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# Deprivation and childhood obesity: a cross sectional study of 20 973 children in Plymouth, United Kingdom

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**Abstract**

***Objective*—To study the association between socioeconomic deprivation and childhood obesity.**

***Design*—Cross sectional study.**

***Setting*—All state primary schools in Plymouth. Plymouth is a relatively deprived city in the United Kingdom, ranking 338th of 366 local authorities on the Department of the Environment Index of Local Conditions.**

***Subjects*—20 973 children between the ages of 5 and 14 years, 1994–96.**

***Main outcome measure*—Numbers of obese children (body mass index (BMI) above the 98th centile) by quarters of Townsend score.**

***Results*—Plymouth had a rate of childhood obesity two and half times that expected nationally (5% *v* 2%). The obesity prevalence increased with age, being almost double in the oldest age quarter (boys 6.2%; girls 7.0%), compared with the youngest age quarter. Within Plymouth, there was a significant trend for higher rates of obesity related to increasing deprivation in both boys (p=0.017) and girls (p=0.018). The odds ratio (OR) for childhood obesity (highest-lowest quarter of Townsend scores) had borderline significance in boys (OR 1.29, 95% confidence intervals (CI) 1.00 to 1.65, p=0.049) but was larger and more significant in the girls (OR 1.39, 95% CI 1.08 to 1.80, p=0.011). Unlike boys, the association between obesity in girls and Townsend scores became stronger with age such that in the oldest age quarter (over 11.7 years), girls in the highest quarter of Townsend scores were nearly twice as likely be obese, as compared with the lowest quarter (OR 1.95, 95% CI 1.23 to 3.08, p=0.005). State of pubertal development could not be accounted for as this information was not available.**

***Conclusions*—This study provides evidence for an association between deprivation and childhood obesity in this English population. The health of children from deprived households is affected by a number of adverse influences. The high prevalence of obesity in these children is yet another factor that could predispose to greater morbidity in adult life.**

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Obesity is rapidly becoming one of the most important medical and public health problems of our times. Its role as a health hazard in adults has been well recognised for some time[1] but in the past little attention has been paid to childhood obesity. However, a dramatic increase in its prevalence in developed countries, over a relatively brief time period,[2 3] as well as a growing body of evidence of its short-term and long term consequences,[4–6] has brought this condition into sharper focus. Several studies have investigated the various social, biological and environmental determinants of child obesity.[7–10] One such determinant is socioeconomic status.

Despite popular perceptions and several plausible mechanisms, the relation between socioeconomic deprivation and childhood obesity remains unproven and contradictory.[2 11–18] Plymouth, a relatively deprived part of the UK (ranked 338 of 366 local authorities on the Department of Environment's Index of Local Conditions),[19] also has considerable socioeconomic variations within the city by virtue of having some of the most deprived and affluent electoral wards nationally.[20] It therefore provides an ideal setting for studying the association between deprivation and obesity. We have used a dataset of height and weight measurements of all primary school children in Plymouth (n = 20 973) to examine the association between obesity (body mass index above 98th centile) and socioeconomic deprivation (Townsend scores at the level of enumeration district).

## Methods

### SAMPLE POPULATION AND METHODOLOGY

From 1994 to 1996, the school nursing service in Plymouth weighed and measured all primary school children aged 5–11 years, as part of a growth study coordinated by the local Department of Child Health. The purpose of the study was to determine the feasibility of routine growth surveillance in detecting unsuspected growth problems in childhood. The measurements were carried out at the ages of 5, 7, 9 and 11 years and totalled 25 264. Some children were measured more than once and some early in secondary school. All the school nurses were trained over two days at the start of the study; any new nurses joining later were trained subsequently. All measurements were carried out in vests and pants. Height was measured to the nearest 0.1 cm using a portable self calibrating Raven minimeter (Raven Equipment Limited, Essex, UK). The accuracy of the instrument was checked with a calibrated rule both before and after each measuring session. The feet were placed together with heels, buttocks and shoulder blades against the wall and head in Frankfurt plane with anthropometric square. The head was unstretched and the child was encouraged to relax the shoulders and breathe normally. Timing of the measurements was in the mornings or early afternoons. An average of three readings was taken. Weight was measured once with electronic Seca scales (Seca, Birmingham, UK) to the nearest 0.1 kg. The information was recorded on to the Plymouth Hospital NHS Trust's Child Health Computer System.

