Factors associated with weight for height and skinfold thickness in British children

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Abstract

Study objective – To examine the associations of social and biological factors with measures of obesity in children.

Design – The study had a cross sectional design.

Setting – The analyses were based on data from two national study of health and growth cross sectional surveys. The “representative sample” comprised 1990 data from 22 English areas and 1990–91 data from 14 Scottish areas; the “inner city sample” comprised 1991 data from 20 English areas.

Participants – The subjects were primary school children aged mainly 5–11 years living in England and Scotland. The “representative” sample included 10 628 children – 6463 living in England and 4165 living in Scotland. The “inner city” sample included 7049 children – 2183 white, 1124 Afro-Caribbean, 2696 Indian subcontinent, and 1046 from other groups. Due to missing values on continuous variables, 8374 children were included in the analyses.

Measurements and main results – The relation between social environment and childhood overweight was studied using several indicators of obesity. Triceps, subscapular, the sum of triceps and subscapular skinfolds, and weight for height were used as dependent variables. The analyses were carried out in two stages. Firstly, multiple linear regression analyses were used to assess the factors associated with dependent variables treated as continuous. Secondly, multiple linear logistic regression analyses were used to examine the association between independent factors and overweight and fatness defined as binary variables. Birth weight, mother’s body mass index (BMI), and father’s BMI were consistently associated ($p < 0.001$) in all models and were the variables that contributed most to the explained variation in the dependent variables. In the multiple regression analyses there was a consistent interaction between the effects of ethnic origin and family size on each outcome variable. In the logistic regression analyses the interaction was not significant, and highly significant associations between both overweight and fatness with the number of children were shown. Ethnic group was not significantly associated with overweight but it was with fatness. The strengths of the remaining significant associations were slight and inconsistent in

relation to the dependent variables or the type of analysis.

Conclusion – Very few variables were associated with measures of overweight and fatness. The only useful factor that was highly associated with all measures of fatness was the parents’ BMI. Strategies to prevent childhood obesity should be aimed at the total population and special emphasis should be placed on families in which one or both parents are overweight.

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Obesity is one of the most important public health problems of our time.¹ In adults, it increases the risk of coronary heart disease, type II diabetes, gall bladder disease, and some forms of cancer.^{1–9} Although the effects of childhood obesity have been studied less, clinically obese children have also been shown to have an increased risk of long term morbidity and mortality.^{10–12} Gortmaker *et al*¹³ have shown that being overweight during adolescence has important social and economic consequences, which could be greater than those of many other chronic physical conditions.

Increases in the body mass index (BMI) have been reported in Britain for young adult women^{14,15} and in Sweden for men during the 1980s.¹⁶ The prevalence of obesity has also increased for children¹⁷ and for adults¹⁸ in the United States. Recently, increasing trends in weight for height and triceps skinfold have been reported for English girls and Scottish children.¹⁹

The risk of overweight children becoming obese in adulthood is not well known. A study reported that only 21% of obese 36 year olds had been obese at 11 years of age, and when social factors were taken into account the predicted percentage was much lower.²⁰ Other studies have reported that between 40%²¹ and 85%^{22–24} of overweight children will become obese adults.

Rolland-Cachera *et al*²⁵ have suggested that age at rebound, which is the onset of the second period of rapid growth in body fat, is the best predictor of the subsequent development of fatness but the reasons for the rebound have not been established. Interventions to prevent childhood obesity could prevent adult obesity as well as reduce the risk of morbidity and mortality in adult life. However, to implement effective interventions the knowledge of the risk factors associated with childhood obesity²⁶ is required and these remain controversial and poorly understood.²⁷

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During past decades, several studies have investigated the association between social, biological, and environmental factors and childhood obesity. The season of measurement,²⁶ ethnic group,^{28 29 42} parents' weight and height,³⁰⁻³³ family size,³² birth weight,³³ excessive television viewing, and short sleep²⁸ were all variables found associated with proxy measures of obesity. Social class is perhaps the variable studied most. Some studies reported strong associations,³⁴ but others have shown that after adjustment for other confounding factors, social class explains only a small percentage of variation in weight for height.³³ These studies included in the analysis only a few factors previously associated with overweight. Differences in the way that potential confounders were included in the analysis could have led to the different results.

