British Journal of Nutrition (2002), **88**, 555–561
DOI: 10.1079/BJN2002706

Predictors of micronutrient status in men and women over 75 years old living in the community*

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(Received 24 September 2001 – Revised 16 June 2002 – Accepted 15 July 2002)

Serum ferritin, serum vitamin B_{12}, erythrocyte folate, plasma vitamin C and plasma 25-hydroxycholecalciferol levels were measured in 208 men and 197 women, >75 years old and living in the community, in order to assess micronutrient status. Anthropometric measurements (height, weight, demispan and mid-upper arm circumference) were made and a 114-item questionnaire covering a wide range of health and diet-related topics was administered by an interviewer. Only 4 % of subjects had a BMI < 20, but the prevalence of marginal deficiency of the micronutrients ranged from 7 % for Fe to 47 % for vitamin D. There was no association between low micronutrient status (defined as being in the lowest third of the distribution of micronutrient status) and having BMI or mid-upper arm circumference in the lowest third of the distribution for any of the nutrients. Leaving food on the plate was strongly associated with both low Fe status and low vitamin D status. Having breakfast cereal less than once per week was strongly associated with low folate status, while having fresh fruit juice less than once per week, having had less than two portions of fruits and vegetables the previous day and believing that food is not important for health were strongly associated with low vitamin C status. Low vitamin D status was strongly associated with a wide range of general health and disability measures. Having a weekly household income of less than £150 was associated with low status of Fe, folate, vitamin C and vitamin D.

Nutritional deficiency: Anthropometric measurements: Elderly

In recent years, evidence has been accumulating that the diet of the elderly has an impact on morbidity and mortality. Several studies have shown that dietary patterns that conform to healthy eating guidelines are associated with increased overall survival (Trichopolou *et al.* 1995; Huijbregts *et al.* 1997; Kumagai *et al.* 1999). Generalised health consequences of low micronutrient status may include reduced immune function (Lesourd & Mazari, 1999), impaired cognitive function (Selhub *et al.* 2000) and increased risk of complications during hospitalisation (Larsson, 1993). More recent studies have suggested that there may be an increased risk of stroke in elderly people with low vitamin C intake (Gale *et al.* 1995) and an increased risk of CHD in those with low fruit and vegetable consumption and folate status (Eicholzer *et al.* 2001).

Although elderly people in hospitals and residential care are known to be at high risk of nutritional problems, elderly people living in the community are also at greater risk of nutritional problems than younger adults (Steen & Rothenberg, 1998). The classical picture of malnutrition in the elderly is one of generalised malnutrition with low body mass and muscle wasting. However, it is now recognised that: 'besides a clinical, clearly visible malnutrition, selective nutrient deficits are much more frequent' (Stähelin, 1999). This may be because ageing is associated with a reduction in energy requirements due to a loss of lean tissue mass and a decline in physical activity. As a result, older people may be able to maintain body weight on a low energy intake, but will be at risk of specific deficiencies unless their diet includes foods that are rich in micronutrients.

The growing awareness of the importance of nutrition in the elderly in recent years has led to the development of several nutrition assessment tools such as the Nutrition

Abbreviation: OR, odds ratio.

*Copies of the full questionnaire used in the present study are available from the corresponding author on request.

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Screening Initiative (Lipschitz *et al.* 1992) and the Mini Nutritional Assessment (Guigoz *et al.* 1994). These tools include general questions on appetite and weight loss and incorporate assessment of protein–energy malnutrition through anthropometric measurements and routine hospital laboratory tests such as serum albumin or cholesterol. Although Mini Nutritional Assessment scores have recently been shown to be associated with blood measures of a number of micronutrients (Vellas *et al.* 2000), the score does not provide information on the likelihood of micronutrient deficiencies in individuals. Without access to laboratory tests of nutritional status, health professionals working in the community have little opportunity to assess the risk of a given micronutrient deficiency in their patients and to give appropriate nutritional advice.