MEASURES

*Body mass index*

The recordings for heights and weights were used to calculate the Quetelet Body Mass Index defined by the formula $y = w/h^2$, where $w$ and $h$ are the individual's weight (in kg) and height (in m) respectively.[21 22] The BMI in childhood varies with age and between sexes and therefore cannot be compared directly. The results were therefore standardised to the British reference population using an excel macro provided by the Child Growth Foundation (UK).[23] This macro uses the same data as that used to produce the reference BMI curves for the British children, to provide the BMI z scores and centiles.[21]

*The Townsend score*[24]

The Townsend Material Deprivation Score uses four Census variables to assess the following: general lack of material resources and insecurity (unemployment); material living conditions (overcrowding); wealth (owner occupation is used as proxy indicator); and income (car ownership is used as a proxy indicator). For the purposes of this study, Townsend scores were calculated, from 1991 census data, at enumeration district level (approximately 150 households) and standardised to the Devon County population. Enumeration district level Townsend scores were available for all but 63 children; ward level scores were used for these children instead. Townsend scores tend to range from −12 (least deprived) to +12 (most deprived), although in certain circumstances they can lie outside this range.

*Age*

Age was calculated to the precise day by subtracting the date of birth from the date of examination.

STATISTICAL ANALYSIS

Data were analysed using the STATA software version 5. The BMI centiles were treated as a binary variable (presence or absence of obesity) and the presence of obesity was considered as the main outcome. To study the effect of deprivation, the main explanatory variable (Townsend score) was divided into four equal categories—quarters of Townsend score. Age was treated as both categorical (quarters of age) and a continuous variable. Logistic regression modelling was used to calculate the odds ratios and confidence intervals, as well as to test for presence of a trend. Univariate analysis was followed by the introduction of an age variable in the model. Finally interaction terms were introduced between the age and the Townsend score variables.

KEY POINTS

- The problem of childhood obesity in the UK may be growing, as suggested by this study.
- Socioeconomic deprivation seems to be an important determinant of obesity in childhood.
- Appropriate measures to safeguard the health of poorer children, from this additional emerging problem, need to be considered.

## Results

THE DATASET

The original dataset contained the heights of 25 264 and weights of 25 222 children. Of these 25 047 were matched records (where system numbers matched). Some 24 583 (98%) records from the above, also had valid postcodes. Some of these were multiple records on the same children; first observations were kept and the subsequent ones were dropped. There were finally 20 980 complete single records. Of these, seven observations for BMI z scores were considered to be implausible (more or less than seven standard deviations (SD)). Analysis was carried out with and without these seven observations, without any significant difference in the results; however the normality of the distribution of the BMI z scores was significantly affected by the inclusion of these values. The results presented below are therefore, for 20 973 records.

DISTRIBUTION OF THE VARIABLES

*Age*

The median age of the children was 8.8 years (range = 5.1 to 14.6). The age quarters had means (ranges) in years as follows: 6.4 (5.1 to 7.1); 8.1 (7.2 to 8.9); 9.7 (9.0 to 11.7); 12.2 (11.8 to 14.6).

*Sex*

There were 10 693 boys (51%) and 10 280 girls (49%).

*BMI*

The BMI z scores were normally distributed with mean = 0.17 (SD=1.08).

*Townsend scores*

The mean Townsend score by enumeration district was 1.23 (SD=3.94). The Townsend score quarters had means (ranges) as follows: −3.3 (−5.4 to −2.1); −0.7 (−2.0 to +0.6); 2.3 (0.7 to 4.2); 6.7 (4.3 to 12.4).

DISTRIBUTION OF OBESE CHILDREN

Overall, there were 1046 obese children (5.0%). There was no significant difference in the overall prevalence of obesity between the

*Table 1 Prevalence of obesity by quarters of age*

| | Boys | | Girls | |
|---|---|---|---|---|
| *Age quarter (y)* | *%* | *n* | *%* | *n* |
| 1 (5.1–7.1) | 3.9 | 104 | 3.3 | 85 |
| 2 (7.2–8.9) | 5.0 | 132 | 3.8 | 99 |
| 3 (9.0–11.7) | 5.7 | 156 | 5.0 | 125 |
| 4 (11.8–14.6) | 6.2 | 161 | 7.0 | 184 |

Test for trend for both boys and girls, p<0.001.

