Fat Content of the Diet Among Preschool Children in Southwest Britain: II. Relationship With Growth, Blood Lipids, and Iron Status

Imogen Sophie Rogers, PhD, MSc; Pauline Marion Emmett, BSc, SRD; and the ALSPAC Study Team

ABSTRACT. *Objective.* **In most countries, it is recommended that adults restrict fat intake to 30% to 35% of energy to reduce the risk of coronary heart disease and certain cancers. However, the appropriate level of fat in the diet of children is hotly debated. It has been generally accepted that fat intake by children under 2 years of age should not be limited because of fears that nutrient intakes and thus growth and iron status might be compromised. However, there is very little longitudinal information on the relationship between fat intake and growth in representative populations of free-living children under 2 years old. The objective of this study was to investigate the relationship between fat intake as a percentage of energy, and nutrient adequacy, growth, blood lipids, and iron status in 18- and 43-month-old children.**

Design. **This study forms part of the Avon Longitudinal Study of Parents and Children (ALSPAC)—a geographically-based cohort study in southwest England. A randomly selected subsample of the ALSPAC cohort attended research clinics approximately every 6 months from birth, at which a variety of anthropometric and other measurements were made. Dietary intakes at 18 and 43 months were assessed using a 3-day unweighed food record. A capillary blood sample was taken at 18 months for measurement of hemoglobin and ferritin levels. Nonfasting venous blood samples were taken at 31 and 43 months and analyzed for total and high-density lipoprotein cholesterol. The children were divided into quartiles of fat intake as a percentage of energy (QFI). QFI groups were compared for the number of children reaching recommended nutrient intakes, and for anthropometry, measures of iron status, and blood lipid levels.**

Participants. **Nine hundred fifty-one children at 18 months and 805 children at 43 months.**

Results. **The mean (standard deviation) percentages of energy from fat in each quartile at 18 months were 31.2 (2.8), 36.1 (0.9), 39.1 (0.8), and 43.1 (2.2), corresponding to a fat intake in grams of 37.3 (8.1), 44.3 (8.1), 50.4 (10.2), and 55.4 (12.7). The number of children failing to reach recommended intake levels for zinc and vitamin A fell with increasing fat intake, while the number of children consuming less than the recommendations for iron and vitamin C rose at both ages. Despite this, there was no association between fat intake at 18 months and mean height or body mass index (BMI) at either 18 or 31 months. Fat intake at 43 months was also unassociated with concurrent or subsequent height or BMI. There was also no significant increase in the number of children falling below the tenth percentile for height or BMI as QFI fell. Mean ferritin levels at 18 months fell in both sexes as QFI increased. Total cholesterol levels at 31 months were significantly associated with QFI at 18 months, and rose from 3.99 mmol/l in the lowest QFI in boys, to 4.31 mmol/l in the highest QFI. QFI at 43 months was unassociated with cholesterol levels.**

Conclusions. **These data do not suggest that fat intakes are an important determinant of growth in these children, even before the age of 2 years, or that children at the bottom of the range of fat intakes are experiencing delayed growth. On the other hand, there is also no evidence in this study that children on higher fat intakes are at a greater risk of becoming obese. In contrast to a number of US studies, we have not found children on lower fat intakes to have lower iron intakes—indeed higher fat intakes were associated with a greater chance of consuming less than the recommended intake of iron and with lower ferritin levels. The association of higher fat intakes with higher total cholesterol levels among boys is of concern, as there is evidence that the process of atherosclerosis begins during the preschool years.** *Pediatrics* **2001;108(3). URL: http://www.pediatrics.org/cgi/content/full/108/3/e49;** ***fat, growth, blood lipids, iron status, preschool children.***

ABBREVIATIONS. ALSPAC, Avon Longitudinal Study of Parents and Children; CIF, Children in Focus; HDL, high-density lipoprotein; QFI, quartiles of fat intake; EAR, estimated average requirement; LRNI, lower reference nutrient intake.

It is generally accepted that it is prudent for adults to moderate the amount of fat in their diet to reduce the risk of coronary heart disease and certain cancers. Fat intakes for adults of between 30% and 35% of energy are recommended in most countries. The advisability of limiting fat intake in children is a much more controversial issue, and different countries make widely varying recommendations on the most appropriate level of fat intake for children over 2 years. This is because of fears that limiting fat intake may affect the supply of minerals and fat-soluble vitamins, and possibly reduce the energy-density of the diet to a point where energy intake is inadequate for normal growth. It has been suggested in 1 report of nonorganic failure to thrive in preschool children[1] that it was the result of "healthy" adult diets being imposed on them by their parents, and this has compounded the fears about the adequacy of low-fat diets for growing children. However, close examination of this report shows that the basic problem among these children was starvation; the fat content of their diets was in some cases quite high (up to 37% of energy). In other reports of growth failure