In the UK, primary care professionals offer an annual health check to all patients >75 years old, although the components of this check can vary between practices (Brown *et al.* 1997). In an earlier study, we identified dietary beliefs and practices of people >75 years old living in the community (McKie *et al.* 2000). Building on this information, we set out to identify factors associated with low micronutrient status, in men and women living in the community, that could be incorporated into a screening tool to be used in the health check for those >75 years old.

Participants and methods

Subjects

Names and addresses of a random sample of those >75 years old living in the community in Aberdeen, Grampian, UK, were obtained from the local Community Health Index, a register of all patients registered with a general practitioner. Each patient's general practitioner was notified of our intention to approach their patient and was asked to exclude those suffering from dementia to the extent that they would have difficulty responding to an interview in their own home. Men (*n* 821) and women (*n* 1122) were sent a letter inviting them to participate, of whom 217 men (25 %) and 191 women (17 %) completed the study. Table 1 shows that the age distribution of the participants (using deprivation categories based on postcode) of those who participated was similar to that of the population of those >75 years old in the Grampian region. Results from the Carstairs deprivation category (derived from postcode) showed that in men the proportions in categories 1–2 (most affluent), 3–4 and 5–7 (most deprived) were very similar to the rest of the population, but in the women who participated, deprivation categories 1–2 were under-represented and 3–4 were over-represented (χ^2 9·64, $P<0·01$).

Protocol

All subjects were visited in their own home on two occasions. On the first visit, a detailed questionnaire about diet and health was administered. On the second visit, 1–14 d later, a research nurse took anthropometric measurements and a venous blood sample. The measurements were carried out over a 12-month period between April 1999 and March 2000. For the subjects seen in summer (June–September), repeat samples were taken in winter (February–March) to estimate seasonal change in vitamin D status. The study protocol was approved by Grampian Research Ethics Committee and all subjects gave written informed consent to participate.

Questionnaire

A questionnaire was developed for the present study to include a wide range of potential dietary and other risk factors for micronutrient deficiencies. As a result of an earlier project exploring attitudes and beliefs about diet in men and women >75 years old (McKie *et al.* 2000), questions on beliefs about the importance of food and self-motivation in relation to health and diet were included. The questionnaire included forty-two questions on general health (appetite, weight loss, medical conditions, medication, exercise and attitude towards health and diet), forty-two questions on intake of foods containing the nutrients of interest, twenty questions on disability in the form of the EASY-care Elderly Assessment System (Philp, 2000) and the ten-item Clifton Assessment Procedure for the Elderly (CAPE) orientation assessment (Pattie & Gilleard, 1975).

The reproducibility of the responses to each item was assessed in twenty-nine men and twenty-nine women: for 57 % of questions the values of Cohen's kappa or Kendall's tau-b were >0·6 and for 20 % the values were >0·8 (Vyvyan *et al.* 2000). All questionnaires were administered by the same interviewer and data from the questionnaire were entered into a personal computer using the Teleform

Table 1. Distribution (%) of age and deprivation scores in participants compared with the rest of Grampian population aged >75 years old*

		Age category (years)			Deprivation category†		
	n	75–79	80–84	>85	1–2	3–4	5–7
Men							
Present study	207	51·7	31·4	16·9	49·8	28·0	22·2
Rest of Grampian	11 426	53·3	27·4	19·3	50·1	28·0	21·9
Women							
Present study	191	44·5	31·9	23·6	41·9	36·6	21·5
Rest of Grampian	21 697	42·2	28·4	29·4	50·8	27·4	21·9

* For details of subjects, see Table 2 and p. 556.
† Carstairs & Morris (1990).

data entry package version 5 (Cardiff software, Vista, CA, USA).

