Review Article

Eating well: ageing gracefully!

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The potential impact of dietary manipulation on the maintenance of physical and cognitive function between middle and old age has profound consequences for optimization of health, independence and well-being for the latter years. This review article considers four key areas: the role of diet and longevity; potential dietary measures to prevent sarcopenia; diet and cognitive function; and dietary interventions with regard to primary or secondary prevention of age-related chronic disorders. Caloric restriction has been shown to slow ageing and maintain health status in both primates and rats. The evidence has limited applicability to humans, since it is unlikely that 30% reduced diets could be maintained long-term. The causes of sarcopenia, which manifests as loss of strength, disability and reduced quality of life, are multifactorial. However, resistance with ageing to regulatory amino acids known to modulate translation and initiation, particularly leucine, raise possibilities with regard to dietary intervention. The pattern of protein intake appears to be important in whole-body protein retention in older adults. A body of evidence is emerging that associates various dietary factors with a reduction in cognitive decline with age, or a delay in the progression of Alzheimer’s disease, particularly with regard to intake of vitamin E and C-containing foods, as well as fish intake. Epidemiological evidence demonstrates a role for dietary intervention in the primary prevention of chronic diseases, even in old age. However, the potentially harmful effects of micronutrient supplementation in the secondary prevention of coronary heart disease raise concern regarding appropriate dietary messages for the elderly. The role of the antioxidants, lycopene, lutein and zeaxanthin, in the prevention of cataracts and age-related macular degeneration support the almost universal dietary guideline ‘eat more fruit and vegetables’. In future dietary guidelines for the elderly need to be evidence-based and take into account protective food patterns, rather than target specific foods.

Key words: ageing, chronic diseases, cognitive function, micronutrient status, sarcopenia.

Introduction

Health promotion activities, including changes in diet and exercise patterns, can contribute to an increase in life expectancy and better health. Such benefits are most effective when healthy lifestyles are adopted early in life, however, positive effects can occur at any age.1 This review article will focus on four key areas that are currently receiving much attention in the research domain: (1) the role of diet and longevity; (2) potential dietary measures to prevent sarcopenia; (3) diet and cognitive function and (4) dietary interventions with regard to primary or secondary prevention of age-related chronic disorders. Finally, consideration will be given to the translation of dietary recommendations and goals into practical dietary guidelines for older persons themselves.

Longevity and energy restriction – how feasible is it for human populations?

Studies in a wide range of primate and non-primate animal species have shown repeatedly that caloric restriction slows the ageing process, lengthens the lifespan and maintains health status. However, the evidence has limited applicability to humans, since it is unlikely that 30% reduced diets could be maintained long-term. It is not the purpose of this paper to review the extensive literature on animal studies of caloric restriction, but rather to briefly consider the feasibility of the levels of caloric restriction in humans. An underlying principle of the caloric restriction hypothesis is that the diet must contain adequate amounts of protein, vitamins and minerals and only be deficient in energy. Such diets are hard to find in real life situations. Many negative effects of caloric restriction are demonstrated in populations where food intake is restricted beyond the control of the individuals due to poverty, famine, war and other external circumstances. An important consideration for older individuals is that a lowered immune response is evident in populations subject to chronic low energy intakes.2 The effects of chronic low energy intakes on morbidity in old age in human subjects have not been adequately investigated, probably due to the complexity of designing scientifically sound studies that are able to take into account all of the potential confounding variables, such as, genetic predisposition, physical activity, cardiovascular fitness, and access to medical services.
Epidemiological studies have reported that women with a low body mass index and reporting a history of weight loss have lower bone mass and greater fracture risk than heavier women and men. A 3 year study of 827 older women demonstrated that thinner women with larger weight loss had less bone at the femoral neck than average. Weight loss in obese women increases the rate of bone turnover and bone loss and it has been proposed that the reason for this could be related to a slow rise in parathyroid hormone and a reduction in sex hormones. A 10% reduction in body weight, the level recommended as being a long-term achievable target for weight loss interventions, has been shown to result in a 1–2% loss in bone mass density. The potentially detrimental health consequences and reduced enjoyment of food intake associated with caloric restriction need to be weighed up against the somewhat shaky evidence of potential longevity and disability-free life years in humans.

Roth et al. have published findings from preliminary studies which suggest the existence of other dietary agents, such as 2-deoxyglucose (a sugar analogue with limited metabolism), which may mimic the effects of caloric restriction. Leptin signalling could also have a potentially important role in the anti-ageing action of caloric restriction.