From the Unit of Paediatric and Perinatal Epidemiology, Division of Child Health, University of Bristol, Bristol, United Kingdom.
Received for publication Oct 24, 2000; accepted May 7, 2001.
Reprint requests to (P.E.) Unit of Paediatric and Perinatal Epidemiology, Division of Child Health, University of Bristol, 24 Tyndall Ave, Bristol, BS8 1TQ. E-mail: p.m.emmett@bristol.ac.uk

related to dietary restriction, it is again difficult to separate the effects of low fat intake from caloric insufficiency.[2] In 1 study of growth retardation attributable to self-imposed dieting, the average fat content of the diets was above 30%,[3] and in another that related growth failure to dietary treatment of hypercholesterolemia, the participants with linear growth failure consumed <60% of their recommended daily energy intake.[4]

The fear that growth might be compromised has meant that children under the age of 2 are traditionally regarded as "untouchable" in terms of recommendations to limit fat intake. Despite this, 1 supervised intervention study has found that fat intake can be reduced to as little as 22% of energy in this age group without affecting growth.[5] Furthermore, a recent report in Britain suggests that rising levels of obesity among preschool children may well be more of a problem than growth failure.[6] Indeed, the mean heights and weights of children in Britain and the United States have been increasing over a period when fat intake has been falling. Although the fall in absolute fat intakes in the United States seems to have leveled out since 1990, fat intake as a percentage of energy is still falling slightly.[7] In Britain, both percentage of energy from fat and absolute fat intake continue to fall.[8–10] However, there is very little longitudinal information on the relationship between fat intake and growth in representative populations of free-living children under the age of 2.

Reducing blood cholesterol levels, and hence the rate of progression of atherosclerosis, is one of the main justifications for limiting fat intakes by adults. An argument for limiting fat intake by children is that atherogenesis is a lifelong process, and may be accelerated by a high-fat diet attributable to the effect on blood lipid levels. Postmortem studies have shown that the relationship between blood lipid levels and the extent of atherosclerotic lesions is already present in childhood.[11,12] In addition, blood lipid levels have been shown to track throughout childhood.[13,14] However, there is a relatively limited amount of information about the relationship between fat intake and blood lipid levels in preschool children. The iron status of preschool children consuming different levels of fat is also of interest, as some studies have shown lower-fat diets to be lacking in iron,[15] whereas others have found the iron content of the diet to decrease with increasing fat intake. Iron deficiency anaemia can, if left uncorrected, adversely affect psychomotor development and cognitive skills.[16–19] In an earlier analysis, we examined the relationship between the intake of fat and that of other nutrients in a representative sample of British children at 18 and 43 months. In this study we present information on the relationship between fat intake and growth, blood lipids and iron status, and on dietary adequacy for selected nutrients particularly relevant to this.

METHODS

Study Sample and Design

This study forms part of the Avon Longitudinal Study of Parents and Children (ALSPAC), a geographically based cohort study investigating factors influencing the health and development of children. All pregnant women resident within a defined part of the county of Avon in southwest England with an expected date of delivery between April 1991 and December 1992 inclusive were eligible. Between 80% and 90% of these enrolled (14 893 pregnancies). The ALSPAC cohort was broadly representative of pregnant women nationally in terms of characteristics such as housing tenure, marital status, access to a car, etc, although when compared with 1991 national census data of women with children aged under 1 year, mothers participating in ALSPAC were more likely than those in Britain overall to live in owner-occupied accommodation and to have access to a car, and less likely to have 1 or more persons per room and to be from a nonwhite ethnic group. The biases in the ALSPAC cohort have been described in more detail elsewhere.[20,21] A proportion of the children born in the last 6 months of the study (equivalent to 10% of the whole cohort) were selected at random to take part in a substudy known as Children in Focus (CIF). These children attended research clinics at which a variety of physical and developmental measures were taken approximately every 6 months.[22] The dietary and anthropometric information used in this study was obtained at the CIF clinics held between December 1993 and June 1994, January and July 1995 and 1996, and July 1997 and January 1998, when the children were 18, 31, 43, and 61 months old, respectively. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Subcommittee and from the 3 medical ethics committees in the Avon study area.

Dietary Assessment

Diets at 18 and 43 months were assessed using unweighed dietary records completed for 3 days, not necessarily consecutive, including 2 weekdays and 1 weekend day. A week before the clinic visit, the child's primary carer was sent three 1-day dietary diaries in which they were asked to record in household measures everything the child ate or drank. The diaries were coded using the computer program Diet In, Data Out which is designed for direct entry of dietary records and has been shown to improve the speed and accuracy of dietary coding compared with manual methods.[23] Portion size assumptions in this study were based largely on the booklet "Food Portion Sizes"[24] which describes standard British portion sizes, and scaled down appropriately for children. The output from Diet In, Data Out was analyzed using an in-house dietary analysis program and a British nutrient database (based on McCance and Widdowson's "The Composition of Foods"[25] and its supplements[26–34] along with manufacturers' data) to produce estimates of daily nutrient intake. The dietary methods used have been described in more detail elsewhere.[9,35,36]

Anthropometric Measurements

Height was measured to the nearest 0.1 cm using a Leicester height measure (Cranlea, Birmingham, United Kingdom). Weight was recorded to the nearest 100 g with the child wearing only underwear, using a Seca scale, Model 835 (SECA Ltd, London, United Kingdom).