Limited understanding of the associations between social factors and overweight has led to the proposal of different prevention strategies. Some investigators have suggested strategies focused on high risk groups^{28 34} while others have indicated population based strategies.^{29 32}

In the national study of health and growth (NSHG), a monitoring system to assess nutritional status in primary school children, analyses have been carried out to assess the factors that influence weight for height and triceps skinfold in British children³³ and to estimate the change in these anthropometric measurements over time.^{19 35} In the previous analyses we used a limited number of variables to characterise the biological background and the social environment.

In the analysis undertaken, we included new variables reflecting other aspects of the child's environment collected in the NSHG 1990 and 1991 surveys in order to re-examine the associations between social and biological factors and obesity. The implications of the findings for primary prevention are discussed.

Methods

SUBJECTS

Data were taken from the NSHG, which was set up in 1972 to monitor growth of primary school children aged 5-11 years living in England and Scotland. Two samples were recruited into NSHG. The initial sample included children from schools in 22 employment exchange areas in England and six in Scotland, which were selected by stratified random sampling.³⁶ Children were eligible to take part while attending schools selected for the study. This sample was surveyed annually from 1972 to 1982 and in even years thereafter for England. The Scottish sample was enhanced by a further eight areas in 1983, and data were collected over a two year period. The characteristics of children from this sample are similar to those of the general population^{29 37} and the sample will be referred to as "representative" in this paper.

In 1983, a second sample was recruited by identifying 10 electoral wards in England with a high prevalence of overcrowding, male unemployment, or shared household amenities.

In addition five wards were selected which had a high proportion of families from Indian subcontinent backgrounds, and five which had a high proportion of families from Afro-Caribbean backgrounds. The wards selected because of their ethnic composition also had characteristics of deprivation.²⁹ This sample will be referred to as "inner city". For the present analysis, data were analysed together for the 1990 English, the 1990-1991 Scottish representative sample, and the 1991 English inner city sample.

MEASUREMENTS

Children were measured at school by school nurses and 10% of the measurements were checked by a full time fieldworker from the study team. Height was measured on a specially designed stadiometer (Holtain) using the method described by Tanner, Whitehouse, and Takaishi.³⁸ Height was recorded to the last 0.1 cm. Weight was recorded to the last 100 g: children were wearing underclothes, normally pants only. Triceps and subscapular skinfold thickness were measured as described by Tanner and Whitehouse,³⁹ except that for the triceps skinfold the midpoint between the top of the acromion and olecranon was marked with the arm hanging straight rather than bent. Harpenden skinfold callipers were used for the measurements. Readings were recorded to the last 0.2 mm on the calliper scale.

OUTCOME VARIABLES

The weight for height index ((weight-9)/height^{3.7}, where height is in m and weight in kg) and triceps, subscapular, and triceps plus subscapular skinfold thickness standard deviation scores (SDS) were used as outcome variables. The weight for height index is a measure of overweight that includes an assessment of many tissues besides fat, and triceps and subscapular skinfolds are direct measures of fatness. We used four outcome variables in the analysis in order to check if there was a different pattern of association depending on the outcome measure used.

As height⁴⁰ and weight⁴¹ each show increasing variation with age in children, it is necessary to transform data by including several age groups before the analysis. SDS expresses a measurement for a child, transformed as necessary to a normal distribution, as the difference from the reference group mean for that child's age and sex, divided by the SD for the age and sex, so that for the reference group mean SDS is zero and the SD is one.

Chinn *et al*⁴¹ showed that log ((weight-9)/height^{3.7}) has constant variance, and is approximately normally distributed, so SDSs were calculated from its distribution. SDSs for triceps skinfold thickness were calculated as described by Cole.⁴² This required smoothing the mean, the coefficient of variation and a third parameter accounting for skewness over age. All SDSs were calculated using the English 1990 data as standard.

EXPLANATORY VARIABLES

In addition to the children's measurements, the child's parent or guardian was asked to complete a self administered questionnaire containing questions relating the child's health and the social background of the family. The questionnaire also requested information concerning the parents' height and weight and the child's birth weight.

