Is there a deprivation and maternal education gradient to child obesity and moderate-to-vigorous physical activity? Findings from the Millennium Cohort Study

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Summary

Objective: The primary aim was to examine associations between individual-level and area-level measures of socioeconomic status (SES) and different measures of overweight/obesity in 7-year-old English children. A secondary aim was to examine associations between individual-level and area-level measures of SES and moderate-to-vigorous intensity physical activity (MVPA).

Methods: Data were from wave four of the Millennium Cohort Study. Children were classified as normal weight, overweight/obese and centrally obese. MVPA was accelerometer derived. Individual-level and area-level SES were defined using self-reported maternal education and the 2004 English Indices of Multiple Deprivation, respectively. Adjusted linear and multinomial logistic regressions were conducted.

Results: Three thousand seven hundred seventeen children (1890 girls) had complete data. Children in the lowest maternal education group and highest deprivation decile were at greatest risk of overweight and central obesity. MVPA was inversely associated with deprivation, and the most deprived children were most likely to achieve 60 min of daily MVPA.

Conclusions: Individual-level and area-level SES were independently related to overweight and central obesity. Higher rates of overweight and central obesity among deprived children are not due to physical inactivity. Further research examining the concurrent effect of diet and MVPA on child weight status by deprivation is warranted.

Keywords: deprivation, maternal education, obesity, physical activity.

Introduction

Child obesity develops from a sustained positive energy balance between intake and expenditure (1). Child obesity is associated with poorer health throughout the life-course (2). In the UK, almost one third of children aged 2–15 years have overweight or obesity (3), and evidence suggests that low socioeconomic status (SES) strongly predicts child obesity.

Two distinct areas of research have investigated the SES–child obesity relationship. One theme of research has focused on the individual characteristics of low SES children (e.g. low family income and parental education) and has examined how these characteristics predispose children to obesity (4). Maternal education is a consistent inverse predictor of child obesity (5), which is thought to influence knowledge, attitudes and beliefs within the family, which are important for maintaining a healthy lifestyle and offsetting child obesity (4). Maternal educational level though does not capture the financial element of SES and the physical environment within which children live, which are also contributory factors to child obesity (6).

The second theme of research has embraced a socioecological approach to health promotion (7) and focused on the contribution of the neighbourhood environment to child obesity. Obesogenic environments encourage the consumption of unhealthy food and/or discourage physical activity (PA). Deprived children are more likely to live in an obesogenic environment. Several studies have showed that deprived neighbourhoods have a greater...
concentration of fast-food outlets (8), are less walkable (9) and have limited access to self-contained gardens/yards compared with affluent neighbourhoods (9). Such characteristics place deprived children at greater risk of developing obesity compared with their less affluent peers (10,11).

Associations between SES and obesity have been reported for maternal education (12) and deprivation (9), but no English study has concurrently examined deprivation and maternal education gradients to child weight status. Moreover, there is a paucity of published studies that have assessed the influence of SES on lifestyle behaviours that may predispose children to obesity (e.g. low PA). To our knowledge, only one study has assessed concurrent individual-level and area-level measures of SES on child weight status and PA. However, the study was undertaken in Canada with adolescents and relied on self-reported body mass index (BMI) alone as a measure of obesity (13) rather than alternative measures of obesity such as waist circumference (WC) and waist-to-height ratio (WHtR) that carry greater health risks (14). To fill this research gap, the present study examined associations between individual-level and area-level SES and different measures of overweight/obesity in 7-year-old English children. A secondary aim was to examine associations between individual-level and area-level SES and child moderate-to-vigorous intensity PA (MVPA), because the influence of SES on MVPA is a likely mechanism linking SES with child overweight and obesity.

