Review article

Nutrition, ageing and ill health

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There are physical, mental, social and environmental changes which take place with ageing; for example, decreased physical activity, increase in body fat, decrease in lean body mass and consequently decreased energy intake may be associated with physiological functions that affect metabolism, nutrient intake, physical activity and risk of disease. There are now many studies which have found that undernutrition is prevalent and often unrecognized in patients admitted to hospitals and institutions. There is also evidence which links protein–energy undernutrition or its markers with clinical outcomes in acute and non-acute hospital settings and that nutritional supplements can improve outcomes in some of these settings. However, most clinically-available nutrition screening instruments lack sensitivity and specificity, and abnormal nutritional indicators may simply reflect effects of age, functional disability, or severe underlying disease. Thus, causal relationship cannot be assumed without a sufficiently powerful intervention study which adequately adjusts for the effects of non-nutritional factors, such as the number and severity of co-morbid conditions on clinical outcome.

Nutrition: Ageing: Ill health: Clinical outcome

Many Western societies have experienced a considerable increase in the number of elderly in the population. This has created a need for additional knowledge of age-related changes relevant to nutrition, which has importance in the treatment and prevention of disease and in maintaining good health and quality of life in an ageing population. Ageing, disease, lifestyle and environmental factors account for many of the changes observed in older individuals. It is well recognized that with advancing age there is a high incidence of chronic diseases, and evidence points to the importance of nutrition in the development, susceptibility and outcome of these diseases. There are, however, problems in diagnosing undernutrition in the elderly because of physical and biochemical changes which may take place as part of normal ageing. Also, the neglect of nutritional assessment in the setting of acute clinical medicine is well known (Garrow, 1994). McWhirter & Pennington (1994) reported that in Britain undernutrition is prevalent and largely unrecognized in hospital in-patients on admission, and tends to get worse during their hospital stay. There is no doubt that good nutrition contributes to the health and well-being of the elderly and to their ability to recover from illness (Department of Health, 1992).

Ageing changes relevant to nutrition

Gastrointestinal tract

Ageing in man may be accompanied by changes which may impair the search for food and its subsequent intake, but such changes are complex and difficult to document. However, objective changes in smell and taste have been observed which may directly decrease food intake or alter the type of foods which are selected. With ageing there may be a progressive loss in the number of taste buds per papilla on the tongue. The taste buds remaining which detect primarily bitter or sour tastes show a relative increase with ageing (Heber & Bray, 1980). In addition, the ability to identify foods while blindfolded decreases with advancing age. This is a common perceived problem among elderly individuals who complain of loss of both taste and smell (Exton-Smith, 1980). Impaired appetite is often associated with reduction in taste and smell which occur in up to 50 % of elderly people (Busse, 1980). Taste thresholds are higher among institutionalized elderly men than in healthy elderly men, and the use of drugs, particularly anti-hypertensive medication, appears to be a contributing factor (Spitzer, 1988). However, none of the previously

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Abbreviations: PEU, protein–energy undernutrition; RDA, recommended dietary allowance; tlc, total lymphocyte count.

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mentioned factors have been shown in prospective controlled studies to affect oral intake or nutritional status of the elderly.

Dental health is important in old age and 74% of the elderly in England and Wales in 1978 were edentulous (Todd & Walker, 1980). There is evidence linking nutritional status to dentition (McGandy *et al*. 1966; Department of Health, 1979*a*; Geissler & Bates, 1984), but a causal relationship is yet to be established in randomized controlled intervention trials. There are some documented gastrointestinal changes in the elderly which could affect their food intake; for example, changes in peristaltic activity of the oesophagus which may result in delay of oesophageal emptying (Heber & Bray, 1980). Absorption of some nutrients, in particular vitamin B_{12}, may be impaired because of mild ageing-related achlorhyria, but the evidence here is incomplete (Russell, 1986). Southgate & Durnin (1970) found no evidence of impaired absorption between young and elderly subjects when they measured the nutrient composition of food eaten and urine and faeces excreted using chemical analysis. Some researchers have reported widespread nutritional deficiencies associated with bacterial contamination of the small bowel (Roberts *et al*. 1977; McEvoy *et al*. 1983; Haboubi & Montgomery, 1992). McEvoy *et al*. (1983) found that seventeen of twenty-four malnourished patients had bacterial contamination of the small bowel. Roberts *et al*. (1977) and Haboubi & Montgomery (1992) reported a significant improvement in nutritional status in elderly patients after treatment of bacterial contamination with antibiotics. All these elderly patients had an anatomically-normal small bowel. However, these studies included non-randomly-selected malnourished patients and the numbers studied were small. Lipski *et al*. (1992) randomly selected and studied three groups of fifty-four young fit subjects, 103 fit community-living elderly and seventy-three elderly long-stay hospital patients. All subjects had simultaneous lactulose-H breath tests and [^{14}C]-glycocholic acid breath tests for assessment of bacterial contamination of the small bowel. Nutritional state was assessed by anthropometry (weight, height, triceps skinfold thickness and mid-arm circumference), haematology (haemoglobin, serum vitamin B_{12} and erythrocyte folate), and biochemistry (serum albumin, Ca and alkaline phosphatase (*EC* 3.1.3.1.)). They found significantly more positive breath tests in the elderly group compared with young fit subjects and there was no association between positive breath tests and anthropometry, haematology and biochemistry. The most likely interpretation of these apparently-conflicting reports is that bacterial contamination of an anatomically-normal small bowel in the elderly is the result rather than the cause of malnutrition. Of the studies reviewed previously, few have attempted to give a specific and objective definition of malnutrition. In the study by Haboubi & Montgomery (1992), for example, malnutrition was implied on the basis of hypoalbuminaemia and a skinfold thickness $<$25th percentile, although the authors do not quote the source of normative data.

The mechanisms through which malnutrition might cause bacterial growth is not fully understood but there is evidence that the activity of several enzyme systems involved in bactericidal processes may be reduced in malnutrition (Chandra, 1983).

Body mass and composition

Changes in body composition seen with ageing include a decrease in lean body mass and an increase in body fat (Forbes & Reina, 1970). Decreased physical activity accounts for the increased body fat and this may lead to decreased energy intake with ageing (Morley, 1986). These changes in body composition, including those in fat distribution, may be associated with changes in various physiological functions that affect metabolism, nutrient intake, physical activity and risk for chronic disease (Chumlea *et al*. 1992).

There is also alteration in bone density that results from a decrease mineral content which occurs with ageing (Durnin & Womersley, 1974). Severe osteoporosis may cause the bones in the legs to bow under the weight of the body. This bowing, together with changes of the spine, makes measurement of height unreliable in some elderly subjects, even in those elderly who are able to stand unaided (Miall *et al*. 1967).

Body weight is easily affected by short-term environmental aspects of life, in addition to the effects of acute and chronic diseases or undernutrition. Studies of body weight should be longitudinal and also take into account changes in anthropometric indices and alteration in relative amount and anatomical distributions of adipose and muscle tissues with old age (Chumlea & Vellas, 1994).