Measurement of Blood Lipid, Hemoglobin, and Ferritin Levels

Nonfasting venous blood samples for lipid analysis were taken when the children were 31 and 43 months of age. These blood samples were analyzed for total and high density lipoprotein (HDL) cholesterol by standard methods described in more detail elsewhere.[37] Non-HDL cholesterol was calculated from the difference between total and HDL cholesterol. At 18 months, a capillary blood sample was taken and analyzed for hemoglobin and ferritin levels using standard procedures; this has also been described in more detail elsewhere.[38]

Statistical Methods

The children were divided into 4 groups according to their quartile of fat intake as a percentage of energy (QFI).

Analysis of variance was used to test for association between QFI and continuous variables. The continuous variables investigated were height, body mass index (BMI), hemoglobin, ferritin and total, HDL and non-HDL cholesterol levels. If necessary, variables were transformed to reduce skewness in the distribution before analysis. Mean values are presented for untransformed variables, and geometric mean values are presented for transformed variables.

Pearson χ^2 test and the Mantel-Haenszel test for linear association were used to test for association between QFI and categorical variables. The categorical variables investigated were nutrient intakes above or below the estimated average requirement (EAR),[39] height, BMI, and ferritin above or below the tenth or ninetieth centile, and whether or not the child had been breastfed for at least 3 months. The centiles used for height, BMI, and ferritin were centiles within the CIF population, rather than centiles with reference to an external standard.

Analyses relating to anthropometric measures were performed separately for boys and girls, and differences in hemoglobin and ferritin and cholesterol levels were investigated using a 2-way analysis of variance adjusting for sex.

The CIF sample included a mixture of ethnic groups and both twin and singleton births. A number of studies have found ethnic group to influence both anthropometry and blood lipid levels.[40–43] As the number of nonwhite children in the sample was too small to analyze separately they have been excluded from statistical analyses to prevent confounding. Twins have also been excluded from statistical analyses as they were oversampled and thus did not represent a random sample, and as it was felt that the growth curves of twins might differ from those of singletons.

RESULTS

Response Rate

One thousand one hundred ninety-two white, singleton children were invited to the 18-month clinic—out of these, completed dietary diaries were received from 517 boys and 434 girls (80% of invitees). At 43 months, completed dietary diaries were received from 488 boys and 375 girls—72% of the white singletons invited. At 18 months, the mean (standard deviation) heights and weights of children with completed dietary records were 82.3 (2.8) cm and 11.7 (1.3) kg for boys, and 80.8 (2.6) cm and 11.1 (1.2) kg for girls. There were no significant differences in height or weight between those children who did and did not complete a dietary record at 18 months. Boys who did not have their diet recorded at 43 months were slightly taller and heavier than those who did (100.5 vs 99.6 cm, $P = .025$; and 16.8 vs 16.4 kg, $P = .036$, respectively). There no significant differences in height and weight between girls who did and did not complete a dietary record at 43 months—among girls who completed a dietary record, the mean heights and weights were 98.6 (3.7) cm and 16.0 (2.0) kg, respectively.

Because of the difficulty inherent in taking blood samples from young children, data on ferritin and blood lipid levels were not available for all the children with dietary data. The number of participants in each analysis is given in the tables.

The mean percentage of energy from fat, fat intake in grams, and energy intake in the 4 quartiles of fat intake at 18 and 43 months are shown in Table 1. There was no association between gender and QFI.

Nutrient Adequacy and QFI

In Britain, the dietary reference values are the benchmark most commonly used to assess the nutritional adequacy of a diet. These are a set of estimated requirement levels, specific to age and sex group. They include the EAR, which is the amount considered to be sufficient for 50% of the population, and the lower reference nutrient intake (LRNI), which is the amount that is judged to be inadequate for all but 2.5% of the population. Diets that provide less that the EAR could therefore be considered to place a child at an unacceptable risk of consuming too little of a nutrient, while diets providing less that the LRNI are almost certainly inadequate in that nutrient. Mean and median intakes of most nutrients at 18 and 43 months were well in excess of the EAR, the exceptions being vitamin C, vitamin A, iron, and zinc. Table 2 shows the proportion of children at 18 and 43 months consuming less that the EAR or LRNI for these nutrients according to QFI.

