Review Article

Eating well: ageing gracefully!

Karen E Charlton MSc, MPhil(Epidemiol), SRD

Division of Nutrition and Dietetics, Department of Medicine, University of Cape Town, South Africa

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.

Correspondence address: Karen E. Charlton, Division of Nutrition and Dietetics, Department of Medicine, University of Cape Town, Observatory, South Africa.
Tel: +27 21 406 6534; Fax: +27 21 448 6815
Email: kc@uctgsh1.uct.ac.za

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.[3,4] 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.[5] 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.[6] 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.[6] 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.[7] Leptin signalling could also have a potentially important role in the anti-ageing action of caloric restriction.[8]

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).[9] 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.[10] 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.[11]

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.[12–14] 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.[15]

Table 1. Characteristics of wasting, cachexia and sarcopenia, in the elderly

	Wasting	Cachexia	Sarcopenia
Weight	↓	↔	↔
Fat	↓	↓	↔
Muscle	↓	↓	↓
Appetite	↔	↓	↔
Energy intake	↓	↔	?
REE (per kg FFM)	↓	↑	↔

Taken from Walters *et al.*[9]

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).[16,17] 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.[18] 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.[19,20] 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.[21] 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).[22] 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

Table 2. Dietary guidelines for older Australians

1	Enjoy a wide variety of nutritious foods.
2	Keep active to maintain muscle strength and a healthy body weight.
3	Eat at least three meals a day.
4	Care for your food: prepare and store it correctly.
5	Eat plenty of vegetables (including legumes) and fruit.
6	Eat plenty of cereal, bread and pastas.
7	Eat a diet low in saturated fat.
8	Drink adequate amounts of water and/or other fluids
9	If you drink alcohol, limit your intake.
10	Choose foods low in salt and use salt sparingly.
11	Include foods high in calcium.
12	Use added sugars in moderation.

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.[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 *in vitro* and *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.[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.

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.[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 folate in homocysteine metabolism. Hyperhomocysteinaemia has been suggested to represent a metabolic link in the pathogenesis of old age dementias.[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.[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 β-carotene was significantly associated with impaired cognitive function (< 0.9 mg/day *vs* ≥ 2.1 mg/day, OR = 1.9; 1.2–3.1).[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.[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 ≥ 20 g/day was protective.[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.[38] In the Basel Longitudinal Study memory performance was shown to be associated with plasma vitamin C and β-carotene samples taken 22 years earlier.[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.[40] In this study, no association was found between memory and plasma vitamins A, C, β-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.[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 (≤ 0.6 mg/dL) than controls (OR = 2.99; 95%

CI = 1.05 – 8.54; $P < 0.05$). (Rabinowitz T. *et al.,* unpubl. data, 2002).

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.[42,43] 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.[44] 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.[45,46] 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.[47] 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.[48] 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.[49] 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).[50]

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 carotinoids 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

Carotenoid	Age-related condition	Food sources	Recommendations for intake based on current epidemiological or experimental evidence
Lycopene	Prostate cancer	Tomatoes, tomato products (sauce, paste, juice, pizza sauce, ketchup, sun-dried tomato in oil), watermelon, pink grapefruit, papaya, guava.	**Health Professional's Follow-Up study.**[51] Prospective study. *N* = 47 894, 6 years follow-up. Risk reduction of 35% associated with weekly consumption of > 10 servings of tomato products, compared to < 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.
			Seventh Day Adventist men.[52] Prospective study. *N* = 14 000, 6 year follow-up. Risk reduction of 40% associated with weekly consumption of > 5 servings of tomatoes, compared to < 1 serving.
	Cardiovascular disease		**Multi-centre study of men with MI in 10 European countries:**[54] 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).
Lutein and zeaxanthin	Age-related cataracts	Lutein: Cabbage, watercress, spinach, parsley, greens, peas, broccoli, lettuce, green pepper. Zeaxanthin: Pepper, corn, spinach, turnip greens, collard greens, lettuce, spinach, kale, tangerine, mandarine.	**Nurse's Health Study:**[60] 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)
			Beaver Dam Eye Study:[61] 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.
			Health Professional's Follow-up Study:[62] 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)
	Age-related macular degeneration (AMD)		**Eye Disease Case Control Study:**[57,83] 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).
			Beaver Dam Eye Study:[58] Retrospective cohort study. *N* = 1968, including *N* = 344 with AMD, 43–86 years. No difference found between highes and lowest quintiles of lutein and zeaxanthin dietary intakes (864 vs. 155 mg/1000 kcal/day).

