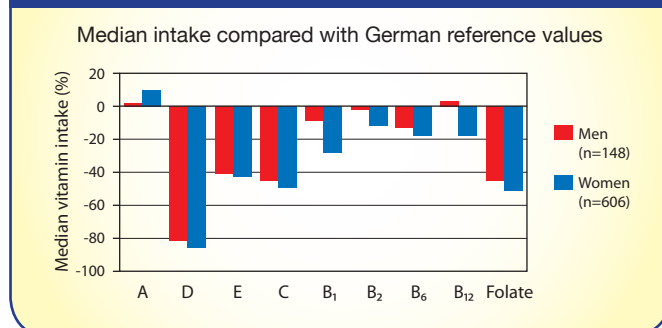
Dietary requirement and intake of key nutrients

The dietary intake recommendations for other nutrients, such as calcium, phosphorus, magnesium, iron, zinc and selenium, as well as vitamins A, B and C, do not differ substantially in the elderly when compared with younger adults. The recommended intake for vitamin D, however, is markedly higher in older people, with adults aged greater than 65 years having a Daily Recommended Intake (DRI) of 10 µg (400 IU) of vitamin D, compared with 5 µg (200 IU) in younger adults. This increased amount is intended to prevent deficiency in the elderly.

“Nutritional needs may vary with health status, with energy and protein requirements in chronic and acute disease being higher than in healthy persons.”

German data on dietary intake in community-living elderly show that the median intake of most minerals and vitamins clearly exceeds the RDA. However, median intake of fibre and calcium is below the recommended amount, with two thirds of the population not reaching the reference value for fibre and calcium. In addition, the median intakes of vitamin D and folate fall below the recommended levels. Similarly, data from the US NHANES study indicate that the intake of dietary fibre, vitamin D, calcium, vitamin E, vitamin K and potassium are low in the elderly.⁵ Of note, these results are derived from community-living, healthy elderly; the requirements and intake may well differ

Figure 2: Vitamin intake of nursing home residents in Germany



in frail, handicapped, chronically or acutely ill older adults.

The German Nutrition Report examined the dietary intake of nursing home residents and found an overall low intake of all nutrients. In particular, the daily intake of dietary fibre, calcium, vitamin D, folate, vitamin E and calcium were markedly low in this elderly cohort [Figure 2]. Importantly, nutritional needs may vary with health status, with energy and protein requirements in chronic and acute disease being higher than in healthy persons.

Nutritional needs may vary according to health status

Older individuals often suffer from various diseases, and nutritional deficiency may coexist with other comorbidities. For example, in patients with gastrointestinal diseases characterised by impairment in digestion and/or absorption, there is a significant risk of nutrient deficiency and malnutrition. Another common ailment in the elderly is gastric atrophy, which is reported in up to one third of the elderly population. Hydrochloric acid secreted in the stomach is reduced in these patients, which results in impaired absorption of several nutrients, such as vitamin B12, calcium and iron. Use of multiple medications is another important cause of poor nutrient absorption from the gastrointestinal tract. All these factors may contribute to nutritional deficiency states in the elderly, despite adequate intake of key nutrients.

Nutrient deficiencies may aggravate functional decline and contribute to further deterioration of health in this vulnerable age group. The detrimental impact of poor nutritional intake has been demonstrated in the CHIANTI study involving a cohort of 800 community-living elderly in Northern Italy, in which being in the lowest quintile of intake of energy and several nutrients significantly increased the risk of frailty.⁶ Further research is required to predict the exact amounts of specific nutrients which are necessary to slow the progression of physical or cognitive functional decline, reduce the risk of chronic age-related diseases or improve immune function.

Strategies to ensure adequate dietary intake in older adults

Measures that can be adopted to ensure adequate dietary intake in older adults include ensuring availability of palatable meals with foods rich in high-quality protein, essential fatty acids, vitamins and minerals, and other essential nutrients. Early recognition of nutritional problems such as low intake, loss of appetite, unfavourable dietary habits and weight loss in the elderly can be facilitated by routine screening for malnutrition. Proactive steps can then be taken to eliminate the underlying causes of malnutrition.

