A 2-year longitudinal nutritional survey of 405 Northumberland children initially aged 11·5 years

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1. Children (405), initially of average age 11·5 years, recorded all food and drinks consumed for three consecutive days (with an interview on the fourth day) on five separate occasions over a 2-year period. Food tables (Paul & Southgate, 1978) enabled nutrient intakes to be calculated. The data collected were found to be of high reliability (Hackett *et al.* 1983).

2. The mean energy intakes showed broad agreement with other recent British dietary surveys but were well below those recorded in the prewar study by Widdowson (1947) and the FAO/WHO (1973) recommended levels. They were slightly below the current Department of Health and Social Security (DHSS; 1979) recommended intakes.

3. Over the 2-year period, the energy intake of the boys increased by 13% compared with an increase of only 7% in the girls.

4. The iron and vitamin A intakes of all groups of children were low compared with current recommendations (DHSS, 1979). This seems to be a result of falling energy intake. Mean calcium intakes were also only marginally in excess of the recommended intake, and those of most of the girls would fall below the recommendation if the proposal to end the fortification of flour (DHSS, 1981) is implemented.

The purpose of this study of a large group of young adolescents was to relate an estimate of each individual's mean dietary habits to his or her observed dental caries increment. However, the nutritional information collected is of wider interest and is presented in the present paper as it gives a recent estimate of intake of a group of northern English schoolchildren from a variety of backgrounds. It is also unique amongst British surveys, being longitudinal in design.

SUBJECTS AND METHODS

In July 1979, seven middle schools in the Morpeth, Ashington and Newbiggin area of South Northumberland, chosen to give a representative range of social classes, were invited to participate in the study. All third-year children, initially aged 11–12 years old, were asked by their headmasters to volunteer for the survey which was aimed at relating their dietary habits to their dental caries increment. The study was also described in a letter to their parents, who were asked to consent to their child taking part. Those who did not volunteer were not approached further. Ethical approval for all aspects of the study was obtained from the Northumberland Area Health Authority.

Each child was dentally examined (including bite-wing radiographs) in October 1979, 1980 and 1981, in a purpose-built mobile examining van. Their heights and weights (without shoes and jackets) were also measured at these times by the same person. A discussion of the children's height, weight and growth in relation to their diet will be published separately.

On five occasions between September 1979 and July 1981, each child recorded, in a specially-designed diary, all foods and drinks taken for three consecutive days. The children

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Table 1. *Summary of subjects taking part*

	No.	%	
Total no. of second-year children	784	100	—
Volunteers	466	59·4	100
Moved or absent for one or more surveys	54	6·9	11·6
Withdrew	2	0·3	0·4
Rejected	5	0·6	1·1
Completed all aspects of survey	405	51·7	86·9

Table 2. *Subjects grouped into social class by father's occupation (Registrar General, 1970)*

Social class	No.		%	
High				
I	20	85	5	21
II	65		16	
Middle				
III	172		43	
Low				
IV	96	118	24	29
V	22		5	
VI, VII and VIII	30		7	
Total	405		100	

also recorded their times of consumption, estimations in household measures of the quantity eaten, whether each item was eaten alone or in combination with any other item, and their bedtimes. They were each then interviewed on the fourth day by one nutritionist, to verify and enlarge on the information provided. By questioning and with the aid of food models, a quantitative record of food intake is thought to have been obtained (Hackett *et al.* 1982) and the method has been described in more detail (Hackett *et al.* 1983).

All the information collected was stored in a computer and the weights of food consumed were analysed using computerized food tables (Paul & Southgate, 1978). The food tables were modified and supplemented as required.

The occupation of the father of each child was also recorded and coded as social class (Registrar General, 1970). Social classes I and II were then labelled 'high', III as 'middle' and IV and V as 'low'. Groups VI (unclassifiable), VII (retired or unemployed) and VIII (unknown) were excluded from any analysis by social class due to the small number of subjects involved.