At 18 months, the chances of a child falling below the EAR was significantly associated with QFI for all 4 nutrients. As fat intake increased, the chances of consuming a diet that was inadequate in vitamin C or iron increased, whereas the chances of consuming too little vitamin A or zinc fell ($P < .001$ in all cases). A particularly high proportion of children were consuming too little iron—in the highest QFI at 18 months, nearly 70% of children were consuming less that the EAR, and 36% were consuming less than the LRNI. A small proportion of children at 18 months were consuming less than the LRNI for vitamin A—this fell with increasing fat intake from 6% in the first QFI to 1% in the fourth.

The pattern was similar at 43 months, with the chances of consuming less than the EAR for iron and zinc rising with increasing fat intake, while the chances of having a diet low in zinc or vitamin A fell. However, at 43 months, a greater proportion of children reached the EAR for all nutrients, and the relationship between fat intake and zinc did not reach significance ($P = .068$). The proportion of children consuming below the EAR for iron at 43 months was still high, ranging from 25% in the first QFI to 37% in the fourth. Negligible numbers of children consumed

TABLE 1. Mean (Standard Deviation) Nutrient Intakes at 18 and 43 Months According to Quartile of Fat Intake

	QFI			
	1	2	3	4
18 months				
Fat (% energy)	31.2 (2.8)	36.1 (0.9)	39.1 (0.8)	43.1 (2.2)
Fat (g)	37.3 (8.1)	44.3 (8.1)	50.4 (10.2)	55.4 (12.7)
Energy (kJ)	4413 (865)	4536 (817)	4771 (968)	4754 (1044)
43 months				
Fat (% energy)	30.4 (2.5)	34.8 (0.9)	37.7 (0.9)	41.8 (2.0)
Fat (g)	44.4 (10.1)	52.4 (9.0)	59.3 (11.1)	66.9 (13.2)
Energy (kJ)	5385 (1085)	5564 (966)	5811 (1076)	5924 (1122)

TABLE 2. Percentages of Children Falling Below the Dietary Reference Values for Selected Nutrients According to Quartile of Fat Intake

Nutrient	Quartile of Fat Intake as Percentage Energy				χ^2	*P* Value
	1	2	3	4		
Percentage of children falling below the EAR*						
18 months (*n* = 951)						
Vitamin C	12.0	15.0	15.3	27.1	22.0	<.001
Vitamin A*	22.7	10.2	7.2	2.1	57.5	<.001
Iron	44.6	52.0	55.9	69.9	32.2	<.001
Zinc	28.3	17.1	10.2	9.3	39.9	<.001
43 months (*n* = 805)						
Vitamin C	8.3	9.5	15.2	18.2	11.7	.008
Vitamin A*	28.5	21.9	22.1	7.1	30.5	<.001
Iron	25.4	26.2	28.9	37.4	8.6	.035
Zinc	20.2	22.4	17.6	12.6	7.1	.068
Percentage of children falling below the LRNI at 18 months						
Vitamin A*	6.4	2.0	2.1	0.8	15.4	.002
Iron	10.7	9.8	13.6	27.1	35.7	<.001

* Retinol equivalents.

below the LRNI for any of these nutrients at 43 months.

Mean Height and BMI and QFI

Mean height and BMI at 18 and 31 months were compared according to QFI at 18 months, and mean height and BMI at 43 and 61 months were compared according to QFI at 43 months. No association was found in either boys or girls at either age (Tables 3 and 4). It was hypothesized that effects on height and BMI might be restricted to the extremes of fat intake. To investigate this the analysis was repeated, comparing height and BMI in those below the fifth percentile for fat intake, those in the middle 90%, and those above the 95th percentile. Again, there were no significant associations with height or BMI at either age (data not shown).

Centile Category for Height and BMI and QFI

The proportions of the children falling into different centile categories of height and BMI according to QFI at 18 and 43 months are shown in Tables 5 and 6 respectively. There was no association between QFI at 43 months and centile category for height at 43 or 61 months. However, among boys, QFI at 18 months was significantly associated with the proportion of children falling below the tenth percentile for height, with an excess of short children in the first and fourth QFIs. The pattern was similar for height at 31 months, but failed to reach significance. Among girls there was a nonsignificant drop in the number of children under the tenth centile for height at 18 and 31 months as QFI at 18 months increased. There was no relationship between QFI at 18 months and BMI centile category in either sex. Among boys there was a nonsignificant trend toward increasing numbers of children below the tenth percentile of BMI at 61 months as QFI increased (*P* = .064).