Assessment of body composition in the elderly

Many body-composition assessment methods have limited application to the elderly. For example, underwater weighing may be unsuitable for disabled individuals, isotope-dilution techniques are not universally accessible, and other models face similar limitations because they require combinations of such measurements obtained in the same individual. Many studies have been undertaken using a variety of simple bedside measurement techniques from which body composition can be predicted, but these techniques have not been validated specifically for use in elderly people. Recently, Fuller *et al*. (1996) have undertaken a study to evaluate a range of body-composition prediction techniques and equations against total body water, measured using isotope dilution, considered to be a suitable method for elderly people. Body composition predictors, including weight, height, skinfold thickness, bioelectrical impedance and near-infrared interactance, were evaluated against total body water in twenty-three randomly-selected men over 75 years old, and dual-energy X-ray absorptiometry in fifteen volunteers from this group. Comparisons were made between anthropometric and impedance methods for estimating limb muscle mass. They found that some body composition predictions are unacceptable (at least for total body water) in older men, and care is recommended when selecting from these methods or equations. The authors also reported that dual-energy X-ray absorptiometry is not the most appropriate reference method for assessing muscle mass; further studies using scanning techniques, such as magnetic resonance imaging and computer-aided tomography scans, as the preferred reference methods, are recommended.

Physical activity

Reduced physical activity will obviously reduce the total energy expenditure of an individual, and this is an important factor contributing to reduced energy requirement in the elderly (Durnin & Lean, 1992). But the energy cost of normal activities has been reported to increase with age for men (Durnin, 1985). In Nottingham, healthy women aged 70 years had a 20 % higher energy cost for walking at a standard speed than either men of the same age or younger women (Bassey & Terry, 1986, 1988). In a questionnaire survey based on a sample of the general population resident in private (non-institutional) households in Britain, information was collected from 3691 people aged 65 years or over about participation in physical activities in the previous 4 weeks. In the 60–69 years age-group about 70 % recorded no outdoor activity in the previous 4 weeks, and this proportion was even higher in the over 70 years age-group (Office of Population Censuses and Surveys, 1989). A survey in Nottingham of customary activity of elderly people found that the average reported daily time in active pursuits was less than 1 h and lower still in those aged 75 years or more. Furthermore, 4 years later a significant decline in activity levels was found in the 620 survivors (Dallosso *et al*. 1988; Bassey & Harries, 1993).

Another feature of ageing which may restrict physical activity is the liability to a variety of degenerative and chronic diseases; chronic obstructive airway disease, angina and arthritis are examples.

Physical activity contributes to good physical and psychological health at all ages (Royal College of Physicians, 1991), and inactivity associated with a minor illness in the elderly often leads to loss of muscle tone and mass and, thereafter, former physical activity levels may never be regained.

Social and medical conditions related to ageing

There are physical changes such as decreased visual acuity, joint problems, hand tremors and hearing problems which in combination may make the task of food preparation and eating more difficult for the elderly. Other risk factors which may affect nutritional status in the elderly include: isolation with an inability to go out shopping, loss of spouse, depression and bereavement, decreased mobility, dementia, anorexia due to disease (especially cancer), medications, poor dentition, alcoholism and, most important of all, acute illness (Department of Health and Social Security, 1972, 1979*a*,*b*). In institutions, lack of supervision and assistance at mealtimes may be an important factor resulting in poor food intake (Hoffman, 1993).

Since old people are disproportionately isolated, are on low income or disabled, socio-economic factors and disease are likely to have more influence on their nutritional status than age alone. A report from the USA (Dawson *et al*. 1987) shows an increase in disability with age, from 3·5 % of people aged 65–69 years who had difficulty preparing food rising to 26·1 % of those aged over 85 years; the numbers with difficulty with shopping rose from 1·9 % in the younger group to 37 % in the very-elderly group. The Nottingham Longitudinal Survey of Activity and Ageing which studied a sample of 1042 elderly people (Dallosso *et al*. 1988) was thought to be representative of the elderly population in the UK in terms of social class, age, sex and the number living alone. Subjects were asked whether they did cooking and shopping: 6 % of women aged 65–74 years said they did not do their own cooking, rising to 12 % of women aged over 74 years; 11 % of women aged 65–74 years did not do their shopping rising to 30 % for those over 74 years. Food-associated problems and perceived health may also have a role to play. Ultimately, identification of those ambulatory elderly people at risk of undernutrition requires an understanding of their social, cultural and economic environment.

Energy requirement

To date, the scientific evidence about energy requirement in the elderly is often incomplete and highly variable. The reasons for this include paucity and variability of data on energy intake and requirements and, most important of all, diversity of physical activity patterns in the elderly population. In a series of studies, elderly subjects from the USA (McGandy *et al*. 1966; Uauy *et al*. 1978*a*) consumed on average more energy than subjects in European studies (Durnin, 1961; Bunker & Clayton, 1989; Loenen *et al*. 1990); however, the USA trials included less people compared with the European studies. The Department of Health and Social Security (1979*a*) longitudinal study which examined energy intake in 365 elderly people in 1967–8 and 5 years later found that the average energy intake had fallen from 9320 to 8970 kJ (2235 to 2151 kcal)/d for men and from 7135 to 6822 kJ (1711 to 1636 kcal)/d for women. A similar trend for energy intakes to fall with age over 5 years was observed in a study of 269 elderly people in Gothenberg, Sweden (Lundgren *et al*. 1987).

Energy expenditure

BMR

BMR reflects the energy requirements for maintenance of the intracellular environment and the mechanical processes, such as respiration and cardiac function, which sustain the body at rest (Heber & Bray, 1980). It usually accounts for between 60 and 75 % of total energy expenditure (Horan & Pendleton, 1995). The FAO/WHO/UNU Expert Consultation (World Health Organization, 1985), used equations to predict BMR (Schofield *et al*. 1985). These equations may be less appropriate for the elderly population, especially older men, because of small numbers in the study, since more data have been collected which allowed a more precise estimate of current energy requirement in the elderly. BMR increases with body size, particularly with lean body mass, and this explains why it is higher in men than women, and 10–20 % less in old people because of reduced muscle mass and increased fat mass with ageing (McGrandy *et al*. 1966; Munro *et al*. 1987).

Physical activity

In most working populations physical activity accounts for

10–35 % of total energy expenditure. The energy expenditure of different activities depends on the amount of work being carried out, the weight of the individual and the efficiency with which that work is carried out. In general, ageing is associated with a reduction in efficiency, so that standard tasks, e.g. walking, account for up to 20 % more energy expenditure in older individuals (Durnin & Lean, 1992). This reduced efficiency may be one reason why older individuals slow down. It may be contributing to negative energy balance, weight loss and undernutrition in some settings.

Thermogenesis

The term thermogenesis encompasses a wide variety of phenomena, which include energy expenditure and heat generation associated with feeding, body temperature maintenance and thermogenic response to various specific stimuli such as smoking, caffeine and drugs. Thermogenesis has also been postulated to play a role in the regulation of body weight. This field of research is complex in human subjects and the theory is derived mainly from animal models (Durnin & Lean, 1992). In the elderly, resting circulating catecholamine concentrations are elevated (Lake *et al*. 1977), and the responsiveness to catecholamines may decline with age, as is the case in experimental animals (Rothwell & Stock, 1983). However, Poehlman (1993) examined the evidence with regard to human subjects on the thermic effect of ingestion of a meal and ageing and reported that the thermic response to ingestion of a meal appears to be influenced by age, physical activity and body composition.

It is possible that the fall in the capacity for thermogenesis with age may explain the increased risk of hypothermia in the elderly. However, in most cases of hypothermia there is a precipitating physical cause, such as stroke, which may or may not have a direct effect on thermogenesis.

