Micronutrient undernutrition in British schoolchildren

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There are few studies in children, particularly in the UK, aimed at examining relationships between the intake of specific micronutrients and currently accepted biochemical/functional indices of status. Consequently, the normal range of values for biochemical indices of status in this age-group, and the functional significance of low biochemical status, is unknown. Hence, dietary requirements have not been adequately established.

As pointed out in the Committee on Medical Aspects of Food Policy (COMA) report (Department of Health, 1991), there is insufficient information on nutrient requirements for all age-groups to establish dietary reference values (DRV) with any great confidence, but there is a particular problem in relation to children over the age of 1 year. For the vitamins A, C, B_{12}, riboflavin and folate, and the trace minerals Zn, Cu, and Se, DRV for children have been interpolated between values for infants and adults, or extrapolated from adult values with a factor for body weight or growth increment included in the calculation. The COMA Panel (Department of Health, 1991) found very little evidence from which to determine thiamin requirements of children. Values for vitamin B_6 (1–18 years) are set at the adult level, whilst those for Fe vary, but no rationale for the calculation of these values is presented in the text.

Despite the uncertainty with which DRV for children have been set, it is 'very improbable that an individual consuming the reference nutrient intake (RNI) will be consuming insufficient amounts of that nutrient' (Department of Health, 1991). As the proportion of a population having intakes below the RNI increases, there is an increasing risk of deficiency in that population. In the absence of any other standard, the RNI is commonly used in many studies as a bench mark by which the adequacy of nutrient intake is judged. In the first section of the present paper, therefore, the micronutrient intakes of British schoolchildren are examined in relation to the current UK reference values. This is followed by presentation of available information on the incidence of low biochemical indices of micronutrient status in children and consideration of the value of intake data for prediction of micronutrient status in this age-group. A number of studies have been performed on the micronutrient intake and status of adolescents and younger children in other countries, but despite the paucity of UK data we have resisted the temptation to make use of these results and have largely confined the discussion to the UK situation.

INTAKE

The largest, most recent survey of the diets of British schoolchildren (*n* 3285, 10–15 years) was commissioned by the Department of Health and Social Security and the Scottish Home and Health Department (Department of Health, 1989). Intakes of Fe, thiamin, riboflavin, nicotinic acid, vitamin C, retinol, β-carotene, vitamin D and vitamin

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B_6 were calculated for 10–11- and 14–15-year-olds, separately, using a 7 d weighed intake method of recording. In Fig. 1 these values have been adapted to present average values for 10–15-year-olds, and comparisons are made with current RNI, rather than RDA. In general, intakes were approximate to or well in excess of the RNI, where values have been set. One exception was Fe, with mean intakes for all, except older boys, being below the recommended value.

Studies involving comparisons of micronutrient intake with recommended intakes continue to appear regularly in the literature. However, in the absence of any measurements of biochemical or functional indices of status the interpretation of findings from these studies rests upon the individual view of the author(s). Intake values may be used to support the hypothesis that the diet is 'largely' adequate, or that, where intakes fall below recommendations, that the diet is inadequate with respect to these micronutrients, or that, if no gross signs of malnutrition are observed in individuals consuming less than recommended amounts, that the recommended levels are set too high. It is well recognized that, while in any group there may be individuals with nutrient intakes below the RNI, this does not necessarily imply dietary deficiency. Deficiency can be established only by clinical and biochemical evidence. It is also well known that the absorption of several micronutrients is influenced markedly by a range of physiological and dietary factors, so that estimation of total amounts consumed may be of little use in determining adequacy. Nutritional studies of children which rely entirely on measurements of total micronutrient intake, therefore, add nothing to our understanding of the nutritional value of their diet.