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 older[56] 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 results[61] 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 postmenopausal 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 women[65] 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 B_{12}, vitamin D; vitamin C, vitamin E and selenium; and iron and zinc.
2. **Intermediate priority**: Vitamin A and vitamin K; thiamin, riboflavin and vitamin B_6; 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, phytooestrogens, 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.[74] 'Risky food patterns' in old age have been described by Wahlqvist and include: large, rather than smaller frequent, meals or snacks; alcohol excess, or no alcohol-free days and/or alcohol without food; eating alone most of the time; and the use of salt or salty food.[75] Data from South Africa has demonstrated evidence of nutrient dilution with high sugar intakes in older women (but not men) of low socioeconomic status.[76]

It is the role of nutrition professionals to translate nutrient-based dietary goals into practical and achievable food-based dietary messages for various target audiences. In Australia, 12 dietary guidelines for the elderly have been developed by the National Health and Medical Research Council (Table 2). These guidelines have used a combination of both a food-based and nutrient-based approach.

As with any age group, dietary recommendations for the elderly need to be evidence-based. For example, the Modified Food Pyramid Guide, which has been developed for people over the age of 70 years in the United States,[77] recommends that daily fluid or water intake should be at least eight glasses a day. This recommendation is based on the premise that elderly people are susceptible to dehydration due to an inability to conserve salt and water, and an impaired thirst response. Lindeman *et al.* found no evidence of dehydration in community-dwelling elders ingesting six glasses of fluid per day.[78] The authors concluded that, because a high fluid intake leads to increased urine volume, more opportunities for urinary incontinence and frequent wakenings in the night, there is little point in encouraging a fluid intake above a level that is comfortable for the elderly in the absence of evidence that eight or more glasses a day is beneficial.

Regarding the need for country-specific dietary guidelines for the elderly, an example relating to the impact of financial need on food availability in this age group is given. In the SENECA multicountry study of elderly Europeans, budget problems were virtually nonexistent, except for the case of Poland and Portugal where 40% and 50% of subjects, respectively, reported financial difficulties.[79] In developing countries, household food insecurity, due mainly to poverty, is an underlying cause of undernutrition and the elderly are particularly marginalized in this regard. In South Africa, a novel index termed 'household food poverty' was devised, whereby secondary analyses were carried out on data from over 28 000 households collected during the national 1995 Income and Expenditure Survey (IES).[80] Monthly household spending on 143 foods was combined with information on the cost of a basic subsistence diet in 24 sites around the country. A food poverty indicator assessed whether the amount spent by a household on food was adequate to purchase a basic subsistence diet. Results showed that 50% of elderly headed households (i.e. headed by persons aged 60 years and older ($n = 7194$)), were considered to be in food poverty, compared to 40.1% of young households (i.e. headed by persons younger than 60 years; $n = 21\,510$; $P < 0.001$).[81] Black elderly headed households had 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.[82] 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.