Explanatory continuous variables

The explanatory factors which were used in this study as continuous variables were the maternal and paternal BMI, the mother's age at child's birth, and the child's birth weight.

Categorical variables

Categorical variables were classified as follows:

- Twin or triplet (classified as yes, no, and unknown);
- Family size (specifying the number of children in the family and classified as: up to eight or more and unknown);
- Type of lunch at school (classified as school meal, home meal, packed lunch, buy lunch outside school, any combination including school and unknown);
- Free school meals (classified as received, not received, not applicable, and unknown);
- Vegetarian (classified as yes, no, unknown);
- Child drinking milk at school (classified as yes, no, and unknown);
- Hours worked by the mother outside the home (classified as fewer than 15/week, 15–25, more than 25, no outside work, and unknown);
- Mother's and father's highest education (classified as primary, secondary, commercial or technical, university, no school education, and unknown);
- One parent family (classified as both parents living at home, only child's mother living at home, only child's father living at home, neither child's father and mother living at home (child guardian) and unknown);
- Paternal social class (classified as I, II, IIIN, IIIM, IV, V, and unknown);
- The receipt of benefits – unemployment benefit, income support, and family credit (classified as yes, no, and unknown);
- Ethnic group of the child – classified according to the language spoken at home and by the fieldworker's subjective assessment of the child's ethnic group. The categories used in this analysis of ethnic group were as follows: white living in England (1990 representative sample), white living in Scotland (1990/1991 representative sample), white living in a inner city area (1991 inner city sample), Afro-Caribbean, children speaking Punjabi, Gujarati, Urdu, others from Indian subcontinent and other Asian or Mediterranean;
- A variable which defined the relationship between the father's and mother's overweight was created as follows. Firstly, the mother's and father's BMIs were divided into quartiles. Mother's BMI in the top quarter which had a value equal to or higher than 25.38 and father's BMI in the top quarter with a value equal to or

higher than 26.23 were considered overweight. Secondly, a variable was defined with four categories as follows: neither mother nor father overweight, only the father overweight, only the mother overweight, and both the mother and father overweight.

- To investigate a possible interaction between birth weight and age, age was categorised in four groups: children <7 years old, from 7 to 8, from 9 to 10, and >10.

Cases containing values in the outcome variables outside the range -4.5 to $+4.5$ SDs and those with missing values on the continuous variables were excluded from the analysis. For categorical variables containing missing values an "unknown" category was defined for each variable.

STATISTICAL ANALYSIS

Two main analyses were carried out in this study. Firstly, a multiple linear regression analysis was used to explore independent associations between explanatory variables and any of the outcome variables (treated as continuous). Four models were fitted, one for each dependent variable (outcome) with explanatory variables described above. Backward elimination of variables was carried out and the final model included only variables significant at the 5% level. Independent variables were entered as continuous or categorical according as previously indicated. Secondly, a logistic regression analysis was performed to assess the relationship between child's overweight (treated as a binary variable) and the independent factors.

Although there is not a clear criterion for the cut off point to define overweight in children as there is in adults, several studies^{20 27 28} have carried out analysis using weight for height, classified as a binary variable (normal weight/overweight), obtaining different patterns of association. In order to determine whether there is a different pattern of association when dependent variables are used as a continuous or binary variable, multiple linear logistic regression analyses were used with the outcome variables treated as binary variables. Those in the first, second, and third quarter were classified as not overweight and those in the top quarter were considered overweight. In order to see differences in the odds ratios (ORs) at different levels, we introduced birth weight categorised in quartiles in this analysis. Backward elimination was carried out until the *p* values of all the remaining independent variables were less than 0.05.

Results

Data for the 10 628 children of the representative sample (6463 living in England, 4165 living in Scotland) and for the 7049 of the inner city sample (2183 white children, 1124 Afro-Caribbean, 2696 Indian subcontinent, and 1046 from other groups) were available for the analysis.