Breastfed children are smaller and lighter than formula-fed children, and this difference can persist into the second or third year of life.[44] It was speculated that the anthropometric difference between the different QFIs at 18 months might be confounded by different proportions of breastfed children in the groups. It was found that the proportion of children who had been breastfed for 3 months or more fell as fat intake increased, from 55.8% in the lowest quartile of fat intake to 42.3% in the highest quartile (Mantel Haenszel χ^2 = 9.06, *P* = .003). In an attempt to determine whether the relationship between growth and fat intake was modified by breastfeeding history, a 2-way analysis of variance was performed, with height or BMI at 18 months as the outcome and QFI and breastfeeding history as the factors. No significant relationships with either QFI or breastfeeding history were found in either sex (data not shown).

Iron Status and Blood Lipids According to QFI

Table 7 shows mean hemoglobin, ferritin, and blood lipid levels at various ages in the different fat intake groups.

There was no significant association between hemoglobin levels and fat intake, but mean ferritin levels at 18 months fell significantly with increasing QFI in both boys and girls. We also investigated the number of children with ferritin values below the tenth percentile (calculated for the whole CIF group)[38] according to QFI. This increased significantly from 4.7% of children in the first QFI to 14.8% in the fourth (Pearson χ^2 = 10.103, *P* = .018, Mantel-

TABLE 3. Mean (95% Confidence Interval) Height/Length (cm) and BMI in kgm^{-2} at 18 and 31 Months According to Fat Intake at 18 Months

	n	Quartile of Percentage Energy From Fat				*P* Value
		1	2	3	4	
Boys						
Length 18 m	504	81.9 (81.5, 82.4)	82.5 (82.0, 83.0)	82.7 (82.3, 83.1)	82.6 (82.0, 83.1)	.118
Height 31 m	457	91.7 (91.1, 92.2)	92.3 (91.8, 92.9)	92.3 (91.8, 92.8)	92.4 (91.6, 93.1)	.277
BMI 18 m	499	17.3 (17.0, 17.5)	17.3 (17.1, 17.5)	17.4 (17.2, 17.6)	17.3 (17.0, 17.5)	.921
BMI 31 m	457	16.7 (16.5, 17.0)	16.7 (16.4, 16.9)	16.7 (16.5, 16.9)	16.8 (16.6, 17.1)	.751
Girls						
Length 18 m	423	80.7 (80.2, 81.3)	80.9 (80.4, 81.5)	80.9 (80.5, 81.4)	80.9 (80.5, 81.3)	.931
Height 31 m	378	90.6 (89.8, 91.4)	91.0 (90.4, 91.6)	91.0 (90.3, 91.6)	91.0 (90.4, 91.5)	.805
BMI 18 m	421	17.0 (16.7, 17.3)	17.0 (16.7, 17.3)	16.8 (16.6, 17.0)	17.0 (16.8, 17.3)	.546
BMI 31 m	378	16.6 (16.3, 16.9)	16.5 (16.3, 16.8)	16.6 (16.2, 16.9)	16.5 (16.3, 16.7)	.976

TABLE 4. Mean (95% Confidence Interval) Height in cm and BMI in kgm^{-2} at 43 and 61 Months According to QFI at 43 Months

	n	Quartile of Percentage Energy From Fat				*P* Value
		1	2	3	4	
Boys						
Height 43 m	439	99.9 (99.2, 100.5)	99.6 (98.9, 100.3)	99.9 (99.1, 100.6)	99.3 (98.7, 99.9)	.581
Height 61 m	387	110.7 (109.9, 111.5)	110.8 (109.9, 111.6)	111.0 (110.1, 111.9)	109.9 (109.1, 110.7)	.274
BMI 43 m	438	16.6 (16.4, 16.8)	16.5 (16.3, 16.8)	16.5 (16.3, 16.8)	16.3 (16.1, 16.5)	.431
BMI 61 m*	383	16.1 (15.8, 16.3)	15.9 (15.6, 16.1)	16.0 (15.7, 16.3)	15.7 (15.5, 16.0)	.217
Girls						
Height 43 m	351	99.9 (98.0, 99.8)	98.3 (97.6, 99.0)	98.8 (98.0, 99.5)	98.3 (97.6, 99.1)	.651
Height 61 m	323	110.0 (108.9, 11.1)	109.6 (108.8, 110.4)	110.2 (109.2, 111.1)	109.3 (108.3, 110.3)	.564
BMI 43 m	351	16.6 (16.3, 16.9)	16.4 (16.1, 16.6)	16.5 (16.1, 16.9)	16.4 (16.1, 16.7)	.784
BMI 61 m*	323	16.1 (15.7, 16.4)	16.0 (15.7, 16.3)	15.9 (15.5, 16.4)	16.1 (15.8, 16.4)	.943

* Geometric mean shown as variable transformed to the natural logarithm.