Supplementation studies of single nutrients have generally failed

to show benefits.⁷ However, supplemental intake of specific nutrients may be reasonable and are indicated in specific circumstances, eg, vitamin B12 in atrophic gastritis, vitamin D in homebound individuals with reduced sun exposure, and calcium in subjects with lactose intolerance. In addition, if natural sources of essential nutrients cannot be consumed in adequate amounts, oral nutritional supplements are often indicated. A Cochrane review that included 62 randomised trials involving a total of 10,187 older participants reported that oral nutritional supplementation produced a small but consistent weight gain, a statistically significant reduction in mortality in the undernourished, and a possible beneficial effect on complications.⁸

Summary

The nutrient needs of the community living, healthy elderly do not differ significantly from that of young adults. However, nutritional needs may vary depending upon the health, functional and nutritional status of individuals. The exact amount of nutrients necessary for optimal preservation of health, physical and mental functions remain to be ascertained. Until further in-depth evidence is available, currently recommended intake levels should be ensured in all elderly at risk of malnutrition, such as those with a frail functional status or with multiple comorbidities. Routine nutritional supplementation of all elderly persons is not necessary; however, if natural sources of essential nutrients cannot be consumed in adequate amounts, specific oral nutritional supplements are indicated. Nutritional supplementation may improve nutritional status and reduce the risk of complications and mortality, at least in malnourished individuals.

References

1. Nationwide Food Consumption Study II. Max-Rubner-Institut 2008.
2. Report of a Joint WHO/FAO/UNU Expert Consultation. Available at: http://whqlibdoc.who.int/trs/WHO_TRS_935_eng.pdf. Accessed 4 October 2010.
3. Castaneda C, et al. *Am J Clin Nutr* 1995;62:30-39.
4. Houston DK, et al. *Am J Clin Nutr* 2008;87:150-155.
5. Lichtenstein AH, et al. *J Nutr* 2008;138:2297-2306.
6. Bartali B, et al. *J Gerontol A Biol Sci Med Sci* 2006;61:589-593.
7. Wald DS, et al. *Am J Med* 2010;123:522-527.
8. Milne AC, et al. *Cochrane Database Syst Rev* 2009;(2):CD003288.

Vitamin D in the older adult: What is needed, what is safe and where do I get it?



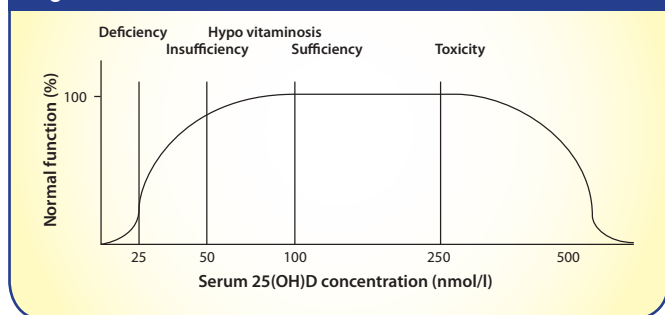
Professor Kevin Cashman

University College Cork
Cork, Ireland

The primary action of vitamin D is maintenance of calcium and bone homeostasis. In its active form, vitamin D (1,25-dihydroxyvitamin D-1,25(OH)₂D) helps to regulate and control serum calcium levels by working in concert with other calciotropic hormones on three target tissues: the intestines, kidneys and bone. Severe vitamin D deficiency results in aberrations in calcium metabolism, leading to metabolic bone disease, which is exhibited in children as rickets, and adults and the elderly people as osteomalacia. The inactive, storage form of vitamin D is 25-hydroxyvitamin D, and a serum level of this metabolite below 25 nmol/L is indicative of severe vitamin D deficiency [Figure 3].¹

Vitamin D status is also very important in the context of another metabolic bone disease – osteoporosis, characterised by decreased

Figure 3: Vitamin D status¹



bone mass and bone micro-architectural deterioration, both of which contribute to increased bone fragility. As mentioned above, 1,25 (OH)₂ D facilitates the intestinal absorption of calcium and, working in conjunction with parathyroid hormone, regulates bone turnover rates, which together impact on bone mineral density (BMD). Additionally, this active form of vitamin D has an important independent effect on muscle strength and function. Decreased muscle strength and BMD, acting independently and concurrently, negatively impact on fracture risk.²

There is a growing body of evidence to suggest possible links between vitamin D status and chronic diseases, such as cardiovascular disease, diabetes, inflammatory disease and certain cancers, as well as cognitive performance in the elderly. However, it is necessary to confirm these associations with data from randomised controlled trials to provide evidence of causality.¹