Anthropometric measurements

Weight was measured to the nearest 0·1 kg on Soehle bathroom scales (CMS Weighing, London, UK) that were calibrated with standard weights at intervals during the measurement period. Subjects wore indoor clothing but no shoes for the measurements. Height was measured to the nearest 0·001 m using a portable stadiometer (Leicester Height Measure; CMS Weighing). Demispan was measured as the distance between the sternal notch and the web space between the third and fourth fingers on the left hand (or the right hand if the left arm could not be fully extended), using a tape designed for the purpose (CMS Weighing). Mid-arm circumference was measured as the circumference of the upper left arm mid-way between the acromion and olecranon processes, with the arm hanging loosely at the side. BMI was calculated as weight (kg)/height $(m)^2$; demiquet was calculated as weight (kg)/demispan $(m)^2$ in men, and mindex was calculated as weight (kg)/demispan (m) in women (Lehmann *et al.* 1991). In twenty-one subjects (eleven men and ten women), height measurements were considered unreliable as the subjects had difficulty standing erect, and in five subjects (three men and two women) the demispan was considered unreliable as the subjects could not extend either arm fully. These subjects were excluded from the analyses involving anthropometric measurements.

Blood measurements

Blood samples were taken after a light breakfast of tea and/or white bread or toast, with no fruit juice or breakfast cereals allowed prior to the sample. Samples were stored on ice for transport to the laboratories within 2 h of collection. Samples for ferritin, vitamin B_{12} and serum and erythrocyte folate were taken to the haematology laboratory at Grampian University Hospitals; samples for vitamin D were frozen at −70°C and samples for vitamin C were treated with metaphosphoric acid and frozen at −70°C. Serum ferritin, serum vitamin B_{12} and serum and erythrocyte folate were analysed by a Technicon Immuno 1 radioimmunoassay (), with quality control assessed under the UK External Quality Assessment Scheme for Haematology. Plasma vitamin C samples were analysed by reversed-phase HPLC using an ion-pairing reagent with u.v. detection (Ross, 1994) as described by Duthie (1999). Serum 25-hydroxycholecalciferol was measured in duplicate using a manual extraction radioimmunoassay (Diasorin Ltd, Saluggia, Italy). The functional sensitivity of this assay is 6 nmol/l and the CV is $<8\,\%$ across the concentration range 15–1000 nmol/l. The assay cross-reacts on an equimolar basis with 25-hydroxy vitamin D_3 and 25-hydroxy vitamin D_2. There was no significant difference in ferritin levels between the nine men and seven women who had leucocyte counts $>10 \times 10^9$/l and those with lower leucocyte counts, so all ferritin results were included in the analysis. Cut-off points for deficiency were chosen at the upper end of the range of published values, as they were designed to estimate the prevalence of marginal deficiency states rather than established clinical deficiency.

Data analysis

Responses to each item on the questionnaire were classified as either 'high risk' or 'low risk'. The cut-off point selected was based on the distribution of the responses to the original question, so that the 'high risk' group did not contain <15 or $>50\,\%$ of the subjects. The anthropometric measurements and blood results were classified as low or normal using the 33rd percentile as the cut-off point. Men and women were combined to define these cut-off points for BMI and blood measures, as there was no reason *a priori* to assume that the relationship between predictor variables and blood measurements would be different between gender. The 33rd percentiles were: BMI 23·9 kg/m^2; demiquet 106·3 kg/m^2; mindex 78·9 kg/m; mid-arm circumference 0·29 m. The 33rd percentiles of

Table 2. Characteristics of study subjects*
(Median values and ranges)

	Men (*n* 207)		Women (*n* 191)	
	Median	Range	Median	Range
Age (years)	79	75–93	80	75–96
BMI (kg/m^2)†	25·3	16·6–35·0	25·6	16·6–34·1
Demiquet (kg/m^2)‡	112·8	74·9–155·7	n/a	n/a
Mindex (kg/m)§	n/a	n/a	85·4	58·8–184·2
Mid-arm circumference (m)	0·302	0·219–0·384	0·300	0·210–0·402
Serum ferritin (μg/l)	74·9	3·8–1847	47·6	4·4–1232
Serum vitamin B_{12} (pmol/l)	244	39–1474	247	74–1474
Erythrocyte folate (nmol/l)‖	607	66–2268	544	107–2179
Plasma vitamin C (μmol/l)	35·7	0–137·9	45·6	0–131·2
Serum 25-hydroxycholecalciferol (nmol/l)	33·0	6·0–82·0	28·0	70–82·0

n/a, Not applicable.
* For details of procedures, see p. 556.
† *n* 190 men and 181 women.
‡ *n* 204 men.
§ *n* 189 women.
‖ *n* 204 men and 187 women.