As the standard deviations showed a tendency to vary with the means, the coefficient of variation for each variable is given as the measure of variation. To allow for the possibility of skewness in the results, when comparing the nutrient intakes to the recommended daily allowances (RDA) the number of subjects falling below the RDA has been calculated.

Differences in mean intake between social classes were tested for statistical significance by the analysis of variance and differences in proportions of children below the RDA by χ^2 analysis of 3×2 contingency tables.

Table 3. *Average daily macronutrient and sugars intake by survey and sex*

Survey...	1		2		3		4		5	
Date	Sept 1979–Feb 1980		Feb 1980–July 1980		Sept 1980–Dec 1980		Dec 1980–Apr 1981		Apr 1981–July 1981	
Sex	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Energy (MJ)	8·9	8·1	8·9	8·4	9·3	8·3	10·0	8·7	10·3	8·8
Protein (g)	62·3	54·4	60·2	53·1	63·1	54·9	67·7	56·5	68·3	58·8
Fat (g)	92·6	86·6	97·1	93·3	99·5	90·8	109·6	97·1	108·5	94·8
Carbohydrate (g)	273·8	248·8	269·1	254·3	284·7	251·7	300·0	257·3	316·9	268·3
Sugars (g)	121·0	114·0	117·7	115·9	121·8	109·2	126·4	111·4	132·6	115·9

Coefficients of variation were virtually the same for either sex at each survey and were approximately: energy 22%, protein 24%, fat 25%, carbohydrate 23%, sugars 33%.

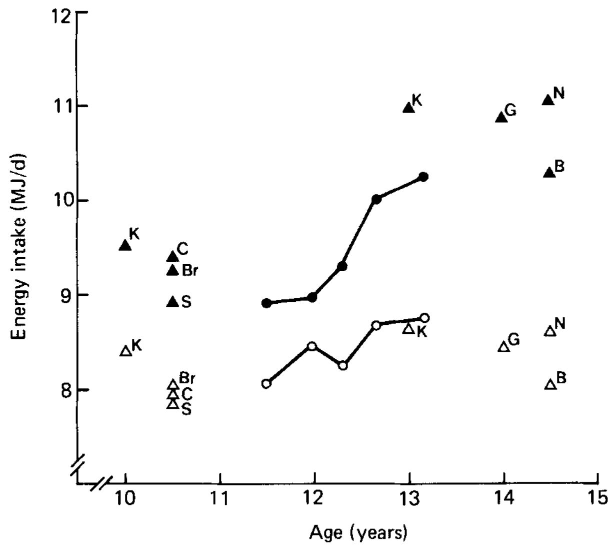

Fig. 1. Average energy intake on five occasions over a 2-year period of 193 boys (●) and 212 girls (○) in Northumberland compared with some other published British surveys of boys (▲) and girls (△) in Kent (▲K, △K) (Cook *et al.* 1973), Glasgow (▲G, △G) (Durnin *et al.* 1974), Newcastle (▲N, △N) and Birmingham (▲B, △B) (Darke *et al.* 1980) and Bristol (▲Br, △Br), Croydon (▲C, △C) and Sheffield (▲S, △S) (Darke & Disselduff, 1981).

RESULTS

Of those asked, 466 children (59·4%) volunteered. This rather low acceptance rate may be related to the subsequent extremely low drop-out rate (0·4%, Table 1). All aspects of the study were completed by 212 girls and 193 boys. The social class distribution (Table 2) showed that despite the low volunteer rate, the various social classes were all well represented.

The mean dietary intakes of the boys and girls at each of the five surveys are shown in Table 3. The boys ate consistently more than the girls and the difference became more pronounced over the 2-year study period: the boys increased their average energy intake by about 13% while that of the girls increased by about 7% (estimates by regression analysis). Fig. 1 shows the energy intake for the boys and girls for each of the five surveys plotted alongside results from other recent British surveys of young adolescents in Kent (Cook *et al.* 1973), Glasgow (Durnin *et al.* 1974), Newcastle and Birmingham (Darke *et al.* 1980) and Bristol, Croydon and Sheffield (Darke & Disselduff, 1981). All these authors used the 7 d weighed inventory method. The average energy intake of the children in the present study corresponded with the intakes reported by these other authors.