TABLE 5. Percentages of Children in Various Categories of Height and BMI According to Percentage Energy From Fat at 18 Months

	n	Percentile Category	QFI				χ^2	*P* Value	Linear χ^2	*P* Value
			1	2	3	4				
Boys										
18 m height	504	<10th	14.0	8.5	3.3	13.8	10.8	.013	0.257	.612
31 m height	457	<10th	13.4	8.5	4.4	12.3	6.6	.085	0.495	.482
18 m BMI	499	<10th	9.3	9.4	6.6	13.1	3.2	.787	0.649	.420
		>90th	10.9	10.2	9.9	9.0				
31 m BMI	457	<10th	10.9	9.3	7.0	9.4	4.0	.678	0.004	.951
		>90th	11.8	10.2	6.1	11.3				
Girls										
18 m height	423	<10th	11.0	12.8	7.4	5.7	4.1	.249	2.932	.087
31 m height	378	<10th	14.1	8.2	9.3	6.1	3.7	.299	2.719	.099
18 m BMI	421	<10th	10.1	11.9	10.3	5.7	6.3	.396	0.024	.876
		>90th	14.1	11.0	6.5	9.4				
31 m BMI	377	<10th	9.4	12.2	6.3	9.2	5.6	.464	0.657	.418
		>90th	12.9	10.2	10.4	5.1				

TABLE 6. Percentages of Children in Various Categories of Height and BMI at 43 and 61 Months According to QFI at 43 Months

	n	Percentile of Height	QFI				χ^2	*P* Value	Linear χ^2	*P* Value
			1	2	3	4				
Boys										
43 m height	439	<10th	10.3	10.3	6.7	11.8	1.7	.630	0.008	.929
61 m height	387	<10th	10.8	10.0	6.5	11.8	1.7	.629	0.000	.982
43 m BMI	438	<10th	9.4	9.4	9.5	10.0	1.6	.955	0.018	.893
		>90th	8.5	13.2	10.5	9.1				
61 m BMI	383	<10th	7.1	5.6	11.8	14.9	8.8	.187	3.43	.064
		>90th	11.1	8.9	14.0	6.9				
Girls										
43 m height	351	<10th	10.8	7.8	6.5	13.4	3.0	.397	0.229	.632
61 m height	323	<10th	10.1	5.4	8.2	14.3	4.1	.253	1.225	.268
43 m BMI	351	<10th	2.7	11.8	10.8	11.0	7.4	.287	2.05	.152
		>90th	10.8	8.8	12.9	6.1				
61 m BMI	323	<10th	5.8	6.5	14.1	10.4	7.2	.307	0.360	.548
		>90th	8.7	6.5	12.9	9.1				

Haenzsel χ^2 = 9.859, P = .002). Measures of iron status after the age of 18 months were not available.

There was no association between any blood lipid level at 43 months and QFI at 43 months. However, total cholesterol levels at 31 months were significantly associated with QFI at 18 months (P = .006). The effect of fat intake on total cholesterol level seemed to differ between boys and girls, and the interaction between sex and fat intake was marginally significant (P = .052). Among boys total cholesterol levels were higher in the third and fourth QFI than in the first and second, whereas among girls the highest total cholesterol level was in the third QFI and the lowest was in the fourth. There was a marginally significant relationship (P = .054) between non-HDL cholesterol level and QFI, which followed a similar pattern to that with total cholesterol. There was no association between QFI at 18 months and HDL cholesterol levels.

Effect of Underreporting

All the statistical analyses relating to anthropometry, blood lipid levels, and hemoglobin and ferritin were repeated, excluding those children considered to be underreporting. This was defined as a reported energy intake of <120% of basal metabolic rate, as calculated from the equations given in the 1985 World Health Organization/Food and Agriculture Organization/United Nations University report on energy and protein requirements.[45] The results obtained were almost identical (data not shown).

TABLE 7. Ferritin, Hemoglobin, and Blood Lipid Levels at Various Ages According to QFI (Mean/Geometric Mean With 95% Confidence Interval)