**Methods**

**Participants**

This study is a secondary analysis of data derived from wave four of the Millennium Cohort Study (MCS). The MCS is a nationally representative UK sample of children born between September 2000 and January 2002. The sample design allowed for over-representation of ethnic minority families and families living in areas of high deprivation. The first survey was conducted throughout 2001–2002 and contained information on 18 819 children in 18 533 families, collected from the parents when children were 9 to 11 months old. Further surveys were administered at the ages of 3, 5 and 7 years. All measures were collected in the child’s home. The present study used data on English children only from MCS4 where PA was measured using ActiGraph waist-worn accelerometers (ActiGraph GT1M, Pensacola, Florida). Ethical approval for the original study was granted by the Northern and Yorkshire Research Ethics Committee (07/MRE03/32).

**Measures**

Maternal education was used as a measure of individual-level SES. Mothers reported the highest educational qualification achieved by the time the child was 7 years of age and classified into four categories [Higher education/degree {1}, A-levels {2}, O levels/GCSE A*-C {3}, CSE’s/GCSE D-G/none {4}]. Higher qualification represented higher SES. Area-level SES (i.e. deprivation) was calculated from home postcodes using the 2004 English Indices of Multiple Deprivation (IMD; (15)). The IMD is a UK Government produced measure comprising seven areas of deprivation (income, employment, health, education, housing, environment and crime). Higher decile scores represented higher deprivation. The following demographic data were also collected: child’s gender, age, ethnicity (16) and poverty level income (17).

Stature was measured to the nearest millimetre using a portable stadiometer (Leicester Height Measure, Seca, Birmingham, UK), and body mass measured to the nearest 0.1 kg using Tanita HD-305 scales (Tanita UK Ltd, Middlesex, UK). BMI was calculated from stature and body mass (kg m⁻²). The International Obesity Taskforce age-specific and gender-specific BMI cut-points were used to classify children as normal weight or overweight/obese (18). WC was measured at the midpoint between the bottom rib and the iliac crest to the nearest 0.1 cm using a non-elastic measuring tape (Seca, Birmingham, UK). WHtR was used as a measure of central obesity. A WHtR ≥0.5 indicated central obesity (14).

Physical activity was assessed using waist-worn ActiGraph GT1M accelerometers between May 2008 and August 2009. Full details on the PA data collection procedures have been described previously (19). Briefly, accelerometers were programmed to record data at 15-s intervals (15-s epoch length). Children were instructed to wear the accelerometer for 7 consecutive days during all waking hours except when engaged in water-based activities (e.g. showering and swimming). Data were downloaded using ActiGraph software V.3.8.3 (ActiGraph, Pensacola, Florida, USA). Accelerometer non-wear time was defined as consecutive 20-min periods of zero counts (20), and extreme count values above a threshold of ≥11 715 c.p.m. were removed. MVPA and sedentary time were classified as more than 2241 and 100 c.p.m., respectively (21). A total of 6675 children (3499 girls) met the inclusion criteria, which was classified as having at least 2 d with 10 h or more of wear time (22). Total time spent in MVPA and sedentary time for each valid day was divided by the total number of valid days. Children were
classified into two groups; those who achieved a daily average of 60 min of MVPA [UK guideline recommendation] and those who did not.

**Analyses**

Analyses were conducted using SPSS v. 24 (SPSS Inc.; Chicago, IL, USA), and statistical significance was set at $p \leq 0.05$. Preliminary Kolmogorov–Smirnov and Levene’s tests assessed data distribution and variance, respectively. Descriptive statistics were calculated for all measured variables. Multinomial logistic regression analyses examined the likelihood of children being classified as overweight, centrally obese and meeting the MVPA guideline based on deprivation and maternal education level. The lowest level of maternal education and the highest level of deprivation were chosen as the reference categories. Analyses were adjusted for gender. For the main analyses, outcome variables were BMI, WC and MVPA. Linear regression analyses examined associations between maternal education, deprivation and outcome variables. Analyses were conducted separately for each outcome variable and adjusted for gender, sedentary time, accelerometer wear time (MVPA), BMI (MVPA), WC (MVPA) and MVPA (BMI and WC).