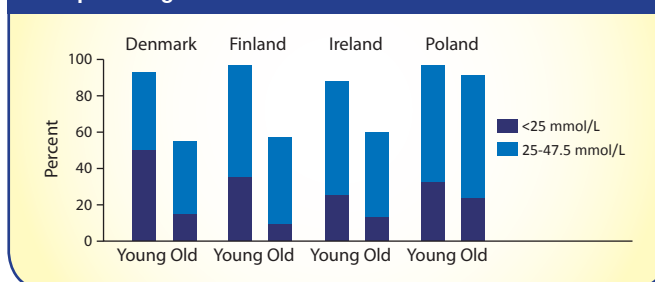
Vitamin D: Dietary intake versus dietary targets

While the traditional serum/plasma 25-hydroxyvitamin D level used to define vitamin D deficiency is 25 nmol/L (which is based on prevention of rickets and osteomalacia), there is intense international debate around the serum value that represents optimal vitamin D status. In terms of non-skeletal disease, a body of epidemiological evidence suggests that a serum 25-hydroxyvitamin D level above 50 nmol/L is associated with a reduced risk of certain chronic non-skeletal diseases, such as tuberculosis, rheumatoid arthritis, multiple sclerosis, inflammatory bowel diseases, hypertension, and specific types of cancer, with some evidence indicating an even higher threshold level of up to 100–120 nmol/L benefiting both skeletal and non-skeletal health outcomes.¹

It is important to place these cut-off values into the context of population data on vitamin D status for Europe. In a cross-sectional observational study conducted on 199 teenage girls and 221 community-dwelling elderly women in Denmark, Finland, Ireland and Poland it showed that the vitamin D status is relatively low during winter in these northern European countries. For example, most girls (92%) and 67% of the elderly women had serum 25-hydroxyvitamin D levels below 50 nmol/L [Figure 4]. None of the participants had serum levels greater than 80 nmol/L as suggested by some experts as the definition of optimal status.³ These data clearly highlight that low vitamin D status is potentially a huge public health concern during winter months in northern Europe.

It is not surprising to see low vitamin D status in European populations. There are two sources of vitamin D, sun and diet. Vitamin D is primarily produced by the skin on exposure to ultraviolet B radiation from summer sunlight. However, the strength of sunshine (specifically the proportion of ultraviolet B radiation reaching the earth) during the winter months in certain parts of the globe (those above 40 degrees) is insufficient to allow the skin to produce vitamin D. The resultant

Figure 4: Percentage of young and elderly achieving adequate serum 25-hydroxyvitamin D levels in Northern Europe during winter²



diminished dermal production is reflected in the much reduced vitamin D status during the winter months. Furthermore, quite rightly from a public health perspective, dermatologists have been cautioning against excessive sun exposure and advising the use of sunscreen to protect against ultraviolet rays, in an attempt to lower skin damage and cancer risk. A sunscreen of protection factor 8 (if applied in the recommended amount) has the potential to reduce dermal synthesis of vitamin D by 92%.³ Skin pigmentation, clothing and time outside also impact on the skin's ability to synthesise vitamin D. In addition, an elderly person has only about a quarter of the capacity of a younger adult to synthesise vitamin D in the skin when exposed to exactly the same amount of unprotected summer sun exposure. This is because of changes in the thickness of skin in the elderly making it less efficient at producing vitamin D. Therefore, while by nature's design sun is an important source of vitamin D, in the absence of sufficient ultraviolet B radiation for dermal synthesis (for reasons outlined above), vitamin D becomes an essential nutrient. However, food sources of vitamin D are few and typical average vitamin D intakes in populations within the European Union (EU) are generally around 2–5 µg (80–200 IU)/d.

The recommended dietary intake of vitamin D for older European adults (>65 years of age) is 10 µg (400 IU)/day. In the United States (US), the recommended intake for vitamin D for adults (18–50 years) is 5 µg (200 IU)/day, 10 µg (400 IU) for older adults (50–70 years) and 15 µg (600 IU) for elderly (>70 years). It is important to note that many of the agencies responsible for establishing vitamin D recommendations are currently re-evaluating their requirement estimates. It is likely that if serum 25-hydroxyvitamin D cut-offs of higher than the traditional 25 nmol/L are deemed appropriate then future vitamin D dietary recommendations may be higher than the current recommendations.