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

1. Chernoff R. Nutrition and health promotion in older adults. J Gerontol A Biol Sci Med Sci 2001; 56A: 47–53.
2. Uliajszek SJ. Nutritional status and susceptibility to infectious disease. In: Harrison GA, Waterlow JC, eds. Diet and Disease. New York: Cambridge University Press 1990, 137–154.
3. Ensrud KE, Cauley J, Lipschitz R, Cummings SR. Weight changes and fracture risk in older women. Arch Intern Med 1997; 157: 857–863.
4. Langlois JA, Visser M, Davidovic LS, Maggi S, Li G, Harris TB. Hip fracture risk in older men is associated with change in body weight from age 50 years to old age. Arch Intern Med 1998; 158: 990–996.
5. Nguyen TV, Sambrook PN, Eisman JA. Bone loss, physical activity and weight change in elderly women: the Dubbo Osteoporosis Epidemiology Study. J Bone Miner Res 1998; 13: 1458–1467.
6. Compston JE, Laskey MA, Croucher PI, Coxon A, Kreitzman S. Effects of diet-induced weight loss on total bone mass. Clin Sci 1992; 82: 429–432.
7. Roth GS, Ingram DK, Lane MA. Caloric restriction in primates and relevance to humans. Ann N Y Acad Sci 2001; 928: 305–315.
8. Shimokawa I, Higami Y. Leptin and anti-aging action of caloric restriction. J Nutr Health Aging 2001; 5: 43–48.
9. Waters DL, Baumgartner RN, Garry PJ. Sarcopenia: current perspectives. J Nutr Health Aging 2000; 4: 133–139.
10. Roubenhoff R. The pathophysiology of wasting in the elderly. Nutrition 1999; 129 (Suppl.): 256S–259S.
11. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, Garry PJ, Lindeman RD. Epidemiology of sarcopenia among elderly in New Mexico. Am J Epidemiol 1998; 147: 755–763.
12. Vellas B, Baumgartnmer R, Garry P, Albarede J. The role of nutriton, body composition in falls, gait, balance disorders in the elderly. In: Morley JE, Rubenstein LZ, eds. Geriatric Nutrition, 2nd edn. New York: Raven Press, 1995.
13. Baumgartner R, Koehler K, Gallagher D, Romero L, Heymsfield S, Ross R, Garry PJ, Lindeman RD. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998; 147 (8): 755–763.
14. Baumgartner R, Waters D, Gallagher J, Morley J, Garry P. Predictors of skeletal muscle mass in elderly men and women. Mech Ageing Dev 1999; 107: 123–136.
15. Payette H, Hanusaik N, Boutier V, Morais JA, Gray-Donald K. Muscle strength and functional mobility in relation to lean body mass in free-living frail elderly women. Eur J Clin Nutr 1998; 52: 45–53.
16. Chilima DM, Ismail SJ. Nutrition and handgrip strength of older adults in rural Malawi. Public Health Nutr 2000; 4 (1): 11–17.
17. Pieterse S, Manandhar M, Ismail S. The nutritional status of older Rwandan refugees. Public Health Nutr 1998; 1 (4): 259–264.
18. Morley JE. Anorexia of ageing: physiological and pathological. Am J Clin Nutr 1997; 66: 760–773.
19. Roberts SB, Fuss P, Heyman MB, Evans WS, Tsay R, Rasmussen H, Fiatarone M, Cortiella J, Dallal GE, Young VR. Control of food intake in older men. JAMA 1994; 272: 1601–1606.
20. Roberts SB. Regulation of energy intake in relation to metabolic state and nutritional status. Eur J Clin Nutr 2000; 54 (Suppl. 3): 564–569.
21. Das SK, Moriguti JC, McCrory MA, Saltzman E, Mosunic C, Greenberg AS, Roberts SB. An underfeeding study in healthy men and women provides further evidence of impaired regulation of energy expenditure in old age. J Nutr 2001; 131: 1833–1838.