Information on continuous and categorical explanatory variables was collected from the

Table 1 Percentage of unknown values for outcome and explanatory variables by sample

Variables	England 1990 (n = 6463) (%)	Scotland 1990–1991 (n = 4165) (%)	Inner city 1991 (n = 7049) (%)
Outcome:			
Weight for height (SDS)	0.7	0.3	5.7
Triceps skinfold (SDS)	0.4	0.2	5.3
Subscapular skinfold (SDS)	0.3	0.3	5.3
Triceps + subscapular skinfold (SDS)	0.5	0.3	5.3
Explanatory (categorical):			
Family size	11.4	5.4	25.3
Twin or triplet	10.0	7.0	27.8
School lunch	7.4	3.4	19.7
Lunch free	14.7	8.9	28.4
Vegetarian	8.7	4.2	22.8
Milk at school	10.0	4.5	21.7
Mother at work	6.8	4.8	21.7
Mother's education	8.9	4.3	24.8
One parent family	8.0	3.7	21.7
Father's education	11.5	7.0	31.7
Father's social class	26.4	24.8	55.7
Unemployment benefit	18.2	17.4	49.9
Income support	12.3	8.8	29.6
Family credit	17.1	15.8	48.3
Explanatory (continuous):			
Father's body mass index	30.1	31.4	58.7
Mother's body mass index	20.5	22.4	52.7
Birth weight	11.7	8.5	39.7
Mother's age at child's birth	8.6	4.4	25.1

SDS = standard deviation score.

Table 2 Mean (SEM) of outcome variables included and excluded by sample

Sample	No	No (%)	SDS		
			Weight for height Mean (SEM)	Triceps Mean (SEM)	Subscapular Mean (SEM)
England:					
Included	4062	(62.8)	0.004 (0.01)	-0.009 (0.01)	-0.013 (0.01)
Excluded	2401	(37.1)	0.004 (0.06)	0.002 (0.06)	0.010 (0.06)
Scotland:					
Included	2450	(58.8)	0.055 (0.02)	-0.009 (0.02)	0.130 (0.01)
Excluded	1715	(41.1)	0.080 (0.02)	-0.010 (0.02)	0.160 (0.02)
Inner city:					
Included	1862	(26.4)	-0.140 (0.02)	-0.160 (0.02)	0.140 (0.02)
Excluded	5187	(73.5)	-0.170 (0.01)	-0.220 (0.01)	0.160 (0.01)

SDS = standard deviation score.

Table 3 Associations between weight for height and biological and social environment factors. Models defined using multiple regression analysis

	Weight for height (SDS)	
	Coefficient (SEM)	p value
Intercept	-3.469 (0.094)	
Mother's education:		0.0125
Primary school	0	
Secondary education	0.076 (0.068)	
Further education	0.108 (0.071)	
University/Polyt.	0.099 (0.074)	
No school education	-0.147 (0.111)	
Unknown	0.378 (0.129)	
One parent family:		0.0022
Both parents at home	0	
Only mother at home	0.102 (0.033)	
Only father at home	0.337 (0.137)	
Neither at home	0.057 (0.100)	
Mother's BMI	0.049 (0.002)	0.0001
Father's BMI	0.068 (0.003)	0.0001
Mother's hours of work:		0.0175
More than 25 h/wk	0	
Between 15–25 h/wk	-0.050 (0.034)	
Less than 15 h/wk	-0.085 (0.038)	
No work outside home	-0.104 (0.031)	
Unknown	-0.052 (0.094)	
Ethnic origin and family size interaction:	*	0.0190
Birth weight (<7 y)	0.309 (0.048)	
Birth weight and age interaction:		0.004
Difference in slope from <7 y age group		
7–8 y	0.004 (0.061)	
9–10 y	-0.135 (0.060)	
>10 y	-0.153 (0.063)	
R ²	0.13	

* 80 levels not shown, but explained in the text. SDS = standard deviation score; BMI = body mass index.

self administered questionnaire which parents or guardians completed. The response rate was 92.3% for the representative sample and 85.3% for the inner city sample, but there was variation in the degree of completeness according to the type of variable and sample.

Table 1 shows the number and percentage of unknown values for the dependent and independent categorical and continuous variables. A very small number of children had missing values for dependent variables. Missing values were higher in the inner city sample and they were mainly due to refusal to measurement or not being at school on the survey day.

