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Iron Deficiency Risk in Children: Discrepancy between Dietary and Biochemical Assessments

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Summary: A random sample group of 300 children and adolescents (aged 0.5 to 16 years) from a Mediterranean town of Spain, were investigated as part of a health education program. Analysis of dietary iron intake and the biochemical parameters of iron status (red cell volume, erythrocyte protoporphyrin concentration, transferrin saturation percentage and serum ferritin) were measured.

Based on dietary assessment, the percentage of children with iron intake levels below the Catalonia Recommended Daily Amounts varied from 24% to 77% and showed age and sex differences. The percentage of children with iron intakes below their own individual requirements varied between 7% and 41%. The age groups with the highest risk of iron deficiency were girls aged between 6 and 24 months, and boys aged between 13 and 16 years.

However, based on the biochemically assessed iron status, the results revealed an overall prevalence of iron deficiency varying from 0 to 23.3%. The highest prevalence was encountered in boys and girls between 6 and 24 months (23.3%), compared with only 3.3% between 13 and 16 years.

Despite conducting the investigation with the recommended controlled methodology, the results from dietary assessed risk of iron deficiency were significantly different from those assessed biochemically. Hence, caution is required when designing health programme strategies based exclusively on nutritional intake assessments.

Introduction

Epidemiological studies based on analyses of dietary intake and biochemical evaluation shows that iron deficiency is one of the most frequent nutritional problems in industrialized countries. In recent years, studies of nutritional iron intake levels in certain populations have been carried out [8, 13, 16, 18, 21, 24, 26] using various methods to evaluate dietary intake, such as the 24-hour recall or dietary history. Results, when com-

pared to International Recommended Daily Amounts, indicate iron deficiency risk in various groups.

When a considerable risk of iron intake insufficiency is observed in any study group, the next step, to reveal a more accurate indication of the prevalence of iron deficiency, ought to be a biochemical assessment of iron status using an appropriate technology applicable on an epidemiological scale.

In a study based on children and adolescents living in a Mediterranean town in Catalonia (Spain), we carried out an evaluation of the risk of iron deficiency by analysing dietary intake and, concurrently, biochemically determining the prevalence of iron deficiency. The aim of our study was to compare the efficacy of the two approaches to the analysis of nutritional iron deficiency in a defined population.

Material and Methods

300 boys and girls aged between 6 months and 16 years, resident in the town of Reus, were studied. The subjects were chosen by random sampling from the municipal census and stratified according to age and sex. Each of the five age groups (0.5–2, 2–6, 6–10, 10–13 and 13–16 years) comprised 30 boys and 30 girls.

The evaluation of iron status was carried out using:

a) Dietary intake evaluation: using 24-hours recall method [9] on three non-consecutive days including one non-working day. As an aid to portion-size assessment, photographic files of previously-weighed foodstuffs were used along with kitchen equipment of known capacities. The INSERM-ISTA Foodstuff Composition Tables were used to calculate nutrient intakes.

The adequacy of the nutrient intake estimate was assessed as follows. First, the proportion of the study population not meeting the Catalonian Recommended Daily Amounts (RDA-C) [11] was identified. Second, the distribution of nutrient intakes below the RDA-C was determined, and combined with probability statistics [1] to calculate the number of subjects likely to have intakes below their own individual requirements in relation to the various sufficiency levels estimated in the RDA-C. Third, levels of absorbable iron were estimated using the method of Monsen *et al* [20] which considers, separately, the observed total iron intake, heme and non-heme iron intake, ascorbic acid and meat and fish intake. The distribution of absorbable iron below the iron requirements [12] was determined, and combined with probability statistics to calculate the number of subjects likely to have absorbable iron intakes below their own individual requirements [12].

b) Biochemical evaluation: Mean cell volume (MCV) was measured in a Model S-7 Coulter Counter; erythrocyte protoporphyrin concentration (EP) by fluorometry using an Automatic Model 5 Hematofluorometer (Aviv Biomedical); serum transferrin (ST) was assessed by a nephelometric assay [6] on a Behring Laser Nephelometer; total iron binding capacity (TIBC) was deduced from the ST readings; transferrin saturation capacity (TSC) was calculated as the ratio of serum iron to TIBC and expressed as a percentage; serum ferritin (SF) was measured by an immunoenzymatic method using an Enzyme Linked Immunoabsorbent Assay [27] and standardised against international reference sera (NIBSC, London UK).