*Table 2 Prevalence of obesity by quarters of Townsend score*

| | Boys | | Girls | |
|---|---|---|---|---|
| *Townsend score quarter** | *%* | *n* | *%* | *n* |
| 1 | 4.3 | 114 | 4.2 | 109 |
| 2 | 4.9 | 131 | 4.7 | 119 |
| 3 | 6.0 | 159 | 4.6 | 119 |
| 4 | 5.6 | 149 | 5.7 | 146 |

*1=least deprived quarter, 4=most deprived quarter; test for trend for both boys and girls, p<0.001.

two sexes (boys 5.2%, girls 4.8%; $\chi^2$ test p=0.2). In both sexes, there was a significant trend for higher levels of obesity with age (p<0.001), the effect becoming almost double in the oldest age group, as compared with the youngest (table 1). The prevalence of obesity also increased with increasing Townsend scores, in both boys and girls (table 2).

UNIVARIATE ANALYSIS

On logistic regression, the crude odds ratio for obesity in the highest quarter of Townsend scores when compared with the lowest quarter was 1.29 (95% CI 1.01 to 1.67, p=0.041) for boys and 1.39 (95% CI 1.08 to 1.79, p=0.011) for girls. Age was also found to be an independent risk factor for obesity with the odds ratio for oldest to youngest age quarter being 1.64 for boys (95% CI 1.28 to 2.11, p<0.001) and 2.17 for girls (95% CI 1.67 to 2.83, p<0.001).

MULTIVARIATE ANALYSIS

On using multiple logistic regression, the relation between obesity and Townsend scores was not confounded by age. The age adjusted odds ratio for obesity between the highest and lowest quarter of Townsend score for both boys (OR=1.29, 95% CI 1.00 to 1.65, p=0.049) and girls (OR=1.39, 95% CI 1.08 to 1.80, p=0.011) was similar to the corresponding crude odds ratio (table 3). In both boys (p=0.017) and girls (p=0.018), there was a significant trend test for increasing obesity with increasing deprivation scores. On introducing the interaction terms in the model, there was a significant interaction between Townsend score and age in the girls (p=0.029) but not the boys (p=0.138). On examining this further, the association between obesity and deprivation was found to be significant only in the oldest age group of girls (11.7 to 14.6 years) with the odds ratio of the highest quarter as compared with the youngest being 1.95 (95% CI 1.23 to 3.08, p=0.005), see table 4.

*Table 3 Crude and age adjusted odds ratio for obesity by Townsend score quarters: boys and girls*

| | | Age adjusted† | | |
|---|---|---|---|---|
| *Townsend score* | *Crude OR* | *OR* | *95% CI* | *p value* |
| *Boys* | | | | |
| 1 | 1 | 1 | | |
| 2 | 1.13 | 1.12 | 0.87 to 1.45 | 0.374 |
| 3 | 1.40 | 1.39 | 1.08 to 1.77 | 0.010 |
| 4 | 1.29 | 1.29 | 1.00 to 1.65 | 0.049 |
| *Girls* | | | | |
| 1 | 1 | 1 | | |
| 2 | 1.13 | 1.14 | 0.88 to 1.49 | 0.319 |
| 3 | 1.11 | 1.10 | 0.84 to 1.43 | 0.478 |
| 4 | 1.39 | 1.39 | 1.08 to 1.80 | 0.011 |

*1=least deprived quarter, 4=most deprived quarter. †Test for trend: boys (p=0.017), girls (p=0.018).