Protein requirement

There is almost a consensus regarding the current recommendation for daily protein intake of free-living healthy elderly adults which is between 0·75 and 0·8 g/kg (World Health Organization, 1985; Department of Health, 1991). Total protein contained in lean body mass falls with age, and protein synthesis, turnover and breakdown all decrease with advancing age (Golden & Waterlow, 1977; Uauy *et al*. 1978*b*; Lehmann *et al*. 1989). Based on a series of studies and a literature review, Munro & Young (1980) stated that progressive loss of protein is a major feature of ageing throughout adult life. This appears to affect some tissues, notably muscle, more than others. There is no direct evidence to suggest that this erosion of tissue protein is due to lack of adequate amounts of protein in the average diet.

Ill health, trauma, sepsis and immobilization may upset the equilibrium between protein synthesis and degradation (Munro & Young, 1980; Reeds & James, 1983; Rennie & Harrison,1984; Beaumont *et al*. 1989; Lehmann *et al*. 1989). Campbell *et al*. (1994) studied the dietary protein requirements of twelve elderly men and women aged 56–80 years using short-term N-balance techniques and calculations recommended by the Joint FAO/WHO/UNU Expert Consultation (World Health Organization, 1985). They also recalculated N-balance data from three previous protein requirement studies in elderly people. From the current and retrospective data they reported that a safe protein intake for elderly adults would be 1·0–1·25 g/kg per d.

Micronutrients

Vitamins

Because of low food intake and increased incidence of physical diseases which may interfere with intake, absorption, metabolism and utilization, vitamin deficiency is more likely in the elderly than in the young. Intake of most vitamins is reduced in smokers, and alcoholics are more likely to suffer from folate and thiamin deficiency (Ferro-Luzzi *et al*. 1988). Up to 50 % of the elderly in the surveyed populations ingest vitamin supplements even though there is no documented benefit from this practice when the diet is adequate (Gupta *et al*. 1988). Brocklehurst *et al*. (1968) studied eighty long-term geriatric in-patients, most of whom had stroke or dementia. Patients were randomly allocated to placebo or a multivitamin supplement that contained three to twelve times the recommended daily allowance of thiamin, nicotinamide, riboflavin, and pyridoxine plus 200 mg ascorbic acid. Before the trial, 78 % had low vitamin C status and 76 % had low thiamin status. At 12 months, 91 % of the intervention group had normal blood levels *v*. 14 % of controls. Skin haemorrhage and capillary fragility significantly improved in the intervention group compared with the controls. In a randomized double-blind placebo-controlled trial of vitamin C supplementation on ninety-four elderly long-term institutionalized people, Schorah *et al*. (1981) found that in the subjects who received the supplement there were significant improvements in weight, in the levels of serum albumin and pre-albumin, and in clinical rating of purpura. These studies have not been replicated since. Most of the other studies which examined vitamin supplementation tended to show no consistent statistically significant difference between supplement and placebo administration (Drinka & Goodwin, 1991).

Two large surveys of vitamin status in elderly people within the past 7 years have improved knowledge of this subject: the Boston Nutritional Status Survey (Hartz *et al*. 1992), and the Survey in Europe on Nutrition and the Elderly (Euronut SENECA Study; de Groot *et al*. 1991). Russel & Suter (1993) reviewed the literature, including the SENECA and the Boston surveys, on vitamin requirements of the elderly with reference to the National Research Council recommended dietary allowances (RDA; National Research Council, 1989). They concluded by saying: 'For now, there are data to indicate that the 1989 RDA are too low for the elderly population (i.e. $\geq$51 years) for riboflavin, vitamin B_6, vitamin D and vitamin B_{12} – at least for certain groups of elderly people. The present RDA for elderly people appear to be appropriate for thiamin, vitamin C and folate, but are probably too high for vitamin A. There are not enough data to make judgement on the appropriateness of the RDA, or safe and adequate intakes for elderly people for vitamin K, niacin, biotin and pantothenic acid'.

Vitamins B_{12} and folate

The use of serum vitamin B_{12} to diagnose deficiency in older people is complicated by difficulties in the interpretation of low normal results. Recently, it has been shown that haematological manifestation of deficiency and the accumulation of intermediates of vitamin B_{12} metabolism, i.e. homocysteine and methylmalonic acid, may be detected in some patients before the serum vitamin B_{12} concentration falls below the usual lower limit of the reference range (150–600 pmol/l; Metz *et al*. 1996). In another study (Joosten *et al*. 1993), the serum concentrations of vitamin B_{12}, folate, vitamin B_6 and four metabolites were measured in ninety-nine healthy young people, sixty-four healthy elderly subjects and 286 elderly hospitalized patients. The prevalence of tissue deficiency of vitamin B_{12}, folate and vitamin B_6, as demonstrated by the elevated metabolite concentrations, was found to be substantially higher than that estimated by measuring concentrations of the vitamins. In a prospective, multicentre, double-blind controlled study (Naurath *et al*. 1995), the effect of an intramuscular vitamin supplement containing 1 mg vitamin B_{12}, 1·1 mg folate and 5 mg vitamin B_6 on serum concentrations of methylmalonic acid, homocysteine, 2-methylcitric acid and cystathionine (metabolic evidence of vitamin deficiency) in 300 elderly people with normal serum vitamin concentrations was compared with that of placebo in 175 elderly subjects living at home and 110 in hospital. The response rate to vitamin supplements suggested that metabolic evidence of vitamin deficiency is common in elderly subjects with normal serum vitamin levels.

Fruit and vegetables (antioxidants)

There are several reasons why consumption of fruit and vegetables merits special attention. Besides contributing to NSP, they are rich sources of vitamins and minerals such as carotene, vitamins A, E and C, and potassium. Several of these micronutrients have antioxidant properties and they may have a role in protecting against oxidative free radicals which may be involved in the mechanism of atherosclerotic injury.

In Britain, for example, rates of stroke and CHD are highest in regions where consumption of fruit and vegetables is lowest, and the same ecological study suggested an inverse association between fruit and vegetable consumption and incidence of stroke (Acheson & Williams, 1983). There have been three major epidemiological complementary studies of the association between low plasma concentration of diet-derived antioxidants and the risk of IHD and stroke: the WHO MONICA Project (1989); the Edinburgh Angina-Control Study (Riemersma *et al*. 1991); the Basel Prospective Study (Gey *et al*. 1993). These studies consistently revealed an association between increased risk of IHD (and stroke) and low plasma concentrations of antioxidants. Two large cohort follow-up studies reported in 1995 (Gale *et al*. 1995; Gillman *et al*. 1995). One from the UK (Gale *et al*. 1995) was a 20-year follow-up of 730 randomly-selected elderly subjects free of history or symptoms of stroke or CHD living in the community. They all had their vitamin C status assessed by dietary intake and plasma concentration. During 20 years follow-up, 643 subjects died, 124 deaths being from stroke. Low vitamin C was strongly related to subsequent risk of death from stroke but not from CHD. The other study was part of the Framingham population-based longitudinal study (Gillman *et al.* 1995) in which the diet of 832 men, aged 45–65 years, was assessed by a single 24 h recall, and subjects were followed up for 20 years. The risk of completed stroke or transient ischaemic attack was adjusted for BMI, cigarette smoking, glucose intolerance, physical activity, blood pressure, serum cholesterol, and energy, ethanol and fat intake. There was an inverse association between fruit and vegetable intake and the development of stroke. A small hospital-based study in which the dietary and plasma vitamin C status was assessed in a non-randomly selected group of patients with a high probability of cerebral thrombosis and within 5-year age-matched controls failed to demonstrate a relationship between vitamin C status and the risk of stroke (Barer *et al.* 1989). Hitherto, little was known about the possible protective effect of antioxidants and their concentrations during and immediately following acute ischaemic stroke and functional outcome. de Keyser *et al*. (1982) studied serum concentrations of vitamins A and E in eighty patients with acute middle cerebral artery ischaemia within 24 h of admission and compared them with eighty controls matched for age and sex who had various neurological disorders other than acute cerebral ischaemia. Outcome was assessed within the first 21 d. Their results suggested a beneficial effect of a high serum vitamin A concentration on early outcome in ischaemic stroke.