STATUS

A number of studies have been performed in relation to the Fe status and requirements of infants and preschool children in the UK (James *et al.* 1988; Morton *et al.* 1988; Grant, 1990), and within this group Fe-deficiency anaemia has been found in 5–30%, and low Fe stores in 21–55%, of children screened (Parks & Wharton, 1989). The prevalence of Fe deficiency in older children in the UK, however, is unknown. A study examining Fe status in adolescents in Ireland (Armstrong, 1989) found that 40% of 14–18-year-olds (*n* 234) were Fe deficient on the basis of serum ferritin measurements (<10 ng/l); 13 and 7% of the young men and women had a haemoglobin (Hb) concentration of <130 and <120 g/l respectively. Using multiple criteria (Hb, mean corpuscular Hb concentration, serum ferritin), Nelson *et al.* (1993) found that 10·5 and 3·5% of 12–14-year-old girls (*n* 197) and boys (*n* 202) respectively in Epsom could be classified as anaemic, whilst in a smaller study of the micronutrient status of 13–14-year-olds (*n* 54) in Norwich approximately 17% of subjects were classified as Fe deficient on the basis of serum ferritin concentration, but only 4% had a low Hb concentration (Southon *et al.* 1992). At present there is insufficient information concerning Hb and serum ferritin concentrations in teenagers to judge the extent of the problem more generally.

In the absence of any other relevant information, consideration of the status of schoolchildren in Britain with respect to other micronutrients is based on our own study of 13–14-year-olds (*n* 54, nineteen boys and thirty-five girls) in the Norwich area. Further details of this study are presented elsewhere (Finglas *et al.* 1993; Southon *et al.* 1992). In general, the parents of the children recruited to this study could be assigned to social classes I–III on the basis of occupation. Nutritional problems associated with low income