A recent 22-week randomised, placebo-controlled, double-blind, interventional study in 225 Irish men and women aged 64 years or older, which aimed to establish the dietary intake of vitamin D required to maintain optimal serum 25-hydroxyvitamin D concentrations during winter-time, showed that a vitamin D intake of 8.6 µg (344 IU) /day maintained winter-time 25-hydroxyvitamin D concentrations above 25 nmol/L in 97.5% of the cohort. However, the intake required to maintain winter-time serum 25-hydroxyvitamin D concentrations above 50 nmol/L in 97.5% of the cohort was 24.7 µg (988 IU)/day.⁴ These estimates of dietary vitamin D requirement far exceed the typical average vitamin D intakes in populations within the EU, which are generally around 2–5 µg (80–200 IU)/d.

Bridging the gap between vitamin D requirement and intake

It has been repeatedly emphasised that there are only a limited number of public health strategies available to correct low dietary vitamin D intake, which include the following. 1) Improving intake of naturally-

occurring vitamin D-rich foods – however this is the least likely strategy to counteract low dietary vitamin D intake due to the fact that there are very few food sources that are rich in vitamin D, and furthermore most of these are not frequently consumed by many in the population. 2) Supplementation with vitamin D – this has been shown to significantly improve vitamin D intake across a variety of age, race, ethnic and gender groups. However, evidence seems to suggest that the population intake of vitamin D from supplements is quite low. This is mainly a function of the relatively low vitamin D content of most supplements [2.5–7.5 µg (100–300 IU)] relative to requirement. Some experts are of the view that while not highly effective at a population level, vitamin D supplementation may be appropriate in high risk groups such as the elderly. Interestingly, the Standing Committee of European Doctors recently put forth a policy paper concluding that the serum 25-hydroxyvitamin D cut-off that was most appropriate for the elderly, particularly the frail elderly, was 50 nmol/L, and that the mode by which this might be achieved is to provide a supplement containing 15–20 µg (600–800 IU) of vitamin D per day. 3) Vitamin D fortification – this has been viewed by some as a feasible and effective measure once applied in an evidence-based approach. In response to concerns about widespread vitamin D deficiency, many countries have implemented either mandatory or discretionary food fortification. Fortification of foods with vitamin D in the US and Canada has an important impact on the mean daily intake of vitamin D by the average adult. Fortified foods constitute the largest contributor (65–87%; and fortified milk alone contributes 40–64%) to dietary vitamin D intake in the US population. However, data on the impact of mandatory vitamin D fortification practices within Europe on mean daily intakes of the vitamin in different member states⁵ suggest current levels of addition may be too low to effectively allow populations to reach the dietary targets.

“The Standing Committee of European Doctors recently concluded that the serum 25(OH)₂ D cut-off most appropriate for the elderly was 50 nmol/L, and this might be achieved with a supplement containing 15–20 µg (600 – 800 IU) of Vitamin D per day.”

There are some concerns regarding hypercalcaemia associated with increasing levels of vitamin D in supplements or the addition of more vitamin D to fortified foods. This has been driven to a great extent by a relatively low tolerable upper intake level for vitamin D of 50 µg (2,000 IU) per day for adults aged 18 years and older in the US and the EU. Of note, these recommendations are based on an evidence base of a few clinical trials conducted prior to 1997. Since then, a number of interventional studies have been published that have confirmed the safety of supplementation with high doses of vitamin D in excess of 250 µg (10,000 IU) per day in adults, which is five times higher than the current tolerable upper intake levels (UL). In a major review of the area, John Hathcock and colleagues concluded that “Collectively, the absence of toxicity in trials conducted in healthy adults that used vitamin D doses >250 µg/day (10,000 IU vitamin D₂) supports the confident selection of a revised upper level of 250 µg/day.”⁶

Summary

The amount of vitamin D in the diet required to maintain 25-hydroxyvitamin D in the free-living elderly above the minimum threshold level of 25 nmol/L is 10 µg (400 IU) per day and as high as 25 µg (1,000 IU) per day if the cut-off of 50 nmol/L is used, one which is gaining increasing acceptance for the elderly. However, the current dietary

intake of vitamin D in the elderly populations is substantially below even 10 µg (400 IU) per day and this poses a major challenge. There is a need for effective strategies to improve vitamin D status, particularly in the vulnerable elderly population. Vitamin D supplementation and/or fortification is a possible means of addressing this mismatch between current intakes, and existing and potentially higher new dietary recommendations for vitamin D. The safety of supplementation with high doses of vitamin D in excess of 250 µg (10,000 IU) per day in adults, which is five times higher than the current UL, has been confirmed in a number of clinical trials, and revised vitamin D recommendations for RDI and UL are expected soon.