*Table 4 Odds ratio for obesity in girls by quarters of Townsend score and age*

| *Townsend score quarter** | *Odds ratio* | *95% CI* | *p value* |
|---|---|---|---|
| *5.1 to 7.1 years* | | | |
| 1 | 1 | | |
| 2 | 0.87 | 0.48 to 1.58 | 0.653 |
| 3 | 0.67 | 0.35 to 1.28 | 0.223 |
| 4 | 1.13 | 0.64 to 1.99 | 0.683 |
| *7.2 to 8.9 years* | | | |
| 1 | 1 | | |
| 2 | 0.81 | 0.44 to 1.52 | 0.522 |
| 3 | 1.12 | 0.63 to 2.00 | 0.691 |
| 4 | 1.44 | 0.84 to 2.48 | 0.187 |
| *9.0 to 11.7 years* | | | |
| 1 | 1 | | |
| 2 | 1.04 | 0.63 to 1.71 | 0.879 |
| 3 | 0.74 | 0.43 to 1.26 | 0.266 |
| 4 | 1.04 | 0.64 to 1.72 | 0.853 |
| *11.8 to 14.6 years* | | | |
| 1 | 1 | | |
| 2 | 1.72 | 1.07 to 2.77 | 0.024 |
| 3 | 1.87 | 1.18 to 2.96 | 0.007 |
| 4 | 1.95 | 1.23 to 3.08 | 0.005 |

*1=least deprived quarter, 4=most deprived quarter. Tests for trend by age quarter: 5.1–7.1, p=0.872; 7.2–8.9, p=0.105; 9.0–11.7, p=0.834; 11.8–14.6, p=0.006.

## Discussion

The results demonstrate a strong positive association between childhood obesity and socioeconomic deprivation. Plymouth, a relatively deprived part of UK had prevalent rates of obesity two and half times that expected nationally (5% *v* 2%). Within Plymouth, rates of childhood obesity were 29% (boys) to 39% (girls) higher in the poorest fourth of the city as compared with the richest fourth. Although some studies have previously reported this association,[12–14] others have either failed to confirm it,[2 15] shown very modest effects[2 16 17] or even found a negative association.[18] A comprehensive literature review was similarly inconclusive.[11] One possible reason why we have been able to demonstrate this association so convincingly is the setting of the study. Plymouth is not only deprived but also has huge socioeconomic variations. The size and nature of the dataset was also an advantage as it included more than 95% of the primary school age population of the city (limiting the effect of chance) with limited ethnic variability (therefore limiting bias), being an almost entirely white population (98.8%).[19] Although only state schools were included in the study, the potential bias associated with omitting private schools would be in the direction of underestimating the influence of material deprivation on the outcome.

MEASUREMENT OF OBESITY

The other possible explanations for differences in the results of various studies lie around methodological issues. The biggest variations are in the measurement and classification of obesity. Although skinfold thickness is useful in clinical settings, BMI (weight/height$^2$) is now becoming the measure of choice for public health purposes because of its reasonable reliability and validity and also its ease and comfort.[22 25 26] Although there seems to be a consensus developing around the use of BMI as the measurement tool of choice, there is less consensus about the cut off value to define obesity. Previous studies have used cut offs between 75th to 98th centile without any convincing scientific basis. We have opted for the 98th centile primarily for reasons of consistency—this is the suggested cut off for obesity in the UK growth charts, which we have used to calculate our centiles.[21] We argue a sound theoretical basis for this choice. There is significant evidence to suggest that most obese children do not become obese adults. However, a larger proportion of obese adults were obese as children and there is an exponential relation between the severity of obesity in childhood and chances of obesity in adulthood.[27–29] Hence using a cut off like the 98th centile increases the chances of selecting a population of children most likely to end up as obese adults and suffer the adverse consequences of obesity.

MEASUREMENT OF DEPRIVATION

The other issue is around the measurement and classification of socioeconomic deprivation. Previous studies have used indicators such as maternal education, single parent families or father's social class. We have used the Townsend material deprivation score that has been used extensively by researchers in the UK. The main disadvantage of using this score is the problem of "ecological fallacy", as the data were not collected at individual level and may not accurately reflect the socioeconomic status of the child. However, we have tried to limit the effect of this fallacy by using Townsend scores at enumeration district level, which represents approximately 150 households. There is, however, an argument in favour of using area-based measures in studies looking at health effects of socioeconomic position by virtue of the inclusion of the contextual effects of residing in poor neighbourhoods[30] such as access to cheap and healthy food options and sporting facilities.[31]