Evidence is also accumulating to show that free-radical damage may be important in other diseases, e.g. Parkinson's disease, Alzheimer's disease, chronic inflammatory disease and cancer, and that some of the diseases (cardiovascular and cancer) may be prevented or delayed to some extent by dietary changes such as reduction in fat intake and increased consumption of fruits, grains and vegetables (Halliwell, 1994). Table 1 shows some of the antioxidants, their possible mechanism of action, and also some of the recent studies in relation to oxidative stress and the elderly.

However, lower antioxidant defences and increased oxidative damage may be a consequence of tissue injury rather than the cause of it. Moreover, many epidemiological studies and dietary surveys which have led to the assumption that dietary intake of essential antioxidants, such as vitamin A, β-carotene, C and E, is inversely related to the risk of stroke and CHD have not adequately adjusted for confounding effects, such as lifestyle and other environmental risk factors.

Minerals

Sodium and potassium

Studies in hypertensive rats have found that high K intake protects against death from stroke even though blood pressure was not affected (Tobian *et al.* 1985). Khaw & Barrett-Connor (1987) reported an inverse association between K intake and stroke mortality, irrespective of hypertensive status. Clinical, experimental and epidemiological evidence suggests that a high dietary intake of K is associated with lower blood pressure (Langford, 1983; MacGregor, 1983; Treasure & Ploth, 1983). A major inter-population study has shown a correlation between the average Na intake and the slope of blood pressure *v*. age, and a

Table 1. Dietary antioxidant and oxidative stress (adapted from Halliwell, 1994)

Constituent	Action(s)
Known to be important	
Vitamin E (fat soluble)	General name for group of compounds, of which α-tocopherol is most important, that inhibit lipid peroxidation. May be important in protection against cardiovascular disease In a 2-year randomized placebo-controlled trial, 1300 mg α-tocopherol/d given to patients with moderate Alzheimer's disease delayed by 50 % the combined end point of death, admission to an institution, inability to perform the activities of daily living, or severe dementia (Sano *et al*. 1997) In another trial eighty-eight healthy people aged 65 years or older were randomized to receive α-tocopherol (mg/d; 40, 130 or 430) or placebo. After 4 months of follow-up, those who had taken vitamin E supplements showed significant improvement in the indices of immune response mediated by T cells (Meydani *et al*. 1997). In a 3-month double-blind placebo-controlled intervention trial among elderly subjects aged 65 years and over, De Waal *et al.* (1997) found that low dose 100 mg DL-α-tocopheryl acetate had no beneficial effect on the overall immune response
Widely thought to be important	
Vitamin C (ascorbic acid)	Probably assists α-tocopherol in inhibition of lipid peroxidation by recycling the tocopherol radical. Good scavenger for many free radicals and may help to detoxify inhaled oxidizing air pollutants (ozone, NO_2, free radicals in cigarette smoking) in the respiratory tract A recent cohort study in Finnish men aged over 60 years has shown that vitamin C deficiency, assessed by a low plasma ascorbate concentration, is a risk factor for CHD. However, it is not known whether supplementation with vitamin C reduces the risk (Nyyssonen *et al*. 1997)
Probably important, but not necessarily as antioxidants	
β-carotene, other carotenoids, related plant pigments	Several previous epidemiological studies suggest that high intake of such molecules is associated with diminished risk of cancer and cardiovascular disease, especially in smokers A randomized trial in 22 071 male doctors aged 40–84 years found that β-carotene had no effect on incidence of cancer and cardiovascular disease after 14 years of follow-up (Hennekens *et al*. 1996). Epidemiological evidence indicates that diets high in carotenoid-rich fruits and vegetables may be associated with a reduced risk of lung cancer (Peto *et al*. 1981). A randomized, double-blind, placebo-controlled primary prevention trial of daily supplementation with vitamin E, β-carotene, or both, for 5 years in a total of 29 133 male smokers aged 50–69 years from Finland followed-up for 5–8 years found no reduction in the incidence of lung cancer. In fact, this trial raises the possibility that these supplements may actually have harmful as well as beneficial effects (The Alpha-Tocopherol, β-carotene Cancer Prevention Study Group, 1994). In another trial, the β-carotene and retinol efficacy trial, involving a total of 18 314 smokers, former smokers and workers exposed to asbestos, subjects received 30 mg β-carotene/d and 7·5 mg vitamin A in a randomized, double-blind, placebo-controlled design. After an average of 4 years of supplementation, the combination of β-carotene and vitamin A had no benefit and may have had an adverse effect on the incidence of lung cancer and on the risk of death from lung cancer, cardiovascular disease, and any cause in smokers and workers exposed to asbestos (Omenn *et al*. 1996)
Possibly important	
Flavonoids, other plant phenolics	Plants contain many phenolic compounds that inhibit lipid peroxidation and lipoxygenases *in vitro* (e.g. flavonoids), although (similar to ascorbate) they can sometimes be pro-oxidant if mixed with Fe ions *in vitro*. How many of these products are absorbed from the gut or become available *in vivo* to act as antioxidants is unknown

negative correlation between K intake and blood pressure levels (Intersalt Cooperative Research Group, 1988). Clinical studies in which manipulations of dietary Na and K have brought about changes in blood pressure in elderly subjects provide further evidence (Fotherby & Potter, 1992).

Experimentally, excess salt intake causes hypertension, not only through simple volume expansion but also through Na-accelerated vascular smooth-muscle cell proliferation, and enhances thrombosis by the acceleration of platelet aggregation (Yamori, 1993). Moreover, Yamori *et al*. (1994) have shown that there are also protective nutritional factors, such as K, Ca, Mg, dietary fibre, protein, some amino acids and some fatty acids, which counteract the adverse effect of Na or cholesterol intake, as well as other basic pathogenic processes in hypertension, atherosclerosis and thrombosis.

Calcium and vitamin D

There is some speculation that age-related renal impairment decreases the renal hydroxylation of vitamin D, thereby decreasing the amount of active vitamin D available for Ca absorption (Heaney *et al*. 1982). Many institutionalized and free-living elderly (up to 50 % in some studies) have inadequate vitamin D intake, and the possible causes for this include sunlight deprivation, decreased intake of diary products, lactose intolerance and malabsorption of fat-soluble vitamins (Hoffman, 1993).