the blood results were: ferritin 38·3 μg/l; vitamin B_{12} 208 pmol/l; erythrocyte folate 458 nmol/l; vitamin C 27·7 μmol/l; 25-hydroxycholecalciferol 25 nmol/l. Associations between being at high *v.* low risk according to the questionnaire items or having low *v.* normal anthropometric measurements and having low *v.* normal blood measurements were assessed with Mantel-Haenszel odds ratios (OR). Those taking dietary supplements were excluded from calculations of OR for nutrients contained in the supplement. Comparisons between serum 25-hyroxycholecaliferol in summer and winter were carried out by paired *t* test on log-transformed data. All analyses were carried out with SPSS version 10.0 (SPSS, Chicago, IL, USA).

Results

The age, anthropometric measurements and blood levels of micronutrient status in the subjects are given in Table 2. Only 4·1 % of men and 3·9 % of women had a BMI <20, while 5·6 % of men and 12·2 % of women had a BMI >30. Of men, 34 % lived alone and of women, 69 %. Subjects taking supplements containing Fe, vitamin B_{12}, folate, vitamin C and vitamin D were 8, 9, 9, 12 and 24 % of men and 6, 10, 9, 15 and 30 % of women respectively.

The cut-off points used to define marginal micronutrient deficiency and the prevalence of marginal deficiency of the five micronutrients in the total study population are shown in Table 3. For Fe, vitamin B_{12} and folate the prevalence of marginal deficiency was fairly similar in men and women, but marginal deficiency of vitamin C was more common in men, while marginal deficiency of vitamin D was more common in women. Those aged ≥ 80 years old were not more likely to have low micronutrient status than those aged 75–79 years old except in the case of vitamin D deficiency (OR 2·23; 95 % CI 1·35, 3·66). Season was also a determinant of vitamin D status: in thirty-one men and twenty-four women who had samples taken in the summer and winter the median 25-hydroxycholecalciferol levels were 31 (range 9–78) nmol/l in summer compared with 24 (range 7–92) nmol/l in winter ($P<0·001$).

BMI, demiquet, mindex and mid-arm circumference were poor predictors of low micronutrient status: there were no significant associations between being in the lowest third of these measurements and having blood levels in the lowest third for any of the five nutrients apart from an association between mindex and serum ferritin in women (OR 2·36; 95 % CI 1·21–4·46). Dietary supplements of the specific nutrient were associated with being in the middle or upper third of blood levels of vitamin B_{12}, folate, vitamin C and 25-hydroxycholecalciferol (OR (95 % CI): 2·73 (1·11, 6·73), 18·15 (2·49, 132·33), 4·29 (1·78, 10·32) and 8·17 (4·09, 16·29) respectively); but the association between taking supplements containing Fe and being in the middle or upper third of the distribution of serum ferritin was not statistically significant (OR 1·89; 95 % CI 0·75, 4·79). Apart from taking supplements containing vitamin B_{12}, the only significant predictor of being in the lowest third of the distribution of vitamin B_{12} status was not having any natural teeth (OR 1·71; 95 % CI 1·09, 2·70).

Table 4 shows the items from the questionnaire for which the 'high risk' responses were associated with low Fe, folate, vitamin C or vitamin D status. There were a further twelve questions (age, living alone, recent weight loss, not seeing people often, having heart problems, having oily fish less than once per month, having difficulty seeing, standing, holding cooking pans, opening tins or bathing, and overall EASY-care score (Philp, 2000)) that were strongly associated with having low vitamin D but not Fe, folate or vitamin C status (all $P<0·01$). The only item associated with low status of all four nutrients was having an income of less than £150 per week.