Measurement	Age	M/F	n	QFI at 18 months 1	2	3	4	P QFI	P Sex	P Intake
Ferritin (μg/l)	18 m	M	319	29.5 (26.3, 33.0)	26.7 (23.7, 30.0)	25.6 (22.8, 28.9)	24.7 (22.1, 27.6)	.018	.080	.872
Ferritin (μg/l)	18 m	F	278	30.8 (27.5, 34.5)	30.5 (27.1, 34.3)	27.6 (24.5, 31.0)	25.9 (22.9, 29.1)			
Hemoglobin (g/l)	18 m	M	360	116.6 (114.6, 118.7)	115.8 (113.9, 117.7)	116.8 (114.8, 118.8)	116.4 (114.3, 118.6)	.504	.107	.537
Hemoglobin (g/l)	18 m	F	306	116.6 (114.8, 118.5)	118.1 (116.3, 119.9)	119.1 (116.7, 121.4)	116.6 (114.6, 118.6)			
TC (mmol/l)	31 m	M	215	3.99 (3.80, 4.17)	4.04 (3.88, 4.21)	4.29 (4.11, 4.46)	4.31 (4.15, 4.48)	.006	.772	.052
TC (mmol/l)	31 m	F	176	4.06 (3.84, 4.29)	4.11 (3.90, 4.33)	4.42 (4.16, 4.69)	3.94 (3.72, 4.15)			
HDLC (mmol/l)	31 m	M	164	0.88 (0.82, 0.94)	0.84 (0.78, 0.89)	0.82 (0.76, 0.89)	0.83 (0.74, 0.92)	.834	.896	.773
HDLC (mmol/l)	31 m	F	134	0.84 (0.79, 0.89)	0.84 (0.78, 0.89)	0.86 (0.77, 0.95)	0.82 (0.73, 0.92)			
Non-HDLC	31 m	M	161	3.12 (2.92, 3.33)	3.15 (2.95, 3.36)	3.41 (3.22, 3.60)	3.39 (3.17, 3.61)	.054	.667	.197
Non-HDLC	31 m	F	133	3.29 (3.02, 3.56)	3.28 (3.03, 3.54)	3.57 (3.25, 3.88)	3.08 (2.83, 3.33)			
TC (mmol/l)	43 m	M	262	3.41 (3.19, 3.63)	3.52 (3.30, 3.75)	3.54 (3.33, 3.75)	3.44 (3.28, 3.61)	0.944	0.367	0.871
TC (mmol/l)	43 m	F	205	3.58 (3.33, 3.83)	3.51 (3.29, 3.73)	3.57 (3.36, 3.78)	3.55 (3.23, 3.87)			
HDLC (mmol/l)	43 m	M	260	1.07 (1.01, 1.14)	1.00 (0.94, 1.07)	1.06 (0.99, 1.12)	1.07 (1.01, 1.13)	0.513	0.067	0.149
HDLC (mmol/l)	43 m	F	205	0.97 (0.90, 1.04)	1.02 (0.96, 1.09)	1.06 (1.00, 1.12)	0.98 (0.91, 1.05)			
Non-HDLC	43 m	M	259	2.33 (2.09, 2.56)	2.53 (2.30, 2.77)	2.48 (2.27, 2.70)	2.36 (2.19, 2.53)	0.968	0.158	0.500
Non-HDLC	43 m	F	204	2.60 (2.35, 2.86)	2.49 (2.27, 2.71)	2.51 (2.29, 2.74)	2.56 (2.23, 2.89)			

TC indicates total cholesterol; HDLC, HDL cholesterol; Non-HDLC, total cholesterol minus HDL cholesterol.

DISCUSSION

In this free-living group of children, there was a wide range in the proportion of dietary energy derived from fat. This was associated with large variations in the proportion of children receiving inadequate amounts of vitamin C, vitamin A, iron, and zinc. Despite these significant dietary differences, there was no effect on mean height or weight at any age. The number of girls below the tenth centile for height increased as fat intake at 18 months fell, but this increase was nonsignificant and no similar effect was observed in boys. On the other hand, low-fat diets were associated with better iron status as measured by ferritin levels at 18 months, and among boys lower fat intakes at 18 months were associated with lower levels of total cholesterol sampled a year later.

We assessed diet using a 3-day, unweighed food record. Although a longer recording period than 3 days would have been desirable for estimation of micronutrient intakes, it should be adequate for estimation of fat and energy intakes.[46] Furthermore, it seems that fewer days of dietary record are required to estimate intakes accurately in young children than in other age groups.[46] Within person variation in nutrient intakes is random and so likely to have reduced the strength of observed relationships, and it is possible that we may have missed an association of truly low fat intakes with delayed growth. However, the absence of any trend toward lower mean heights or weights in the lower QFI groups makes this seem unlikely. This was despite the fact that a higher proportion of children in the lower fat intake groups had zinc intakes below the recommended levels. Zinc deficiency has been shown to be associated with growth retardation[47] and with impairment of the immune system.[48,49]

A strikingly high proportion of children in the higher QFI groups were consuming inadequate amounts of iron. This occurred in conjunction with a high frequency of suboptimal intakes of vitamin C, an enhancer of iron absorption.[50] Unsurprisingly, mean ferritin levels fell, and the number of children below the tenth percentile for ferritin rose with increasing QFI. This association of higher fat intakes with lower iron intakes and ferritin levels is of concern, as iron deficiency anaemia is a common problem among British toddlers, and iron intakes by preschool children have been falling progressively since 1950.[51]