WIDENING SOCIAL DIFFERENCES IN OBESITY DURING ADOLESCENCE

An important finding of the study is the strongest association in the girls in the oldest age quarter (over 11.7 years). It was not possible to control the results of this association for pubertal status in girls of this age, as the data were not available. Absence of information on pubertal status makes it very difficult to interpret growth changes during adolescence. However, prima facie, controlling for pubertal status would have strengthened the association, based on studies that have shown a positive association between early pubertal onset and increased body mass index[28 32] as well as an early onset of puberty in children from higher social classes.[33] However, more recent studies have not found a social class differential in pubertal onset in developed countries,[32 34] possibly because of better nutrition. These results reflect the results of some of the previous studies that have shown that social differences for obesity heighten during adolescence.[14 34 35] This would also explain the gender difference in the results; a larger proportion of boys in this cohort being pre-pubertal as compared with the girls.

WHY ARE POORER CHILDREN FATTER?

Some studies, largely in adults, have tried to understand the reasons for secular trend in obesity, especially in the poorer classes. A population shift towards positive energy balance because of concurrent consumption of calorie dense food and decline in physical activity is implicated.[2] This is likely to be more prominent in lower socioeconomic groups where limited finances force the poor to buy more efficiently. These efficiencies often lead to the purchase of foods richer in energy (high in fat and sugar) to satisfy hunger; which are much cheaper per unit of energy than less fattening foods (like fruits and vegetables).[31] There is some evidence for decreased physical exercise in poorer people.[10] Behavioural studies also suggest that adolescent girls in higher socioeconomic groups tend to be more image conscious and are therefore more likely to put in greater efforts in terms of dietary restraint and physical exercise.[11 27] Gender differences in dieting[27] and greater amount of physical exercise[10] could contribute to the observed weaker association in boys.

IMPLICATIONS OF THE FINDINGS

This study highlights the growing problem of childhood obesity, especially in deprived populations. Evidence from other studies suggests that children from poorer households are also more likely to grow into severely obese adults.[35] There is evidence that children from poorer households are more likely to have other risk factors adverse to health leading to greater overall morbidity and mortality in adulthood.[6] Suitable interventions promoting healthy eating and physical activity from the early school years onward, need to be considered. Such interventions must be directed at lower socioeconomic groups and be relevant to them. Most importantly, these will have to be accompanied by appropriate policy measures that enable the underprivileged to access cheap and nutritious foods.

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**Contributors**
All three, SK, RN and GL were involved in designing the study and writing up of the manuscript. RN provided the Townsend scores and SK carried out the statistical analysis. SK is the guarantor of the study.