The data were also analysed comparing the questionnaire items shown in Table 3 with having marginal deficiency of the micronutrients as opposed to being in the lowest third of the distribution of blood levels. For Fe and vitamin B_{12}, none of the factors showed any significant associations, though due to the low prevalence of marginal deficiency of these nutrients the power of these tests was low. For folate, marginal deficiency was associated with having breakfast cereal less than once per week (OR 2·83; 95 % CI 1·61, 4·97), having less than two

Table 3. Cut-off points for marginal deficiency and prevalence of marginal deficiency in the study population*

	Men (*n* 207)		Women (*n* 191)	
	Cut-off point	Prevalence (%)	Cut-off point	Prevalence (%)
Serum ferritin (μg/l)	20†	6·3	15†	7·3
Serum vitamin B_{12} (pmol/l)	147‡	10·1	147‡	12·6
Erythrocyte folate (nmol/l)§	356¶	14·5	356¶	16·8
Plasma vitamin C (μmol/l)	23‖	32·9	23‖	24·6
Serum 25-hydroxycholecalciferol (nmol/l)	30**	37·2	30**	56·5

* For details of subjects and procedures, see Tables 1 and 2 and p. 556.
† International Nutritional Anemia Consultative Group (1985).
‡ World Health Organization (1968).
§ *n* 204 men, 187 women.
‖ Sauberlich (1977).
¶ Sauberlich *et al.* (1974).
** Sauberlich (1999).

Table 4. Odds ratios for being in the low rather than middle or high third of the distribution of blood micronutrient levels†

Predictor from questionnaire	Subjects at risk (%)	Iron	Folate	Vitamin C	Vitamin D
Variable or poor appetite	15·3	2·10*	–	–	3·27***
Irregular meal pattern	34·2	–	–	–	3·10***
Leaving food on the plate	26·4	2·53***	–	–	2·80***
Having breakfast cereal less than once per week‡	31·4	–	3·18***	–	–
Having fruit juice less than once per day	56·0	–	–	3·09***	–
Having fresh tomatoes less than once per week	24·4	–	–	2·82***	–
Having green vegetables less than once per week§	19·8	1·99*	–	–	–
Having less than two portions of fruits and/or vegetables yesterday	25·9	–	2·52***	3·14***	–
Having oily fish less than once per month‖	35·2	–	–	2·18**	1·94**
Having no natural teeth	35·4	–	1·80*	–	2·62**
Having poor general health	21·4	–	–	–	5·52***
Taking five or more medicines per d	25·6	2·10**	–	–	2·83***
Believing food makes no difference to health	43·2	–	–	2·17***	–
Not trying to go out most days	20·1	2·22**	–	–	2·66**
Not taking any exercise other than walking	44·0	1·64*	–	–	4·80***
Not having social activities each week	50·8	–	1·81**	–	2·67***
Unable to go shopping without help	35·2	–	–	–	2·72***
Unable to climb stairs without help	17·6	–	–	–	3·23***
Feeling sad some of the time in the past month	24·6	2·02**	–	–	3·61***
Not having a sunny holiday in the last 6 months	78·1	–	2·69**	–	1·97*
Income below £150 per week¶	36·4	1·76*	2·12***	1·80**	2·13**

*$P<0·05$, **$P<0·01$, ***$P<0·001$.
† For details of subjects and procedures, see Tables 1 and 2 and p. 556.
‡ Fortified and unfortified cereals.
§ Cabbage, broccoli, spinach etc., but not peas or green beans.
‖ Herring or kippers, mackerel and salmon.
¶ Combined income for couples.

portions of fruits and/or vegetables the previous day (OR 1·92; 95 % CI 1·07, 3·43) and having a household income less than £150 per week (OR 1·96; 95 % CI 1·12, 3·41). For vitamin C and vitamin D, the associations were very similar to those shown in Table 4.