Bone mass declines with age especially in white females. This is associated with osteoporosis and an increased fracture risk. Ca alone without oestrogens cannot fully ameliorate post-menopausal bone loss, but Ca supplementation of 1000 mg daily with exercise does slow bone loss (Prince *et al*. 1991). Although Ca supplementation may be necessary for certain groups of elderly people, it may be harmful in patients with a history of Ca stones, primary hyperparathyroidism, sarcoidosis or renal hypercalcuria (Heaney *et al*. 1982). Recently, a randomized double-blind placebo-controlled trial of the effects of 3 years of dietary supplementation with Ca and vitamin D in 176 men and 213 women over 65 years of age reported that dietary supplementation significantly reduced bone loss measured in femoral neck and spine, and reduced the incidence of non-vertebral fractures (Dawson-Hughes *et al*. 1997).

Magnesium

Levels of Mg are controlled by the kidneys and gastro-intestinal tract and appear closely linked to Ca, K and Na metabolism. Serum levels, which are those generally measured, reflect only a small part of the total body content of Mg. The intracellular content can be low, despite normal serum levels in individuals with clinical Mg deficiency. Serum Mg may be of value when there are symptoms suggestive of Mg deficiency. Urine Mg analysis, especially after Mg administration, may be of value in clinical practice provided the patient's dietary history, kidney function and urine volume are taken into account (Reinhart, 1988). In patients with chest pain admitted to hospital the frequency of hypokalaemia was found to be greater among hypomagnesaemic patients than normomagnesaemic patients (Salem *et al*. 1991). Stroke patients have been reported to exhibit deficits in serum and cerebrospinal fluid Mg. Acute Mg or K deficiency can produce cerebrovascular spasm, and the lower the extra-cellular concentration of either Mg or K the greater the magnitude of cerebral arterial contraction (Altura *et al*. 1984). Potential causes of Mg deficiency such as low dietary intake and the use of diuretic therapy are more likely to occur in elderly people, especially those who are ill.

Iron

The elderly population may have lower Fe requirements to maintain adequate Fe status than when they were younger, and those with Fe deficiency can increase their Fe absorption to the same extent as young adults (Marx, 1979). However, because of a higher prevalence in elderly people of disorders which interfere with efficient Fe absorption, such as atrophic gastritis and post-gastrectomy syndromes, a proportion of elderly people have reduced dietary availability of Fe (Russel, 1988). Blood loss associated with hiatus hernia, peptic ulcer, haemorrhoids and cancer, as well as with non-steroidal anti-inflammatory drug use, is more likely in elderly people. In a study of housebound and hospitalized elderly patients, the dietary Fe intakes were lower than the intakes of a group of free-living elderly subjects. However, when expressed in relation to energy intake, the Fe densities of the diets were similar for hospitalized and free-living subjects (Thomas *et al*. 1989). This finding confirms the importance of maintaining an adequate food intake if micronutrient requirements are to be met from a normal diet.

Zinc

In the UK, healthy elderly subjects living at home and eating a self-selected diet were in metabolic balance for Zn on a mean daily intake of 137 μmol (9 mg), with leucocyte Zn levels comparable with those of healthy young subjects (Department of Health, 1991). Institutionalized elderly subjects are at increased risk of Zn deficiency (Thomas *et al*. 1988; Senapati *et al*. 1989). Zn has been found to promote healing of damaged tissues, especially skin, but only in those who are Zn deficient (Chandra, 1989). Zn is also important in cell-mediated immunity. In an open and uncontrolled study, a group of Zn-deficient elderly who were anergic developed positive skin tests after Zn supplementation (Wagner *et al*. 1983). Zn deficiency adversely affects cellular immunity at all ages (Wagner *et al*. 1983; Bogden *et al*. 1988). However, pharmacological doses of Zn may also impair cellular immunity (Chandra, 1989).

Trace elements

Knowledge of the exact role and dietary requirements for some of the trace elements Co, Cu, Cr, Fl, I, Mn, Mo and Se is incomplete for three reasons: they have only recently been found to be essential; dietary deficiencies of many are unknown; the utilization of one may be affected by the amount of other elements present. However, for some of these there are recommended daily intakes which may be adequate and safe, but their optimum intakes are unknown (Ministry of Agriculture, Fisheries and Food, 1995).

Food intake and ill health

Studies of elderly patients in hospitals and residential or nursing homes are in agreement that food intakes are less than those reported for free-living elderly people (Sandstrom *et al*. 1985; Elmstahl & Steen, 1987). The reasons for this are likely to be the combined effects of poor food intake as well as the extra energy cost of the metabolic disturbances associated with illness or disability. Many illnesses, infections, inflammatory states, trauma (including surgery), tissue necrosis or tumours lead to metabolic changes such as fever in which the basal metabolism rises, and the acute-phase response to acute illness remains fully active even in advanced old age. In one study, chest infection in elderly patients was accompanied by a 32·5 % rise in resting energy expenditure even though average rise in body temperature was only 1° (Hodkinson *et al*. 1990). Klipstein-Grobsch *et al*. (1995) studied the energy balance in a randomly-selected group of twenty-eight acute admissions to a geriatric unit, and reported that moderate negative energy balance is common in this patient group, and that these patients are at risk of undernutrition during their hospital stay. Negative energy balance has been described in long-stay and psycho-geriatric settings (Sandman *et al*. 1987; Thomas *et al*. 1988; Prentice *et al*. 1989).

Physical activity during disease

Activity generally falls during illness. In long-term illness, lean body mass declines and BMR also tends to fall. However, some illnesses may be associated with an increased muscle activity from disease, which may lead to increased energy needs. Elderly sufferers from Parkinson's disease had a 25 % increase in resting energy expenditure when compared with controls, which suggests that muscle rigidity and involuntary movements have a considerable energy cost (Levi *et al*. 1990). Dementia sufferers may be very active, often eat poorly and a high proportion are very thin (Sandman *et al*. 1987).

Identification of protein–energy undernutrition

Protein–energy undernutrition (PEU) is a state of starvation resulting in a reduction in body cell mass. Identification of PEU have been based on objective measurements, including anthropometric, haematological, biochemical, immunological and clinical assessment scores. No single measurement is highly sensitive and specific in identifying PEU (Souba, 1997). At present, nutritional assessment has three main goals: the first is to define the type and severity of PEU; the second is the identification of high-risk patients; the third is to monitor the efficacy of nutritional support. Tables 2 and 3 show some of these measures, their role in identifying patients at risk of PEU and their limitations in relation to the elderly.