Capillary blood samples were taken from those subjects who were under 2 years of age while venous blood samples were taken from the older subjects. All samples were taken between 9 am and 12 mid-day.

The cut-off limits used for iron status indicators were: for MCV <70 fl for those subjects under 2 years of age, <73 fl between the ages of 2 and 5 years, <75 fl for the 6–14 year age group, and <80 fl for the over-14s; for TSC, $\leqslant 16\%$; for EP, $\leqslant 3$ µg/g; for SF, <12 µg/dl.

Subjects were considered to present iron deficiency if they possessed two or more abnormal values of the following parameters: MCV, EP, TSC and SF.

Results

Figure 1 shows the mean (± SD) of iron intake grouped according to age and sex in relation to the RDA-C [11]. The percentage of children and adolescents with iron intake levels below the RDA-C values varies considerably in all age groups (Tab. 1), ranging from 24% in the 6–24 month group to 77% in the 13–16 year old female group.

Table I shows the Percentage of children likely to have Iron Intakes below their own individual requirements (PII) and the Percentage of children with Absorvable Iron Intakes levels below their own individual needs (PAII). On this basis the percentages of children, observed, with indications of having an insufficient intake for their needs (PII) reaches its lowest level (7%) in the 13–16 year old male group and also among the youngest children (15%).

The percentage of children with indications of having an insufficient absorbable iron intake for their needs (PAII) increases with age, ranging from 24% and 22% in the 0.5–6 years groups to 91% in the 13–16 year female group.

In contrast, the biochemically assessed prevalence of iron deficiency is higher in the 0.5–2 year group with 23%, which coincides with the recall-assessed risk prevalence. The older age groups show a prevalence which diminishes with age through 8.3%, 1.7% and 0% followed by a slight rise of 3.3% during adolescence in both the male and female groups; the females of this last group showed a marked deviation from the prevalence risk indicated by the dietary assessment.

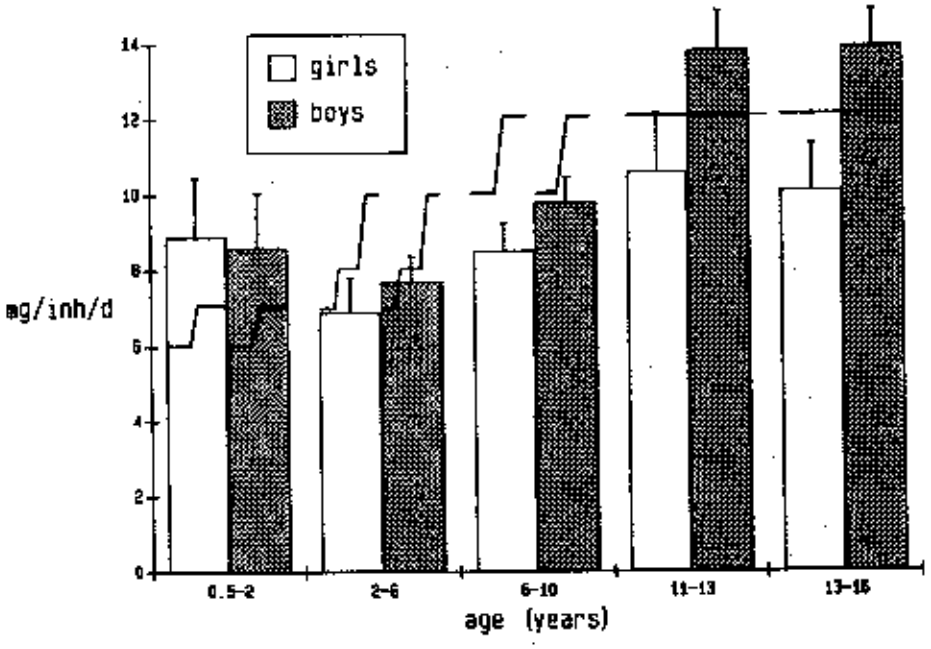

Figure 1: Mean (± SD) of iron intake grouped according to age and sex in relation to RDA-C.

