

## Dietary iron deficiency and sports anaemia

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In order to determine whether dietary inadequacies can explain the sub-optimal iron status widely documented in endurance-trained athletes, the food intake records of Fe-deficient and Fe-replete distance runners and non-exercising controls of both sexes were analysed. In all the male study groups the mean dietary Fe intake met the recommended dietary allowances (RDA; > 10 mg/d (US) Food and Nutrition Board, 1989). However, both female athletes and controls failed to meet the RDA with regard to Fe (< 15 mg/d) and folate (< 200 µg/d). There was no difference in the total Fe intakes of Fe-deficient and Fe-replete athletes and the controls of each sex. However, Fe-deficient male runners, but not female runners, consumed significantly less haem-Fe ( $P = 0.048$ ) than their comparative groups. This suggests that the habitual consumption of Fe-poor diets is a factor in the aetiology of athletes' Fe deficiency.

**Athletes: Sports anaemia: Iron status: Dietary iron: Recommended dietary allowances**

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Decreased serum ferritin (SF) levels (< 20 µg/l), suggestive of a precarious iron balance, are widely reported amongst endurance-trained athletes (Clement & Asmundsen, 1982; Dickson *et al.* 1982; Magnusson *et al.* 1984*a, b*; Weight *et al.* 1988), particularly women (Colt & Heyman, 1984; Lampe *et al.* 1986; Matter *et al.* 1987). The aetiology of this compromised Fe status is not clear, although lack of easily-absorbed dietary Fe is an important causative factor in the deficiency prevalent in both developed and Third World countries (Dallman *et al.* 1984). However, it would seem somewhat paradoxical that trained athletes, who presumably consume more kilojoules than a sedentary person, should become deficient in this mineral considering the correlation between the total energy and Fe content of the diet (Buskirk, 1977). However, it is also possible that some athletes do not practise dietary regimens that are nutritionally adequate, particularly vegetarians and those attempting to maintain low body-weights by energy restriction (Snyder *et al.* 1989). Nevertheless, such practices do not explain the apparently high incidence of Fe deficiency in distance runners.

The present study was, therefore, undertaken to document the relationship between dietary Fe intake and stores in male and female distance runners, and a non-exercising control group.

### METHODS AND MATERIALS

#### *Subjects*

Sixteen male and twenty female distance runners who had been training 50–120 km/week for more than 2 years were stratified into two groups according to their haematological profile. Fe deficiency was designated when two of the three established clinical criteria

(Cook *et al.* 1976), i.e. haemoglobin (Hb; g/l) < 140 for males and < 120 for females, SF < 20  $\mu\text{g/l}$ , and percentage transferrin saturation (% sat) < 18 %, were met. The first group thus comprised four male and eight female Fe-deficient athletes, and the second, twelve male and twelve female athletes who were Fe replete (Hb > 140 g/l and 120 g/l for males and females respectively, and SF > 20  $\mu\text{g/l}$ ). The control sample of eight males and eight females were recruited from among the University staff. None participated in any form of regular exercise, but were in good health and did not smoke nor take any prescription medication. Neither the distance runners nor controls were consuming supplementary Fe, vitamins or minerals at the time of the study, nor had done so regularly in the previous 6 months. Any person who had voluntarily donated blood in the previous 12 months was excluded from the study.

Once the subjects had given their informed consent to participate in the study, a further blood sample was taken under the same conditions as in the screening study to confirm their haematological status. None of the female subjects were amenorrhoeic, and haematological and dietary data were collected at all phases of the menstrual cycle.

#### *Dietary record*

All participants were instructed to maintain their customary eating patterns and to record their intake for seven successive days. Standardized apparatus consisting of a balance, measuring cup and spoon was used to measure the mass of all solid and semi-solid foodstuffs, or volume of all liquids eaten during this 7 d period. Subjects were given detailed written and illustrated instructions on how to quantify specific food items and also to record only the amount of food actually consumed; that is, to subtract any plate waste. The recorded diets were analysed using the Floro Diet Programme (1987), which is based on the food composition tables compiled by the National Research Institute for Nutritional Diseases (Gouws & Langenhoven, 1981), in order to obtain the daily average intake of all macro- and micronutrients. The proportion of haem- and non-haem-Fe in the diet was calculated according to the guidelines of Monson *et al.* (1978). Specifically, that 30 % of the Fe in pork, liver and fish, and 50 % in beef, lamb and chicken is in the form of haem-Fe. All other dietary Fe was assumed to be non-haem. None of the athletes were informed of their Fe status and to which study group they had been assigned before completing the dietary record.

