Uptake and excretion of iron by healthy elderly subjects

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SUMMARY Metabolic balance studies for iron have been carried out on 24 apparently healthy elderly people (11 men and 13 women) aged 69.7 to 85.5 years living in their own homes and eating self selected diets. Several biochemical and haematological indices of iron state were also measured. The mean daily iron intake was 176 μmol , with a range of 55–321 μmol . Eight women and six men consumed diets which provided less than the recommended daily dietary allowance for iron of 179 $\mu\text{mol/day}$. Mean daily retention of iron, however, was $-7 \mu\text{mol}$, a value which did not significantly differ from equilibrium. No sex difference was noted between any of the biochemical and haematological measurements. Mean values of iron concentration, iron binding capacity, iron binding saturation, and ferritin and haemoglobin concentrations were 20 $\mu\text{mol/l}$, 59 $\mu\text{mol/l}$, 34%, 77 $\mu\text{g/l}$, and 14.3 g/dl, respectively.

We have shown that in apparently healthy elderly people who are in equilibrium for iron balance, several biochemical and haematological measurements of iron state do not differ from the normal ranges established in younger adults.

There is little information concerning the dietary iron requirements of the elderly. The existing British and American recommended daily dietary allowance of 179 $\mu\text{mol/day}$ ^{1,2} is based on data obtained in younger individuals.

A number of surveys carried out in the United Kingdom over the last 30 years³⁻⁸ have found evidence suggesting that iron deficiency may be an important factor in anaemia of the elderly. The last large scale survey was carried out by the Department of Health and Social Security in 1972–73.⁸ The overall incidence of anaemia was 12.5% and iron concentrations below normal were found in 19% of the men and 25% of the women studied.

Although the extent of the non-haematological effects of iron deficiency is controversial, mild iron deficiency without anaemia may produce various symptoms such as headache, fatigue, heartburn, changes in appetite, and diminished work performance. Many of these features are also encountered in the elderly.

There is evidence⁹⁻¹¹ that the elderly may have a decreased absorption of iron. Jacobs and Owen¹¹ found that it was only non-haem iron absorption

which was affected by age and they suggested that hypochlorhydria may be responsible. A later study¹² found no effect of age on the absorption of ferrous ammonium sulphate. Hydrochloric acid is not, however, an important factor in the absorption of ferrous salts.

The bioavailability of dietary iron is dependent on many factors.^{2,13} Haem iron is absorbed more readily than non-haem iron and its absorption is less affected by the presence of other dietary components. Non-haem iron absorption is enhanced by ascorbic acid and the presence of meat or fish and inhibited by tannates and phosphates. In old age the proportion of the daily iron obtained from meat tends to decrease while that obtained from cereals increases.¹⁴ This may reduce the bioavailability of iron in the diet consumed by many old people.

We have carried out metabolic balance studies in 24 selected apparently healthy elderly people. In addition, several biochemical and haematological indices of iron state have been measured. These results should provide data relevant to findings for iron state in healthy elderly people, with which results from other groups of elderly people may be compared.

Material and methods

SUBJECTS

Eleven men (mean age 78.2, range 73.3–85.2 years) and 13 women (mean age 75.8, range 69.7–85.5) volunteered to take part in this study. All were apparently healthy, lived independently in their own homes, and ate self selected diets. The results of preliminary balance data for 10 of these subjects have been published previously¹⁵ and are included in the present study. The study had the approval of the joint ethical sub-committee of the Faculty of Medicine of the University of Southampton and Southampton and South West Hampshire Health Authority.

SAMPLE COLLECTION AND ANALYSIS

Balance material

Duplicate samples of diet, faeces, and urine were collected over five day periods into containers free of trace elements using previously described techniques.¹⁶ The collection of all samples was carefully supervised by an experienced dietitian, who explained all procedures to the volunteers and who was in attendance at all meal times. The subjects were encouraged to maintain their normal daily routines for the duration of the study, but were asked to shop for and prepare double their usual quantity of fluids and food. Prepared food was divided (using accurate laboratory scales) either by the dietitian herself or by the subject under the dietitians' supervision to form a meal and an exact duplicate for analysis. Any food left on the subjects' plate was saved separately for analysis. Urine was collected into a plastic jug and then transferred to a bottle containing hydrochloric acid as a preservative. Carmine was used as a faecal marker. Stools were collected on to polythene sheeting and then frozen.