Table I: Risk of iron deficiency and prevalence of biochemically iron deficiency.

	age groups (years)				
	0.5–2	3–6	6–10	10–12	13–16 ♀ - ♂
Intake below RDA-C (%)	24	60	73	55	77–29
PII (%)	15	32	30	27	41– 7
PAII (%)	24	22	43	47	91–48
Biochemically prevalence of iron deficiency (%)	23.3	8.3	1.7	0	3.3

Discussion

In order to evaluate nutritional intake we used the 24-hour recall method as applied by Pekkarinen *et al* [23] and Block [4] with modifications which permit increased precision [25].

Even with assiduously collected intake data, the subsequent stage in the assessment process (the use of tables indicating the nutritional composition of foodstuffs) can be a source of variation and error as illustrated by Black *et al* [3]. For example, comparison of the estimates of iron contents of meat, fish, seafood, milk, cereals and other common commodities of the average diet in the U.K. and France differ by as much as 200–300% depending on the information source (McCance Widowson tables [22] of the U.K. and the INSERM-ISTA tables from France). We opted for the INSERM-ISTA tables as they are more recent and are derived from analysis of foodstuffs very similar to our own.

Similarly, International Recommended Daily Amounts (RDA) for iron intake also vary widely even for groups of the same age and sex. For example, the iron RDA levels for females of 10–12 years of age in industrialized countries vary between 10 mg and 18 mg according to the RDA consulted [28]. Because of these inconsistencies in RDA values, they should only be considered as a term of reference i.e. that an intake below the recommended levels only indicates a *possible* risk of a nutritional deficiency and that a low intake should not necessarily mean that the intake level is insufficient for the individual subject's needs; interindividual processing of invested material varies considerably and can markedly affect the conclusions.

Based on the recall method the calculations of the risk of iron deficiency in our investigation appear high throughout the various age groupings; the lowest numbers at apparant risk being the 0.5–2 year old group.

In order to arrive at better estimates of the risk of iron deficiency among the general population, we proceeded to calculate the PII among these children. These calculations are based on the supposition that intake levels far removed from recommended levels have a higher probability of being insufficient than other values which might be lower, but not notably so, than the recommended levels [2]. This method in our study reduces the calculated percentage of children at risk of an iron intake deficiency. The most favoured groupings are now the 0.5–2 year old group and the 13–16 year old male group (Tab. I).

Even though this method leads to a more sensitive evaluation of deficiency risks, it shares the same limitations with the previous method in that it continues to be based on use the RDA.

In assessing the effect of the bioavailability of iron, we estimated the amounts of total iron absorption [20]. This method introduces 5 dietary variables in the calculation without correcting for other nutritional factors which may act as inhibiting agents not for other factors such as the iron reserves already within the organism [12]. Even though more complex, this method of analysing the percentage of individuals at risk of an iron absorption deficiency (PAII) has the same limitations as previous methods and does not materially alter the findings (Tab. I) were the risk of insufficient iron absorption in relation to the individual needs is again high, especially in the 13–16 year female group.

The evaluation of iron status by the biochemical indicators, although considerably more reliable on an individual basis, involves a number of handicaps and limitations. Firstly, in order to evaluate biochemical iron status in the organism, one needs to select various iron indicators to evaluate the different phases and stages relating to iron metabolism. The indicator which offers the best diagnostic sensitivity is the SF which measures reserves. The least sensitive is the hemoglobin which frequently evaluates only the most advanced stage of anaemia [7, 8, 14]. Secondly, biochemical sensitivity represents a further problem since a percentage of false positives or false negatives can occur when the child under investigation is suffering from certain ailments such as the slight infections and inflammations which are so frequent during infancy [7, 8, 14]. Finally, the reference ranges take on greater significance during infancy and adolescence since these values are influenced by body-growth requirements. For the indicators of iron levels we used the lower limit of the normality parameters which are internationally recognised [7, 8, 14]. Even so, the biochemically assessed prevalence of iron deficiency reveals only one group of individuals with a high percentage of deficiency i.e. the 6–24 month age group; a finding which has been observed in other epidemiological studies in industrialized countries [5, 10, 15, 17, 19].

In conclusion, identification and classification of children «at risk» from iron deficiency varies considerably with the type of assessment used and can be profoundly misleading since, at least in the present study, groups considered as high risk using a dietary assessment are shown to be at low risk or even at optimum iron status when assessed biochemically. Hence caution should be excersed if such data is to be used as a basis of nutritional intervention.

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