Nutritional status in acute and non-acute care settings

PEU may be common in geriatric practice (Horan & Pendleton, 1995). It usually arises in a setting of increased energy needs (e.g. trauma, burns, infection). The effect of ill health on the nutritional status of hospitalized patients can be limited to the time of acute illness. Once the patient recovers, the nutritional disadvantage should be overcome, but elderly people are particularly at risk because of decreased nutritional reserves and the effect of repeated ill health (Exton-Smith, 1980). In Sweden, Cederholm & Hellstrom (1992) studied the nutritional status, by measuring weight, triceps skinfold, serum albumin and delayed cutaneous hypersensitivity reaction, of ninety-six consecutive hospital admissions over the age of 70 years and a 100 randomly-selected age- and sex-matched free-living controls. Patients classified as undernourished were required to display at least two variables below the cut-off limits chosen according to national reference data and one of the variables had to be anthropometric. Of the patients, 39 % were undernourished compared with the controls, and undernutrition was related to the nature of the disease rather than age. There was a marked difference in undernutrition between free-living and hospitalized persons which indicated that disease played a major role in the development of a negative energy balance. Also, the highest prevalence and the most advanced forms of undernutrition were observed in patients with multiple organ disease and malignancy. The 1967–8 survey of the Department of Health and Social Security (1979*b*) showed that elderly people who believed that they had a poorer health status than average tended to have lower energy intakes and lower body weight. The study of Morgan *et al.* (1986) showed that weight, body composition and dietary intakes were markedly different in samples of elderly people who were day patients or in-patients when compared with the free-living elderly population. A housebound group of elderly in Southampton, aged from 69 to 85 years, suffering from various chronic disorders (although known hepatic, renal, gastrointestinal diseases, malignancies and acute illnesses were excluded) had diets that were at greater risk of deficiencies of protein, Zn, Cu, Fe, Se, Ca and P when compared with those of apparently-healthy individuals of similar ages (Bunker & Clayton, 1989). Vir & Love (1979) randomly selected 196 institutionalized subjects in hospitals in Belfast, and found that the energy intake of females in hospitals was comparatively low and dietary nutrients most lacking were Mg, K, vitamin D and vitamin B_6. A non-randomly-selected group of institutionalized elderly from Boston, USA had a dietary and nutritional assessment. Subjects were free of clinically-apparent terminal or wasting illness and people who were mentally incompetent were excluded. Compared with a free-living elderly group, the institutionalized group had lower values of vitamin A, retinol-binding protein, Zn, albumin, pre-albumin and transferrin but no specific nutrient deficiency was identified (Sahyoun *et al*. 1988). In Newcastle (UK), Lipski *et al*. (1993) studied the nutritional status of ninety-two randomly-selected long-stay hospital patients. The findings were compared with a randomly-selected control group of forty-two fit young people and ninety-two fit community-living elderly subjects. They reported that elderly long-stay hospital patients had significantly lower values for triceps skinfold thickness, mid-arm circumference, and arm fat area compared with controls and their dietary intake did not satisfy basal metabolic demands.

Dehydration is another complication of disease and hospitalization which shares similar risk factors to those of undernutrition. Weinberg *et al*. (1995) reviewed the literature concerning dehydration in the elderly population from MEDLINE from 1976 to 1995. They reported that early diagnosis is sometimes difficult because the classical physical signs of dehydration may be absent or misleading in an older patient. Many different aetiologies place the elderly at particular risk. In patients identified as being at risk for possible dehydration, an interdisciplinary care plan with regard to prevention of clinically-significant dehydration is critical if maximum benefit is to result.

As well as the possible effects of illness on nutritional status, many drugs which are commonly used in the elderly may have specific interaction with nutrition (Durnin & Lean, 1992). A list of the more common interactions is shown in Table 4.

It is very likely that the use of poor sampling techniques, inadequately validated and inappropriate reference data to diagnose undernutrition in different studies are the cause of different prevalence and incidence rates found in some of the studies previously described and other studies.

Protein–energy undernutrition, ill health and outcome

The identification of PEU has serious implications during ill health, even though abnormal nutritional indicators may reflect effects of age, functional disability, or severe underlying disease. Thus, it remains to be determined to what extent non-nutritional factors, such as the number and severity of co-morbid conditions, are the cause of both apparent poor nutrition and poor clinical outcome.

Dempsey *et al*. (1988) carried out a chronological review of studies relating poor nutritional status to increased surgical morbidity. Their review included retrospective and/or non-randomized trials. They found that although many studies did not control for non-nutritional variables, and some were poorly defined, the evidence is overwhelmingly in favour of a strong association between poor nutritional status and poor outcome in surgical patients. In a recent study of the relationship between nutritional status

Table 2. Assessment of nutritional status in relation to elderly people

Measures of nutritional status	Comments	Limitation in elderly people
Dietary surveys, types 1. Dietary history by interview 2. Recall interviews (previous 24 h) 3. Weighed food intakes 4. Chemical analysis	More useful when used with social, economic, environmental, clinical and laboratory data. Dietary history or recalls give only crude information. Weighed records most appropriate when dietary intakes are to be related to clinical findings. Chemical analysis most accurate, but expensive and time-consuming Evidence suggests that unbiased retrospective estimates of diet are unobtainable	Increased age found to be associated with decreased recall ability in some studies Diet stability in the elderly may improve recall
Anthropometric measurements 1. Skeletal size (height, demispan, arm span, weight and BMI 2. Skinfold thickness (triceps, biceps, subscapular, dorsum of the hand, supra iliac, thigh skinfold thicknesses, arm fat area and waist : hip ratio) 3. Mid-arm circumferenc**e** (MAC) and arm muscle circumference	Total arm length and total span are reported to change with age less than height. Measurement does not need a trained observer and the subject can remain seated. Arm span approximates to height at maturity and is another alternative to measurement of height in the elderly The measurement of skinfold thickness using constant-pressure callipers provides a cheap and non-invasive assessment of subcutaneous fat. The technique is reliable in practised hands	Changes in the spine as a result of ageing and inability of some of the elderly to stand makes height measurements alone unsatisfactory Although standards for the elderly exist for MAC and skinfold thickness, the major difficulty is the definition of normality and referral values, and also lack of good correlation with biochemical measures
Biochemical measures Serum albumin, transferrin, pre-albumin, retinol-binding protein, ceruloplasmin plasma fibronectin and urinary creatinine excretion (CHI) (Viteri & Alvarado, 1970)	CHI may be used as an estimate of skeletal muscle mass provided renal function is stable and there is no significant element of rhabdomyolysis present such as in septic conditions	Values affected by presence of coexisting diseases and multiple drugs. Problems in collecting accurately-timed urine samples, forgetfulness, dementia, incontinence makes CHI measurement difficult
Immunological measures Lymphocytopenia and anergy to skin tests	There is some evidence to support a causal relationship between malnutrition, impaired cell-mediated response and infections	The similarity of the effects of ageing and malnutrition on immune function places the usefulness of routine immunological testing in this population in question
Clinical assessment scales 1. History and physical examinations 2. Mini nutritional assessment (MNA; Guigoz *et al*. 1994) 3. SCALES (Morley,1993)	MNA is said to be simple and a quick screening tool. It includes: anthropometric measurement, dietary questionnaire, global and subjective assessment SCALES reported to have high sensitivity to detect people potentially at risk of malnutrition	History and examination may be as effective as other objective measurements. MNA and SCALES have not been tested on a wider scale

SCALES, sadness, cholesterol, albumin, eat, shopping.

Table 3. Nutritional assessment aims and limitations

Aims	Measures used to assess nutritional status	Limitations
Defining type and severity of malnutrition	Clinical assessment (the history and physical examination). The simplest way is to ask about unintentional weight loss Anthropometric: weight, weight:height, triceps skinfold thickness, arm muscle area and arm fat area Biochemical: serum albumin concentration is the most widely used. To a lesser extent transferrin, pre-albumin, retinol-binding protein and ceruloplasmin (Dionigi *et al*. 1986)	May be as effective as other objective measurements. Needs to be studied more scientifically Lack of definition of normality or referral data May vary between and within population No single biochemical indicator has proved better than any other (Dionigi *et al*. 1986). Variation may be due to causes other than malnutrition, such as abnormal distribution in the extravascular space, or increased catabolism, or net loss, disease process, or a combination
Identification of high-risk patients	Different combinations of several markers have been proposed by workers such as Buzby *et al*. (1979), identified four related factors (serum albumin, serum transferrin, triceps skinfold thickness and delayed hypersensitivity) Klidjian *et al*. (1982), has shown that reduced arm muscle circumference and impaired skeletal function measured by forearm muscle dynamometry have been positively correlated with an increased risk of post-operative complications	Standardized nutritional variables are not yet available in clinical practice The factors determining the risk of malnutrition are multiple and interrelated, and include the patient's previous nutritional status, the disease process itself and the magnitude and anticipated duration of associated catabolic stresses (Souba, 1997)
Monitoring the efficacy of nutritional support	Selected biochemical variables such as serum albumin concentration, pre-albumin concentration, transferrin value, retinol-binding protein value and fibronectin***** are used to determine if a patient is responding to the nutritional support programme Maintenance of a positive N balance and weight gain may be useful as well	Monitoring should be more intensive in the early phases and major functions (renal, hepatic, cardiovascular) should be evaluated Monitoring the efficacy of nutritional support is the most difficult and controversial. Different centres use different approaches (Dionigi *et al*. 1986)

* Fibronectin is an opsonic glycoprotein. During starvation values fall by 25–30 %. It has been proposed as a sensitive index of nutritional depletion and repletion (Howard *et al*. 1984).