Explanatory continuous variables had a higher proportion of missing values, especially for mother's and father's BMI. The highest missing values were for the father's BMI, mainly because of missing weight. In the inner city sample, 57% of values for weight were missing in contrast to 29.4% in the Scottish sample and 28.8% in the English sample. Missing values for father's height were 35.0% for the inner city sample, in contrast with 11.6% in the Scottish sample and 15.6% in England. Similar proportions of missing values were observed for mother's weight and height, but these were slightly lower. In the inner city sample the father's BMI had the highest percentage of missing values (58.7%). Birth weight and mother's age at the child's birth had a lower number of missing values, but proportions were also higher in the inner city sample – 39.7% and 25.2% respectively. The same pattern was shown for categorical variables in general, with a lower percentage of missing values, except for social class, and the highest percentage missing for the inner city sample.

Those children with missing values for continuous variables were excluded from the analysis. After all exclusions, data from 8374 (47.3%) children were available for analysis. Table 2 shows the number and percentage of inclusions and exclusions by sample. The highest number of exclusions was from the inner city sample – 5187, 73.5%, compared to 41.1% for the Scottish sample and only 37.1% for the English one. This table also shows the mean (SEM) values for dependent variables according to whether they were excluded or included in the analysis. There were no significant differences between the mean values of those included and those excluded except for triceps skinfold which was less in those excluded in the inner city sample. The distribution of categorical variables between included and excluded children, however, was significantly different in most cases ($p < 0.001$).

Table 3 gives the final model of the variables associated with weight for height (SDS) in multiple regression analysis. Weight for height (SDS) was significantly associated with mother's education ($p < 0.05$), one parent family ($p < 0.05$), mother's BMI ($p < 0.001$), father's BMI ($p < 0.001$), mother's hours of work ($p < 0.05$). The family size effect was modified in relation to ethnic origin ($p < 0.005$). However, the interaction was mainly due to the effect of a heterogeneous group which included Arab, Chinese, Vietnamese, Somalis, Sudanese, and

Table 4 Associations between proxy indicators of obesity and biological and social environment factors. Models defined using multiple regression analysis

Variables	Subscapular skinfold (SDS)		Triceps skinfold (SDS)		Subscapular & triceps skinfold (SDS)	
	Coefficient (SEM)	p value	Coefficient (SEM)	p value	Coefficient (SEM)	p value
Intercept	-2.226 (0.151)		-2.454 (0.162)		-4.672 (0.295)	
Drinks milk at school:		0.0014				0.0106
Yes	0				0	
No	0.055 (0.023)				0.077 (0.046)	
Unknown	-0.140 (0.056)				-0.252 (0.109)	
Birth weight	0.117 (0.018)	0.0001	0.140 (0.020)	0.0001	0.256 (0.036)	0.0001
Mother's BMI	0.040 (0.002)	0.0001	0.038 (0.002)	0.0001	0.078 (0.005)	0.0001
Father's BMI	0.044 (0.003)	0.0001	0.043 (0.003)	0.0001	0.087 (0.006)	0.0001
Mother's age at child's birth	0.006 (0.002)	0.0014	0.007 (0.002)	0.0005	0.013 (0.002)	0.0005
Ethnic origin and family size interaction *		0.0080	*	0.0182	*	0.0048
R ²	(0.08)		(0.08)		(0.08)	

* 80 levels not shown, but explained in the text.

other children who could not be classified into any of the large groups in the analysis. When this group was excluded from the analysis, the interaction was not significant. An interaction between age and birth weight was also found to be significant ($p < 0.05$). The increasing trend in weight for height with birth weight decreased with increasing age groups.

Table 4 gives the final model of the variables associated with subscapular, triceps and the sum of subscapular and triceps skinfold. In these three models, four variables were consistently associated in all models: birth weight, mother's BMI, father's BMI, and mother's age at the child's birth. The first order interaction

between ethnic group and family size was also significant in these models. As in the analysis of weight for height, the interaction was mainly due to the ethnically heterogeneous group defined above and, in the analysis of subcutaneous skinfold, the Gujarati group also.

The pattern of association varied slightly within the four models shown in tables 3 and 4. Although birth weight and mother's and father's BMIs were associated in all models, the mother's age at the child's birth was only related to skinfold thickness, and mother's hours of work to the weight for height index only. A low percentage of variance was explained: in the weight for height model this was only 13% and in the models for triceps, subscapular, and the sum of triceps and subscapular skinfolds only 8%. Birth weight and parental BMI were the variables that contributed most to the explained variance.