**Sarcopenia – causes, consequences and potential preventive dietary interventions**

Skeletal muscle mass and function declines between the ages of 20 and 70 years. The age-related loss of muscle mass has been characterized into three categories: wasting, cachexia and sarcopenia, the physiological characteristics of which differ (Table 1). Sarcopenia is defined as the specific loss of skeletal muscle unlike wasting, which is largely due to an inadequate intake and malabsorption, or cachexia, which is primarily an inflammatory process resulting in accelerated muscle protein degradation. A study of 833 elderly Hispanic and white men and women from New Mexico, USA found that 13.5–24.1% of those under the age of 70 years had sarcopenia, compared to 43–60% in subjects aged 80 years and older.

The functional consequences of loss of muscle mass in the elderly places those with more than a 2 SD below young controls at a 3–4 times greater risk of disability and 2–3 times greater risk of falls. Data from very old, frail, institutionalized women in Canada (mean age = 81.5 ± 7 years), has shown that suboptimal protein status, defined as a lean body mass below 63% of total body weight, resulted in significantly lower muscle strength, using either measures of handgrip (upper body) strength or timed ‘up and go’ (lower body strength) tests.

Evidence regarding the impact of undernutrition on independent functioning is beginning to emerge, even from developing countries. In 1992, the London School of Hygiene and Tropical Medicine, in collaboration with HelpAge International, began a programme of research on the nutrition of older people in two countries in Africa and in a slum setting in Bombay, India. In the two survey sites of Tanzania and Malawi, nutritional status was related to functional ability, with the strongest relationship found for handgrip strength (a measure of the strength of the upper limb). Undernutrition, using either BMI or MUAC measurements, was associated with higher risk of impairments in psychomotor speed and coordination, mobility, and the ability to carry out activities of daily living independently, even after controlling for age, sex and existing disease. Body mass index and MUAC explained 13% and 15%, respectively, of the variation in handgrip strength, controlling for age and height.

### Causes of weight loss with ageing

A negative energy balance, associated with diminished food intake, is thought to be the major cause of weight loss in the elderly. Prescription medicines, depression and social isolation are contributors to inadequate energy intake in older adults, as are reduced sensations of taste and smell and poor dentition. In addition, it has been suggested that a diminished ability to regulate food intake in older age is associated with the ‘anorexia of ageing’. Roberts et al. have demonstrated that clear differences exist between young and elderly men in body weight change and voluntary food intake in response to overfeeding and underfeeding. While both groups gained similar amounts of weight and body fat during overfeeding, young men tended to lose all the excess weight after the period of overfeeding, while the weight of the elderly men remained the same. This difference was attributed to the fact that younger men significantly decreased their voluntary energy intake after overfeeding, while the energy intake of the older men was elevated relative to their previous weight-maintenance requirement. Comparable results were obtained during the underfeeding part of the study. Young men gained back their weight lost during underfeeding, while older men maintained their weight loss.

In terms of metabolic adaptations to short-term food restriction, data from a 6 week underfeeding study in young and older men and women showed that older individuals experience an overall decrease in the ability to conserve energy during undereating. In other words, the decrease in resting energy expenditure during underfeeding was smaller in the old subjects than the young subjects, after controlling for the concomitant effect of other factors. This finding, together with those that suggest an inability to compensate...
(subconsciously) for the normal day-to-day fluctuations in energy intake in older adults, may at least partially explain the increased susceptibility of the elderly to either weight loss or weight gain.

The Australian dietary guidelines for older adults include ‘Enjoy a wide variety of nutritious foods’ as the first and most important nutrition message (Table 2).25 Certainly, in younger adults, an increased variety of food intake from each of the 10 food groups investigated was positively associated with energy intake \((r = 0.27–0.56; P < 0.05)\).23 An interesting observation was made regarding the dietary variety of different types of foods. A greater variety of intake from the sweets, snacks, condiments, entrees and carbohydrates group was associated with increased body fatness, however, an inverse relationship was seen with vegetables: the greater the variety of vegetables included in the diet, the lower the proportion of body fat. Despite the effects of age not being investigated in that study, the findings could perhaps be extrapolated to the elderly, in that dietary variety is usually reduced with advancing age, and most of the variety tends to come from items other than vegetables, thus weight loss in older individuals may be due, in part, to a restricted choice of foods. More than a decade ago, social isolation was demonstrated to be a risk factor for poor nutritional status. De Castro and de Castro reported that, on average, 30% less energy is eaten at meals taken alone, compared to meals eaten in the company of others.24 In developed countries, as individuals age, their families are typically dispersed, they retire from employment and they often experience the loss of a spouse, other kin or friends, leaving them living alone.