22. National Health and Medical Research Council. Dietary Guidelines for Older Australians. National Health and Medical Research Council, Canberra, 2000.
23. McCrory MA, Fuss PJ, McCallum JE, Yao M, Vinken AG, Hays NP. Dietary variety within food groups: association with energy intake and body fatness in adult men and women. Am J Clin Nutr 1999; 69: 440–447.
24. De Castro JM, de Castro ES. Spontaneous meal patterns of humans: influence of the presence of other people. Am J Clin Nutr 1989; 50: 237–247.
25. Russell R, Rasmussen H. The impact of nutritional needs of older adults on recommended food intakes. Nutr Clin Care 1999; 2 (3): 164–176.
26. Millward DJ, Fereday A, Gibson N, Pacy PJ. Aging, protein requirements, and protein turnover. Am J Clin Nutr 1997; 66: 774–786.
27. Long SJ, Jeffcoat AR, Millward DJ. Effect of habitual dietary protein intake on appetitie and satiety. Appetite 2000; 35: 79–88.
28. El-Khoury AE, Sanchez M, Fukagawa NK, Gleason RE, Tsay RH, Young VR. The 24-h kinetics of leucine oxidation in healthy adults receiving a generous leucine intake via three discrete meals. Am J Clin Nutr 1995; 62 (3): 579–590.
29. Arnal M-A, Mosoni L, Boirie Y, Houlier M-L, Morin L, Verdier E, Ritz P, Antoine J-M, Prugnaud J, Beaufrère B, Mirand PP. Protein pulse feeding improves protein retention in elderly women. Am J Clin Nutr 1999; 69: 1202–1208.
30. Arnal M-A, Mosoni L, Boirie Y, Houlier M-L, Morin L, Verdier E, Ritz P, Antoine J-M, Prugnaud J, Beaufrère B, Mirand PP. Protein feeding pattern does not affect protein retention in young women. J Nutr 2000; 130: 1700–1704.
31. Dardevet D, Sornet C, Bayle G, Prugnaud J, Pouyet C, Grizard J. Postprandial stimulation of muscle protein synthesis in old rats can be restored by a leucine-supplemented meal. J Nutr 2002; 132: 95–100.
32. Coyle JT, Puttfarcken P. Oxidative stress, glutamate and neurodegenerative disorders. Science 1993; 262: 689–695.
33. Parnetti L, Bottiglieri T, Lowenthal D. Role of homocysteine in age-related vascular and non-vascular diseases. Ageing Clin Exp Res 1997; 9: 242–257.
34. Kalmijn S, Launer LJ, Ott A, Witteman JC, Hofman A, Breteler MMB. Dietary fat intake and the risk of incident dementia in the Rotterdam Study. Ann Neurol 1997; 42: 776–782.
35. Warsama Jama J, Launer J, Witteman CM, den Breeijen JH, Breteler MMB, Groee DE, Hofman A. Dietary antioxidants and cognitive function in a population-based sample of older persons. The Rotterdam Study. Am J Epidemiol 1996; 144: 275–280.
36. Engelhart MJ, Ruitenberg A, Sweieten JC, Witteman JCM, Hofman A, Breteler MMB. Dietary antioxidants and the risk of dementia. The Rotterdam Study. Neurobiol Aging 2000; 21: 1S: S203 (Abstract).
37. Kalmijn S, Feskens EJM, Launer LJ, Kromhout D. Polyunsaturated fatty acids, antioxidants and cognitive function in very old men. Am J Epidemiol 1997; 145: 33–41.
38. Goodwin JS, Goodwin JM, Garry PJ. Association between nutritional status and cognitive functioning in a healthy elderly population. JAMA 1983; 249: 2917–2921.
39. Perrig WJ, Perrig P, Stahelin HB. The relation between antioxidants and memory performance in the old and very old. J Am Geriatr Soc 1997; 45: 718–724.

