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Review Article

Socioeconomic Inequalities in Childhood Obesity in the United Kingdom: A Systematic Review of the Literature

Abdulrahman M. El-Sayed[a, b, c] Peter Scarborough[a] Sandro Galea[b]

[a]Department of Public Health, University of Oxford, Oxford, UK, [b]Department of Epidemiology, Columbia University, New York, NY, [c]College of Physicians and Surgeons, Columbia University, New York, NY, USA

Key Words
Obesity · Child · Pediatric · Poverty · Deprivation · Socioeconomic status · Socioeconomic position · United Kingdom · England · Wales · Scotland

Abstract
Childhood obesity is a major public health challenge worldwide. There is a growing literature documenting socioeconomic inequalities in childhood obesity risk. Here we draw inference from the literature about inequalities in childhood obesity risk in the UK. We summarize and appraise the extant peer-reviewed literature about socioeconomic inequalities in childhood obesity in the UK. Common area-level indices of socioeconomic position, including the Carstairs Deprivation Index, the Index of Multiple Deprivation and the Townsend Deprivation Index, as well as common household and individual-level metrics of childhood socioeconomic position, including head-of-household social class and maternal education, were generally inversely associated with childhood obesity in the UK. We summarize key methodological limitations to the extant literature and suggest avenues for future research.

Introduction

Childhood obesity is a growing worldwide epidemic [1]. Recent research about trends in global childhood overweight and obesity over the last several decades have demonstrated increases in almost all countries for which data is available [2, 3]. According to the World Health Organization (WHO), 42 million children under the age of 5 were overweight in the

Abdulrahman M. El-Sayed
Department of Epidemiology, Mailman School of Public Health
Columbia University
722 W. 168th Street, Room 521, New York, NY 10032 (USA)
ame2145@columbia.edu

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year 2010 worldwide [4], and available evidence suggests that up to 79% of these children will progress to overweight and obesity in adulthood [5–7]. Obesity has important social and psychological consequences among children and adolescents, as it has been shown to predict abuse from peers among children and depression among adolescents [8, 9]. Moreover, as an important determinant of chronic disease risk and mortality in childhood and adulthood, childhood obesity is a looming threat to the public's health [10–20].

Socioeconomic position (SEP) is a measure of the structural location of individuals with respect to access to resources relative to others in a society [21]. In their work on fundamental causes, Link and Phelan [22] contend that lower SEP will always predict worse health, as SEP portends access to health-promoting resources, even as those resources may change over time. Poor SEP is a well-known predictor of adverse health outcomes among diverse populations.

There is a large literature that has demonstrated inequalities in obesity in both high- and low-income contexts worldwide – however, the direction of this association differs by economic context [23–25]. In high-income contexts, like the UK, there is a strong inverse association between metrics of SEP and obesity, whereas SEP and obesity are directly associated in low-income countries [23]. Moreover, with time, and as low-income countries have developed, there have been concomitant increases in obesity prevalence [26], as, for example, is taking place in China [27]. Research about socioeconomic inequalities in obesity among children worldwide has demonstrated similar trends [4, 25].

Already among the highest in the world, risk for childhood obesity is increasing in the UK [28, 29]. Between 1995 and 2007, the rate of obesity in children aged 2–15 years in England increased from 12 to 17% [30]. Rising obesity rates among children have received considerable attention among public health officials. For example, they have substantiated recommendations to ban marketing toward children of unhealthy foods, and to allocate greater than 3 h/week for physical activity among children in schools in the UK [31, 32].

Several studies about health inequalities in the UK have demonstrated socioeconomic differences in self-rated health, heart disease, chronic bronchitis, smoking, diet, exercise, and overall mortality [33, 34]. A recent review about health inequalities in England highlighted SEP inequalities in morbidity, self-reported health, psychopathology, accidental injury, and mortality [35]. Studies also suggest widening inequalities in several important population health metrics in the UK, such as life expectancy and mortality rates between the early 1980s and 2000s [35, 36].

Several studies have suggested socioeconomic disparities in childhood obesity in the UK, with poor children at higher risk for obesity [37–43]. A recent report from the UK's National Obesity Observatory showed consistent inequalities in obesity among children at both reception year and year 6 by area-level deprivation, with some evidence of increasing inequalities among boys [44]. However, we know of no attempts to systematically appraise or synthesize findings regarding socioeconomic inequalities in obesity in this context.