As well as an inadequate dietary intake, others factors that contribute to the development and progression of loss of muscle mass with ageing include: a reduction in physical activity; decreased circulating concentrations of three hormonal systems involved in muscle metabolism [i.e. insulin, growth hormone and insulin-like growth factor; sex steroid hormones (oestrogen and testosterone); and dehydroepiandrosterone (DHEA)]; oxidative stress damage to muscle tissue; and inflammatory processes that alter fat and protein metabolism, particularly elevated levels of proinflammatory cytokines (interleukin-1, tumour necrosis factor, interleukin-6 and interferon).

### Dietary interventions to prevent sarcopenia

Much has been written in the literature about the beneficial role of progressive resistance exercise training in the reversal and prevention of sarcopenia, however, relatively little attention has focused on dietary interventions. In terms of prevention of loss of muscle mass in old age, the nutritional factors that regulate protein retention are of particular interest. The progressive decrease in total body protein with age is also accompanied by a shift in the overall pattern of whole body protein synthesis and breakdown. A reduced total energy intake, which in turn reduces protein intake, together with the potential for reduced dietary protein utilization increases protein requirements in the elderly. The optimal protein requirements for older adults are an area of controversy. It has been suggested that 0.8 g/kg/day is an adequate protein intake for this age group,25 however, Millward et al. have argued that protein requirements appear to fall with age from 0.98 ± 0.17 g/kg to 0.69 ± 0.22 g/kg.26 The satiating effect of dietary protein has been shown to be inversely associated with habitual protein intake in adults \((r = -0.36; P < 0.05)\),27 which may be detrimental in older people who often have small appetites and who have suboptimal protein and energy intakes.

It appears that not only the amount of protein eaten daily may be important in the prevention of loss of lean mass in the elderly, but also the type of meal pattern in which it is consumed. In young adults, it has been shown that spreading protein and energy intake in multiple small meals over the day leads to a lower nitrogen retention than using three meals of the same energy and protein value.28 It seems that, in young adults fed at an adequate protein level, spreading daily protein intake over three meals a day is the optimal protein feeding pattern.

However, Arnal et al. demonstrated that providing most (80%) of the protein intake to elderly women at midday (i.e. a ‘pulse’ protein pattern) had a more beneficial impact on nitrogen balance than the same amount of protein (1.7 g protein/kg fat-free mass/day) spread over the daily mealtimes (i.e. ‘spread’ diet).29 This is reflective of a better postprandial anabolism due to the marked increase in blood free amino acid levels associated with the pulse pattern. When the same experiment was repeated in young women...

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**Table 2.** Dietary guidelines for older Australians

<table>
<thead>
<tr>
<th>No.</th>
<th>Dietary Guideline</th>
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<tbody>
<tr>
<td>1</td>
<td>Enjoy a wide variety of nutritious foods.</td>
</tr>
<tr>
<td>2</td>
<td>Keep active to maintain muscle strength and a healthy body weight.</td>
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<tr>
<td>3</td>
<td>Eat at least three meals a day.</td>
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<tr>
<td>4</td>
<td>Care for your food: prepare and store it correctly.</td>
</tr>
<tr>
<td>5</td>
<td>Eat plenty of vegetables (including legumes) and fruit.</td>
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<tr>
<td>6</td>
<td>Eat plenty of cereal, bread and pastas.</td>
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<tr>
<td>7</td>
<td>Eat a diet low in saturated fat.</td>
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<tr>
<td>8</td>
<td>Drink adequate amounts of water and/or other fluids.</td>
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<tr>
<td>9</td>
<td>If you drink alcohol, limit your intake.</td>
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<tr>
<td>10</td>
<td>Choose foods low in salt and use salt sparingly.</td>
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<tr>
<td>11</td>
<td>Include foods high in calcium.</td>
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<tr>
<td>12</td>
<td>Use added sugars in moderation.</td>
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of mean age 26 years, no difference was detected on whole body protein turnover, nor protein synthesis or breakdown for each of the feeding patterns.\textsuperscript{30} In these studies, it is important to note that nitrogen intake was adjusted to fat free mass, rather than total body weight, thus compensating for differences in body composition between the age groups.