40. Perkins AJ, Hendrie HC, Callahan CM, Gao S, Unverzagt FW, Xu Y, Hall KS, Hui SL. Association of antioxidants with memory in a multiethnic elderly sample using the Third National Health and Nutrition Examination Survey. Am J Epidemiol 1999; 150: 37–44.
41. Sano M, Ernesto C, Thomas RG, Klauber MR, Schaffer K, Grundman M, Woodbury P, Growdon J, Cotman CW, Pfeiffer E, Schneider LS, Thal LJ. A controlled trial of selegeline, alpha-tocopherol, or both as treatment for Alzheimer's Disease. N Engl J Med 1997; 336: 1216–1222.
42. Ortega RM, Requejo AM, Andrés P, Lopez-Sobaler AM, Quintas ME, Redondo MR, Navia B, Rivas T. Dietary intake and cognitive function in a group of elderly people. Am J Clin Nutr 1997; 66: 803–809.
43. Paleologos M, Cumming RG, Lazarus R. Cohort study of vitamin C intake and cognitive impairment. Am J Epidemiol 1998; 148: 45–50.
44. Gale C, Martyn CN, Cooper C. Cognitive impairment and mortality in a cohort of elderly people. BMJ 1996; 312: 608–611.
45. Rimm EB, Stampfer MJ, Ascherio E, Giovannucci GA, Colditz GA, Willett WC. Vitamin E consumption and risk of coronary heart disease in men. N Engl J Med 1993; 328: 1450–1456.
46. Stampfer MJ, Hennekens JE, Manson JE, Colditz GA, Rosner B, Willett WC. Vitamin E consumption and the risk of coronary heart disease in women. N Engl J Med 1993; 328: 1444–1449.
47. Losonczy KG, Hams TB, Havlik FJ. Vitamin E and vitamin c supplement use and risk of all-cause and coronary heart disease mortality in older persons. The Established Populations for Epidemiologic Studies of the Elderly. Am J Clin Nutr 1996; 64: 190–196.
48. Stephens NG, Parsons A, Schofield PM, Kelly F, Cheeseman K, Mitchinson MJ. Randomised controlled trial of vitamin E in patients with coronary disease. Cambridge Heart Antioxidant Study (CHAOS). Lancet 1996; 347: 781–786.
49. Schnyder G, Roffi M, Pin R, Flammer Y, Lange H, Eberli FR, Meier B, Turi ZG, Hess OM. Decreased rate of coronary restenosis after lowering of plasma homocysteine levels. N Engl J Med 2001; 345: 1593–1600.
50. Barnett Y. Ageing. Biological aspects. Encyclopaedia of Human Nutrition. Academic Press, San Diego, 1999; 29–35.
51. Gioyannucci EL, Ascherio A, Rimm EB, Stampfer MJ, Colditz GA, Willett WC. Intake of carotenoids and retinol in relationship to risk of prostate cancer. J Natl Cancer Inst 1995; 87: 1767–1177.
52. Mills PK, Beeson WL, Phillips RL, Fraser GE. Cohort study of diet, lifestyle and prostate cancer in Adventist men. Cancer 1989; 64: 598–604.
53. Clinton SK. Lycopene. Chemistry, biology and implications for human health and disease. Nutr Rev 1998; 56: 35–51.
54. Kohlmeier L, Kark JD, Gomez-Gracia E, Martin BC, Steck SE, Kardinaal AF, Ringstadt J, Thamm M, Masaev V, Riemersma R, Martin-Moreno JM, Huttunen JK, Klok FJ. Lycopene and myocardial infarction risk in the EURAMIC study. Am J Epidemiol 1997; 146: 618–626.
55. PayetteH, Gray-Donald K, Cyr R, Boutier V. Predictors of dietary intake in a functionally dependent elderly population in the community. Am J Public Health 1995, 85, 677–683.
56. Goldberg I, Flowerdew G, Smith E, Brody IA, Tso MOM. Factors associated with age-related macular degeneration. An analysis of data from the First National Health and Nutrition Examination Survey. Am J Epidemiol 1988; 128: 700–710.
57. Seddon IM, Ajani UA, Sperduto RD, Hiller R, Blair N, Burton JC, Farber MD, Gragoudas ES, Haller J, Miller DT. Dietary carotenoids, vitamins A, C, E and advanced age-related macular degeneration. JAMA 1994; 272: 1413–1420.
58. Mares-Penman IA, Klein R, Klein BE, Greger JL, Brady WE, Palta M, Ritter LL. Association of zinc and antioxidant nutrients with age-related maculopathy. Arch Ophthalmol 1996; 114: 991–997.
59. Klein B, Klein R, Linton K. Prevalence of age-related lens opacities in a population. The Beaver Dam Eye Study. Ophthalmol 1992; 99: 546–552.