Understanding socioeconomic inequalities in childhood obesity in the UK may yield important inferences about SEP inequalities in childhood obesity more broadly for several reasons. First, with a nationalized health system, public health research and policy in the UK are relatively centralized and unified. Therefore, the UK features several high-quality government-sponsored datasets that include information about childhood obesity, including the annual Health Survey for England, the Scottish Health Survey and the National Childhood Measurement Programme, as well as others. Moreover, UK health policy has been explicit about both addressing inequalities in health as well as childhood obesity, featuring national targets to reduce levels of overweight and obesity among children to below year 2000 levels by the year 2020 [45], and to eradicate childhood poverty by the year 2020 [46]. Moreover, in 2007, the National Obesity Observatory was established to

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monitor obesity in the UK, complementing several other initiatives in place to combat the childhood obesity epidemic, including the 'Food in Schools' program, the 'School Fruit and Vegetable Scheme', and the 'Physical Education, School Sport and Club Links Programme' [47], although these programs are under threat following recently established budget cuts. Second, despite the substantial attention to both childhood obesity as well as childhood poverty on the part of the UK government, there remain strong associations between metrics of SEP and childhood obesity in the UK [37–43]. Therefore, the UK presents an ideal opportunity to examine etiological mechanisms relating SEP and obesity among children, including the roles of ethnic minority socioeconomic segregation, individual versus area-level production of socioeconomic inequalities, and the production of inequalities throughout the childhood life course.

Here, we review the extant peer-reviewed literature published in the past 30 years about socioeconomic disparities in childhood obesity. We summarize important differences in the prevalence and determinants of obesity by socioeconomic metrics in the UK, attempting to identify and isolate key indicators in the SEP environment likely to influence childhood obesity risk. Additionally, we comment on generalizable themes in this area of research, considering methodological limitations to the extant literature.

We reviewed the literature about socioeconomic inequalities in obesity in the UK so as to understand how SEP influenced obesity risk in the UK. We limited our review to the UK for several reasons. First, we were interested in ascertaining mechanisms that maintained SEP inequalities in the UK, and these mechanisms may plausibly differ across countries. Second, because national health systems may differ with regard to the relation between SEP and access to healthcare services as well as the focus placed on prevention within systems, generalizing across countries with regard to the relation between SEP and childhood obesity may not be warranted. Third, because of the correlation between ethnicity and SEP in high-income countries and because ethnic minority groups may have differential risk for childhood obesity than whites [48–52], countries with different proportions of ethnic minority groups may show different relations between SEP and obesity, precluding generalization across countries.

Methods

This review encompassed the peer-reviewed literature published between January 1, 1980 and March 8, 2010. We limited our review to these years so as to reflect current thinking about the relation between SEP and health. We identified the literature reviewed through the MEDLINE database using the 'pubmed.gov' interface, and it included papers that included any empirical assessment of the relation between metrics of SEP and metrics of obesity. We used MeSH search terms 'Obesity' and 'Great Britain' for English-language articles published in the peer-reviewed literature. All queries were carried out by the primary author during the month of March, 2010.

Our original search yielded 1,189 articles, 233 of which were judged to consider the relation between SEP and obesity in the UK after screening by title. Upon screening by abstract for empirical articles set in the UK, we were left with 102 articles. After reading the remaining articles, another 54 were discarded because they did not meet the following criteria: i) considered differences in outcomes by at least one defined metric of SEP and described attribution of SEP metrics among respondents; ii) described the method used to define obesity, including metric of interest, and threshold for overweight or obesity utilized in analysis; and iii) conducted a direct empiric analysis of differences in obesity outcome by metric of SEP. Reference lists from these articles were searched, and yielded a further 10