#### *Haematological measurements*

The subjects reported to the laboratory for venepuncture at 08.00 hours after an overnight fast. They had not performed any running training in the preceeding 24 h. A total of 20 ml venous blood was drawn from an ante-cubital vein without stasis into appropriate vacutainers (Vacutest; Radem Laboratories, Sandton). A full blood count including Hb, packed cell volume, erythrocyte count, leucocyte count, mean cell volume, mean cell Hb and mean cell Hb concentration were performed on EDTA-blood using a Coulter Counter Model S II<sup>+</sup> (Rowan *et al.* 1979). Serum was stored frozen ( $-20^{\circ}$ ) for later determination of serum Fe (SI) and total Fe-binding capacity (TIBC) according to the method described by the International Committee for Standardization in Haematology (1978*a, b*), and SF levels by radioimmunoassay (Addison *et al.* 1972) using a commercial kit (Amersham International Plc, Amersham, UK). % Sat was calculated from SI and TIBC levels.

#### *Statistical analysis*

An analysis of variance (ANOVA) was applied to the grouped data (Cary, 1985) to determine whether there were any significant differences between the groups. The data for the three male and three female groups were pooled into two groups according to sex, and

Table 1. Demographic details of iron-deficient and Fe-replete endurance-trained athletes and their non-exercising controls†

(Means and standard deviations)

n...	Males						Females					
	Fe-deficient 4		Fe-replete 12		Control 8		Fe-deficient 8		Fe-replete 12		Control 8	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	39.8	11.1	34.0	6.9	32.8	8.1	31.9	7.3	34.4	9.1	32.8	9.6
Mass (kg)	64.3	6.8	69.8	6.0	73.0	7.4	53.5	3.8	56.3	4.4	51.8	5.6
Body mass index	21.4*	1.5	22.5	1.8	25.0	1.7	20.0	3.2	20.5	1.7	20.2	1.3
Distance run weekly (km)	93.8	19.2	104.0	29.0			78.8	29.0	65.9	22.0		
No. of years running	8.6	5.7	8.6	6.1			4.1	2.2	5.7	2.6		
Marathon best time (h:min)	2:57	0:25	2:39	0:17			3:14	0:20	3:36	0:38		

Mean value for Fe-deficient male athletes was significantly different from that for male controls: \*  $P < 0.05$ .

† For details of groups, see pp. 253–254.

scatter plots were constructed with the variables energy, protein, Fe, ascorbic acid and body mass, v. SF. A stepwise regression procedure using these same variables, with SF levels as the dependent variable, were then performed (Cary, 1985) in order to determine which indices should be used in a regression model. As this procedure did not reveal any significant trends, further analysis was not considered necessary. For all analysis  $P < 0.05$  was taken as the level of significance.

## RESULTS

The demographic, haematological and dietary details are recorded in Tables 1, 2 and 3 respectively. The body mass index of the Fe-deficient male athletes was significantly lower ( $P < 0.05$ ) than that of the other male groups. Although three criteria were used to assign the athletes to their study groups (SF concentration, Hb level and % sat), the former appears to be the most critical factor given the significant differences in this variable between the male and female groups.

### *Dietary and haematological status of the male athletes*

The mean SF level of the Fe-deficient male athletes ( $14.8 \mu\text{g/l}$ ) was significantly lower than that of their Fe-replete counterparts ( $64.9 \mu\text{g/l}$ ;  $P = 0.0002$ ) and the male controls ( $73.2 \mu\text{g/l}$ ;  $P = 0.014$ ). There was no significant difference in mean Hb concentration, nor any other nutritional variable including Fe, between the groups.