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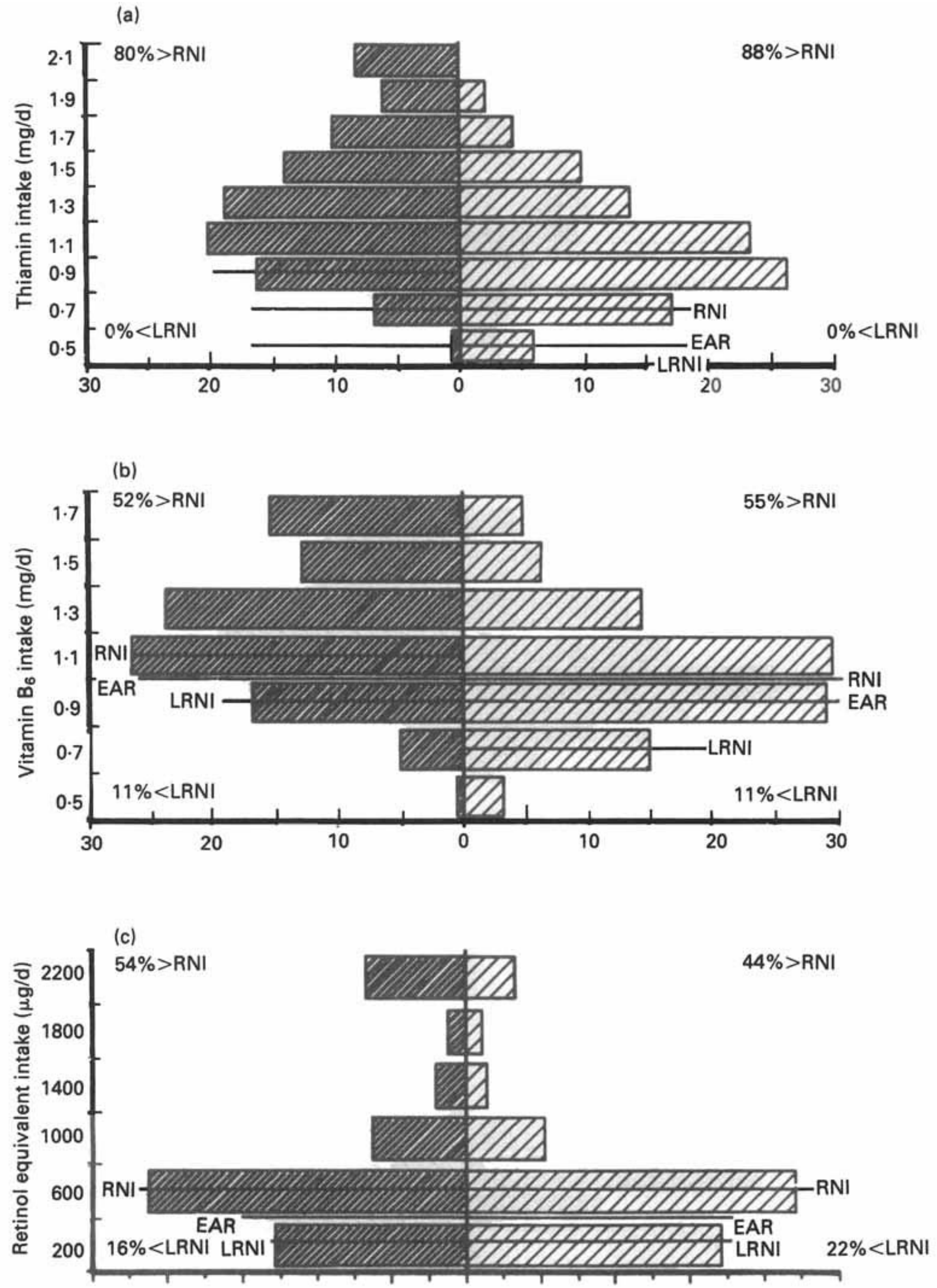
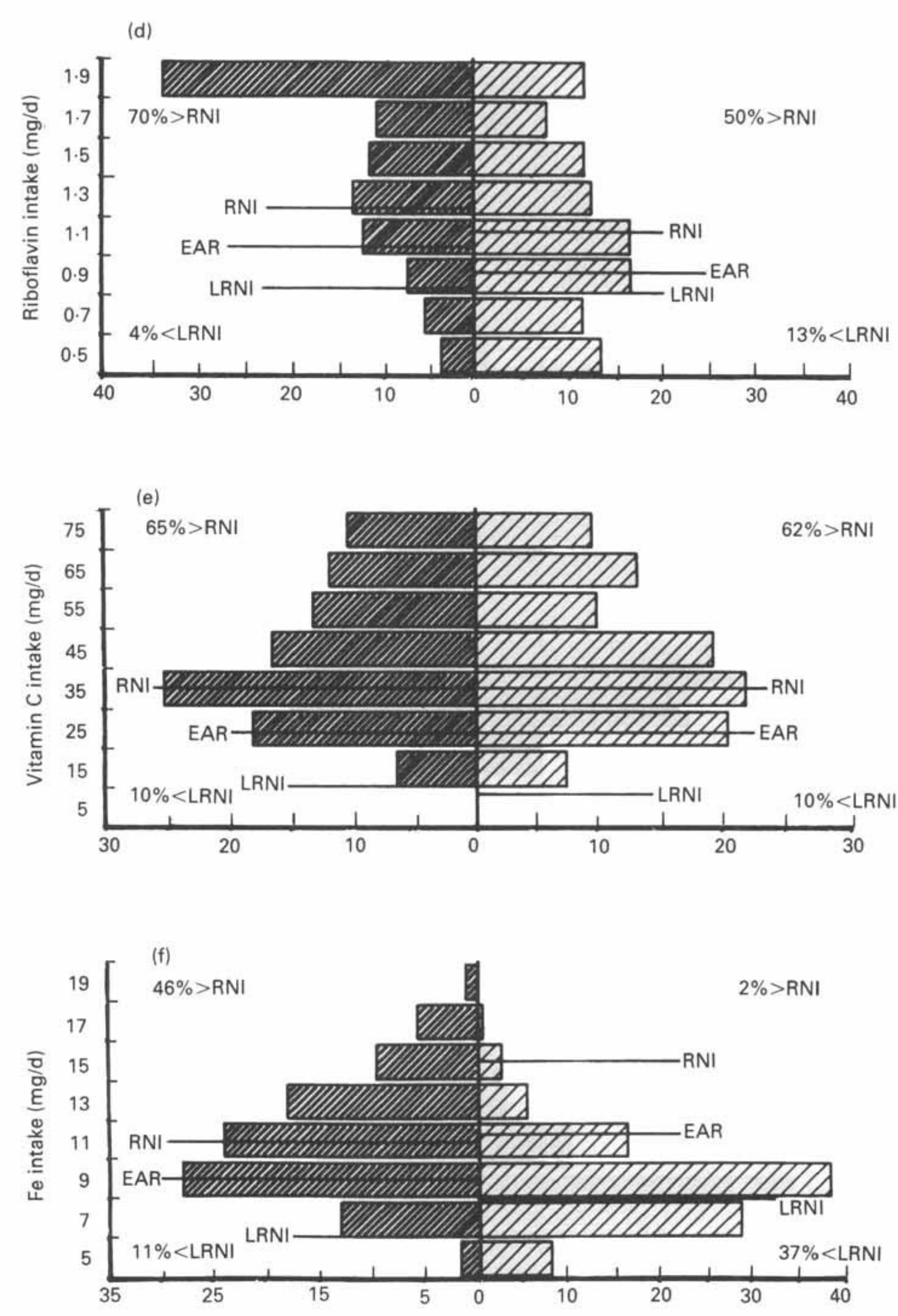