**Results**

Data were available for 3717 children (1890 girls). Preliminary analyses confirmed that the data were normally distributed, and no differences were found between participants included and excluded from analyses. The descriptive characteristics of the sample are presented in Table 1. Twenty per cent of the sample were below poverty level income ($n = 756$), 18% and 23% lived in the most and least deprived areas, respectively ($n = 671; 845$), 86% were White British ($n = 3193$), 17% were overweight ($n = 643$), 14% were centrally obese ($n = 516$), 52% achieved the MVPA guideline ($n = 1921$) and 45% of mothers achieved a degree qualification ($n = 1668$). The most

### Table 1 Descriptive characteristics of sample

|                      | All ($n = 3717$) | Boy ($n = 1827$) | Girl ($n = 1890$) |
|----------------------|-----------------|-----------------|-----------------|
| **Age (years)**      | 7.22 (0.25)     | 7.22 (0.25)     | 7.22 (0.25)     |
| **Ethnicity (White British)** | 85.90 | 85.80 | 86.00 |
| **Stature (cm)**     | 123.77 (5.50)   | 124.21 (5.49)   | 123.36 (5.47)   |
| **Body mass (kg)**   | 25.26 (4.61)    | 25.38 (4.63)    | 25.14 (4.60)    |
| **BMI (kg m$^{-2}$)** | 16.40 (2.16)    | 16.37 (2.18)    | 16.43 (2.14)    |
| **Overweight/obese** | 17.30           | 15.30           | 19.20           |
| **WC (cm)**          | 56.70 (5.60)    | 56.87 (5.57)    | 56.54 (5.62)    |
| **WHtR (cm)**        | 0.46 (0.04)     | 0.46 (0.04)     | 0.46 (0.04)     |
| **WHtR >0.50**       | 13.90           | 12.40           | 15.30           |
| **Total accelerometer wear time (min)** | 4091.15 (1236.74) | 4200.70 (1246.59) | 3985.26 (1218.13) |
| **Sedentary time (min d$^{-1}$)** | 383.29 (52.44) | 378.63 (52.93) | 387.79 (51.57) |
| **MVPA (min d$^{-1}$)** | 63.31 (21.74)  | 69.98 (22.14)  | 56.87 (19.28)  |
| **Achieve MVPA guideline** | 51.70 | 64.50 | 39.30 |
| **Poverty income**   | 20.30           | 20.10           | 20.60           |
| **IMD decile score** |                 |                 |                 |
| Most deprived        | 18.10           | 18.20           | 18.00           |
| Fourth               | 18.20           | 18.30           | 18.20           |
| Third                | 20.50           | 20.50           | 20.50           |
| Second               | 20.40           | 20.10           | 20.90           |
| Least deprived       | 22.70           | 22.90           | 22.50           |
| **Maternal education level** |            |                 |                 |
| Higher education/degree | 44.90 | 45.50 | 44.20 |
| A-levels             | 14.10           | 14.30           | 13.90           |
| O levels/GCSE A*-C   | 26.30           | 25.20           | 27.50           |
| CSE's/GCSE D-G/none  | 14.70           | 15.00           | 14.40           |