Amino acids play an important role in regulating muscle protein synthesis, both \textit{in vitro} and \textit{in vivo}. Resistance with ageing to regulatory amino acids known to modulate translation and initiation, particularly leucine, raise possibilities with regard to dietary intervention. Recently, the defect in postprandial stimulation of protein synthesis observed in old rat muscle was overcome when the meal was supplemented with leucine.\textsuperscript{31} The effect was due mainly to the increase in leucine availability to peripheral tissues since all other amino acids, as well as insulin, did not differ significantly from those in rats fed a control meal. Since high protein diets may have deleterious effects on renal function in the elderly, chronic supplementation with leucine may be a good alternative for maintaining protein muscle mass in older adults. However, long-term benefits of this dietary intervention in humans, with regard to improved physical function and quality of life remain to be seen.

It may be argued that these findings provide a rationale for the development of food products, particularly fortified dairy products, for the elderly by the food industry, similar to specialized products to meet infant’s needs. However, the desirability for such foods by the elderly themselves would need to be market researched.

\textbf{Impact of nutritional status on cognitive function}

A number of studies have suggested that dietary intervention with various nutrients may help to delay the progression of age-associated mental deterioration. In terms of biological plausibility, there are two main theories. The free radical theory implicates antioxidant nutrients as being protective against damage to the brain. The brain is a good substrate for oxidation; it is a large consumer of oxygen; and polyunsaturated fatty acids, a major component of cell membranes, are highly susceptible to lipid peroxidation.\textsuperscript{32} In addition, there are areas in the brain that are rich in pro-oxidant iron. The second theory involves the role of vitamin B12, B6 and folic acid in homocysteine metabolism. Hyperhomocysteinaemia has been suggested to represent a metabolic link in the pathogenesis of old age dementias.\textsuperscript{33}

Consideration will be given here only to observational (prospective) and intervention studies pertaining to the role of antioxidants in cognitive function in older adults. The first population-based study in this regard, the Rotterdam study, was conducted in 5386 non-demented men and women aged 55 years or older at baseline. At follow-up 4 years later, baseline dietary intake data were analysed according to incidence of dementia and Alzheimer’s disease.\textsuperscript{34} After adjustment for age, sex, education, and energy intake, high intakes of the following nutrients were associated with an increased risk of dementia: total fat [RR = 2.4; (1.1–5.2)], saturated fat [RR = 1.9 (0.9–4.0)] and cholesterol [RR = 1.7 (0.9–3.2)]. Fish consumption greater than 18.5 g/day was inversely associated with incident dementia. (RR = 0.4 (0.2–0.9)). A lower intake of \(\beta\)-carotene was significantly associated with impaired cognitive function (\(\leq 0.9 \text{ mg/day} \) vs \(\geq 2.1 \text{ mg/day} \), OR = 1.9; 1.2–3.1).\textsuperscript{35} Vitamin E intake was protective; for every standard deviation increase in intake, a 17% (OR = 0.83; 0.70–0.99) and 19% (OR = 0.81; 0.66–0.99) reduced risk for dementia and Alzheimer’s disease, respectively, was found.\textsuperscript{36} Vitamin C and vegetable intake were also found to be protective.

Similarly, another Dutch prospective study, the Zutphen Elderly Study, carried out over 5 years in men aged 69–89 years, found that, after adjustment for confounders, a higher linoleic (polyunsaturated) fat was positively associated with cognitive impairment, whereas a fish intake of \(\geq 20 \text{ g/day} \) was protective.\textsuperscript{37}

Nutritional factors have also been implicated in memory decline with age. A study of 260 healthy elderly aged > 60 years found a significant association (\(r = 0.15 \)) between plasma vitamin C concentrations and a memory function test.\textsuperscript{38} In the Basel Longitudinal Study memory performance was shown to be associated with plasma vitamin C and \(\beta\)-carotene samples taken 22 years earlier.\textsuperscript{39} An inverse association between vitamin E per unit cholesterol and memory tests was demonstrated in a multiethnic sample, adjusted for confounders, included in the Third National Health and Nutrition Examination Survey.\textsuperscript{40} In this study, no association was found between memory and plasma vitamins A, C, \(\beta\)-carotene or selenium.

Regarding intervention studies to investigate the role of diet in the retardation of cognitive decline, a 2 year controlled trial of selegiline (a selective monoamine oxidase inhibitor), vitamin E (2000 IU/day), or both, as treatment for Alzheimer’s disease was undertaken in 341 patients.\textsuperscript{41} In analyses that included the baseline score on the Mini-Mental State Examination as a covariate, there were significant delays in the time to the primary outcome (i.e. death, institutionalization, loss of the ability to perform basic activities of daily living, or severe dementia), in subjects assigned to the selegiline, vitamin E or combination groups. No difference in outcome was found between the selegiline or vitamin E groups, and no additive effect with combined therapy was seen. It is noteworthy that the dosage of vitamin E provided was almost 1000 times higher than the recommended dietary allowance.