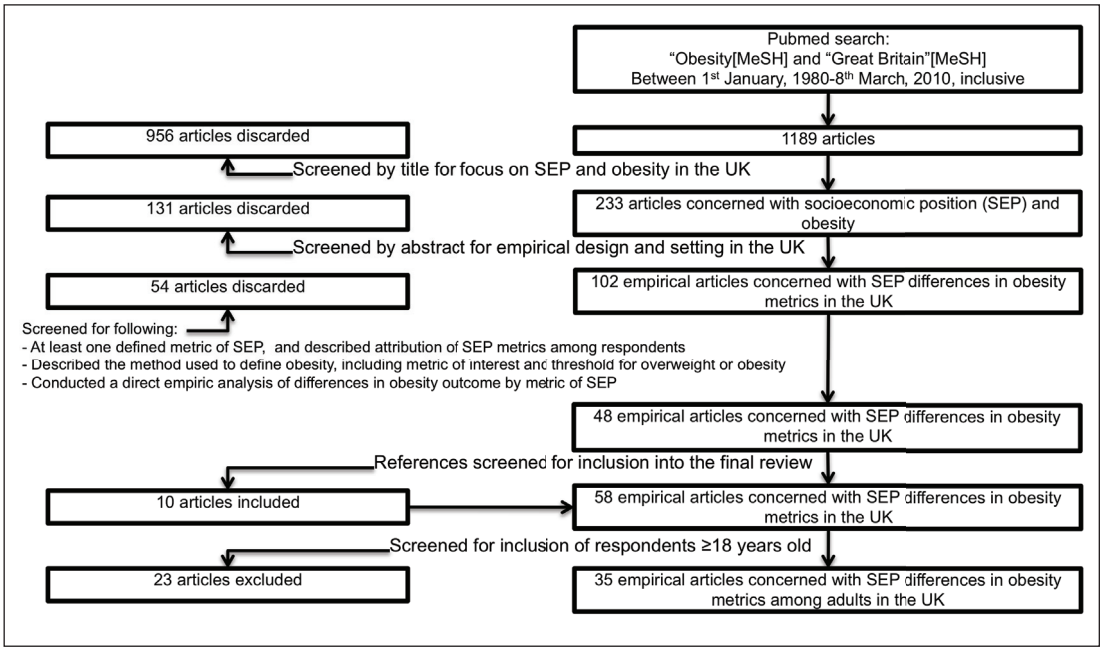

Fig. 1. Search strategy: Socioeconomic inequalities in childhood obesity in the UK.

articles which fulfilled the inclusion criteria, yielding a total of 58 articles. Finally, 35 articles that did not include outcome measures among respondents under the age of 18 years were excluded, yielding a total of 23 articles reviewed here. A diagram of the search strategy employed in the present article is shown in figure 1.

For each of these papers, the primary author extracted the following information: SEP metric(s); definition of obesity; population and setting; sample and methods; findings and conclusions. The use of 20 different area-level and individual/household-level metrics to measure SEP as well as of 17 different metrics for obesity in the studies reviewed here precluded meta-analysis of the results.

Results

The studies considered in this review utilized two empirical study designs: 5 studies included in this review were longitudinal analyses, while the remaining 18 were cross-sectional in nature. There were 20 different metrics used to ascertain child SEP as well as 17 different metrics used to measure childhood obesity. Only three studies included socioeconomic metrics collected at multiple levels (area-level, household/individual-level), and none of these studies utilized multilevel or complex systems approaches during analysis. None of the studies reviewed assessed mechanisms that mediated socioeconomic inequalities in obesity risk in the UK.

Eight of the studies we report on here used data from regional datasets from localities throughout the UK (London, Peterborough, etc.). The remaining studies reported on representative data from at least one country in the UK. Five studies reported findings from Northern Ireland; there were 7 studies that reported on data from Wales; 10 reported on data from Scotland; and 18 studies reported on data from England (table 1).

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Table 1. Studies about socioeconomic disparities in childhood obesity in the UK, August 1980 to March 2010

