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Food, vitamins and IQ

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The quality of children's diets in the United Kingdom is of great concern, and we hear pronouncements daily about the ways in which nutrients such as sugar and fat are having an adverse effect on our children's health. One argument rests on the notion that these two nutrients, taken in the form of 'sweet fat' such as cakes, biscuits and confectionery, are diluting the diet to such an extent that micronutrient intakes are falling below adequate levels. The degree of inadequacy may not be so great as to result in classical signs of frank deficiency, but are more likely to have adverse effects in terms of reduced resistance to infection and undesirable changes in behaviour and learning capability. One hypothesis might, therefore, be that the diets of British schoolchildren are so imbalanced and so lacking in micronutrients that learning ability is impaired.

A recent paper by Benton & Roberts (1988) examined this hypothesis in a group of 12–13-year-old Welsh schoolchildren. The children recorded what they had to eat and drink for 3 d, and the authors concluded that the intakes of a great range of nutrients were inadequate: the mean intakes of folic acid, calcium, copper, iodine, iron, magnesium, zinc, and several other nutrients were substantially below the US recommended dietary allowance (RDA; National Research Council, 1980). The authors then gave mineral and vitamin supplements to one subgroup of the children, and a placebo to another, and claimed to show that at the end of 9 months the non-verbal intelligence in the supplemented group had increased substantially over that of the placebo group. The report has been subject to much criticism, and we have taken the opportunity to re-test the hypothesis using more rigorous techniques of dietary assessment.

FOOD CONSUMPTION AND NUTRIENT INTAKES IN 11–12-YEAR-OLD CHILDREN

Schoolchildren (143 aged 11–12 years) attending secondary schools in North London completed 7 d weighed inventories of diet. Table 1 shows the percentage contribution of specific foods to the energy and sugar intake of boys. Soft drinks, confectionery and table sugar contributed 10% of dietary energy and 40% of the sugar in the diet, and these foods are in any case likely to be under-reported. Chips and crisps contributed 11% of energy, and cakes and biscuits, puddings and ice cream a further 12% of energy and 16%

Table 1. *Percentage contribution of specific foods to the energy and sugar intake of seventy-six 11–12-year-old British schoolboys*

Food	g/week	Percent of energy	Percent of sugar
Soft drinks	1800	4·7	21·4
Milk	1577	6·9	10·0
Bread	560	11·4	1·7
Fruit juice	497	1·4	5·2
Potatoes	400	3·3	0·2
Fresh fruit	385	1·4	5·3
Chips	361	7·4	0·1
Other meat products	301	5·8	0·1
Cakes and biscuits	271	9·4	11·2
Vegetables, other fresh	251	0·7	0·8
Breakfast cereals	240	6·7	6·0
Pasta and rice	236	2·1	0·3
Puddings and ice cream	205	2·6	5·1
Carcass meat	150	3·0	0·0
Confectionery	146	4·7	12·1
Crisps	84	3·5	0·1
Sugar	65	2·0	8·9
Mean intakes:		7·74 MJ (1850 kcal)	107·9 g

of sugar. Thus, at least one-third of dietary energy and 56% of sugar were contributed by foods often villified by health educators.

Several questions arise. Given this dietary profile, are the children with high energy intakes achieving these by increasing the proportion of sugar and fat in the diet? Is an increase in the percentage of energy from sugar, say, associated with an increase in weight? And is an increase in the percentage of energy derived from sugar an important factor in reducing the nutrient density of the diet?

Table 2 shows the mean sugar and fat intakes by thirds of the distribution of energy intakes in 11–12-year-old schoolchildren. As expected, the sugar and fat intakes increased with increasing energy intake, but there was no change in the proportion of energy from sugar in any of the groups, and only a small, statistically non-significant rise in the percentage energy from fat. This suggests that the higher intakes were obtained by eating more of the same type of diet, rather than altering the diet towards more sugary or fatty foods. Surprising, perhaps, was the lack of difference in the body mass index (BMI) between the energy groups, suggesting that differences in energy intake were associated with differences in levels of activity as the mean heights and weights were virtually identical in all three groups within each sex.

If we examine the data according to the percentage of energy derived from sugar, some surprising results emerge. Table 3 shows that sugar was being substituted for fat as the percentage energy from sugar increased, but this change seemed to have remarkably little effect on nutrient density. When comparing nutrient densities (nutrients/4·18 MJ (1000 kcal)) between the thirds of the distribution of percentage energy from sugar, there were no statistically significant differences for any nutrient amongst the boys, and only

Table 2. *Mean sugar and fat intakes, by thirds of energy intake, in 11–12-year-old British schoolchildren*

	Boys (*n* 76)			Girls (*n* 67)		
Energy intake . . .	Low	Medium	High	Low	Medium	High
Energy: MJ/d	5·96	7·72	9·54	6·13	7·47	8·76
kcal/d	1425	1845	2279	1464	1786	2093
Sugar (g/d)	79	107	138	81	103	116
Fat (g/d)	58	77	97	61	76	91
Percentage energy from sugar	21·1	21·7	22·5	20·7	21·6	20·9
Percentage energy from fat	36·6	37·3	38·6	37·8	38·3	39·2
BMI (kg/m^2)	19·2	18·3	19·5	19·8	20·1	19·5

BMI, body mass index.