Table 5 shows the associations of over weight with independent variables using logistic regression analysis. In contrast to multiple regression analysis, social class was the only extra variable included in the final model ($p < 0.05$). The interaction between family size and ethnic group was not significant and family size was included in the model, with a trend for the risk of overweight to decrease with increased family size ($p < 0.001$). The interaction between birth weight and age was not significant and birth weight was included in the model. The risk of overweight increased with birth weight. Those children at the top quarter of birth weight had a nearly twofold risk of overweight. A protective effect was found for children whose mothers worked for fewer than 15 hours a week outside the home or did not work at all. Those children with only one parent in the family were at a higher risk of overweight. When only the mother was present the OR was 1.35 (95% CI 1.02, 1.78). When only the father was in the family, however, the risk increased to 2.26 (95% CI 1.26, 4.04). With regard to the social class of the father, only those in skilled manual occupation were at higher risk of overweight, the OR being 1.37 (95% CI 1.02, 1.85). The child's birth weight was also associated with overweight – as it increased, the risk of overweight increased. When both parents were obese, the OR increased to 3.48 (95% CI 2.93, 4.13).

Multiple logistic regression analysis was also used to fit models for obesity defined by the

Table 5 Associations between child overweight and social and biological factors by multiple logistic regression analysis. ($n = 8374$)

Variables	No	No (%) overweight	OR*	OR†	95% CI‡
Family size:					
1	625	196 (31)	1	1	
2	3726	980 (26)	0.78	0.78	(0.64, 0.94)
3	2122	524 (24)	0.71	0.71	(0.58, 0.87)
4	798	178 (22)	0.62	0.63	(0.49, 0.80)
5	296	51 (17)	0.45	0.49	(0.34, 0.71)
≥ 6	212	43 (20)	0.35	0.35	(0.19, 0.61)
Unknown	595	133 (22)	0.63	0.67	(0.49, 0.92)
Mother's hours of work:					
>25 h/wk	1599	472 (29)	1	1	
Between 15–25 h/wk	1776	466 (26)	0.84	0.91	(0.77, 1.07)
<15 h/wk	1182	293 (24)	0.78	0.82	(0.69, 0.99)
No work outside home	3443	786 (22)	0.70	0.80	(0.69, 0.92)
Unknown	374	88 (23)	0.80	0.50	(0.58, 1.27)
Mother's education:					
Primary school	272	56 (20)	1	1	
Secondary education	5216	1320 (25)	1.31	1.20	(0.87, 1.64)
Further education	1690	449 (26)	1.40	1.28	(0.91, 1.78)
University/polytechnic	983	251 (25)	1.32	1.29	(0.90, 1.83)
No school education	155	15 (9)	0.41	0.50	(0.27, 0.94)
Unknown	58	14 (24)	1.23	1.28	(0.64, 2.55)
One parent family:					
Both parents at home	6917	1719 (24)	1	1	
Only child's mother at home	1069	288 (26)	1.12	1.35	(1.02, 1.78)
Only child's father at home	54	22 (40)	2.08	2.26	(1.26, 4.04)
Guardian or unknown	334	76 (22)	0.89	1.25	(0.75, 2.06)
Father's social class:					
I	333	68 (20)	1	1	
II	1910	499 (26)	1.38	1.31	(0.97, 1.76)
IIIN	525	112 (21)	1.06	1.01	(0.70, 1.44)
IIIM	2633	713 (27)	1.45	1.37	(1.02, 1.85)
IV	929	216 (23)	1.18	1.18	(0.85, 1.64)
V	236	49 (20)	1.02	0.98	(0.64, 1.52)
Unknown	1808	448 (24)	1.28	1.11	(0.76, 1.61)
Child's birth weight:					
1st Quarter	2149	406 (18)	1	1	
2nd Quarter	2087	517 (24)	1.41	1.36	(1.17, 1.58)
3rd Quarter	2104	564 (26)	1.57	1.50	(1.29, 1.74)
4th Quarter	2034	618 (30)	1.87	1.73	(1.50, 2.01)
Parent's obesity:					
Neither father nor mother obese	4929	955 (19)	1	1	
Father obese	1393	422 (30)	1.81	1.85	(1.61, 2.12)
Mother obese	1361	421 (30)	1.86	1.90	(1.66, 2.19)
Both obese	691	307 (44)	3.33	3.48	(2.93, 4.13)