Reference	Inequality measure	Obesity-related outcome	Location	Sample	Methods	Conclusions
Area-level metrics						
Armstrong et al., 2003 [37]	Scottish postcode sector level Carstairs-Morris deprivation category assessed for child's place of residence	BMI > 95th and/or 98th percentile based on UK 1990 reference data [58]	Scotland	Representative sample of 74,500 children aged 39–42 months in 1998/1999 Scottish National Preschool Child Health Surveillance System	A retrospective cross sectional analysis of coexistence of social inequalities in un dernutrition and childhood obesity	8.8% of the most deprived group had a BMI greater than 95% percentile of the UK 1990 reference, as compared to 7.8% in the least deprived group. 4.7% of the most deprived group had a BMI greater than 98% percentile of the UK 1990 reference, as compared to 3.7% in the least deprived group. Those living in the most deprived areas had 1.43 (95% CI 1.16, 1.77) higher odds of having a BMI at or greater than the 98% percentile of UK 1990 reference data after adjusting for birth weight
Cecil et al., 2005 [38]	School-level metric of socioeconomic status based on the percentage of students entitled to free school meals in each school; two groups (high vs. low income) were defined	Overweight and obesity (using IOTF [59] BMI cutoffs)	Dundee, Angus, and Fife, Eastern Scotland	1,240 boys and 1,214 girls between 4–10 years old recruited from 47 primary schools	A cross-sectional analysis of the prevalence and socio-economic context of overweight and obesity in a cohort of Scottish children	Prevalence of overweight was 24.6% and obesity was 6.1%. Income group was inversely associated with obesity risk ($p < 0.0001$) in regression models adjusted for sex. Obesity and overweight were higher among low-income boys and girls. There was no significant difference (age and sex adjusted) in weight among high and low income groups, although there was a significant difference (age and sex adjusted) in height, with the lower income children on average 1.26 cm shorter than their higher income counterparts
Kinra et al., 2000 [39]	1991 enumeration district Townsend Material Deprivation Score assessed for child's place of residence	Obesity (BMI > 98th percentile of UK growth charts [58])	Plymouth	10,693 boys and 10,280 girls between 5 and 14 years old, 1994-1996	Cross-sectional analysis of the relation between deprivation and childhood obesity	Deprivation was associated with obesity ($p<0.001$); the prevalence of obesity in the lowest quartile among boys was 4.3% compared to 5.6% in the highest quartile, and the prevalence among girls was 4.2% in the lowest quartile, and 5.7% in the highest quartile. In multivariate models adjusted for age, boys in the highest deprivation quartile had 29% higher odds (95% CI 1.00–1.65) of obesity, and girls in the highest quartile had 39% higher odds (95% CI 1.08–1.80) of obesity relative to those in the lowest quartile. There was a significant interaction between deprivation and age among girls, but not among boys. Among girls aged 11.8–14.6 years old, those in the highest deprivation quartile had 95% (95% CI 1.23–3.08) higher odds of obesity than those in the lowest quartile

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Table 1. Continued

Reference	Inequality measure	Obesity-related outcome	Location	Sample	Methods	Conclusions
Rutter, 2008 [40]	Index of multiple deprivation, 2007 assessed by child's school location	Obesity (using IOTF [59] BMI cutoffs)	UK	Over 876,000 children who were measured at ages 4–5 or 10–11 in 2006-7	Cross-sectional analysis of obesity among children in the UK	There was a significant association between deprivation and obesity prevalence
Wardle et al., 2006 [43]	1991 enumeration district Townsend Material Deprivation Score assessed for child's place of residence	Overweight and obesity (using IOTF [59] BMI cutoffs); waist circumference standard deviation scores (relative to UK 1990 reference data [58])	London, England	5,863 students recruited from 36 schools at age 11–12 in 1999	A longitudinal analysis of ethnic and socioeconomic differences in the development of obesity in adolescence	In models adjusted for ethnicity, girls in the most deprived fifth had higher rates of overweight or obesity (all $p < 0.001$) over the study period. Averaged over the five years and after adjustment for ethnicity, 35.2% of the most deprived fifth were overweight or obese compared to 27.8% of other girls. In boys, the most deprived also had the highest overweight and obesity rates, but differences by class were not significant. Waist circumferences were significantly higher among lower socio-economic status groups ($p < 0.007$). There was a trend toward higher waist standard deviation scores with increasing deprivation score ($p = 0.016$)
Brunt et al., 2008 [53]	2001 lower super output area Townsend material deprivation Score assessed for child's place of residence	Overweight (BMI 17.9–19.6 kg/m^2 among boys and 17.6–19.4 among girls) and obesity (BMI ≥ 19.7 kg/m^2 among boys and ≥ 19.5 kg/m^2 among girls)	Swansea, Neath, and Port Talbot, South Wales	21,301 children aged 3 years old measured between 1995 and 2005	A serial cross-sectional analysis of the relation between area-level deprivation and childhood overweight and obesity over time	Overweight and obesity among both boys and girls rose over the 11-year study period. There was no association between area-level socioeconomic status and overweight or obesity in amalgamated data. However, when analyzed by year, there was an insignificant decrease in the proportion of obese children in the least deprived areas (4.3–5.6%) and an insignificant increase in the proportion obese children in the most deprived areas (3.7–6.3%). Overweight in the least deprived areas increased insignificantly from 14.6 to 16.0%, and in the most deprived areas increased insignificantly from 12.8 to 18.3%)
Dummer et al., 2005 [54]	Index of multiple deprivation 2000 by electoral ward of child's school	Overweight and obesity (using IOTF [59] cutoffs)	Liverpool, England	7,902 boys and 7,514 girls aged 9–10 from 106 primary schools from all parts of Liverpool between January 1998 and March 2003	Cross-sectional analysis of the relation between contextual deprivation and risk for overweight and/or obesity between 1998 and 2003	More girls (20%) than boys (15.3%) were classed as overweight ($p < 0.001$). There was no association between deprivation score and proportions of boys or girls who were overweight or obese, nor between any component deprivation score and overweight or obesity among boys or girls