60. Chasen-Taber L, Willet WC, Seddon IM, Stampfer MJ, Rosner B, Colditz GA, Speizer FE, Hankinson SE. A prospective study of carotenoid and vitamin A intake and risk of cataract extraction in US women. Am J Clin Nutr 1999; 70: 509–516.
61. Lyle BJ, Mares-Penman IA, Klein BE, Klein R, Greger JL. Antioxidant intake and the risk of incident age-related nuclear cataracts in the Beaver Dam Eye Study. Am J Epidemiol 1999; 149: 801–809.
62. Brown L, Rimm EB, Seddon IM, Giovannucci EL, Chasen-Taber L, Spiegelman D, Willett WC, Hankinson SE. A prospective study of cataract extraction in US men. Am J Clin Nutr 1999; 70: 515–524.
63. Kennedy AR. The evidence for soybean products as cancer preventive agents. J Nutr 1995; 125: 7335–7345.
64. Messina MJ, Persky V, Setchell KDR, Barnes S. Soy intake and cancer risk: a review of the in vitro and in vivo data. Nutr Cancer 1994; 21: 113–131.
65. Lee YP, Gourley L, Duffy SW, Esteve J, Lee J, Day NE. Dietary effects on breast cancer risk in Singapore. Lancet 1991; 337: 1197–1200.
66. Yuan J-M, Wang Q-S, Ross RK, Henderson BE, Yu MC. Diet and breast cancer in Shanghai and Tianjin, China. Br J Cancer 1995; 71: 1353–1358.
67. Potter SM, Baum JA, Teng H, Stillman RJ, Shay NF, Erdman JW. Soy protein and isoflavones: their effects on blood lipids and bone density in postmenopausal women. Am J Clin Nutr 1998; 68 (Suppl.): 1375S–1379S.
68. Setchell KDR, Casidy A. Dietary isoflavones: biological effects and relevance to human health. J Nutr 1999; 129: 758S–767S.
69. Albertazzi P, Pansini F, Boneccarsi G, Zanotti L, Forini E, De Abysio D. The effect of dietary soy supplementation on hot flushes. Obstet Gynecol 1998; 91 (1): 6–11.
70. Reinli K, Block G. Phytoestrogen content of foods. Nutr Cancer 1996; 26: 123–148.
71. Nestle PJ, Yamashita T, Sasahara T, Pomeroy S, Dart A, Komesaroff P, Owen A, Abbey M. Soy isoflavones improve systemic arterial compliance but not plasma lipids in menopausal and perimenopausal women. Arterioscler Thromb Vasc Biol 1997; 17: 3392–3398.
72. Hodgson M, Puddey IB, Beillin LJ, Mori TA, Croft KD. Supplementation with isoflavonoid phytooestrogens does not alter serum lipid concentration: a randomized controlled trial in humans. J Nutr 1998; 128: 728–732.
73. Bates CJ, Benton D, Biesalski HK, Staehelin HB, van Staveren W, Stehle P, Suter PM, Wolfram G. Nutrition and aging: a consensus statement. J Nutr Health Aging 2002; 6: 103–116.
74. Trichopoulou A, Kouris-Blazos A, Wahlqvist ML, Gnardellis C, Lagiou P, Polychronopoulos E, Vassilakou T, Lipworth L, Trichopolous D. Diet and overall survival in elderly people. Br Med J 1995; 311: 1457–1460.
75. Wahlqvist ML, Kouris-Blazos A, Darmadi I, Purba M. Nutrition and the elderly – a global perspective. S Afr J Clin Nutr 2000; 13: S28–S31.
76. Charlton KE, Wolmarans P, Lombard CJ. Evidence of nutrient dilution with high sugar intakes in older South Africans. J Hum Nutr Diet 1998; 11: 331–343.
77. Russell RM, Rasmussen H, Lichtenstein AH. Modified food guide pyramid for people over seventy years of age. J Nutr 1990; 129: 751–753.
78. Lindeman RD, Romero LJ, Liang HC, Baumgartner RN, Koehler KM, Garry PJ. Do elderly persons need to be encouraged to drink more fluids? J Gerontol A Biol Sci Med Sci 2000; 55A: M361–M365.
79. Schiettwein-Gsell D, Barclay D, Osler M. EURONUT-SENECA Nutrition and the Elderly in Europe. Dietary habits and attitudes. Eur J Clin Nutr 1991; 45: 83–97.

80. Central Statistical Service Living in South Africa – Selected Findings of the 1995 October Household Survey. Pretoria: Central Statistical Service, 1996.
81. Charlton KE, Rose D. Nutrition among older adults in Africa: the situation at the beginning of the millenium. J Nutr 2001; 131: 2424S– 2428S.
82. Charlton KE. Elderly men living alone: are they at high nutritional risk? J Nutr Health Ageing 1999; 3: 42–47.
83. Eye Disease Case Control Study Group. Antioxidant status and neovascular age-related macular degeneration. Arch Ophthalmol 1993; 111: 104–109.