* Unadjusted odds ratio; † adjusted odds ratio; ‡ 95% confidence interval for adjusted OR.

upper quarter of subscapular, triceps, and the sum of triceps and subscapular skinfolds respectively. Birth weight and parent's obesity, as in the other models, were consistently associated in all three models. The interaction between family size and ethnic group was not significant, but family size and ethnic origin were independently associated in all three skinfold models ($p < 0.001$). Scottish, Punjabi, and Urdu children were at higher risk of obesity in the sum of subscapular and triceps skinfold model. In contrast to the multiple regression analysis of the continuous variables, mother's hours of work and mother's age at the child's birth were significantly associated with the outcome variable in all three logistic models.

Discussion

This analysis shows a consistent and highly significant association of all the measures of fatness with the parents' BMI and child's birth weight. In the multiple regression analysis there was also a consistent interaction between ethnic origin and family size for each of the dependent variables. In the logistic regression analysis the interaction was not significant and a highly significant association between overweight and fatness with number of children was shown. The strength of the remaining significant associations were slight and inconsistent in relation to the dependent variable or the type of analysis (multiple regression analysis or multiple logistic regression). Children in one parent families and those whose mothers worked outside the home were more overweight than other children, but these independent variables were not significant in relation to skinfold measurements. Older mothers had children with higher skinfold thickness values. Social class was significantly associated with weight for height in the logistic regression model, but with children of skilled manual fathers showing the highest percentage of overweight and those of unskilled manual workers one of the lowest.

The strengths of this analysis are the large number of children representing most sectors of English and Scottish society (including ethnic minorities), the large sample size studied, the large number of independent variables included in the analysis, and the high percentage of measurements taken from the eligible population. The main weakness of the analysis is the high percentage of missing values of reported parents' BMI. This meant that approximately half the children were excluded from the analyses. This was expected given the large percentage of children in families with only one parent at home and the large proportion of children from ethnic minorities with no reported measurement for a family member. As parents' BMI was the variable showing the strongest and most consistent association with measures of obesity we were reluctant to exclude this variable from the analysis or input values for missing information. There is a possibility that this type of analysis may miss some associations. However, the similarity of the current results with previous analyses on this topic, for the 1972 representative sample³⁵ and for

the 1983 inner city sample²⁹ in which almost all children were included in all analyses or part of it, suggests that this possibility is less likely.

In the published action plan of the Nutrition Task Force⁴³ it was stated that as a first step to combat obesity attention should be directed towards prevention rather than its treatment. In principle, this is a sound recommendation given the appreciable increase in obesity documented in children and adults in Britain and elsewhere.¹⁶⁻¹⁹ Our intention to re-examine the association between sociodemographic and biological factors and obesity, was to identify possible factors that may provide pointers to amenable areas for intervention. The association between the parents' BMI and the child's fatness is indicative of a familial influence. Twin studies suggest that a component of the association is of a genetic nature.^{44,45} Studies of parents and their adopted and biological children have shown that the association is stronger in biological than in adopted families.⁴⁶ In support of the genetic mechanism of the association we would have expected the relation between father and child, and mother and child, to be of the same magnitude in all models. This was shown except in the weight for height model where the effect of the father's BMI was 40% higher than the mother's BMI. This might indicate that other environmental factors are important in explaining this relationship. As the mother is usually more in control of the home environment than the father we would have expected the effect to be greater for the mother's BMI. However, as related people share genes, environment, and lifestyle, it is probable that part of the familial association is due to environmental and lifestyle characteristics that are not easy to measure in population studies, such as physical activity, use of leisure time, and eating behaviour. A further argument in favour of environmental factors is the marked increase of obesity in the population in a period of 20 years.^{19,47} This phenomenon cannot be accounted for by changes in gene frequency in this short time.