Regarding vitamin C status, a study conducted in institutionalized older South Africans demonstrated that the median plasma vitamin C concentrations of subjects with Alzheimer disease (0.60; IQR = 0.70 mg/dL) or senile dementia (0.54; IQR = 0.74 mg/dL) tended to be lower than control subjects with no cognitive impairment (0.84; IQR = 0.74 mg/dL).

Alzheimer and dementia subjects were at almost three times greater risk of having suboptimal plasma vitamin C (\(\leq 0.6 \text{ mg/dL} \)) than controls (OR = 2.99; 95%
It has been shown by other investigators that even in the healthy elderly, a higher level of plasma vitamin C has been found to be associated with better cognitive functioning. A 20 year follow-up study of 921 community-dwelling elderly people in the United Kingdom reported that cognitive impairment was a strong predictor of death from ischaemic stroke, and that low dietary vitamin C intake and low plasma ascorbate concentrations were also important risk factors for death from stroke. The question whether supplementation with vitamin C and other nutrients can prevent the progression of dementia or even reverse symptoms has not yet been answered in intervention trials.

Benefits of dietary intervention in risk factor reduction for age-related disorders

Diet contributes in many ways to the development of age-related diseases. Undoubtedly, the earlier a healthy lifestyle, including an adequate nutritional intake, is adopted the better, however, some examples are given here of nutrition-related benefits that can be gained even in middle and old age.

Data from the Health Professionals and Nurses’ Health studies provide compelling evidence for a protective effect of vitamin E on coronary heart disease in middle aged people. Those men and women who had used a single-entity vitamin E supplement (generally containing at least 100 IU of vitamin E) for two or more years had a lower risk of myocardial infarction, compared to those that had not used supplements (37% reduced risk of death from coronary heart disease for men; 41% for women). However, vitamin E intake from dietary sources or from multivitamins failed to show a protective effect, presumably because of the relatively small intake. Further, the possibility that high-dose vitamin E supplement intake may be a marker for adoption of an overall healthier lifestyle should not be overlooked.

In the USA, an 8 year follow-up study of over 11 000 people aged 67 years and older demonstrated that subjects who took vitamin E supplements had a 47% lower risk of death from coronary heart disease compared with non-users of supplements. In terms of how much vitamin E is needed for optimal health, it appears that doses greater than 100 mg per day may be needed to produce significant protective effects against cardiovascular disease and other degenerative diseases of ageing, as well as to optimize immune function in older adults. This far exceeds, by almost five-fold, the amount of vitamin E that can be provided from even an excellent diet. The question of whether or not widespread food fortification should be adopted, or whether supplementation with vitamin E is warranted for primary prevention on a population level remains to be sufficiently answered.

Caution needs to be exercised when making recommendations regarding vitamin E intake for secondary prevention purposes. The CHAOS study, in which 2002 patients with known coronary heart disease were randomly assigned to either a placebo or a vitamin E supplement group (either 400 or 800 IU/day), found that vitamin E supplementation resulted in a significant reduction in subsequent non-fatal heart attacks, but that there was an excess (albeit non-significant) of cardiovascular deaths in the vitamin E supplemented group. For the moment, the jury is still out on the vitamin E debate and more long-term, well-designed studies are required before a responsible message regarding supplementation can be relayed to the middle-aged and elderly public at large.

Regarding the role of other micronutrients in the secondary prevention of adverse effects associated with atherosclerosis, supplementation with B vitamins appears to be promising. New data suggests that restenosis is accelerated in people presenting with high homocysteine levels. Efficacy of B-vitamin supplementation to reduce restenosis was assessed in a double-blind, placebo-controlled clinical trial involving 205 heart patients aged 61 ± 11 years. Six months after successful surgical intervention patients were randomly assigned to a B-vitamin supplement (1 mg of folic acid, 10 mg of vitamin B6 and 400 µg vitamin B12 per day) or placebo for a period of 6 months. At 6 months follow-up, the minimal luminal diameters of the vessels in both groups had regressed, but minimal luminal diameters remained larger in the vitamin supplemented group. In addition, at 30 weeks follow-up, event-free survival was significantly higher (87.3%) in the vitamin-supplemented group, compared to the control group (75.5%).

