Serum total cholesterol and ferritin and blood haemoglobin concentrations in primary schoolchildren

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Abstract

Serum total cholesterol and ferritin and haemoglobin concentrations were measured in blood samples obtained by venepuncture in 378 of 593 children aged 5-6 or 8-9 years from seven primary schools in Canterbury. This study formed part of an investigation to assess the feasibility of including a venepuncture procedure for monitoring purposes in primary schoolchildren.

Although only one child had a very low haemoglobin concentration of 61 g/l, a large percentage, 25% in the rising 6 years and 7% in the rising 9 years, had concentrations between 100 and 115 g/l – that is, less than the reference fifth centile. Eight per cent had a serum ferritin concentration less than 8 µg/l. Cholesterol concentrations higher than 5.2 mmol/l were found in 20% of the 5-6 year olds and 23% of the 8-9 year olds, and in 19% of boys and 25% of girls. About 5% of children had cholesterol concentrations above 6 mmol/l.

The number of children with anaemia, iron deficiency, and high cholesterol raises serious concerns about the nutritional and coronary heart disease risk of British children.

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In Britain assessment of the nutritional status of children has been based solely on anthropometric measurements of height, weight, and skinfold thickness. The recognition that increased serum total cholesterol is a major risk factor for coronary heart disease,^{1,2} that coronary heart disease is a major killer in Britain,³ and that atherosclerosis may begin in childhood⁴ leads to a strong argument for monitoring cholesterol concentrations in children. Cholesterol concentrations have been studied in the USA^{5,6} and many other countries.⁷ Knuiman *et al* published cholesterol concentrations for 16 countries as early as 1980,⁷ but no substantial epidemiological information has been available for children in Britain.

In a study of the feasibility of venepuncture in primary schools we were also interested to ascertain the need for monitoring iron deficiency in Britain. Screening for anaemia has been the most common laboratory assessment, internationally, of nutritional status in children.⁸ Although iron deficiency is the most common nutritional deficiency in children,⁹

several reports in the USA and Canada have indicated that the frequency of iron deficiency has decreased over the last 20 years.⁹⁻¹² In Britain, however, several studies have reported iron deficiency in preschool and adolescent children.¹³⁻¹⁷

The objective of this study was to ascertain whether serum concentrations of cholesterol and iron are a cause of concern in the health of British children.

Subjects and methods

The sample consisted of 378 children aged 5-6 years or 8-9 years whose parents gave consent to venepuncture and who themselves agreed and were able to provide a sample at the time, as described in the accompanying paper.¹⁸

Blood samples were analysed for haemoglobin using a Coulter JS analyser. Serum ferritin concentrations were measured using a monoclonal antibody solid phase component system from Becton Dickinson. Serum total cholesterol concentrations were measured using an automated cholesterol oxidase-peroxidase method with kits supplied by Boehringer-Mannheim. A Lobas Bio centrifugal analyser was used with single point calibration of the machine with a serum based standard traced to Centers for Disease Control reference material. This standard was run in duplicate in each batch, together with internal quality assurance samples of known value (low, medium, and high). External quality assurance was performed using the UKEQAS and Wellcome schemes, which cover laboratories using a similar system. Insufficient serum was available for complete testing for three samples, for which cholesterol concentrations were available, but not haemoglobin and ferritin. The samples were sent by first class post from Canterbury to a laboratory in Newcastle.

Abnormal results were reported to parents and general practitioners through a local medical collaborator, who stressed the need for reassessment.

ANALYSIS

The means, standard deviations, and distributions of the haemoglobin and cholesterol results were described for the total sample, the two sexes, and the two age groups. Where the results were clearly skewed, data were transformed to a log scale before analysis and hence the geometric mean and 95% range are reported for ferritin results. Percentages of children with values below or above cut off

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Table 1 Serum haemoglobin and ferritin results by sex and age. Values are number (%) of children

	Boys (n=198)	Girls (n=177)	Rising 6 years (n=163)	Rising 9 years (n=206)
Haemoglobin (g/l)				
<115	36 (18)	23 (13)	41 (25)	15 (7)
≥115	162 (82)	154 (87)	122 (75)	191 (93)
Ferritin (μg/l)				
<8	16 (8)	15 (8)	17 (10)	13 (6)
≥8	182 (92)	162 (92)	146 (90)	193 (94)

Total number varies between sex and age groups as ages were not recorded for six children. Total number for haemoglobin and ferritin results is smaller than for cholesterol results as insufficient blood was available for all analyses on some children.

points were compared between age groups using the χ^2 test.

Results

Results for serum ferritin and serum haemoglobin are given by sex and age in table 1 and serum cholesterol concentrations in table 2.

Compared with the reference values developed by Dallman and Siimes,¹⁹ the mean haemoglobin value for this group of children was low (122 g/l compared with 130 g/l) and 23 (13%) girls and 36 (18%) boys had haemoglobin values less than the fifth centile of 115 g/l. Only one child had a haemoglobin result less than 100 g/l. The percentage of children with haemoglobin less than 115 g/l was higher in 6 year old children (25%) than in 9 year olds (7%) ($p<0.001$); the 95% confidence interval for the difference in percentages was from 10 to 25%. Four children with a cholesterol concentration greater than 6.5 mmol/l and a child with a haemoglobin of 61 g/l and serum ferritin of 5 μg/l were considered to have abnormal results, which were reported to their parents and general practitioners.