At the end of the study samples of diet, faeces, and urine were combined and homogenised using a

Table 2 Daily intake excretion and retention of iron in 24 healthy elderly people

	Mean $\pm$ SD (μ mol/day)	Range (μ mol/day)
Intake	176 $\pm$ 65	55 to 321
Urinary excretion	1 $\pm$ 0.3	0.2 to 1.4
Faecal excretion	182 $\pm$ 61	81 to 270
Total excretion	183 $\pm$ 61	82 to 270
Net absorption	-6 $\pm$ 22	-64 to 28
Net retention	-7 $\pm$ 22	-64 to 26

laboratory blender specially adapted¹⁷ to minimise contamination of the samples with extraneous iron. Triplicate samples of dietary, faecal, and urine homogenate were dry ashed overnight at 460°C.¹⁸ Iron was measured in the dry ashed samples by atomic absorption spectrophotometry using a Perkin-Elmer 560 spectrophotometer. National Bureau of Standards bovine liver (NBS: standard reference material 1477) was analysed by the same method and a value of 260 μ g/g dry weight was obtained (assigned value 268 $\pm$ 8 μ g/g). The mean within batch precisions for analysis of iron in dietary, faecal, and urinary homogenate were 2.1, 0.7, and 6.2%, with recoveries of iron added to the samples before ashing being 104, 102, and 91%, respectively.

Blood samples

Standard routine laboratory techniques were used to measure the following variables in venous blood: haemoglobin, packed cell volume, red cell count, mean cell volume, mean cell haemoglobin concentration, and mean cell haemoglobin. Plasma iron concentration, total iron binding capacity, and iron binding saturation were also measured by standard techniques. Ferritin was measured using a Bio-Rad (Bio-Rad Laboratories Ltd, Watford, UK) radioimmunoassay kit.

Table 1 Biochemical and haematological variables measured in 24 healthy elderly people

	Men (n = 11)		Women (n = 13)	
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
Plasma iron (μ mol/l)	20 $\pm$ 6	12–35	20 $\pm$ 4	14–25
Plasma iron binding capacity (μ mol/l)	58 $\pm$ 9	48–75	60 $\pm$ 7	47–70
Plasma iron binding saturation (%)	34 $\pm$ 9	20–55	34 $\pm$ 6	24–44
Plasma ferritin (μ g/l)	86 $\pm$ 90	27–360	67 $\pm$ 25	19–105
Plasma transferrin (g/l)	3.0 $\pm$ 0.5	2.2–3.7	3.0 $\pm$ 0.4	2.4–3.8
Haemoglobin (g/dl)	14.7 $\pm$ 1.2	13.5–16.9	13.9 $\pm$ 0.8	12.9–15.3
Red cell count ($\times 10^{12}$ /l)	4.77 $\pm$ 0.47	4.34–5.50	4.80 $\pm$ 0.35	4.24–5.50
Packed cell volume	0.423 $\pm$ 0.042	0.371–0.451	0.416 $\pm$ 0.027	0.382–0.477
Mean cell volume (fl)	91 $\pm$ 4	85–100	89 $\pm$ 4	84–95
Mean cell haemoglobin concentration (g/dl)	34.1 $\pm$ 1.1	32.6–36.3	33.8 $\pm$ 1.3	30.6–34.9
Mean cell haemoglobin (pg)	30.9 $\pm$ 1.6	28.1–33.3	30.0 $\pm$ 1.5	27.5–32.1

Daily iron balance in 24 elderly subjects.

Statistical analysis

Statistical analysis¹⁹ was performed using an Apple 11 microcomputer. The Mann-Whitney rank test was used to compare groups of results, and a paired *t* test was used to assess the significance of the retention values obtained. A probability level of 0.05 was accepted as significant.

Results

Table 1 gives the results of the analyses of the blood and plasma samples. The results of the balance study are given in Table 2, and the Figure shows the plot of intake against total excretion about the line of equality ($y = x$). Net absorption refers to total intake minus faecal excretion and net retention to total intake minus total excretion.

The mean daily intake of iron was 174 μmol for women and 179 μmol for men, with an overall mean of 176 μmol . The corresponding median values were 154 μmol for women and 166 μmol for men, with a median of 163 μmol for the whole group. Eight women (62%) and six men (55%) had daily intakes below the recommended daily allowance, while three women (23%) and one man (9%) had intakes of less than two thirds of the recommended daily allowance. The mean iron intake expressed in terms of nutrient density—that is, $\mu\text{mol}/10\text{MJ}$ —was 252 for women and 195 for men, with an overall value of 230 $\mu\text{mol}/10\text{MJ}$.

There was no correlation between iron intake, absorption or retention, and any of the blood or plasma measurements used to assess body iron state.

The factor for conversion of SI ($\mu\text{mol}/\text{day}$) to

traditional units (mg/day) is 0.0559. To convert plasma iron and iron binding capacity from $\mu\text{mol}/\text{l}$ to $\mu\text{g}/100\text{ ml}$ the factor is 5.59.