The percentage contribution of the macronutrients (protein, fat and carbohydrate) and sugars to the average energy intake is shown in Table 4. The compositions of the diets were very similar both between the sexes and between the surveys. The large contribution of sugars can be seen; lactose contributed 15·2 g/d (13%) of the total sugars intake. Further breakdown of the sugars intake has not been attempted.

Table 5 shows the macronutrient and sugars intakes for each sex and social class: there were few statistically-significant differences between social classes. More middle-social-class girls had energy intakes below the Department of Health and Social Security (DHSS, 1979) RDA than the other girls. The high-social-class boys consumed more lactose than the low- or middle-social-class boys.

Table 4. *Percentage contribution of macronutrients and sugars to energy intake (from the mean of all five surveys)*

	Percentage of energy intake	
Sex...	♂	♀
Protein	12	11
Fat	40	40
Carbohydrate		
Total	49	48
Sugars	21	21

Table 5. *Average daily macronutrient and sugars intake by sex and social class compared with recommended intakes (DHSS, 1979)*

(No. of children in parentheses)

	Energy		Protein					
Social class	MJ	% below RDA	g	% below RDA	Fat (g)	Carbo-hydrate (g)	Sugars (g)	Lactose (g)
♂								
High (46)	9·4	91	65	48	102	283	127	20
Middle (86)	9·4	85	63	59	100	286	120	16
Low (52)	9·5	81	64	56	102	290	124	17
Significance	NS	NS	NS	NS	NS	NS	NS	*
RDA	11·0	—	66	—	—	—	—	—
♀								
High (39)	8·6	54	58	38	95	256	119	14
Middle (86)	8·3	77	54	44	89	252	113	14
Low (66)	8·6	59	55	44	95	261	111	12
Significance	NS	*	NS	NS	NS	NS	NS	NS
RDA	9·0	—	53	—	—	—	—	—

RDA, recommended daily allowance; DHSS, Department of Health and Social Security.

The coefficients of variation were similar between sexes and social classes with values of approximately: energy 15%, protein 17%, fat 18%, carbohydrate 17%, sugars 24%, lactose 42%.

NS, not significant; * $P < 0{\cdot}05$.

The average intakes of some other nutrients compared with the RDA are shown in Table 6. There were no differences in vitamin A intake between the social classes. The higher-social-class girls had a higher Ca intake than the lower-social-class girls and a higher Fe intake than the middle-social-class girls. The lower-social-class girls also had higher Fe intakes than the middle-social-class girls. Few children had intakes of vitamin C below the RDA, but more girls than boys had Ca intakes below the RDA. In contrast most boys and girls had Fe and vitamin A intakes below the RDA.

Table 7 shows the intake of nutrients per unit energy, giving an index of the quality of the diet (or nutrient density). The Ca intakes per MJ of the higher-social-class boys were higher than those of either the middle- or lower-social-class boys, and the Ca intakes per MJ of the higher- and middle-social-class girls were each higher than those of the lower-social-class girls. The intake of Fe per MJ was higher for the higher-social-class girls than either the middle- or lower-social-class girls.

These few significant results have to be treated with caution because of the large number

Table 6. *Average daily intakes of some nutrients by sex and social class compared with recommended intakes (DHSS, 1979)*

(No. of children in parentheses)

Social class	Fibre g	Calcium mg	Calcium % below RDA	Iron mg	Iron % below RDA	Vitamin A (retinol equivalents) μg	Vitamin A % below RDA	Vitamin C mg	Vitamin C % below RDA
♂									
High (46)	14·6	953	13	10·3	80	721	61	43·3	15
Middle (86)	14·6	864	26	10·8	70	730	62	40·1	14
Low (52)	14·9	871	17	10·6	75	644	71	37·9	15
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
RDA	—	700	—	12·0	—	725†	—	25·0	—
♂									
High (39)	14·2	836	28	10·1	85	654	61	41·0	13
Middle (86)	13·0	780	34	9·0	93	609	74	40·9	14
Low (66)	13·6	742	42	9·6	91	569	76	37·9	14
Significance	NS	*	NS	**	NS	NS	NS	NS	NS
RDA	—	700	—	12·0	—	725†	—	25·0	—

RDA, recommended daily allowance; DHSS, Department of Health and Social Security.