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Table 1. Continued

Reference	Inequality measure	Obesity-related outcome	Location	Sample	Methods	Conclusions
Individual and area-level metrics						
Emerson, 2009 [41]	Material deprivation (number of consumer durable goods not present in the house and/or 'essentials' that were deemed unaffordable); area level index of multiple deprivation	Overweight and obesity (using IOTF [59] BMI cutoffs)	UK	Waves 1–3 of the UK Millennium Cohort Study; 49,819 children between 3 and 5 where English was the primary language spoken	Longitudinal analysis of the relation between developmental delay and obesity	Among 5-year-old non-developmentally delayed children, greater exposure to hardship, and high area-level deprivation were associated with increased obesity prevalence
Sweeting et al., 2008 [42]	Head-of-household social class; Carstairs-Morris postcode-level deprivation	Obesity (BMI > 95% of UK 1990 reference data [58])	Central Clydesdale Conurbation, Scotland	503 15-year-olds interviewed in 1987, 2,145 15 year-olds interviewed in 1999, and 3,019 15 year-olds interviewed in 2006	A serial cross-sectional analysis of the relations between socioeconomic status, obesity, and well-being among 15 year-olds	There were no significant social class differences in obesity at any date among either males or females. Among females there were significant differences in obesity prevalence by post-code level deprivation in 1987 and 2006, with the lowest prevalence among those in the less deprived areas. Obesity increased between 1987-2006 among all social classes and deprivation categories, except for among girls in the least deprived areas
Hawkins et al., 2009 [55]	Neighborhood condition; household income; number of parents in the household; maternal socioeconomic circumstances, maternal educational attainment; maternal employment	Overweight and obesity (using IOTF [59] BMI cutoffs)	UK	13,188 singleton children aged 3 years in the Millennium Cohort study, born between 2000 and 2002, who had complete weight and height data	Cross-sectional analysis of the relation between individual, family, community, and area-level deprivation and overweight and obesity among children	In unadjusted models, lone-parent status (vs. two parents) and maternal work more than 21 h (compared to no work) was associated with overweight. High maternal socioeconomic circumstances, education, and household income were associated with lower risk for obesity ($p < 0.1$). There was no association between neighborhood condition and overweight. After fully adjusting for individual, family, community and area-level factors, lone motherhood, lone-parent status (vs. two parents) and maternal work more than 21 h (compared to no work) remained associated with overweight
Individual metrics						
Chinn and Rona, 1994 [29]	Number of children in the family; father's social class	Weight-for-height, triceps skin fold thickness	England, Scotland	20,703 English and 4,094 Scottish children between 4.5 and 11.99 years old	Serial cross-sectional analysis of trends in growth and obesity in England and Scotland between 1972 and 1990	Between 1972 and 1990, mean triceps folds among English boys increased more among children of non-manual laborers and among families with 5+ children as compared to manual laborers and families with 1–2, or 3–4 children. Among Scottish boys, these trends were reversed. Among English girls, triceps folds increased more among manual relative to non-manual laborers and among children with 3-4 children in their families than other groups. Among Scottish girls, these trends were similar