Discussion

Although there was little anthropometric evidence of malnutrition in these men and women, marginal deficiency of micronutrients was not uncommon, particularly for vitamin C and vitamin D. A high prevalence of marginal deficiency of vitamin D may be expected on the basis of the northerly latitude of the present study location (58° N), but for the other four micronutrients the median levels in subjects aged 75–84 years in the present study were higher than those in community-living subjects of the same age in a recent UK-wide survey (Finch *et al.* 1998) apart from ferritin levels in men, suggesting that our subjects were not unusually malnourished with regard to these nutrients compared with the UK population. Compared with results on vitamin B_{12}, folate and vitamin D in 2600 men and women aged 80–85 years old living in the community in a range of European countries in the Survey in Europe on Nutrition and the Elderly: a Concerted Action (SENECA) study (Haller, 1999), the median values in our present subjects were towards the lower end of the range of values seen in the eleven different countries, particularly for vitamin B_{12}. However, caution is needed in comparing results from different laboratories, as large inter-laboratory variations may occur, particularly in the case of folate levels (Gunter *et al.* 1996).

The lack of association between anthropometric measures and micronutrient status in the present study supports the suggestion that in the elderly, micronutrient deficiencies can occur without generalised protein–energy malnutrition. This is in agreement with an analysis of data from 570 men and 554 women aged 70–75 years in the SENECA study, which showed no relationship between anthropometric indices and plasma vitamin B_{12} or folate levels (Weggemans *et al.* 1997). We also found no relationship between reported weight loss and low Fe, vitamin B_{12}, folate or vitamin C status, although there was an association with low vitamin D status (OR 2·09; 95 % CI 1·22, 3·56). Due to the cross-sectional nature of the present study, we were not able to assess whether clinical measurements of weight change could predict micronutrient deficiency, but this possibility merits testing in future studies. In our test–retest studies, self-reported weight loss in the past 6 months was found to have low reproducibility (Kendall's tau-b 0·17), indicating that in this population it may not provide a reliable estimate of actual weight change.

Of the 114 items on the questionnaire, only four items were strongly associated ($P<0·01$) with low Fe status, five with low folate status and six with low vitamin C status, while twenty-five items were strongly associated with low vitamin D status. It is important to recognise that in this kind of exploratory data analysis with multiple significance tests, weak associations may easily arise by chance, and P values of 0·05 should be treated with caution. Many of the associations with $P<0·01$ are plausible as causal associations, for example, not going out most days could directly affect vitamin D status. The associations between breakfast cereal consumption and folate status and between fresh fruit juice consumption and

vitamin C status could clearly be causal and are all the more convincing in light of the fact that similar associations were also found in an analysis of the national survey data (Gibson, 1998). Other associations may reflect the confounding influence of a third variable, for example, the association between fish intake and vitamin C status could reflect the fact that those who eat more fish also eat more fruits and vegetables. These associations are more likely to be population-specific and may not therefore be valid in other elderly populations with a different diet or lifestyle. The lack of association between questionnaire items and vitamin B_{12} deficiency may be accounted for by the fact that vitamin B_{12} deficiency is more likely to be the result of atrophic gastritis than dietary inadequacy.

The lack of association between anthropometric measurements and micronutrient status in this population indicates that screening tools that focus on protein–energy malnutrition and anthropometric measurements may not be useful for identifying those at risk of micronutrient deficiency. However, the high prevalence of marginal deficiency in this population (Table 3) demonstrates that there is a need for simple dietary advice about intake of key foods and/or micronutrient supplements for those at risk of these deficiencies. From the present study, specific questionnaire items appear to be useful in identifying those at risk and in drawing attention to areas on which dietary advice could be focused. These questionnaire items now need to be compared with biochemical measures of micronutrient status in other populations to assess the possibility of wider application of these findings.

Acknowledgements

The present study was supported by a grant from the Scottish Office (Chief Scientist Office); ref K/OPR/2/2/D334. We thank Anne Ball, Barbara O'Hanrahan, Dr Graham Beatsall, Dr Garry Duthie, Dr Derek King, Grampian GPs and the subjects who participated for their contributions to this study.

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