The coefficients of variation were similar between the sexes and social classes and were approximately: fibre 24%, Ca 24%, Fe 19%, vitamin A 60%, vitamin C 40%.

† The method used by the DHSS to calculate these values may give results about 7% higher than if these values had been calculated using the method of Paul & Southgate (1978). This latter method was used to calculate intakes in the present study (the RDA is estimated at approximately 675 μg by this method).

NS, not significant; * $P < 0·05$; ** $P < 0·01$.

Table 7. *Average daily intake of nutrients (/MJ energy) by sex and social class*

(No. of children in parentheses)

Social class	Protein (g)	Fibre (g)	Calcium (g)	Iron (mg)	Vitamin A (retinol equivalents) (μg)	Vitamin C (mg)
♂						
High (46)	7·0	1·5	100	1·09	75	4·6
Middle (86)	6·9	1·6	92	1·15	77	4·3
Low (52)	6·8	1·6	92	1·12	68	4·0
Significance	NS	NS	*	NS	NS	NS
♀						
High (39)	6·8	1·7	98	1·18	76	4·8
Middle (86)	6·6	1·6	94	1·09	74	5·0
Low (66)	6·5	1·6	86	1·12	65	4·5
Significance	*	NS	**	**	NS	NS

The coefficients of variation were similar between the sexes and social classes and were approximately: protein 10%, fibre 18%, Ca 19%, Fe 11%, vitamin A 56%, vitamin C 39%.

NS, not significant; * $P < 0·05$; ** $P < 0·01$.

of tests carried out and only those results considered to have practical nutritional significance will be discussed further.

DISCUSSION

The 3 d diary and interview method of measuring dietary intake has proved to be an acceptable and efficient means of collecting a very large amount of data from young adolescents of both sexes and all social classes. Using this method, dietary data of high reliability (e.g. reliability coefficient for energy 0·8) has been obtained (Goldstein, 1979; Appleton *et al.* 1983; Hackett *et al.* 1983). The nutrient intakes recorded were in broad agreement with other recent British dietary surveys for children of a similar age-range (Fig. 1) and confirm the long-term downward trend in energy intake (Whitehead *et al.* 1982). The agreement between the present study and the other recent British surveys of children of this age-group further suggests the value of this relatively cheap and simple survey method.

The divergence in the boys' and girls' energy intakes over the 2-year period is similar to the patterns reported by Burke *et al.* (1959) from a longitudinal study, and to that found in the extensive cross-sectional study of Widdowson (1947). However, the actual values recorded are well below those found in these earlier studies. Like these studies, the energy intakes of the boys and girls showed different patterns; the intake of the girls increased considerably less steeply than that of the boys. These differences may be related to the stage of puberty reached, the girls being nearer 'maturity'.

The children's energy intakes were approximately 20% below the FAO/WHO (1973) recommendations, suggesting that these recommendations are not suitable for British children. The average energy intake of the boys was about 14% and that of the girls 5% below the RDA (most of the boys had energy intakes below the RDA but the reasons are not clear). The children might have been under-reporting their intake slightly and the boys' intake being proportionately lower than that of the girls' may support this. However, the DHSS (1979) RDA may be currently a little too high since there has been a downward trend in energy intake for several decades (Whitehead *et al.* 1982). The children's average protein intakes were similar to the RDA.