BMI, body mass index; IMD, Indices of Multiple Deprivation; MVPA, moderate-to-vigorous intensity physical activity; MVPA guideline = 1 h daily MVPA; WC, waist circumference; WHtR, waist-to-height-ratio.
deprived children were more likely to have overweight compared with the second to least (OR = 1.45; p ≤ 0.01; Table 2), and least deprived children (OR = 1.61; p ≤ 0.001), and more likely to have central obesity compared with the second to least (OR = 1.37; p ≤ 0.05), and least deprived children (OR = 1.68; p ≤ 0.001). The most deprived children were also more likely to meet the MVPA guideline compared with the fourth to least (OR = 1.39; p ≤ 0.01), third to least (OR = 1.57; p ≤ 0.001), second to least (OR = 1.55; p ≤ 0.001) and least deprived children (OR = 1.63; p ≤ 0.001). Children from the lowest maternal education group were more likely to have overweight compared with the second to highest (OR = 1.36; p ≤ 0.05), and highest maternal education group (OR = 1.30; p < 0.05), and more likely to have central obesity compared with the second to highest (OR = 1.42; p ≤ 0.05), and highest maternal education group (OR = 1.56; p ≤ 0.001). Linear regression analyses revealed an inverse association between maternal education and BMI (B = −0.07, p < 0.05; Table 3) and WC (B = −0.17, p < 0.05). Deprivation

| Table 2 | Multinomial logistic regressions with outcomes overweight, centrally obese and complying with MVPA guideline (n = 3717) |
| Deprivation | | |
| --- | --- | --- |
| Most deprived – REF (n = 671) | | |
| Q4 (n = 678) | 1.15 (0.88, 1.50) | 0.321 | 1.09 (0.82, 1.46) | 0.546 | 1.39 (1.11, 1.73) | 0.004 |
| Q3 (n = 762) | 1.08 (0.84, 1.41) | 0.542 | 1.30 (0.97, 1.73) | 0.078 | 1.57 (1.26, 1.95) | 0.000 |
| Q2 (n = 761) | 1.45 (1.10, 1.90) | 0.008 | 1.37 (1.03, 1.84) | 0.033 | 1.55 (1.25, 1.93) | 0.000 |
| Least deprived (n = 845) | 1.61 (1.23, 2.11) | 0.001 | 1.68 (1.25, 2.25) | 0.001 | 1.63 (1.32, 2.02) | 0.000 |

| Maternal education | CSEs/GCSE D-G/none – REF (n = 547) | | |
| --- | --- | --- |
| O levels/GCSE A*-C (n = 979) | 1.27 (0.97, 1.66) | 0.080 | 1.23 (0.93, 1.63) | 0.150 | 1.08 (0.87, 1.34) | 0.493 |
| A-level (n = 523) | 1.36 (1.00, 1.86) | 0.052 | 1.42 (1.02, 1.99) | 0.041 | 1.12 (0.87, 1.44) | 0.372 |
| Degree (n = 1668) | 1.30 (1.02, 1.66) | 0.033 | 1.56 (1.20, 2.03) | 0.001 | 1.12 (0.92, 1.37) | 0.272 |

Adjusted for sex in all analyses; BMI, body mass index; CI, confidence interval; MVPA, moderate-to-vigorous intensity physical activity; WHtR, waist-to-height-ratio.

| Table 3 | Linear regression associations between maternal education, deprivation, BMI, waist circumference and MVPA (n = 3717) |
| Maternal education | Deprivation |
| --- | --- | --- | --- | --- | --- |
| | B (95% CI) | SE | β | p | B (95% CI) | SE | β | p |
| Weight status | | | | | | | | |
| Constant | 18.16 (17.36, 18.97) | 0.41 | 17.70 (16.91, 18.49) | 0.40 |
| BMI† | −0.07 (−0.13, −0.01) | 0.03 | −0.04 | 0.28 | 0.13 (0.08, 0.18) | 0.03 | 0.08 | 0.000 |
| Constant | 61.41 (59.93, 63.49) | 1.06 | 60.55 (58.49, 62.61) | 1.05 |
| WC‡ | −0.17 (−0.32, −0.01) | 0.08 | −0.03 | 0.04 | 0.19 (0.07, 0.32) | 0.07 | 0.05 | 0.003 |
| Physical activity | | | | | | | | |
| Constant | 170.27 (162.63, 177.91) | 3.90 | 167.05 (159.48, 174.62) | 3.86 |
| MVPA§ | −0.20 (−0.72, 0.32) | 0.26 | −0.01 | 0.44 | 0.99 (0.57, 1.40) | 0.21 | 0.06 | 0.000 |

†BMI, controlled for gender, MVPA and sedentary time.
‡Waist circumference, controlled for gender, MVPA and sedentary time.
§MVPA, controlled for gender, BMI, waist circumference, sedentary time and accelerometer wear time.