Fig. 1. Micronutrient intake of British schoolchildren (average values for 10–15-year-olds; 1415 boys (▨) and 1282 girls (▧); adapted from Department of Health, 1989); frequency bar charts by sex. Comparison with current dietary recommendations (Department of Health, 1991). RNI, reference nutrient intake.



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and the availability of food are, therefore, unlikely to be an issue in this group of subjects. Nevertheless, a substantial number of these young people had 'low' biochemical indices of status for several micronutrients (Gibson, 1990), as assessed in blood samples taken after an overnight fast. As stated previously, low levels of serum ferritin were found in 17% of subjects (<10 μg/l; 11% of boys and 21% of girls). In addition, a substantial proportion of subjects had low biochemical indices of thiamin status (erythrocyte transketolase (*EC* 2.2.1.1) activation coefficient (ETKAC) >1·14; 22% of boys and 32% of girls), riboflavin status (erythrocyte glutathione reductase (*EC* 1.6.4.2) activation coefficient (EGRAC) >1·20; 37% of boys and 31% of girls) and vitamin B_6 status (plasma pyridoxal-5-phosphate <50·8 nmol/l; 50% of boys and 27% of girls). Plasma vitamin B_{12}, folate and ascorbic acid concentrations were all above the suggested cut-off points for low to deficient status. However, it should be noted that these cut-off points relate largely to the adult population and it has yet to be determined if similar values are appropriate to younger age-groups.

In Fig. 2 the frequency distribution of values obtained for various biochemical indices for the 13–14-years-olds are compared with values obtained for an adult population (20–64 years; seventy-nine males, eighty females; S. Southon, unpublished results) living in the same community. Fig. 2(d) shows a marked difference between the groups in the distribution of serum ferritin concentrations, with the values for the 13–14-year-olds being predominantly in the lower range of values. Armstrong (1989) and Nelson *et al.* (1993) also found that the mean serum ferritin concentration in younger individuals was much lower than that normally obtained for an adult population. Similarly, comparison of plasma vitamin B_6 values for the adolescent and adult groups (Fig. 2(f)) shows that substantially more of the younger subjects had values at the lower end of the range and, although no values for ETKAC are yet available from our adult population, a substantial proportion of the adolescents had values indicative of poor status (Fig. 2(g)). Where values are available (Marktl *et al.* 1982; Widhalm *et al.* 1986; Gans & Harper, 1991), a significant proportion of the adolescent populations studied in other countries also had ETKAC indicative of abnormally low thiamin status, although criteria for establishing normal-, moderate- and high-risk individuals varies slightly between authors. The distribution of EGRAC values indicated a better riboflavin status for the adolescent group as a whole (Fig. 2(e)), but a number of boys, and a smaller number of girls, had values in excess of 1·40, the cut-off point for deficiency. Additional studies are required to ascertain whether or not these differences are largely an age-related phenomenon, and whether current cut-off points for diagnosing poor micronutrient status in childhood and adolescence are appropriate. In determining such cut-off points, however, consideration should be given to the potentially adverse effects of even short-term deficiency. Poorer status may well be commonly associated with rapid periods of growth and development, but this does not necessarily imply that the situation is acceptable, particularly in the light of emerging evidence that Fe deficiency, and possibly other micronutrient deficiencies, may be linked to reduced psychomotor development and cognitive efficiency (Pollitt & Leibel, 1976; Parks & Wharton, 1989), and increased susceptibility to infection (Oppenheimer, 1989), in the young.