Given the strong familial association of obesity it is important to examine the place of prevention in the family. Intervention strategies considering the family as a unit, rather than the child, need to be evaluated in terms of their efficacy and costs. One possible strategy would be that families who are more prone to obesity need to be targeted for intervention studies. Stunkard *et al*³⁴ suggested that attempts should be targeted at those at high risk of obesity. This is not the strategy that we would support. Firstly, because the explained variation in child fatness in our study has been consistently low and most children at high risk of obesity will be left out. Secondly, overweight and obesity are a widespread problem in Britain; around 50% of men and 40% of women have a BMI over 25.⁴⁷ Thirdly, it would be very difficult to identify obese parents and such identification may stigmatise some of the children in the programme and their families. However, primary care workers and school staff should be aware that obese parents are more likely to

have obese children. Thus, to focus advice only on the child may create problems within the family as the child may have limited scope for changing his lifestyle and environment.

The significant interaction of ethnic background and number of children on obesity, mainly due to one ethnic group in the analysis, is indicative of the complexity of the issues that need to be taken into account. In the white sample there is a strong negative association between number of children and obesity. In the logistic regression, in which the interaction was not significant, there was a strong negative association between the number of children and overweight and fatness. However, this association has not been demonstrated consistently in non-white groups in Britain.²⁹ This indicates that the number of children in the family is not directly related to obesity in the white population, but is a proxy for other factors that may be related to values or social characteristics associated with family size.

Of the remaining significant associations in our analysis, birth weight is one that is consistently associated with fatness. These results are consistent with other studies.^{33,48} However, it is difficult to imagine a preventive action that can be derived from this association as most health actions are geared to decrease the percentage of light for date newborns in Britain. The significant interaction of birth weight and age on weight for height may indicate that birth weight is a less important factor in the overweight of older children. However, as the interaction was not significant in the assessment of skinfold thickness we are uncertain of this interpretation. The association of birth weight with fatness is puzzling in relation to the Barker hypothesis.⁴⁹ Obesity is a known contributor to raised blood pressure and total cholesterol levels. Our result indicates that birth weight has a complex effect on risk factors associated with coronary heart disease.

The findings that children whose mother's work outside the home and those in one parent families tended to be more overweight is potentially important. The common characteristic of these two factors is that these children may spend long periods of time on their own and they may eat more frequently than other children. It is difficult to explain from our analysis, however, why this phenomenon is associated mainly with weight for height and not skinfold thickness (except mother's hours of work in the logistic regression). Because we included triceps and subscapular skinfold thickness, it is not possible to hypothesise that distribution of fat may be an explanation. At this stage we would only recommend health workers in the community to be aware of this finding, rather than to act on it.

Mother's age at delivery was related to skinfold thickness but not weight for height. We have consistently shown that the mother's age at delivery is associated with the child's height,⁵⁰ but it is the first time that we have reported a relation with fatness. Our result suggests that the reason why the children of older mothers are taller may be related to the fact that these children are fatter and may be more ad-

vanced in their prepubertal maturation as it is well known that fat children, especially girls, tend to be more advanced in their physiological maturation.⁵¹ It is curious that this association, which was highly significant with skinfold thickness, was not significant with weight for height. We cannot provide an explanation for this finding that is unlikely to be due to chance.

In conclusion, very few variables are associated with measures of overweight and fatness. The only useful factor which is highly associated with all measures of fatness is the parent's BMI. This association may indicate that there are families who are susceptible to becoming obese. We believe that programmes to prevent obesity should take this factor into account. As the percentage of explained variation in our study is low, it would be unwise to focus prevention only on children whose parents are obese. Primary prevention strategies of childhood obesity should be aimed at the total population and special emphasis should be put on those families in which one or both parents is overweight. Any primary prevention programme, however, should be carefully evaluated and monitored. Only interventions of proved effectiveness should be supported. The rest of the variables associated with overweight or obesity do not provide potential for action or the inconsistency of the associations may only provide helpful pointers. Of these the most interesting finding is that children who spend a long time on their own may be more prone to become obese. To progress further, it is possible that measures which look at other events in the child's life such as physical activity, eating behaviour, and use of leisure time need to be developed for use in large surveys.

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