Table 3. *Nutrient densities (per 4·18 MJ (1000 kcal)) in relation to proportion of total food energy from sugar, in 11–12-year-old British schoolchildren*

	Boys (*n* 76)			Girls (*n* 67)		
	Low	Medium	High	Low	Medium	High
Percentage energy from sugar . . .	16·1^{a}	21·4^{b}	27·8^{c}	16·1^{a}	20·6^{b}	26·6^{c}
Fat (g)	45^{a}	42^{b}	38^{c}	45^{a}	43^{b}	40^{c}
Dietary fibre (g)	9·5	9·6	8·9	9·2	10·4	9·2
Calcium (mg)	406	418	436	376	390	413
Iron (mg)	6·6	5·9	5·7	6·0	5·7	5·3
Vitamin A (μg)	323	496	272	444	461	319
Thiamin (mg)	0·63	0·67	0·67	0·58	0·61	0·58
Riboflavin (mg)	0·82	0·93	0·90	0·71	0·74	0·78
Nicotinic acid (mg)	15·5	15·5	14·5	15·2^{a}	14·2^{a}	13·0^{b}
Pyridoxine (mg)	0·7	0·7	0·7	0·7	0·7	0·7
Vitamin C (mg)	31	41	37	28^{a}	43^{b}	46^{b}
Vitamin E (mg)	2·3	2·7	2·3	2·6	2·8	2·5
BMI (kg/m^2)	20·8^{a}	18·2^{b}	17·9^{b}	20·1	20·5	18·7

BMI, body mass index.

^{a,b,c} values with different superscript letters are significantly different (ANOVA: $P<0·05$) from other groups of the same sex.

for two nutrients, nicotinic acid and vitamin C, amongst the girls. For both these nutrients, intakes were very substantially above the RDA, and for vitamin C, the trend was in the direction opposite to that expected due to the increase in sugar consumption associated with higher intakes of fruit and fruit juices. In both sexes, only the intake of Fe fell below the RDA, and although the trend was not statistically significant there did appear to be a dilution of Fe intake with increasing percentage of energy from sugar.

Table 4. *Mean daily intake of energy and nutrients, and percentage of recommended dietary allowance (RDA), in 11–12-year-old British schoolchildren*

	Boys		Girls	
	Intake	% RDA	Intake	% RDA
Energy: MJ	7·74		7·45	
kcal	1850	74*	1781	84*
Protein (g)	61	131	57	128
Calcium (mg)	768	110	701	100
Iron (mg)	11·2	93*	10·0	84*
Retinol (μg)	685	105	718	108
Thiamin (mg)	1·21	119	1·04	120
Riboflavin (mg)	1·62	122	1·33	102
Niacin (mg)	28	184	25	164
Vitamin C (mg)	67	266	68	274
Vitamin D (μg)	1·74	70*	1·50	60*

* Below the Recommended Daily Allowance (DHSS, 1979).

There was no evidence to suggest that a high percentage of energy from sugar was associated with obesity; in fact the average BMI was lowest in the groups with the highest percentage. Thus, the expected dilutant effects of sugar on nutrient density were not apparent, and the putative effect of an increasing percentage of energy from sugar on body-weight also failed to be demonstrated. In spite of an apparent imbalance in the food profile of these children's diets, one cannot say that nutrient adequacy (apart from Fe) or body-weight was being adversely affected.

The average nutrient intakes and percentages of the RDA are shown in Table 4. Intakes were substantially above the RDA for all nutrients except energy, Fe and vitamin D. In spite of energy intakes which were low in relation to the RDA, these children achieved heights and weights which on average exceeded the 50th percentile of the Tanner and Whitehouse (Tanner *et al.* 1966) standards. There was, thus, no deficit in growth, and the low energy intakes were consistent with a generally sedentary life-style. The low intakes of Fe do give cause for concern, particularly amongst the girls. The low values for vitamin D are unlikely to create problems provided the children are adequately exposed to sunlight. One might suggest, therefore, that the low Fe intakes in particular could be associated with adverse effects on the children's performance, both physical and mental, and that an improvement in Fe intake would be associated with improved performance.

NUTRIENT INTAKES AND INTELLIGENCE

With the exception of Fe, the diets which have been described appear to be adequate. Nevertheless, a number of children will have intakes well below the RDA. While this in itself is not evidence of deficiency, the likelihood of deficiency increases the further below the RDA an individual's intake falls. We have tested the hypothesis proposed at the beginning of this talk regarding the effects of subclinical nutrient deficiency on intelligence in two ways. In a double-blind study, the children first recorded diet for 1 week using the weighed inventory method. They were then given tests of verbal and

Table 5. *Intelligence test scores on tests taken before and after administration of a vitamin–mineral supplement, in 11–12-year-old British schoolchildren*

(Mean values with their standard errors)