Over 20% of the children's energy intake was derived from sugars. The increased risk of the development of dental caries from a large sugar intake is generally recognized (DHSS, 1978). Only 10% of the total energy intake from refined or processed sugar has been recommended (United States Senate, 1977). The consumption of less sugars, particularly less table sugar, which apart from carbohydrate is nutrient-free, would be likely to improve the quality of the diet consumed. The dental implications of the sugars intake of these children will be discussed elsewhere. Apart from sugars, the proportion of energy consumed as protein, fat and carbohydrate agreed with current recommendations (DHSS, 1979).

The average Fe intakes of most individuals and all groups of boys and girls were below the RDA. To achieve an intake of 12 mg Fe/d the girls would need to have consumed a diet supplying 1·5 mg Fe/MJ, which is impractical (DHSS, 1979). Anaemia is usually prevented by an intake of 1·3 mg Fe/MJ (DHSS, 1979), a value 15% above the actual average consumption of these groups and above the intakes of most of the groups of adolescents in the British surveys previously listed. Alternatively, the girls would need to have consumed nearly one-third more energy from a diet of similar quality. Energy intake, therefore, appears to be limiting their Fe intake. The Fe intake of the girls was similar to that found in 1970 by Darke *et al.* (1980) in eighty-five 14·5-year-old Newcastle girls (10·9 mg/d) but whose diets were richer in sources of Fe (1·3 mg/MJ). However, a low estimated Fe intake may not necessarily indicate cause for concern as the use of food tables can give rise to very poor estimates of Fe intake (Marr, 1971). Furthermore, a clinical and haematological study is essential before a diagnosis of Fe-deficiency anaemia can be made.

Fe-deficient erythropoiesis has been suggested as a problem during adolescence in 15% of boys living in poverty and 20% of all girls (Marshall, 1976).

The mean Ca intakes were above the RDA and similar to the Ca intakes recorded in the other surveys of adolescents previously discussed. The Ca intakes in the 1971 survey of Durnin *et al.* (1974) are below those recorded by their earlier survey in 1964 (in different children). Possibly Ca intake is falling and, as with Fe, it may be limited by the energy intake. If this is so the proposed removal of the requirement to add Ca to white flour may be to the detriment of those children with the lowest intakes (lower-social-class girls in particular). If the flour consumed in the present study had not been fortified, Ca intakes would have been about 16% lower, the mean intakes of both the middle- and lower-social-class girls falling below the RDA and the mean intake of the high-class girls equalling it. This will be discussed fully elsewhere.

Intakes of vitamin A of most of the girls and boys were below the RDA. This again may be related as much to falling energy intake as to consumption of a poor-quality diet. Calculations from the studies of adolescents previously listed suggest that little change has occurred in the quality of the diet of adolescents over recent years. Calculations from the information collected by Widdowson (1947) between 1935 and 1939 for 12- and 13-year-olds gave the following intakes for boys and girls respectively: protein (g/MJ) 6·8, 6·9; Ca (mg/MJ) 65, 65; Fe (mg/MJ) 1·2, 1·2; vitamin C (mg/MJ) 5·1, 4·4. This suggests that although there has been a marked improvement in the quality of the diet with regard to Ca (in part due to the fortification of flour introduced in 1942) there have been few changes in the quality of the diet in general. This is in agreement with the thesis of Truswell & Darnton-Hill (1981) that the diet of the modern adolescent is not as bad as is commonly thought. However, the progressive fall in energy intake may still lead to a fall in nutrient intakes.

The fibre intake of all groups of children was low compared with the value of 20 g/d found for a typical UK diet (Bingham & Cummings, 1980) and the suggested recommendation of 40 g/d (Stephen, 1981). It has been suggested that bread, fruit and vegetable intakes be increased and that an increased intake of cereal fibre may be beneficial (DHSS, 1981). The maximum value recorded for an individual in the present study (28 g) suggests that 40 g may be an unrealistic recommendation for children of this age at the present time.

As has been found in other studies of adolescents (Cook *et al.* 1973; Durnin *et al.* 1974) there were few, relatively minor differences in macronutrient intake between the social classes. This is in contrast to a study of preschool children which found that the lower-social-class children consumed more energy (Black *et al.* 1976).