The range of plasma vitamin B_{12} concentrations was very similar in the adolescent and adult populations and none of the subjects in either group had levels indicative of a deficiency (Fig. 2(b)). Plasma folate concentrations tended to be higher in the adolescents, particularly the boys (Fig. 2(a)), and plasma ascorbic acid (PAA) concen-

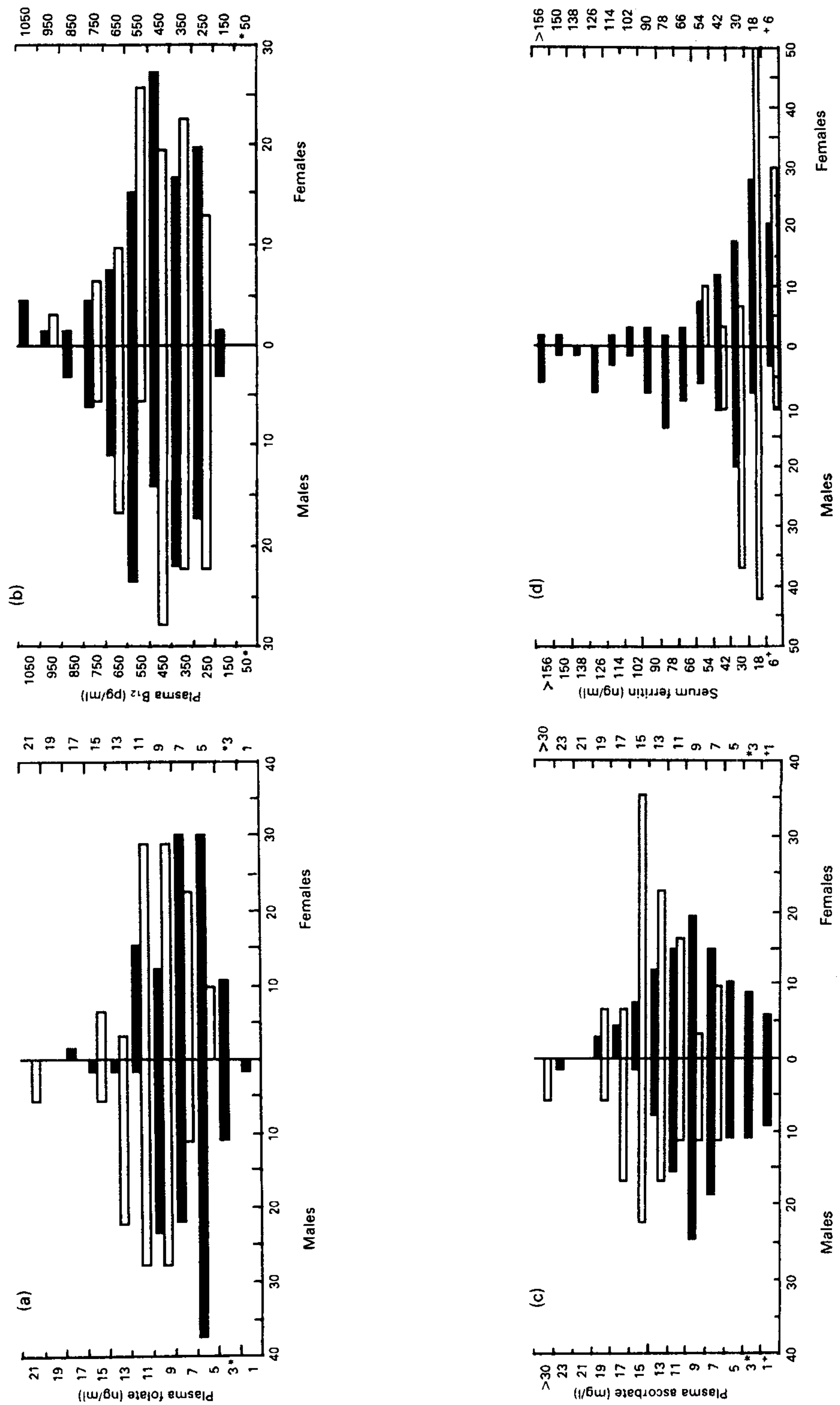
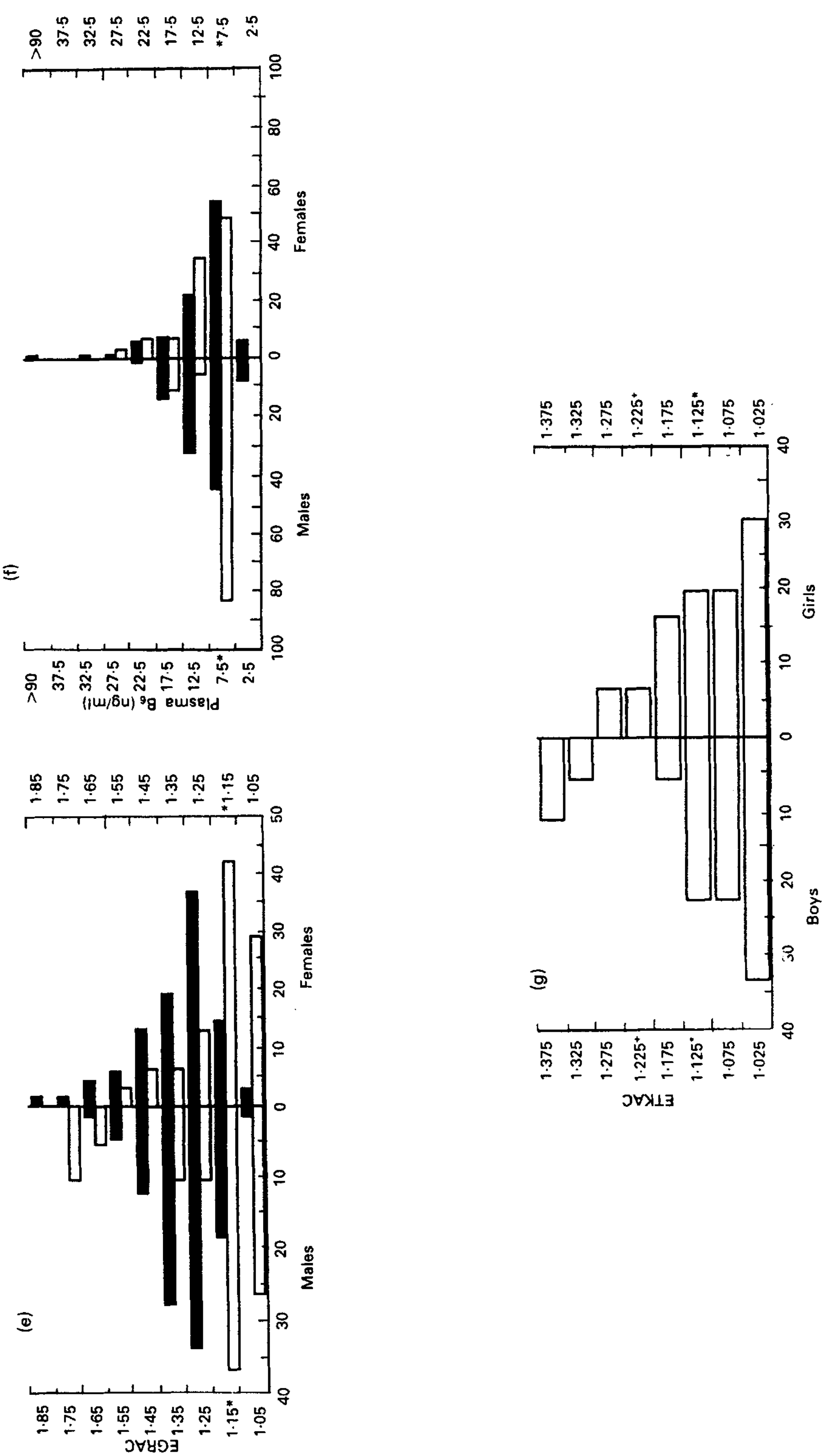