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Jebb et al., 2004 [49]	Head-of-household social class; median gross income	Overweight and obesity (using IOTF [59] BMI cutoffs)	United Kingdom	Nationally-representative sample of 1,836 respondents between 4 and 18 years old	Cross-sectional analysis of the prevalence of obesity among young people in the UK	There was an inverse relationship between social class and obesity, with a significantly higher prevalence of obesity in social classes IV and V than in classes I–III (6.5 vs. 2.7%, p = 0.003). There was also a similar and significant trend for overweight (23.4 vs. 17.7%, p = 0.04). There was also an inverse significant relationship between annual income and overweight, with those in households earning ≥ GBP 20,000 having lower prevalence than those earning less (21.1 vs. 16.8%). In multivariate regression models low social status was a significant predictor of obesity
Duran-Tualeria et al., 1995 [50]	Family size; free school meal status; maternal hours worked; maternal educational attainment; paternal educational attainment; number of parents in the household; paternal social class; benefits receipt;	Overweight (triceps skin fold, subscapular skin fold, triceps and subscapular fold sum, and weight-for-height > 75 percentile)	England, Scotland	An English representative sample of 6,463 children in England in 1990; a Scottish representative sample of 4,165 children living in Scotland in 1990–1991; an inner-city sample of 7,049 mixed-ethnic children from England in 1991. All students aged 5–11	Cross-sectional analysis of the relation between social and biological factors with metrics of obesity in children	In linear regression models adjusted for potential confounders, mother's education was associated with lower weight-for height. One parent families also had higher weight-for-height. Higher maternal hours of work were associated with higher weight-for-height. Metrics of socioeconomic status were not associated with means of other outcomes. In logistic regression models of child overweight (adjusted for family size, mother's hours of work, maternal education, number of parents in the household, father's social class, child's birth weight, and parental obesity), larger family size was associated with lower risk for overweight than smaller size, high maternal work was associated with higher risk than low maternal work, one parent family was associated with higher risk that two parent family, and paternal social class of IIIM was associated with higher risk of overweight than non-manual social class

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Table 1. Continued

Reference	Inequality measure	Obesity-related outcome	Location	Sample	Methods	Conclusions
Rona and Chinn, 1987 [51]	Paternal social class; paternal employment status; maternal education; school meals	Weight-for-height, triceps skin fold	England	13,073 children 5–11 years old who took part in the National Study of Health and Growth in 1982–1983	A cross-sectional analysis of differences in obesity among children by ethnicity	Overall paternal unskilled manual social class predicted lower weight for height. Paternal employment was predictive of the highest weight-for-height. Children whose mothers had no formal education had the lowest weight-for-height. And children not receiving free school meals had the lowest weight-for-height. Children with fathers in non-manual social classes had the highest triceps skin folds, as well as those whose fathers were employed. Mothers with secondary education predicted larger triceps skin folds, as did those paying for school lunch
Mutunga et al., 2006 [60]	Maternal social class	Overweight (BMI ≥ 85th and <95% percentile of UK 1990 reference data [58]) and obesity (BMI ≥ 95% of UK 1990 reference data [58])	Northern Ireland	Representative sample of 2,016 randomly selected 12- and 15-year-old children studied in 2000	Cross-sectional analysis of socioeconomic disparities in risk factors for and prevalence of obesity	16.9% of those in low social class were obese and 16.9% were overweight as compared to 13.3% and 15.2% in high social class. There was no significant difference in overweight or obesity by social class
Ness et al., 2006 [61]	Parental social class; maternal education (at 32 weeks gestation)	Mean BMI; mean trunk fat mass; mean total fat mass; mean weight	Avon	5,917 boys and girls born between April, 1991 and December, 1992 whose mothers were enrolled in the Avon Longitudinal Study of Parents and Children and were followed up at age 9.9	Cross-sectional analysis of the relation between childhood socioeconomic status and fat patterning at 9.9 years old	Social class was associated with BMI, weight, and total fat in bivariate analyses for trend. Social class was also associated with total fat in quadratic bivariate analyses

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Table 1. Continued

Reference	Inequality measure	Obesity-related outcome	Location	Sample	Methods	Conclusions
Peckham et al., 1983 [62]	Father's social class	Overweight (weight exceeding the standard weight by 20%)	England, Wales, and Scotland	13,687 children enrolled in the National Survey of Health and Development born in March, 1946, and 16,994 children enrolled in the National Child Development Study born in March 1958	A longitudinal comparison of the prevalence of obesity at age 7, 11, and 14 in two datasets	In the 1958 cohort, there was a significant association between social class and overweight among girls at all ages, but not among boys. In the 1946 cohort, there was no relation between social class and overweight at any age
Rona and Chinn, 1982 [63]	Father's social class; mother's age at end of full-time education	Triceps skin folds; weight for height	England, Scotland	9,815 children aged 5–11 who were measured as a part of the National Study of Health and Growth from 28 areas in Scotland and England	A cross-sectional analysis of the relation between socioeconomic status and obesity among children in Scotland and England	Neither father's social class nor mother's age at completed education was associated with weight-for-height standard deviation score in children of any age group or overall. Among English boys, there was a relation between poorer social class and increased weight-for-height, although this relation was attenuated upon adjustment for potential confounders. There was a significant ($p < 0.1$) relation between social class and triceps skin fold among boys overall, but not among girls. In multivariable models, social class was associated ($p < 0.1$) with risk of weight-for-height over the 80th percentile among English boys, as well as risk ($p < 0.05$) for triceps skin folds over the 90th percentile among Scottish boys. In multivariable logistic regression models, social class was associated with significantly ($p < 0.1$) higher risk for triceps skin folds over the 80th or 95% percentile among English boys and England and Scottish girls
Saxena et al, 2004 [64]	Head-of-household occupational social class	Overweight and obesity (using IOTF [59]BMI cutoffs)	England	5,689 children and young adults aged 2–20 from the 1999 Health Survey for England	A cross-sectional analysis of the burden of obesity among children by ethnic group and socioeconomic status	In bivariate analyses and multivariate models adjusted for ethnicity, social class was not associated with overweight or obesity among males or females