References

1. Zittermann A. *Br J Nutr* 2003;89:552-572.
2. Andersen R, et al. *Eur J Clin Nutr* 2005;59:533-541.
3. Holick MF. *Am J Clin Nutr* 2004;80:1678S-1688S.
4. Cashman KD, et al. *Am J Clin Nutr* 2009;89:1366-1374.
5. Flynn A, et al. *Food Nutr Res* 2009 Nov 12;53.
6. Hathcock JN, et al. *Am J Clin Nutr* 2007;85(1):6-18.

Hip fracture in the older adult: Prevalence, causes, treatment and role of nutrition



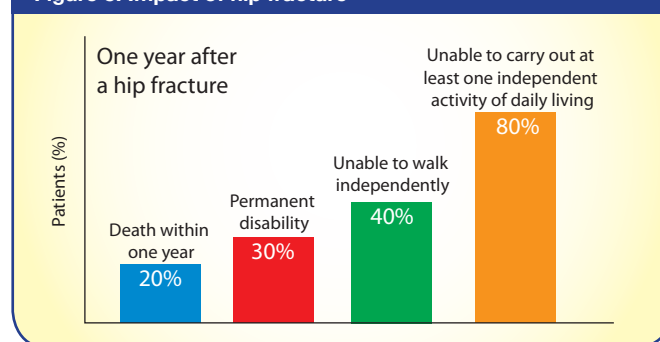
Professor René Rizzoli

Geneva University Hospitals and Faculty of Medicine
Geneva, Switzerland

The incidence of osteoporotic fractures increases with age; one out of every two women and one in every five men above the age of 50 years will experience a fracture during their lifetime.¹ Amongst the three most common osteoporotic fractures, the rate of forearm fracture is reported to increase around the age of 50 years, that of vertebral fracture at approximately age 60, and that of hip fracture mostly after the age of 70 years.

Survival after a hip fracture is markedly decreased particularly in the first year following the fracture, with approximately 20% of people dying within the first year after a hip fracture.² Similarly, there is a two-fold increased risk of death in women and a three times higher risk in men following a proximal femoral fracture. In patients who survive a hip fracture, it has been seen that 1 year following the incident, 30% are permanently disabled, 40% are unable to walk independently and 80% are unable to carry out at least one independent activity of daily living [Figure 5].³ Vertebral fracture is also another fracture associated with an increased risk of mortality.²

Figure 5: Impact of hip fracture³



Osteoporotic fractures occur as a result of two factors: the mechanical overload caused by a fall, and the mechanical incompetence of a fragile bone that cannot withstand the increased load. Following the fracture repair process, rehabilitation is required to restore independence, reduce disability and prevent subsequent fractures.

The risk of osteoporotic fractures increases with age; however, the risk is lower in age-matched individuals with higher BMD.⁴ Other risk factors independent of BMD include prior fracture, family history of hip fracture, current smoking, past history of steroid use, daily intake of more than two units of alcohol, and rheumatoid arthritis.⁵

The treatment costs related to osteoporotic fractures present a major health economic burden, with osteoporotic fracture-related hospital stay, particularly in women, ranking substantially above hospitalisation due to other major ailments such as COPD, breast cancer, stroke, heart failure, diabetes and myocardial infarction.⁶ Furthermore, the burden of osteoporotic fracture is projected to increase worldwide, from 1.66 million hip fractures reported in 1990 projected to 6.26 million by 2050.⁷

Impact of nutrition on muscle and bone homeostasis

Nutrition has an impact on the pathogenesis and management of osteoporotic fractures. Undernutrition is associated with bone fragility, resulting in increased fracture risk and slowing of the fracture repair process. Unfortunately, the prevalence of undernutrition has been found to be high in elderly people living in nursing homes. Patients with hip fracture are particularly undernourished.^{8,9}

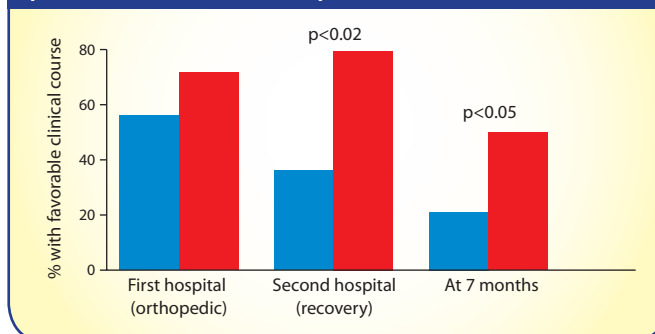
The impact of nutrition is possibly mediated through insulin-like growth factor 1 (IGF-1). IGF-1 influences muscle mass and bone growth and stimulates the production of 1-alpha dihydroxy vitamin D which helps in the intestinal absorption of calcium and phosphorous. IGF-1 also directly influences renal tubular reabsorption of phosphate, thereby improving bone growth and mineralisation. Notably, only certain specific amino acids influence the synthesis of IGF-1, including the aromatic amino acids (phenylalanine, tryptophan and tyrosine). Dairy products are a rich source of these aromatic amino acids.