Discussion

The average daily iron intake of 176 μmol was 98% of the British¹ and American² recommended daily allowances of 179 μmol . Our findings are a little lower than those of 240 and 186 $\mu\text{mol}/\text{day}$ obtained for elderly Swedish men and women.²⁰ They are, however, in good agreement with the calculated daily intake obtained in a recent DHSS study⁸ and in a study of 37 elderly subjects in Belfast.⁷

The intake of iron in relation to that of energy for the women—that is, 252 $\mu\text{mol}/10\text{MJ}$ —is similar to the mean values of 235 and 265 $\mu\text{mol}/10\text{MJ}$ found by other workers.^{8,20} It is also in good agreement with the range of 214–299 $\mu\text{mol}/10\text{MJ}$ generally found in Western diets.²¹ The mean value of 195 $\mu\text{mol}/10\text{MJ}$ for the men in our study was lower than the mean values of 231⁸ and 269 $\mu\text{mol}/10\text{MJ}$ ²⁰ previously found for elderly men.

The overall net iron retention for the 24 subjects was $-7\text{ }\mu\text{mol}/\text{day}$. This value did not significantly differ from equilibrium, which suggests that for most of these people the daily iron intakes were adequate. Our figures take no account of any iron lost in sweat. Figures for such losses vary from a maximum of 9 $\mu\text{mol}/\text{day}$ for all integumentary and sweat losses for elderly men²² to a mean of 6 $\mu\text{mol}/\text{day}$ for younger subjects.²³ But although any additional loss will make the mean iron balance slightly more negative, such losses are unlikely to affect significantly the overall iron balance. To our knowledge there has been only one other study of iron balance in the elderly.²² Elderly men were in mean negative balance ($-8\text{ }\mu\text{mol}/\text{day}$) when consuming 179 μmol iron per day. Over 70% of the iron, however, was supplied in the form of non-haem iron, which is known to be absorbed less readily than haem iron,² particularly in the elderly.¹¹ Therefore it is not possible to make comparisons between the two studies.

The detection of iron deficiency in old age may be difficult. Serum iron concentrations tend to decrease with age,^{24,25} although values may rise again in postmenopausal women.²⁶ Transferrin concentration is reported to fall in the elderly²⁷ as does the total iron binding capacity.²⁵ There is a progressive increase with age in ferritin concentrations in both men (after the age of 20) and women (after the menopause).²⁸ It has been questioned, however, whether this rise in the elderly is due to a true increase in body iron stores or whether it occurs as a result of an increased prevalence of inflammatory processes.²⁰

No sex differences were noted in any of the parameters for iron that were measured in the subjects. All the measurements fell within the reference ranges established for younger adults, with two possible exceptions; one man had a borderline low plasma iron concentration and another had a plasma ferritin concentration at the top of the expected range. By definition, one in 20 measurements will fall outside the reference range and yet still be normal. McLennan⁶ has suggested that serum iron binding saturation may be a good index of body iron stores. A cut off level of 16% saturation was selected, as values below this are not compatible with the bone marrow containing adequate amounts of iron. The mean iron binding saturation level of 32% found for our subjects was well in excess of this cut off level. In health and uncomplicated iron deficiency, serum ferritin concentration correlates with the body iron stores; 1 µg/litre of serum ferritin is equivalent to 8 mg of storage iron.²⁹ Apart from the one measurement already referred to, all ferritin concentrations were within the expected range. This suggests that body iron stores were adequate in these subjects.

Other surveys of iron state of the elderly in the United Kingdom^{5,7,8} have found that a considerable proportion of the subjects studied had plasma iron concentrations below normal. Our subjects were a highly select group of healthy individuals, and this is probably responsible for their good iron states.

Although the mean haemoglobin concentrations for the men (14.7 g/dl) and women (13.9 g/dl) were different, this was not significant ($0.1 < p > 0.05$). This finding is in contrast to other investigations,^{3,4,30} but the number of participants in our study was comparatively small. The haemoglobin concentrations of all the subjects fell within the established reference range for younger individuals. Three red blood cell indices sometimes used in the diagnosis of anaemia and iron deficiency are the mean cell volume, mean cell haemoglobin concentration, and mean cell haemoglobin. All values for these were within accepted reference ranges.

Taking into account all of the parameters of body iron state that were measured, we conclude that these 24 elderly people were in good iron state. Many of them consumed diets which provided less than the recommended daily allowance but, nevertheless, the absorption of iron from their diets must have been sufficient to satisfy their body requirements. It would appear that for this group of selected healthy elderly people in equilibrium for iron balance, several of the biochemical and haematological measurements of iron state do not differ from the normal ranges established in younger adults.

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