As energy intake falls, a higher quality of diet is necessary to maintain the same intake of other nutrients. This may be accomplished by the fortification of some foods eaten by adolescents, improved health education, new-product development or by the provision of high-quality foods. The alternative is to increase energy intake by means of increased exercise.

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REFERENCES

Appleton, D. R., Hackett, A. F., Rugg-Gunn, A. J. & Eastoe, J. E. (1983). *Proceedings of the Nutrition Society* **42**, 107A.

Bingham S. A. & Cummings, J. H. (1980). In *Medical Aspects of Dietary Fibre*, pp. 261–284 [G. A. Spiller and R. M. Kay, editors]. New York: Plenum Press.

Black, A. E., Billewicz, W. Z. & Thomson, A. M. (1976). *British Journal of Nutrition* **35**, 105–113.

Burke, B. S., Reed, R. B., van den Berg, A. S. & Stuart, H. (1959). *Pediatrics* **24**, 922–940.
Cook, J., Altman, D. G., Moore, D. M. C., Topp, S. G., Holland, W. W. & Elliot, A. (1973). *British Journal of Preventive and Social Medicine* **27**, 91–99.
Darke, S. J. & Disselduff, M. M. (1981). *Sub-committee on Nutritional Surveillance: Second Report*, pp. 111–130. London: H.M. Stationery Office.
Darke, S. J., Disselduff, M. M. & Try, G. P. (1980). *British Journal of Nutrition* **44**, 243–252.
Department of Health and Social Security (1978). In *Eating for Health*, pp. 78–79. London: H.M. Stationery Office.
Department of Health and Social Security (1979). *Recommended Daily Amounts of Food and Energy and Nutrients for Groups of People in the United Kingdom. Report on Health and Social Subjects* no. 15. London: H.M. Stationery Office.
Department of Health and Social Security (1981). *Nutritional Aspects of Bread and Flour. Report on Health and Social Subjects* no. 23. London: H.M. Stationery Office.
Durnin, J. V. G. A., Lonergan, M. E., Good, J. & Ewan, A. (1974). *British Journal of Nutrition* **32**, 169–179.
FAO/WHO (1973). *Energy and Protein Requirements. Technical Report Series* no. 522. Geneva: FAO/WHO.
Goldstein, H. (1979). *The Design and Analysis of Longitudinal Studies*, pp. 129–137. London: Academic Press.
Hackett, A. F., Pearce, J., Twist, A., Rugg-Gunn, A. J. & Eastoe, J. E. (1982). *Proceedings of the Nutrition Society* **41**, 92A.
Hackett, A. F., Rugg-Gunn, A. J. & Appleton, D. R. (1983). *Human Nutrition: Applied Nutrition* **37A**, 293–300.
Marr, J. W. (1971). *World Review of Nutrition and Dietetics* **13**, 105–163.
Marshall, W. A. (1976). In *Early Nutrition and Later Development*, pp. 190–197 [A. W. Wilkinson, editor]. London: Pitman Medical.
Paul, A. A. & Southgate, D. A. T. (1978). *McCance and Widdowson's 'The Composition of Foods'*, 4th ed. London: H.M. Stationery Office.
Registrar General (1970). *Classification of Occupations 1970. Office of Population Censuses and Surveys*. London: H.M. Stationery Office.
Stephen, A. M. (1981). *Journal of Human Nutrition* **35**, 403–414.
Truswell, A. S. & Darnton-Hill, J. (1981). *Nutrition Reviews* **39**, 73–88.
United States Senate (1977). *Dietary Goals of the United States*, 2nd ed. Washington DC: US Government Printing House.
Whitehead, R. G., Paul, A. A. & Cole, T. J. (1982). *Human Nutrition: Applied Nutrition* **36**, 57–62.
Widdowson, E. M. (1947). *Medical Research Council, Special Report Series* no. 259, pp. 64–81. London: H.M. Stationery Office.

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