A 10-week study looking at the impact of dietary protein on plasma IGF-1 levels and muscle fibre cross-sectional area in healthy elderly women on a weight-maintenance diet containing either 0.47 (marginal) or 0.94 (adequate) g protein/kg per day, confirmed the role of dietary protein in maintaining muscle mass in the elderly. At 10 weeks follow up, a significant 30% reduction in IGF-1 and 33% reduction in muscle fibre cross-sectional area was observed in subjects fed the marginal protein diet, while corresponding increases of 20% and 22%, respectively, were seen in those fed the adequate protein diet.¹⁰

A systematic review that examined the relationship between protein and bone health in healthy human adults concluded that protein supplementation has a positive effect on lumbar spine BMD in randomised placebo-controlled trials, indicating that there is a benefit of protein on bone health; however, the impact on long-term fracture risk remains to be determined.¹¹

A prospective study evaluated the relationship between protein intake and subsequent incidence of hip fracture in 32,050 women aged 55–69 years, with 104,338 person-years of follow-up. The risk of hip fracture was inversely associated with total protein intake, with animal protein rather than vegetable protein appearing to account for the association. The correlation remained unaffected despite multi-

Figure 6: Benefits of oral protein supplementation in elderly patients with fracture of the proximal femur¹⁴



variate analysis for age, body size, parity, smoking, alcohol intake, oestrogen use and physical activity.¹²

A randomised, double-blind, placebo-controlled trial assessed the impact of oral protein supplements on bone metabolism in patients with recent hip fracture. Patients received calcium, vitamin D and 20g/day of protein supplementation, or isocaloric placebo. Protein supplementation was associated with significantly increased serum levels of IGF-1, attenuation of proximal femur bone loss, and shorter stay in rehabilitation hospitals compared with controls.¹³

The benefits of oral protein supplementation have been examined in elderly patients with fracture of the proximal femur in a prospective, controlled, randomised study. The clinical course was found to be more favourable in the group that received protein supplementation, with fewer complications and deaths and significantly shorter length of hospital stay, compared with the control group [Figure 6].¹⁴

Adequate nutrition for muscle and bone health

Although energy expenditure decreases with age, protein intake should not be reduced, as protein is a mandatory requirement for muscle and bone homeostasis.¹⁵ The decrease in energy intake should be compensated with a decrease in the number of servings of carbohydrate-rich food like bread, pasta or cereals, with the number of servings of animal source protein being maintained above two per day, even in the elderly. It is recommended that older adults consume at least 1.2 g/kg body weight of protein per day in their diet, which is adjudged to be the amount adequate to meet their daily protein requirement.

References

- Lippuner K, et al. *Osteoporos Int* 2009;20:1131-1140.
- Center JR et al. *Lancet*. 1999;353:878-882.
- Cooper C. *Am J Med* 1997;103:12S-17S.
- Kanis JA, et al. *Osteoporos Int* 2001;12:989-995.
- Kanis JA, et al. *Bone* 2004;35:1029-1037.
- Lippuner K, et al. *Osteoporos Int* 2005;16:S8-S17.
- Cooper C, et al. *Osteoporos Int* 1992;2:285-289.
- Kravitz RL, et al. *J Am Geriatr Soc* 1994;42:1229-1234.
- Rubenstein LZ, et al. Nestle Nutr Workshop Ser Clin Perform Programme 1999;1:101-115.
- Castaneda C, et al. *J Nutr Health Aging* 2000;4:85-90.
- Darling AL, et al. *Am J Nutr* 2009;90:1674-1692.
- Munger RG, et al. *Am J Clin Nutr* 1999;69:147-152.
- Schürch MA, et al. *Ann Intern Med* 1998;128:801-809.
- Tkatch L, et al. *J Am Coll Nutr* 1992;11:519-525.
- Rizzoli R. *Best Pract Res Clin Endocrinol Metab* 2008;22:813-829.