The other largest longitudinal study to investigate the relationship between fat intake and growth in children under two was the Special Turku Coronary Risk Factor Intervention Project study in Finland,[5] in which 1062 infants were recruited and assigned to control or intervention groups. Parents of infants in the intervention group were counseled with the aim of keeping fat intake below 35% of energy after 13 months of age, while maintaining energy and nutrient intakes. Growth patterns were compared according to the child's mean fat intake between 13 months and 5 years classified as consistently high (top 5%), increasing (5%), average (80%), consistently low (bottom 5%), or decreasing (5%). No growth differences were apparent between the groups, although fat intake in the consistently low group was only 22% of energy at 13 months of age. Serum total and non-HDL cholesterol concentrations in the control group increased significantly between 7 and 13 months, but there was no such increase in the intervention group.[52]

Two intervention studies in the United States aimed to change fat intake in schoolchildren. In the Dietary Intervention Study in Children[53] 8-year-old children with low-density lipoprotein cholesterol levels between the 80th and 98th percentile were randomized into a control group ($N = 329$) or an intervention group ($N = 334$), where they were encouraged to follow a low-fat (28% of energy), low saturated fat (< 8% of energy) diet. The children were followed up for 3 years—at the end of which time, total and low-density lipoprotein cholesterol levels had decreased significantly more in the intervention than in the control group, although there were no differences between the groups in mean height, growth, or ferritin levels. The Child and Adolescent Trial for Cardiovascular Health[54] succeeded in reducing fat intake and increasing physical activity levels in children over a 2 ½ year period—fat intakes in control and intervention groups at the end of the trial were 32.7% and 30.3% of energy, respectively. No height, weight, or growth differences were observed between control and intervention groups; however, there were also no differences in blood cholesterol levels or blood pressure. Jacobson et al[55] followed up 138 children aged 2 to 15 years referred for dietary treatment of hypercholesterolaemia by the National Cholesterol Education Program Step I diet (30% of energy from fat, 10% from saturated fat). After 3 years, mean total cholesterol levels had fallen in these children but there was no significant change in height or weight *z* score. There was, however, no control group and no monitoring of dietary compliance, so the actual fat content of the diet eaten by these children was unknown.

In the intervention studies there was, of course, monitoring of the adequacy of nutrient intakes. However, observational studies on a range of free-living populations including preschool Hispanic[56] and Scottish[57] and Australian[58] children, and schoolchildren in Australia,[58] the United States,[15] and Norway[59] have found no apparent relationship between fat intake and height or other measures of growth (such as skinfold thicknesses or BMI). The situation is confused by several other studies in school-age preadolescent children where adiposity was positively associated with percentage of energy from fat,[60–64] but the relationship with height was not specifically investigated. In an analysis of data from the Feasibility Study for the National Diet and Nutrition Survey of preschool children in Britain, no cross-sectional relationship was observed between any macronutrient intake and body composition, despite measuring body composition and energy expenditure using highly accurate stable isotope methods[65]—the lack of association between fat intake and BMI observed in the present study is in line with this. A previous analysis of data from CIF found that there was also no association between the intake of fat, or any other nutrient at 18 months and the age of occurrence of adiposity rebound (the increase in BMI after it's childhood nadir)[66]—nutrient intakes at 43 months were also unassociated with adiposity rebound (Ahmad Dorosty, Department of Human Nutrition, University of Glasgow, personal communication).

On balance, it seems that the range of fat intakes normally observed in industrialized countries has a minimal effect on growth in height, although any effect of fat intake on adiposity does not become apparent until after the preschool years. In contrast, several studies have found lower total and saturated fat intakes by children to be associated with a less atherogenic blood lipid profile.[67–71] This is inline with the results in the current study, where at least in boys there was a significant association between higher fat intakes and higher total cholesterol levels, and some evidence of an association with levels of non-HDL cholesterol. This relationship was apparent despite a year's gap between measuring diet and blood lipid levels, which resulted from a delay in ethical approval. The clinical significance of elevated blood cholesterol levels in childhood is uncertain, attributable to the obvious difficulty of relating childhood cholesterol levels to adult disease outcomes. However, evidence showing that the process of atherosclerosis begins as early as 3 years of age,[72] and that blood cholesterol levels track from childhood onwards,[13,14] suggest that a reduction in childhood cholesterol levels could only lower coronary heart disease mortality in later life.

CONCLUSION

This data suggests that very few preschool children in Britain are on fat intakes sufficiently low to affect growth, although the association of low-fat intakes with higher ferritin and lower cholesterol levels represent, if anything, a beneficial effect on health. Even in the lowest quartile, the mean fat intake still exceeded 30% of energy, suggesting that there is little cause for concern that excessively low-fat intakes are prevalent in British children. Perhaps a guideline that fat intake by 1 to 2 year olds should be kept below 40% of energy intake could be considered. If the need to maintain energy intake was stressed, this seems very unlikely to result in adverse effects, and these data suggest that it might result in dietary changes that are associated with improved ferritin levels and blood lipid profiles. Care should be taken, however, to ensure that any drop in fat intakes did not result in a rise in the number of children consuming suboptimal levels of zinc and vitamin A.

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