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Reference	Inequality measure	Obesity-related outcome	Location	Sample	Methods	Conclusions
Stamatakis et al., 2005 [65]	Social class and household income adjusted for household size (after 1997)	Overweight and obesity (using IOTF [59] BMI cutoffs, or taken from UK 1990 reference data [58])	England	14,587 white boys and 14,014 white girls aged 5–10 years old from the National Study of Health and Growth in 1974, 1984, and 1994 and the Health Surveys for England, 1996–2003	A serial cross-sectional analysis of trends in overweight and obesity by socioeconomic status	In multivariable models adjusted for year, social class, sex, age, and household income including all data, social class was not associated with odds of overweight or obesity. Household income above the median was associated with lower odds of obesity, but not overweight. Although non-significant, there was a trend toward increasing socioeconomic disparities in obesity over time
Matijasevich et al., 2009 [66]	Family income (33 months following child delivery); maternal education (at 32 weeks gestation)	Overweight (WHO [59] Multicenter growth charts > 1 SD from the mean) and obesity (WHO [59] Multicenter growth charts > 2 SD from the mean)	Avon, England	3,341 boys and 3,410 girls born between April, 1991 and December, 1992 whose mothers were enrolled in the Avon Longitudinal Study of Parents and Children	Longitudinal comparative analysis of the relations between socioeconomic status and overweight in the UK and Brazil	In bivariate analyses at age 11 among boys, there was an inverse association between maternal education and prevalence of overweight. Among girls, both indicators were inversely associated with prevalence of overweight. In multivariable analyses adjusted for both measures of socioeconomic status and height, maternal education was a predictor of overweight, but family income was not. The same was true among girls.
Semmler et al., 2009 [67]	Maternal education	Overweight (BMI > 91th percentile of UK 1990 reference data [58]) and obesity (BMI > 98% of UK 1990 reference data [58])	England, Wales	333 twin children from families with obese parents or sociodemographically-matched controls with lean parents measured in 1998–1999 and 2005–2006.	A longitudinal case-control analysis of the relations between parental socioeconomic status and obesity, and childhood obesity development between 4 and 11 years old	There was no significant difference in increase in BMI standard deviation score among high vs. low SES households, although at follow-up (age 11) 29% of low SES children were obese compared to 17% of high SES children ($p < 0.05$). 86% of children who were obese in low SES families remained obese compared to 41% of children who were obese in high SES families ($p < 0.05$). There was a significant interaction between parental weight and familial SES for change in BMI between ages 4 and 11 ($p < 0.05$). Among children with lean parents, changes in BMI were similar among both high and low SES groups. Among children with obese parents, children from low SES families had greater increases in BMI standard deviation scores than those from high SES families
Taylor et al., 2005 [68]	Parental unemployment; family access to a vehicle; persons per room in the home; free school meals	Overweight and obesity (using IOTF [59] BMI cutoffs, or taken from UK 1990 reference BMI data [58] where overweight was >85 percentile, obesity was >95 percentile, and extreme obesity was >99.86 percentile in BMI)	East London, England	2,482 children aged 11–14 who participated in the Research in East London Adolescents Community Health Survey	A cross-sectional analysis of ethnic and socioeconomic disparities in overweight and obesity	Family access to a vehicle was associated with higher risk for obesity (according to IOTF cutoffs) among girls, and higher risk for overweight (according to UK 1990 reference data) among boys compared to having access to a vehicle. Parental unemployment was associated with lower risk for overweight (according to IOTF cut-offs) compared to having a working parent

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Area-Level Metrics of SEP and Childhood Obesity

Ten studies assessed the relation between area-level indices of SEP and obesity among children in the UK. The majority (7) of studies assessing area-level SEP metrics and prevalence of obesity among children found that higher area-level deprivation was positively associated with obesity prevalence [37–43], although 3 studies found no association [53–55]. Three studies used the Indix of Multiple Deprivation, 3 studies used the Townsend Deprivation Index [56], 2 studies used the Carstairs Deprivation Index [57], 1 study used a school-based metric, and 1 used a neighborhood condition metric as indices of area-level of SEP.