The mean total energy ingested in both groups of athletes was lower than the recommended dietary allowances (RDA; (US) Food and Nutrition Board, 1989) for sedentary males ( $11.34 \text{ MJ/d}$ ), but all subjects consumed more than  $1 \text{ g protein/kg body mass per d}$  (Table 3). Similarly, the mean Fe intakes of all male groups exceeded the RDA ((US) Food and Nutrition Board, 1989). However, the mean haem-Fe content of Fe-

Table 2. *Haematological characteristics of iron-deficient and Fe-replete endurance-trained athletes and their non-exercising controls*‡

(Mean values and standard deviations)

n...	Males						Females					
	Fe-deficient 4		Fe-replete 12		Control 8		Fe-deficient 8		Fe-replete 12		Control 8	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Haemoglobin (g/l)	132	14	146	7	154	8	123	15	132	15	130	20
Packed cell volume	42.0	0.1	44.0	0.1	46.0	0.0	38.0	0.0	39.0	0.0	40.0	0.1
Mean cell volume (fl)	91.9	8.1	92.1	5.9	88.5	2.1	91.9	7.0	93.3	3.6	89.8	4.1
Percentage transferritin saturation	24.4	8.0	31.9	11.5	39.1	7.1	24.2	12.0	32.3	11.8	30.2	5.6
Serum ferritin ( $\mu\text{g/l}$ )	14.8*††	4.8	64.9	31.1	73.3	50.0	11.0*	4.8	63.8*	31.0	34.9	29.7

Mean values were significantly different from the corresponding control group: \*  $P < 0.05$ .

Mean values for Fe-deficient male athletes were significantly different from those for Fe-replete male athletes: ††  $P < 0.01$ .

‡ For details of groups, see pp. 253–254.

deficient male runners (0.95 mg/d) was significantly lower ( $P = 0.048$ ) than that of the Fe-replete male runners (1.96 mg/d) (Table 3). In all groups there was no correlation between the SF level and total energy, protein, Fe and ascorbic acid intakes, body mass or body mass index.

#### *Dietary and haematological status of the female athletes*

The mean SF level of the Fe-deficient female athletes (11.0  $\mu\text{g/l}$ ) was significantly lower than that of the Fe-replete female runners (63.8  $\mu\text{g/l}$ ;  $P = 0.0001$ ) but not that of the control group (34.9  $\mu\text{g/l}$ ). The mean Hb level, total energy, protein and Fe intakes were not different between groups. In all groups there was no correlation between SF level and total energy, protein, ascorbic acid, body mass or body mass index.

As the mean energy intake of each group failed to meet the RDA (9.24 MJ/d; (US) Food and Nutrition Board, 1989), and although the protein intake was adequate, the diets were sub-optimal with regard to Fe and folate (Table 3). Neither the mean total dietary Fe intake nor the haem proportion thereof was different between the three female groups.

#### DISCUSSION

An important finding in the present study is that endurance athletes of both sexes failed to meet the recommended energy intakes for sedentary persons (Table 3). This anomaly has been previously described in male and female endurance athletes (Weight *et al.* 1988; Snyder *et al.* 1989; Mulligan & Butterfield, 1990) and the broader population (Nieman *et al.* 1989).

A second observation is that, although the deficient athletes of both sexes consumed no less Fe than did their replete counterparts, the mean haem-Fe proportion thereof was

Table 3. Mean daily nutrient intakes of iron-deficient and Fe-replete endurance-trained athletes and their non-exercising controls†  
(Mean values and standard deviations)