B, unstandardized β coefficient; β, standardized β coefficient; BMI, body mass index; MVPA, moderate-to-vigorous intensity physical activity; SE, standard error; WC, waist circumference.
was positively associated with BMI ($B = 0.13$, $p < 0.001$), WC ($B = 0.19$, $p = 0.003$) and MVPA ($B = 0.99$; $p \leq 0.001$).

**Discussion**

This is the first study to examine the influence of individual-level (i.e. maternal education) and area-level SES (i.e. deprivation) on different measures of overweight/obesity and objectively assessed MVPA among English children. We found that maternal education and deprivation were both associated with overweight and central obesity but only deprivation was associated with MVPA. The most deprived children were at greatest risk of overweight and central obesity but were also most likely to achieve the MVPA guideline. Our results evidence a maternal education and deprivation gradient to child overweight and central obesity and reveal that higher rates of overweight and central obesity among deprived children are not due to physical inactivity.

The present study revealed a positive association between deprivation and child overweight and central obesity. This finding is consistent with previous research undertaken in the UK (11) and other developed countries (5). Analysis of the English National Child Measurement Programme data for children aged 10–11 years has revealed a strong positive association between deprivation and obesity but weak associations for overweight (10). National Child Measurement Programme uses school-level deprivation data that may mask the deprivation-overweight association. A recent UK study conducted in Liverpool found that children living in the most deprived neighbourhoods were at greatest risk of overweight and central obesity (9). Our findings extend beyond previous research in this area by evidencing deprivation inequalities in childhood overweight and obesity across England and revealing a deprivation gradient to child overweight and obesity. The relationship between deprivation and child overweight and central obesity was linear, and the greatest disparities were observed between the least and most deprived children. A UK study conducted in Leeds found no evidence of a linear relationship between obesity and deprivation in 11-year-old children (23). However, the study was conducted at the local-level and assessed school-level deprivation rather than neighbourhood-level deprivation that may not reflect the children’s actual living environment. Together, these findings provide further support for obesity intervention programmes targeting deprived children.

Almost all previous studies in this area have defined SES using either an individual-level (i.e. parental education (12)) or area-level measure (IMD, deprivation; (9,23)). These studies have presumed that the strength and direction of the SES–child obesity association would be consistent across SES measures. In this study, we found modest associations between individual-level and area-level SES and child overweight and central obesity. However, we observed stronger associations for area-level SES compared with individual-level SES. This finding is in contrast to a Canadian study involving 11- to 15-year-olds that assessed BMI subjectively and used aggregated census data on individual-level variables as a measure of area-level SES (13). These factors combined are likely to have contributed to the inconsistent findings. Based on our results, both individual-level and area-level strategies are needed to improve child obesity in England.

Although our analyses revealed that the strength and direction of association between SES and child obesity was consistent across SES measures, this was not evident for MVPA. The evidence base linking maternal education to child obesity (5) is more consistent than that for maternal education and MVPA. Inconsistencies throughout the literature are likely due to heterogeneity in study populations, PA measurement methods and definitions used to assess SES indicators. Moreover, the pathways linking different measures of SES to child MVPA are likely to differ. A pooled analysis of 12 770 youths across Europe, Australia, Brazil and the USA found that children whose mothers reported a higher level of education recorded lower levels of objectively measured MVPA (24). The study demonstrated that children from low maternal education are not disadvantaged in terms of PA but did not report on child health outcomes. Given that each SES indicator may influence the development of child obesity and children’s participation in PA differently, we recommend that future studies use both individual-level and area-level SES indicators where possible.