Fig. 2. Biochemical indices of micronutrient status; frequency bar charts by sex for 13–14-year-olds □ (nineteen boys and thirty-five girls). Comparison with values for adults ■ (20–64 years; seventy-nine males and eighty females) living in the same community, where values are available. Cut-off values for marginal (*) and/or deficient (+) status are indicated (Gibson, 1990). EGRAC, erythrocyte glutathione reductase (*EC* 1.6.4.2) activation coefficient; ETKAC, erythrocyte transketolase (*EC* 2.2.1.1) activation coefficient.


(e)
EGRAC
Males
Females
(f)
Plasma B6 (ng/ml)
Males
Females
(g)
ETKAC
Boys
Girls

trations were markedly higher in many of the adolescents compared with the adult group (Fig. 2(c)). None of the adolescents in the Norwich study could be classified as having a low vitamin C status, whilst 5–10% of the adults fell into the 'deficient' category. These higher PAA values in our 13–14-year-olds were associated with vitamin C intakes well in excess of the RNI; the major source being vitamin C-rich beverages (Finglas *et al.* 1993). Where diets do not include high intakes of these relatively expensive beverages, and where there is a lower consumption of fruit and vegetables, vitamin C and folate status might be expected to be poorer.

RELATIONSHIPS BETWEEN INTAKE AND STATUS

Since many studies rely on nutrient intake values, calculated from tables of food composition, as the only source of nutritional assessment in children, it is important to consider whether such values are of any use for the prediction of micronutrient status. This aspect has been discussed in some detail elsewhere (Southon *et al.* 1992), but two points in particular warrant re-emphasis at this stage of the present discussion. First, comparison of 7 d calculated micronutrient intakes with those obtained by direct analysis of duplicate diets in the Norwich study of 13–14-year-olds, indicated that food table values may lead to a substantial underestimation of folate and thiamin intake, whilst Cu, riboflavin and vitamin B_6 intake may be overestimated. Second, on the basis of nutrient intake values alone, diets are often classified as adequate. However, in our study of 13–14-year-olds, the only consistent relationship between total intake and status was for vitamin C intake and plasma ascorbic acid concentration (Southon *et al.* 1992). None of the subjects with a low index of thiamin status had an average thiamin intake below the RNI, and the majority of subjects with low indices of status for the other micronutrients were also assessed as consuming approximately, or well in excess of, current recommended amounts. These results are consistent with much larger studies of adult and elderly populations at our laboratory (S. Southon, unpublished results). Since the total intake of a specific micronutrient appears to provide minimal information with respect to the micronutrient status of an individual or a population, such information should not be relied upon as the primary basis for nutritional assessment.

CONCLUSION

In preparing the present paper, it became increasingly apparent that there is a paucity of information on the micronutrient status of schoolchildren, particularly in the UK. In adult populations nutritional scientists are extending the scope of work in this area to consideration of the functional significance of poor status in relation to health. In children and adolescents we do not even have baseline information on normal ranges for biochemical indices of micronutrient status. It is, therefore, impossible to judge whether a problem exists. In view of the potential nutritional vulnerability of this group, and the possible long-term effects of inappropriate nutrition during early years, further research should be a priority.

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