n...	Males						Females					
	Fe-deficient		Fe-replete		Control		Fe-deficient		Fe-replete		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy (kJ)	9962	1285	10940	1663	12050	2500	6985	1330	6275	1960	6230	1870
Carbohydrate (g)	286	42	301	66	350	99	195	39	164	63	176	65
Protein (g)	77.9	17.3	91.1	16.2	105.8	21.3	61.5	12.7	56.6	17.7	54.3	20.0
Fibre (g)	24.7	6.3	28.2	11.2	23.8	2.6	20.9	7.0	20.4	6.9	17.0	8.4
Total Fe (mg)	12.9	3.0	16.7	4.8	14.9	3.7	11.9	2.7	10.3	3.1	8.9	2.6
Haem-Fe (mg)	0.95*	0.7	1.96	0.9	2.1	0.8	0.71	0.6	1.06	0.7	0.83	0.7
Non-haem-Fe (mg)	14.1	3.0	15.2	4.9	13.6	2.9	10.7	3.3	9.2	3.5	8.1	2.2
Ascorbic acid (mg)	104	83	117	55	104	78	85	84	119	55	83	42
Folate ( $\mu$ g)	284	77	326	158	266	48	176	63	227	96	155	69
Cyanocobalamin ( $\mu$ g)	8.8	10.9	6.9	4.7	5.3	1.4	4.3	3.2	3.6	2.1	2.6	1.4

† Mean value for Fe-deficient male athletes was significantly different from that for Fe-replete male athletes. \*  $P < 0.05$ .

significantly lower in the hypoferritinaemic male runners ( $P < 0.05$ ). No such differences were found between the female study groups. None of the runners or control subjects consumed strictly vegetarian diets, although some excluded red meat.

The absorption of non-haem-Fe is critically influenced by a number of other variables (Monson *et al.* 1978). In this study the amount of ascorbic acid, calcium, dietary fibre, tea (tannin) and coffee (caffeine) ingested daily were also noted but were found to bear no relationship to Fe status. In fact the only study to report a significant correlation between dietary Fe and SF levels was that of Deuster *et al.* (1986) who found a positive association in amenorrhoeic, but not eumenorrhoeic female athletes.

Despite the sub-optimal energy intakes of the male athletes, the individual nutrients content including Fe, but excluding folate, exceeded the RDA ((US) Food and Nutrition Board 1989) in all groups. This data is also comparable with our previous experience (Weight *et al.* 1988).

Conversely, most of the female athletes in the present study consumed nutritionally inadequate diets. Although uncompensated by the ingestion of vitamin and mineral supplements, these dietary practices were generally not reflected in a compromised haematological status. This observation is consistent with that of Miles *et al.* (1984) who comprehensively determined habitual Fe intakes in a representative sample of persons consuming a self-selected Western diet. Fe consumption was found to be consistent throughout a single year in both sexes, but bore no relationship to SF levels which also remained constant, although marginal in the females. Furthermore, the fact that there was no significant difference between the nutritional profiles of the athletic and control groups is in agreement with the observations of Risser *et al.* (1988).

Particular attention was paid to the protein consumption of these athletes, as Yoshimura (1970) and Shiraki *et al.* (1977) have contended that the early stages of training may produce a type of sports anaemia which has been related to an inadequate protein intake. The Japanese authors suggest that in the early stages of training a significant proportion of this macronutrient is used in muscle hypertrophy at the expense of Hb synthesis. However, it would seem unlikely that a fundamental physiological process such as oxygen transport should be compromised in order to facilitate an adaptational but not essential tissue hypertrophy. Moreover, the fact that this transient anaemia has not been confirmed by subsequent studies (Hegenauer *et al.* 1983), and the protein intakes of athletes, including those in the present study, have been shown to be adequate, further invalidates this suggestion regarding the aetiology of sports anaemia.

Although the present study is concerned only with the extent to which the habitual diet contributes to the Fe status of trained athletes, cognizance is given to the possibility of Fe loss. There is contradictory evidence of accelerated dermal, gastrointestinal or menstrual blood loss in rigorously exercising persons (Paulev, 1983), although the more recent studies negate a significant dermal loss. Gastrointestinal bleeding has been described in runners (Stewart *et al.* 1984; Fisher *et al.* 1986) but it is an infrequent occurrence, most usually associated with strenuous racing and often compounded by salicylate abuse.

Therefore, as in the larger population, inadequate Fe nutrition is an important factor in the Fe deficiency experienced by sports persons. Although Fe intake *per se* may be sufficient, habitual consumption of a vegetarian-type diet with a predominance of non-haem-Fe-containing protein effectively compromises the nutritional Fe status of these athletes.

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