Consideration is now given to the potential benefit of antioxidant micronutrients and phytochemicals in order to support the scientific evidence behind the almost universal dietary guideline: ‘Eat plenty of vegetables (including legumes) and fruit’. The protective effect of certain vitamins and minerals in the prevention and delayed progression of many age-related chronic diseases is largely due to their ability to either prevent the formation of free radicals or to scavenge them once they are formed, either directly (e.g. vitamins C, E, and β-carotene) or indirectly (e.g. copper/zinc superoxide dismutase, manganese-dependent superoxide dismutase, selenium-dependent glutathione peroxidase).

It is now generally accepted that supplementation with beta carotene confers little benefit in well nourished populations in the primary prevention of cardiovascular diseases. Further, questions remain unanswered regarding the safety of high dose supplements of this nutrient, specifically among smokers. Recently, attention has been focused on carotenoids other than β-carotene, namely lycopene, lutein and zeaxanthin (Table 3). Lycopene is responsible for the red colour of tomatoes, watermelon, pink grapefruit, guava and a limited number of other foods. Lutein and zeaxanthin are carotenoids that are deep yellow in colour and are found abundantly in dark green leafy vegetables and in smaller amounts in other colourful fruits and vegetables, such as corn, brussels sprouts, and peppers.

Lycopene

Prostate cancer is one of the most common malignancies in men in the developed world. In the Health Professionals Follow-Up study, of all the dietary carotenoids investigated, only dietary lycopene intake (mainly in tomato sauce, tomatoes...
Table 3. Effect of carotenoids on age-related conditions in older adults

<table>
<thead>
<tr>
<th>Carotenoid</th>
<th>Age-related condition</th>
<th>Food sources</th>
<th>Recommendations for intake based on current epidemiological or experimental evidence</th>
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<tbody>
<tr>
<td>Lycopene</td>
<td>Prostate cancer</td>
<td>Tomatoes, tomato products (sauce, paste, juice, pizza sauce, ketchup, sun-dried tomato in oil, watermelon, pink grapefruit, papaya, guava.</td>
<td><strong>Health Professional's Follow-Up Study.</strong> Prospective study. N = 47 894, 6 years follow-up. Risk reduction of 35% associated with weekly consumption of &gt; 10 servings of tomato products, compared to &lt; 1.5 servings (RR = 0.65; 95% CI = 0.44–0.95). For advanced progressive prostate cancer, RR = 0.47; 95% CI = 0.22–1.00. No association with any other carotenoids.</td>
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<td>Seventh Day Adventist men. Prospective study. N = 14 000, 6 year follow-up. Risk reduction of 40% associated with weekly consumption of &gt; 5 servings of tomatoes, compared to &lt; 1 serving.</td>
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<td></td>
<td>Cardiovascular disease</td>
<td></td>
<td><strong>Multi-centre study of men with MI in 10 European countries:</strong> Case control study. N = 1379, mean age = 54 years. Risk reduction of 48% between those with lycopene concentration of adipose tissue biopsies on 90th percentile, compared to those on the 10th percentile (OR = 0.52; 95% CI = 0.33–0.82).</td>
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<tr>
<td>Lutein and zeaxanthin</td>
<td>Age-related cataracts</td>
<td>Lutein: Cabbage, watercress, spinach, parsley, peas, broccoli, lettuce, green pepper. Zeaxanthin: Pepper, corn, spinach, turnip greens, collard greens, lettuce, spinach, kale, tangerine, mandarine.</td>
<td><strong>Nurse's Health Study:</strong> Prospective study. N = 77 466 women aged 45–71y. Follow-up of 12 y. Risk reduction of 22% for cataract extraction surgery in 4th quintile of lutein and zeaxanthin intake. (RR = 0.78; 95% CI = 0.63-0.95)</td>
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<td></td>
<td>Age-related macular degeneration (AMD)</td>
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<td><strong>Beaver Dam Eye Study:</strong> Prospective study. N = 400 men and women, 50–86 years. Five year follow-up. Marginal inverse associations between risk of cataract and lutein intake, according to tertiles (OR = 0.3; 95% CI = 0.1–1.2; P = 0.15 for trend), only in subjects ≥ 65 years.</td>
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<td><strong>Health Professional's Follow-up Study:</strong> Prospective study. N = 36 644 men, 45–75 years. Eight year follow-up. 19% reduction in cataract extraction in highest fifth for lutein and zeaxanthin intake. (RR = 0.81; 95% CI = 0.65 – 1.01; P for trend = 0.03)</td>
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<td><strong>Eye Disease Case Control Study:</strong> Case control study. N = 391 patients with AMD and N = 578 controls, 55–80 years. Significant inverse association between AMD risk and intake of lutein and Zeaxanthin (OR = 0.43, 95% CI = 0.2–0.7 for highest vs lowest quintile).</td>
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<td><strong>Beaver Dam Eye Study:</strong> Retrospective cohort study. N = 1968, including N = 344 with AMD, 43–86 years. No difference found between higher and lowest quintiles of lutein and zeaxanthin dietary intakes (864 vs. 155 mg/1000 kcal/day).</td>
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OR, odds ratio; RR, relative risk.
and pizza) was found to be protective against prostate cancer. The weekly consumption of more than 10 servings of tomato products, as compared with less than 1.5 servings per week was associated with a 35% risk reduction.51 Tomato sauce was the food item that showed the largest inverse association with cancer risk (RR = 0.66; 95% CI = 0.49–0.90). Another cohort study, conducted in Seventh Day Adventist men, found that the relative risk for men who consumed tomatoes more than five times a week compared with those consuming less than one serving per week was 0.60.52 It is thought that lycopene may favourably alter hormone status in a way that inhibits the progression of prostate cancer, or alternatively may have a more direct effect on the prostate itself.53