	1st test		2nd test		Difference	
	Mean	SE	Mean	SE	Mean	SE
Supplement (*n* 80)						
Verbal	22·5	0·9	27·7	1·2	4·9	0·6
Non-verbal	38·2	1·1	45·8	1·2	7·5	0·9
Digit span	11·3	0·4	11·9	0·5	0·5	0·2
Coding	52·4	1·1	59·6	1·4	7·1	0·7
Placebo (*n* 80)						
Verbal	21·5	0·9	27·6	1·0	6·1	0·5
Non-verbal	37·4	1·1	45·0	1·3	7·6	0·6
Digit span	10·8	0·3	11·7	0·3	0·9	0·2
Coding	50·7	1·1	57·4	1·3	6·8	0·8

non-verbal intelligence. Children were matched by sex, height, non-verbal test score and energy intake (in order to take into account possible differences in pubertal development which may have affected test results) and randomly assigned to a supplement or placebo group. They then received either a vitamin–mineral supplement or placebo for 28 d. The supplement has been described elsewhere (Nelson *et al.* 1990), and contained nutrients in amounts equal to or greater than those given by Benton & Roberts (1988), with the exceptions of vitamins C and E. At the end of the 28 d the children were re-tested. The differences in the test scores were compared for the two groups. In addition, the results of the first test were correlated with the nutrient intakes estimated from the weighed inventories.

Table 5 shows the results of the four tests of intelligence before and after the supplement, and the average difference in score in the supplement and placebo groups. The first two tests were general tests of verbal and non-verbal skills. The Digit Span test emphasizes short-term memory, attention, and concentration, while the coding test stresses speed of learning, motivation and accuracy of hand–eye co-ordination as well as short-term memory and attention (Sattler, 1982). No significant differences in tests scores were observed between intervention groups at the first test. As expected, scores increased on the second test, but for none of the tests was there a significantly greater increase in the supplement group compared with the placebo group. These results suggest that the supplement had no effect on test performance and learning ability. One might conclude, therefore, that the children's diets were adequate with regard to the supplemented nutrients before supplementation.

Although we know that 28 d is more than sufficient to rectify any nutrient deficiencies that may have existed at the cellular level, we considered the possibility that the period of supplementation was not long enough. We, therefore, compared the initial test scores of children who reported taking vitamin and mineral supplements for at least 1 month in the year before the start of the study with the scores of those who had not. Supplements consisted mainly of vitamins A, C and D; four children took Fe-containing tablets or tonic. Table 6 shows that there were no significant differences in the initial test scores of

Table 6. *Effect of vitamin–mineral supplements taken before the study on initial test scores, in 11–12-year-old British schoolchildren*

(Mean values with their standard errors)

	Dietary supplement			
	Yes (*n* 48)		No (*n* (104)	
	Mean	SE	Mean	SE
Verbal	22·1	1·0	22·1	0·9
Non-verbal	40·4	1·4	36·9	1·0
Digit span	11·4	0·4	11·1	0·3
Coding	54·6	1·4	50·7	1·0

Table 7. *Effect of vitamin–mineral supplements taken before the study on change in test scores according to study intervention group*

(Mean values with their standard errors)

Dietary supplements . . .		Yes		No	
Change in test score	Intervention group				
	S (*n*)	(27)		(47)	
	P (*n*)	(20)		(55)	
		Mean	SE	Mean	SE
Verbal	S	6·4	1·0	4·4	0·8
	P	7·4	0·8	5·6	0·6
Non-verbal	S	7·5	1·1	7·0	1·4
	P	9·0	1·5	7·8	0·7
Digit span	S	0·4	0·4	0·4	0·3
	P	1·1	0·4	0·8	0·3
Coding	S	7·7	1·1	7·2	0·9
	P	7·4	1·6	6·3	0·9

S, supplement; P, placebo.

the two groups of children. Another possibility was that those children who had not taken supplements would have been expected to show a greater increase in score after the intervention trial than those who had. Again, as can be seen in Table 7, there were no significant differences in the scores of the children in the intervention groups according to whether or not they had taken supplements in the year before the study.

Finally, in order to assess the possible influence of usual diet on test scores, we looked at the correlations between intake measured by 7 d weighed inventory and scores. Although there were a number of associations at $P<0·05$, none was related to micronutrients or explained more than 5% of the variance in test scores. Thus, there was no evidence that pre-existing micronutrient intake or other aspects of diet was significantly related to performance on tests of intelligence. This is despite a wide range of recorded intakes including a number of children whose intakes were apparently less than 50% of the RDA.

We must, therefore, conclude that the diets of these children, although imbalanced in terms of current guidelines, and possibly in terms of long-term health, were of sufficient quality not to impair intellectual performance. The variation in nutrient intake observed in these children is probably, therefore, a minor determinant of mental functioning. Furthermore, it seems highly unlikely that regular consumption of vitamin and mineral supplements will have a significant effect on the average British child's intelligence. One might argue that the range of diet in this study was not sufficiently great, or that the children were not sufficiently disadvantaged, to be able to demonstrate an association between diet and intelligence. Furthermore, one could argue that the period of supplementation in the intervention trial was too short, and that the influence of Fe and the fat-soluble vitamins, in particular, would take considerably longer to demonstrate. We must await further trials to see if either of these possibilities is true.

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