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1 National Institutes of Health Consensus Development Panel on the Health Implications of Obesity. National Institutes of Health Consensus Development Conference Statement. Health Implications of Obesity. *Ann Intern Med* 1985;**103**:1073–7.
2 Troiano RP, Flegal KM. Overweight children: description, epidemiology, and demographics. *Pediatrics* 1998;**101**:497–504.
3 Chinn S, Rona RJ. Trends in weight-for-height and triceps skin-fold thickness for English and Scottish children, 1972–82 and 1982–1990. *Paediatr Perinat Epidemiol* 1994;**8**:90–106.
4 Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics* 1998;**101**:518–25.
5 Mossberg H-O. 40-Year follow-up of overweight children. *Lancet* 1989;2:491–3.
6 Must A, Jacques PF, Dallal GE, *et al*. Long-term mortality and morbidity of overweight adolescents. A follow-up of the Harvard Growth Study of 1922 to 1935. *N Engl J Med* 1992;**327**:1350–5.
7 Schonfeld-Warden N, Warden CH. Pediatric obesity. An overview of etiology and treatment. *Pediatr Clin North Am* 1997;**44**:339–61.
8 Rosenbaum M, Leibel RL. The physiology of body weight regulation: relevance to the etiology of obesity in children. *Pediatrics* 1998;**101**:525–39.
9 Birch LL, Fisher JO. Development of eating behaviours among children and adolescents. *Pediatrics* 1998;**101**:539–49.
10 Kohl HW, Hobbs KE. Development of physical activity behaviours among children and adolescents. *Pediatrics* 1998;**101**:549–4.
11 Sobal J, Stunkard AJ. Socioeconomic status and obesity: a review of literature. *Psychol Bull* 1989;**105**:260–75.
12 Jansen W, Hazebroek-Kampschreur AAJM. Differences in height and weight between children living in neighbourhoods of different socioeconomic status. *Acta Paediatr* 1997;**86**:224–5.
13 Sherry B, Springer DA, Connell FA, *et al*. Short, thin, or obese? Comparing growth indexes of children from high and low poverty areas. *J Am Diet Assoc* 1992;**92**:1092–5.
14 Lissau-Lund-Sorensen I, Sorensen TI. Prospective study of the influence of social factors in childhood on risk of overweight in young adulthood. *Int J Obes Relat Metab Disord* 1992;**16**:169–75.
15 White E, Wilson A, Greene SA, *et al*. Growth screening and urban deprivation. *J Med Screen* 1995;**2**:140–4.
16 Rona RJ, Chinn S. National Study of Health and Growth: social and family factors and obesity in primary school children. *Ann Hum Biol* 1982;**9**:131–45.
17 Duran-Tauleria E, Rona RJ, Chinn S. Factors associated with weight for height and skinfold thickness in British children. *J Epidemiol Community Health* 1995;**49**:466–73.
18 Cernerud L. Are there still social inequalities in height and body mass index of Stockholm children? *Scand J Soc Med* 1994;**22**:161–5.
19 Anonymous. *Public Health Common Data Set 1998: Data definitions and user guide for computer files.* London: Department of Health, December 1998.
20 Mackenzie IF, Nelder R, Maconachie M, *et al*. My ward is more deprived than yours. *J Public Health Med* 1998;**20**:186–90.
21 Cole TJ, Freeman JV, Preece MA. Body mass index reference curves for the UK,1990. *Arch Dis Child* 1995;**73**:25–9.
22 Poskitt EME. Defining childhood obeity: the relative body mass index (BMI). *Acta Paediatr* 1995;**84**:961–3.
23 Child Growth Foundation, UK. *The British 1990 growth reference*. Revised September 1996. Child Growth Foundation, 2 Mayfield Avenue, London W4 1PW, UK.
24 Gordon D, Forrest R. *People and places 2;social and economic distinctions in England.* Bristol: School for Advanced Urban Studies and Bristol Statistical Monitoring Unit, 1995.
25 Dietz WH. Use of the body mass index (BMI) as a measure of overweight in children and adolescents. *J Pediatr* 1998;**132**:191–3.
26 Pietrobelli A, Faith MS, Allison DB, *et al*. Body mass index as a measure of adiposity among children and adolescents: a validation study. *J Pediatr* 1998;**132**:204–10.
27 Serdula MK, Ivery D, Coates RJ, *et al*. Do obese children become obese adults? A review of literature. *Prev Med* 1993;**22**:167–77.
28 Power C, Lake JK, Cole TJ. Body mass index and height from childhood to adulthood in the 1958 British birth cohort. *Am J Clin Nutr* 1997;**66**:1094–101.
29 Braddon FEM, Rodgers B, Wadsworth MEJ, *et al*. Onset of obesity in a 36 year birth cohort study. *BMJ* 1986;**293**:299–303.
30 Ben-Shlomo Y, Davey-Smith G. Commentary: Socioeconomic position should be measured accurately. *BMJ* 1999; **318**:844–5.
31 James WPT, Nelson M, Ralph A, *et al*. Socioeconomic determinants of health. The contribution of nutrition to inequalities in health. *BMJ* 1997; **314**:1545–9.
32 Stark O, Peckham CS, Moynihan C. Weight and age at menarche. *Arch Dis Child* 1989;**64**:383–7.
33 Proos LA. Anthropometry in adolescence—secular trends, adoption, ethnic and environmental differences. *Hormone Res* 1993;**39** (suppl 3):18–24.
34 Spiegelaere MD, Dramaix M, Hennart P. The influence of socioeconomic status on the incidence and evolution of obesity during early adolescence. *Int J Obes* 1998;**22**:268–74.
35 Power C. Moynihan C. Social class and changes in weight-for-height between childhood and early adulthood. *Int J Obes* 1988;**12**:455–53.