Table 4. Some drugs which may interfere with nutritional status in elderly people (Durnin & Lean, 1992)

	Increase	Decrease
Energy intake (appetite or absorption)	Phenothiazines Tricyclic antidepressants Corticosteroids	Metformin Digoxin Many antibiotics Anti-cancer drugs Most analgesics Theophylline
Vitamins		Furosemide (thiamin; Yui *et al*. 1980) 5-Fluorouracil (thiamin; Basu *et al*. 1979) Isoniazid (pyridoxine) Metformin (folate, vitamin B_{12}) Phenothiazines (folate) Tricyclics (folate) Methotrexate (folate) Colchicine (vitamin B_{12}) Cholestyramine (vitamins A, B_{12}, D, E, K) Tetracycline (vitamin C) Aspirin (vitamin C) Corticosteriods (vitamin C) Anticoagulants (vitamin D, folate)
Minerals and electrolytes	Amiloride (K) Spironolactone (K) Corticosteroids (Na) Phenylbutazone (Na) Carbenoxolone (Na) Ethanol (Fe)	Diuretics (Na, K, Ca, Mg, Zn) Phosphates (Fe) Tetracycline (Fe) Antacids (Fe) NSAID (Fe) Fe supplements (Zn)

NSAID, non-steroidal anti-inflammatory drugs.

and hospital outcome, Sullivan & Walls (1994) randomly-selected and studied 350 admissions to a geriatric rehabilitation unit and reported that PEU (discharge serum albumin <35 g/l, and body weight less than 90 % of ideal) appears to be a strong independent risk factor for in-hospital mortality. Several other studies of acute care hospital and institutionalized patients have demonstrated a strong correlation between PEU and an increased risk for subsequent in-hospital morbid events (Keller, 1995; Muhlethaler *et al*. 1995; Potter *et al*. 1995).

Specific markers of undernutrition and outcome

Body weight. There is also evidence of an association between the levels of specific clinical markers of PEU and increased risks of morbidity and mortality; for example, there have been several studies which showed strong association between body weight and mortality (Tayback *et al*. 1990; Keller, 1995; Manson *et al*. 1995; Muhlethaler *et al*. 1995; Potter *et al*. 1995). In a prospective study of undernourished elderly people in a chronic care hospital in Canada, Keller (1995) reported that a weight increase of at least 5 % of body weight is associated with a decreased incidence of death and may reduce morbidity. Tayback *et al*. (1990) from the USA analysed BMI data for 4710 white, National Health and Nutritional Examination Survey respondents who were aged 55–75 years between 1971 and 1975, in relation to their survival over an average of 8·7 years of follow-up. After they controlled for elevated blood pressure, smoking and poverty they found that low body weight was associated with increased mortality.

Serum albumin. Measurement of serum albumin concentration has been found to be one of the best single predictors of morbidity and mortality among the aged (Mitchell & Lipschitz, 1982; Agarwal *et al*. 1988). A recently-completed study involved 287 community-dwelling and 176 institutionalized subjects aged 60 years and over who were followed-up for 9–12 years after nutritional assessment (Sahyoun *et al*. 1996). The results showed that the risk of mortality for subjects with albumin values of 40 g/l and over was 0·46 of the risk for those with albumin values below 40 g/l, after controlling age, blood urea, triacylglycerol, history of disease and ability to shop. Albumin predicted long-term mortality among non-institutionalized subjects and short-term mortality among institutionalized subjects. Reinhardt *et al*. (1980) studied 509 hospitalized veterans with an average age of 59 years and reported that those with serum albumin concentrations greater than 35 g/l had a mortality of 1·7 %, those with levels less than 34 g/l had a 25 % mortality rate, and levels less than 20 g/l resulted in 62 % mortality rate. Rudman *et al*. (1987) also found a relationship between mortality and decreased serum albumin concentrations in undernourished elderly male patients residing in long-term institutions. Hypoalbuminaemia (<35 g/l) has been reported to be a powerful indicator of an increased risk of peri-operative complications in elderly patients undergoing cardiac surgery (Rich *et al*. 1989). A retrospective study of seventy-nine stroke rehabilitation patients found that low serum albumin levels on admission were significantly related to poor outcome during the hospital stay (Aptaker *et al*. 1994). Unfortunately, most of these studies did not control for the effect of non-nutritional confounding variables on clinical outcome. Albumin concentration has long been used as a measure of health and disease (Rothschild *et al*. 1972*a*). Many conditions, such as PEU, catabolism, liver and renal disease, may reduce serum albumin levels (Rothschild *et al*. 1972*b*). The catabolic state and the associated neuroendocrine response which is likely to follow the acute illness may lead to altered serum albumin levels. Hypoalbuminaemia may also represent a metabolic response to severe stress such as extensive burn or prolonged sepsis. A decrease in serum albumin after acute stress represents decreased liver biosynthesis and turnover (Rothschild *et al*. 1972 *a*, *b*). It is possible, therefore, that in catabolic states the synthesis of acute-phase proteins has a priority over serum albumin, and this may partly account for some of the features of plasma protein profile observed during the acute-phase response after injury (Dionigi *et al*. 1986).

Total lymphocyte count

A low total lymphocyte count (tlc) is often associated with decreased serum albumin values; yet when considered alone, tlc is a poor prognostic indicator, possibly reflecting changes in immunological function secondary to PEU. Seltzer *et al*. (1979) studied albumin and tlc in 500 consecutive hospital admissions and noted a 7·6 % incidence of abnormal albumin and 30·2% incidence of abnormal tlc. Abnormal tlc was associated with a fourfold increase in deaths, and abnormal albumin was associated with a sixfold increase in both death and complications. In combination, abnormal tlc and albumin resulted in an eightfold increase in complication rate with a ninefold increase in mortality but, despite mild undernutrition in patients with anergy, nutritional support has failed to correct the response and the cellular immune dysfunction (Christou *et al*. 1995).

There are many studies which have demonstrated a strong relationship between PEU or its markers and morbidity and/or mortality in acute and non-acute hospital settings, but a causal relationship cannot be assumed without properly-designed nutrition intervention studies.