A 10 country multicentre study in Europe investigated the association between myocardial infarction risk and the lycopene content of adipose tissue biopsy samples of men. Lycopene was independently protective, controlling for confounders, with an odds ratio of 0.52 for the 10th compared with the 90th percentiles (95% CI = 0.33–0.82).54

**Lutein and zeaxanthin**

Quality of vision and appetite have been shown to be positive, independent and significant predictors of energy and nutrient intake in a high risk group of elderly receiving community services.55 Age-related macular degeneration (AMD), the prevalence of which is estimated to be 15–30% in North American people aged 75 years and older56 is the leading cause of blindness among elderly in the developed world. The two major epidemiological studies that have investigated the association between lutein and zeaxanthin and AMD risk have reported conflicting results. The Eye Disease Case-Control Study found that subjects in the highest quintile of lutein and zeaxanthin intake had a significantly lower risk of AMD compared to those in the lowest quintile of intake.57 The Beaver Dam Eye Study of almost 2000 subjects, 334 of whom had AMD, found no difference in AMD risk between the highest and lowest quintiles of lutein and zeaxanthin intake.58

While AMD is a major risk factor for blindness in the elderly in developed countries, cataracts are the leading cause of vision impairment blindness in other parts of the world. Regarding cataract risk and diet, lutein and zeaxanthin are the only carotenoids detectable in the human lens of the eye, although at levels lower than in the macula. The prevalence of cataracts increases significantly with age and in the USA, the prevalence among people aged 75–85 years is 40%.59 Data from the Nurses’ Health Study found a significant trend towards reduced risk of cataract extraction surgery with increasing intakes of lutein and zeaxanthin.60 The follow-up of the Beaver Dam Eye Study found similar results61 as did the analysis of data from the Health Professionals Follow-Up Study.62

**Phytochemicals**

Phytochemicals are a complex array of naturally occurring bioactive non-nutrients found in plants, which may provide health benefits over and above the nutritional content of the foods in which they are found. In terms of nutritional interventions aimed at reducing the risk of several chronic diseases, the isoflavones found in soybeans (primarily genistein and diadzein) may be of particular benefit in middle-aged and older adults. Isoflavones are similar in structure to mammalian oestrogens and, as such, have a potential role in the prevention and management of a range of hormone-dependent conditions, including cancer, menopausal symptoms, cardiovascular disease and osteoporosis. Despite having weak oestrogen-like functions, isoflavones apparently exert antioestrogenic effects in a high oestrogen environment, such as, exists in premenopausal women, and oestrogenic properties in a low-oestrogen environment, as is found in postmenopausal women. For example, soy isoflavone consumption may lower breast cancer risk in premenopausal women, while benefiting the cardiovascular system, bone and vasomotor systems in peri- and post-menopausal women. Evidence from epidemiological studies suggest that soybean-based diets may protect against cancer of the breast, prostate and colon.63,64 However, the evidence is not always consistent. In Singapore, an inverse association was demonstrated between intake of soybean products and the risk of breast cancer in premenopausal women65 while a study of Chinese women failed to find a similar association.66

Regarding bone health, a significant increase of 2% in both bone mineral content and density in the lumbar spine has been reported in postmenopausal women after a 6 month dietary intervention in which 40 g protein per day from isolated soy protein (providing 2.25 mg isoflavones/g of protein) was consumed.67 However, the same amount of soy, but containing only 1.39 mg isoflavones/g protein, failed to show a benefit. The role of soy products in the prevention of osteoporosis should be seen as an adjunct to other preventive strategies, not as an alternative approach.