There has been a growing focus by the UK government in recent years to promote and increase MVPA with a view to curbing and reducing child obesity levels (25). Moreover, it is largely considered that the child obesity–deprivation relationship is partly due to physical inactivity (26). However, our results suggest otherwise. Here, we have showed that deprivation is positively associated with MVPA among a large sample of 7-year-old English children. Moreover, counter to what might be assumed, our analyses revealed that although the most deprived children were at greatest risk of overweight and central obesity, they were also most likely to achieve the MVPA guideline than less deprived peers. Similarly, a recent UK study found
that children who lived in deprived neighbourhoods were most likely to commute to school actively yet were also at greatest risk of obesity (27). Disparities in weight status and central obesity in this study are likely to be related to other lifestyle factors not examined here, such as dietary intake.

Regular fast-food consumption has been linked with child obesity (28). Fast-food meals are generally more convenient and affordable than healthy meals and are thought to mediate the association between deprivation and child obesity (8). Moreover, in the UK, deprived neighbourhoods have a greater density of fast-food outlets (8), thereby providing more opportunity for fast-food consumption. As the data reported here were collected between 2007 and 2008, they may not accurately reflect current health inequalities among UK children. For example, in recent years, the number of fast-food outlets has increased (29), and several austerity measures introduced by the Conservative government, which have in general, hit the poorest areas of the UK hardest (30). It is reasonable to suggest that such changes will have impacted most on the lifestyle behaviours of the poor and in doing so, widened child health inequalities.

The results of this study have provided a greater understanding of deprivation and maternal education gradients to child overweight and obesity and MVPA. Disparities in overweight and obesity between the most and least deprived English children are evident at age 7. This finding suggests that interventions for overweight and obese English children are needed in the early years. Given that the most deprived children recorded the highest levels of MVPA, disparities in weight status between deprived and affluent children would appear to be related to inequalities in energy intake rather than expenditure. While the combined effect of MVPA and diet on child weight status is not well understood, our results suggest that among deprived children, poor diet may counter regular PA participation and predispose them to obesity. However, as with any cross-sectional analysis, causation cannot be inferred from the results. Further research examining the concurrent effect of dietary intake and PA on child weight status by deprivation is warranted. To establish strategies for reducing child health inequalities, further research is needed to understand the mechanism by which deprivation and maternal education collectively influence children’s diet and PA habits. Ultimately, to improve child health and alleviate deprivation requires a systems approach to health promotion and actions on inequalities in wider social determinants operating outside the health system.

There are several strengths to this study. The sample was large, and the study covered the whole of England that provided extensive heterogeneity in the sociodemographic characteristics of the participants. We assessed individual-level and area-level measures of SES and considered alternative measures of weight status. Both MVPA and sedentary time were assessed objectively that limited activity intensity misclassification, and analyses were adjusted for known confounding factors. There are also some study limitations to acknowledge. Some children in this study may have been misclassified as overweight/obese as we were unable to adjust for maturational status. Further, MVPA and sedentary time were assessed over 7 d that may not have accurately reflected typical behaviour. Moreover, hip-mounted accelerometers do not capture non-ambulatory (i.e. cycling) and water-based activities that may have underestimated MVPA estimates. While the sample was large, the design was cross-sectional and does not determine causality.

Conclusion

This study provides evidence of a deprivation and maternal education gradient to child overweight and obesity across England. We found that children from the lowest maternal education group and children living in the most deprived neighbourhoods were at greatest risk of overweight and central obesity. Counter to what might be assumed, the most deprived children were most likely to achieve the MVPA guideline. Our results are important as they challenge the notion that higher rates of overweight and obesity among deprived children are the result of physical inactivity. This study demonstrates the importance of considering both individual-level and area-level measures of SES when investigating child PA and health.

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Conflict of interest

The authors declare no conflict of interest.
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