The ferritin results were skewed to the right but were approximately normally distributed when log transformed. The geometric mean (and 95% range) for serum ferritin was 17.4 (5.4–56.6) μg/l for boys and 17.0 (5.8–49.9) μg/l for girls. Eighteen per cent of boys and 20% of girls had serum ferritin concentrations ≤10 μg/l and 8% of boys and girls had serum ferritin ≤8 μg/l, representing iron deficiency. When log ferritin was plotted against haemoglobin results, lower haemoglobin results (less than 110 g/l) were associated with lower serum ferritin concentrations for girls, but there was little association for boys, with the exception of a child with a serum ferritin concentration of 5.0 μg/l and haemoglobin concentration of 61 g/l. Low concentrations of

Table 2 Serum cholesterol results by sex and age. Values are number (%) of children

Serum cholesterol (mmol/l)	Boys (n=200)	Girls (n=178)	Rising 6 years (n=165)	Rising 9 years (n=207)
<5.2	162 (81)	133 (75)	132 (80)	159 (77)
5.2 to <6.0	32 (16)	33 (19)	23 (14)	40 (19)
≥6.0	6 (3)	12 (7)	10 (6)	8 (4)

Total number varies between sex and age groups as ages were not recorded for six children.

ferritin, less than 8 μg/l, were slightly more prevalent in 6 year olds (10%) than in 9 year olds (6%), but the difference was not statistically significant; the 95% confidence interval for the difference in prevalence was from -0.2 to 10%.

Twenty two per cent of the children tested had serum cholesterol concentrations greater than 5.2 mmol/l. Eighteen children (5%) had serum cholesterol results greater than 6.0 mmol/l. Four per cent of the total sample of children had results between 6.0 and 6.5 mmol/l and 1% had results between 6.5 and 7.0 mmol/l. These higher cholesterol results were equally spread between the sexes and the two age groups. Mean cholesterol concentrations were similar for boys and girls and for the two age groups tested.

Discussion

The mean cholesterol concentration for the total sample of children (4.63 mmol/l) was higher than that found in a sample of children aged 8–11 years whose capillary blood samples were analysed using a portable cholesterol analyser by the same workers in 1991 (mean (SD) cholesterol 4.34 (0.65) mmol/l; Hammond J, Chinn S, Rona R, unpublished data) and higher than those of hospital²⁰ and community based²¹ studies of children in Britain, children living in the USA,⁵⁶ and in 16 other countries.⁷ The results are similar to those found by Armstrong *et al* (mean age of sample 12.8 years)²² and Sporik *et al* (sample aged 11 years)²³ in studies of British children. Such comparisons between studies are limited by the lack of standardisation between the analytical methods used to determine cholesterol levels.^{24–26} The laboratory in Newcastle was not part of our previous method comparison study.²⁴

We believe this is the first British study to report serum cholesterol results from a sample of healthy children in the primary school age group.

We have used the haemoglobin centiles developed by Dallman and Siimes¹⁹ as reference values for this paper. These centiles were developed from multiple samples of white children from both the USA and Finland, which excluded results of children with an identified cause of anaemia or iron deficiency in all but one of the samples. The number of children with haemoglobin concentrations less than 115 g/l was larger than we had anticipated for predominantly white, middle class children. The mean haemoglobin concentrations were 8 g/l lower than those found by Dallman and Siimes¹⁹ and in the NHANES II study of American children in 1976–80.²⁷

Serum ferritin has been shown to reflect total iron stores and is a practical marker to assess in children as it can be measured from small amounts of blood, shows no diurnal variation, and children are not required to fast before blood sampling, unlike serum iron and total iron binding concentration measurements.²⁸ As ferritin results are not

normally distributed they are best described by median or geometric mean values. Dallman and Reeves²⁷ suggest that a ferritin concentration less than 10 µg/l at any age is indicative of the depletion of iron stores, whereas Hinchcliffe and Lilleyman use 8 µg/l as evidence of iron deficiency in children in the rising 6 year age group.²⁹

The red cell indices of mean corpuscular volume and mean corpuscular haemoglobin are sensitive to changes in nutritional status.²⁸ As these indices are readily measured in combination with haemoglobin at little extra cost or effort, the inclusion of these variables in a monitoring system should be considered. In our study the delay between venepuncture and analysis of the sample militated against the inclusion of mean corpuscular volume and mean corpuscular haemoglobin.

Whether screening for anaemia should constitute part of a child health surveillance programme for British children has also been a source for some debate. Several studies have reported significant numbers of children with iron deficiency and anaemia.¹³⁻¹⁷ The levels of anaemia and iron deficiency in these studies were similar to or higher than those found in this study. Those studies reporting higher levels included infants in their samples. It is possible that the prevalence of anaemia decreases between the age of 6 years and puberty, as in our study the percentage of children with haemoglobin less than 115 g/l was markedly lower in the older age group, and the prevalence of anaemia in the younger age group is similar to results reported for preschool children.^{13 14 16} Few studies have included children of the age range assessed in this study. If our results are representative of a sample of otherwise healthy children, important questions are raised about the state of their health and nutrition, especially as the results from our study had a bias towards children from higher socioeconomic groups and included few children from ethnic minorities among whom nutritional anaemias are known to be more prevalent.³⁰

The full extent of the health effects of iron deficiency and anaemia in children remains uncertain. Deficits in growth, psychomotor development, and behaviour have been described with iron deficiency anaemia³¹⁻³³ and this should be an important consideration in making a decision about the inclusion of iron deficiency in a nutritional monitoring system.

Results obtained from this study suggest that an apparently healthy sample of predominantly middle class British children have moderately high levels of iron deficiency, anaemia, and higher than desirable serum cholesterol levels. Inclusion of these variables in surveillance studies of the health and growth of British children in the future is important and the development of reference values based on samples of British children is desirable.

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