Some published data exist that associate a high soy intake with relief of menopausal symptoms, such as, hot flushes and vaginal dryness.68,69 However, much of the evidence remains anecdotal. Despite there being no current guidelines for optimal intake of isoflavones, the threshold intake of dietary phyto-oestrogens necessary to achieve a biological effect in humans appears to be 30–50 mg/day, which is readily achievable by the inclusion of modest amounts of soy foods in an average Western diet.69 A serving of 100 g of soymilk or tofu provides about 45 mg and 240 mg isoflavones, respectively.70 Isoflavones are now being extracted to provide commercial phytochemical supplements, as an alternative to consuming a soy protein diet. Two studies have, however, shown that the purified isoflavones do not have the same beneficial lipid-lowering effects as isoflavones in the presence of soy protein.71,72 It is not known at present whether the purified sources have any benefits in terms of preventing bone loss or preventing cancer.

**Translation of dietary recommendations into practical dietary guidelines for the elderly**

A group of scientists met in Stuttgart in November 2000 to develop a consensus statement on nutrition and ageing.73
The following classification was given to various micronutrients, in terms of their perceived importance in optimizing the health status of the elderly:

1. **High priority:** Folate, vitamin B₁₂, vitamin D; vitamin C, vitamin E and selenium; and iron and zinc.

2. **Intermediate priority:** Vitamin A and vitamin K; thiamin, riboflavin and vitamin B₆; calcium, magnesium, potassium, copper, chromium, and iodine.

3. **Low priority:** Niacin, biotin, pantothenic acid; manganese, vanadium, boron, fluorine, phosphorus and silicon.

The expert group felt that there was insufficient information on, among other compounds, carotenoids, phytosterogens, isoflavones, lignans and bioflavonoids. The group concluded that a diet rich in vegetables and antioxidants may contribute to improved cognition and/or memory in the elderly. In addition, the group pointed out that an involuntary loss of body weight over time is a good predictor of inadequate nutrition and that in the future, recommendations for subgroups of elderly individuals at high nutritional risk will be defined. They highlighted the need for special attention to be given to older people in nursing homes and hospitals, and pointed out that low dose dietary supplements and/or fortified foods and beverages should contribute to improve nutrient intake when a balanced diet cannot be achieved solely through oral intake.

In terms of the impact of nutrition on overall health in older adults, it is important to consider dietary patterns, rather than intakes of specific nutrients or food groups. A five-year cohort study of elderly rural Greeks found that a one unit increase in diet score, devised a priori on the basis of eight characteristics of the Mediterranean diet (namely: high monounsaturated-to-saturated fat ratio; moderate ethanol consumption; high consumption of legumes, cereals, fruits, vegetables; low consumption of meats, and milk and dairy products) was associated with a significant 17% reduction in overall mortality.^

A study of elderly people in the United States found that the group with the highest food poverty rates of all groups (65.4%). Despite the lack of evidence on determinants of undernutrition in elderly Africans, these types of data clearly show that the development of any nutrition screening tool or dietary intervention, including food-based dietary guidelines, for use in this age group needs to consider financial constraints.

Another example is given for the case of elderly men living alone. This is considered to be a group at extremely high risk for an overall poor diet. A review of the available literature demonstrates the need for country-specific nutrition interventions aimed at this target group.^

In Australia, older men living with a spouse have a better quality diet (i.e. higher nutrient density) than those living alone or with a person other than a spouse, particularly regarding fruit and vegetable intake. Differences in nutrient intake are not explained by lower energy intakes. In contrast, older men in European countries who live alone appear to have a more favourable dietary intake compared to their counterparts in other living arrangements. Data from the United States suggests that low income elderly men living alone are at high risk of an inadequate dietary intake, and that a low energy intake is the most important predictor of a poor quality diet in this group.
Eating well: ageing gracefully!

Conclusion
Evidence of the potential benefits of eating well in order to age gracefully is available and knowledge of the role of specific nutrients, but more importantly, dietary patterns, in the prevention of age-related disorders is rapidly expanding. The importance of adequate nutrition in older adults is undisputed, however, the challenge remains for health professionals to design appropriate interventions to reach older people in need.

References