Improving nutritional status in hospital and its relation to outcome

The only way to ascertain the benefit of nutritional supplements on undernourished elderly hospital patients is to carry out prospective randomized controlled-intervention clinical trials. There have been positive results of trials of nutritional support given enterally or orally. Bastow *et al*. (1983) studied the effect of overnight nasogastric feeding supplements (4200 kJ) in a randomized controlled trial of elderly women with a fractured neck of femur and showed that treatment was associated with improvements not only in anthropometric and plasma protein measurements but also in clinical outcome, mainly in shortened rehabilitation time and hospital stay. Delmi *et al*. (1990) were able to demonstrate a clinical benefit of oral supplements in a randomized controlled group of elderly patients with a fractured femur which persisted 6 months after injury. In a randomized controlled trial, Woo *et al*. (1994) have recently demonstrated a clinical benefit of oral supplements on a group of elderly patients suffering from chest infection. The powerful study of Larsson *et al*. (1990), on 501 elderly in-patients randomly allocated to receive oral supplements or wards meals only, demonstrated clear benefit of nutritional supplements in terms of mortality, hospital stay, mobility and probability of pressure sores. Very recently, a randomized prospective study of thirty in-patients with persistent dysphagia 14 d following acute stroke, compared percutaneous gastrostomy and nasogastric tube feeding. Patients fed via the gastrostomy tube had significantly lower mortality and a greater improvement in nutritional status at 6 weeks (Norton *et al*. 1996).

In a double-blind placebo-controlled trial, ninety-six independently-living, healthy men and women over 65 years of age were randomly assigned to receive nutrient supplementation. Nutrient status and immunological variables were assessed at baseline and at 12 months, and the frequency of illness due to infection was ascertained. Subjects in the supplement group had higher numbers of certain T-cell subsets and natural killer cells, enhanced proliferation response to mitogen, increased interleukin-2 production, and higher antibody response. Supplementation with micronutrients significantly improved immunity and decreased the risk of infection (Chandra, 1992). Another randomized placebo-controlled trial (Fiatarone *et al*. 1994) compared progressive resistance exercise training, multinutrient supplementation, both interventions and neither intervention in 100 frail nursing-home residents over a 10-week period. High-intensity resistance exercise was found to be a feasible and effective means of counteracting muscle weakness and physical frailty in very old subjects. In contrast, multi-nutrient supplementation without concomitant exercise did not reduce muscle weakness or physical frailty.

Table 5 shows established indications for the use of nutritional support in unselected groups of patients (Souba, 1997).

Some studies (Stableforth, 1986; William *et al*. 1989; Hankey *et al*. 1993) have not shown a clear benefit of nutritional supplements on elderly hospital surgical and non-surgical patients, but they also had problems with compliance and tolerance of supplements. Almost all these studies included smaller number of patients without adequate control for confounding variables when compared with the previously mentioned studies which demonstrated a clear benefit.

Future directions and recommendations

Physical, mental, social and environmental changes which take place with ageing may affect the nutritional status of elderly people. There is evidence that undernutrition is common in elderly people and may influence the clinical outcomes during disease, and that nutritional supplements can improve outcomes in some settings, but differences in the methodology, variability of dietary habits with time, prevalence of disability and selective survival may be part of the reasons for the conflicting reports obtained by different researchers.

To enable physicians to distinguish signs of undernutrition from those due to disease and/or processes of ageing and to be able to intervene appropriately and effectively, we need further research effort in certain areas.

Anthropometric measures

1. Many normative nutritional data on anthropometric measurements used to define undernutrition in elderly people were either derived from a younger population or included few subjects above the age of 65 years, and often without proper quantification of measurement error, or adequate adjustments for age, genetic, racial and cultural differences. For well-defined populations, appropriate anthropometric reference data need to be established using sound experimental design and adequate sample size.
2. Changes in body fat distribution and lean mass are well recognized with ageing, and may be associated with changes in various physiological functions that affect metabolism of drugs, nutrient intake, physical activity and risk for chronic disease. We need a better understanding of these changes and their influence on the well-being of the elderly.

Biochemical measures

1. Biochemical markers such as serum albumin have long been used as a measure of health and disease. Many

Table 5. Established indications for the use of nutritional support for unselected groups of patients (Souba, 1997)

Established indication	Benefit
Patients unable to eat or absorb nutrients for an indefinite period (permanent neurological impairment, oropharyngeal dysfunction or short-gut syndrome)	Preserves nutritional status, lifesaving
Well-nourished, minimally-stressed patients unable to eat for more than 10–14 d	Preserves nutritional status, prevents starvation-induced complications
Severely-malnourished patients who undergo major elective surgical procedures	Pre-operative nutrition decreases the incidence of major septic complications
Patients with major trauma (major blunt or penetrating trauma, head injury or burn injury)	Enteral nutrition is superior to parenteral nutrition in decreasing the incidence of septic complications, nutritional support improves outcome in patients with head injury
Bone-marrow-transplant recipients undergoing intensive anti-cancer therapy	Improves outcome

conditions, such as malnutrition, catabolic conditions, liver and renal disease, may reduce serum albumin levels. However, further research is needed to reveal the true magnitude of the influence of malnutrition on secretory proteins such as serum albumin following acute illness, relative to the influence of the catabolic state and other extraneous causes.

2. There is growing support for the involvement of free radicals in atherosclerotic diseases (e.g. stroke and IHD) and neurodegenerative diseases (especially Alzheimer's or Parkinson's diseases), all of which may be associated with nutritional problems. If this is confirmed, the therapeutic rewards may be great. We need to develop and validate better techniques for direct measurements of antioxidant capacity and oxidative stress, and adjustment for confounding variables.

Detailed clinical measures

1. The value of clinical assessment (history and physical examination) as an effective measurement of nutritional status as opposed to objective measurements deserves particular attention and needs to be studied more scientifically.
2. Energy requirements and expenditure in elderly people during health, and particularly during acute and chronic illness and disability, is of particular concern. Techniques to measure energy requirements and expenditure need to be validated.
3. Knowledge of the requirements for nutrient density of the diet and specific nutrients such as protein during disease and their influence on the ability of elderly people to adapt to periods of stress and recover from disease is incomplete and needs further research.
4. The relationship between undernutrition and a poor outcome has not been definitely established, and could not be assumed without well-designed nutritional intervention studies which adequately adjust for the effect of systematic and random bias.
5. Despite aggressive nutritional support, it is often difficult to attenuate the catabolic response to illness or injury. Several new strategies to achieve this are under investigation. These include the administration of growth hormone to promote anabolism, essential amino acids such as glutamine, and nutrients that can modulate immune function. Although the use of these agents has been advocated, their benefits remain controversial, and further studies are needed to establish their efficacy.

Maintaining and improving nutritional status in the elderly

Finally, based on the present knowledge, firm recommendations to maintain and improve nutritional status in elderly people could still be made.

1. Health professionals should have access to the necessary basic training which will enable them to assess and meet the nutritional demands of elderly patients at risk of undernutrition.
2. Simple clinical assessment of nutritional status, such as asking people about unintentional weight loss, should be a routine aspect of history taking and clinical examination when a patient is admitted to hospital. Some simple and quick screening tool for the detection of early undernutrition could also be integrated into geriatric assessment programmes.
3. Elderly people should be advised to eat a balanced diet containing: a variety of nutrient-dense foods; more fruits, vegetables and grains; foods containing adequate amounts of Ca and vitamin D. This may need to be monitored in certain individuals.
4. Physical activity contributes to good physical and psychological health at all ages. Elderly people should be encouraged to lead an active life, especially after episodes of intercurrent illness.

Good nutrition may contribute to the healthy well-being of the elderly and to their ability to recover from illness. Further research is needed to improve our knowledge in this important field.

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