Townsend Deprivation Index

Of the 3 studies that assessed area-level deprivation via the Townsend Deprivation Index, two found significant associations between deprivation and obesity [39, 43], and one found no association [53]. Kinra and colleagues [39] studied the relation between 1991 enumeration district Townsend material deprivation scores and obesity (BMI > 98th percentile of UK 1990 reference curves [58]) and found a direct relationship between deprivation and obesity risk, as girls and boys in the highest deprivation quartile had 1.39 (95% CI 1.08–1.80) and 1.29 (95% CI 1.00–1.65) higher odds of obesity, respectively, than their least deprived counterparts. Wardle and colleagues [43] found similar results among 5,863 students from 36 schools in London. Brunt and colleagues [53] studied the relation between 2001 residence lower super output area Townsend material deprivation scores [56] and overweight (BMI 17.9–19.6 kg/m^2 among boys and 17.6–19.4 kg/m^2 among girls) and obesity (BMI ≥19.7 kg/m^2 among boys and ≥19.5 kg/m^2 among girls) among 21,301 children aged 3 years old in Swansea, Neath, and Port Talbot in the South of Wales between 1995 and 2005. Although they found no significant relationship between deprivation scores and obesity risk, they found that there was a non-significant decrease in obesity among the least deprived, and a similar increase among the most deprived between 1995 and 2005.

Index of Multiple Deprivation

Among the three studies that assessed area-level deprivation via the Index of Multiple Deprivation, two found significant associations between deprivation and obesity [40, 41], and one found no association [54]. Emerson [41] assessed the relation between area-level Index of Multiple Deprivation and risk for obesity (using International Obesity Taskforce (IOTF) BMI cutoffs [59]) among 48,819 children in the Millennium Cohort Study. He found that high area-level deprivation was associated with increased obesity prevalence. Rutter [40] found similar results in a data briefing about 2006–2007 data from the UK-wide National Child Measurement Programme. Dummer and colleagues [54] used the Index of Multiple Deprivation to assess SEP disparities in overweight and obesity (using IOTF BMI cutoffs [59]) among over 15,000 9- and 10-year-old children in Liverpool. They found no association between area-level deprivation and overweight or obesity among boys or girls.

Carstairs-Morris Deprivation Index

Two studies utilized the Carstairs-Morris Deprivation Index to assess SEP disparities in childhood obesity, and both found that higher deprivation was predictive of higher obesity risk [37, 42]. Armstrong and colleagues [37] assessed the relation between Carstairs Deprivation Index and prevalence of overweight (BMI > 95% percentile relative to UK 1990 reference data) or obesity (BMI > 98% percentile relative to UK 1990 reference data [58]) among a representative sample of 74,500 children aged 39–42 months in Scotland. In their sample, 4.7% of children were obese in the highest deprivation category compared to 3.7%

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in the lowest category. They found that after adjusting for child birth weight, those in the highest deprivation category had 1.43 higher odds (95% CI 1.16–1.77) of obesity compared to those with the lowest category. Sweeting and colleagues [42] assessed the relation between Carstairs-Morris postcode-level deprivation and obesity (BMI > 95% of UK 1990 reference data [58]) among 15-year-old Scottish children in 1987, 1999, and 2006. Among females, there were significant differences in obesity prevalence by post-code level deprivation in 1987 and 2006, with lower prevalence among those in less deprived settings. There were no differences among males.

Miscellaneous

One study used a school-based metric to assess SEP disparities in childhood obesity and showed a positive association between deprivation and obesity prevalence [38], and another used a neighborhood condition metric and found no association [55]. Cecil and colleagues [38] studied 1,240 boys and 1,214 girls between 4 and 10 years old from 47 primary schools in eastern Scotland. Using a school-based metric based on the number of students entitled to free school meals by school, they found that there was an inverse association with material wellbeing and overweight and obesity (both using IOTF BMI cutoffs [59]) risk among boys and girls. Hawkins and colleagues [55] studied 13,188 singletons from the Millennium Cohort Study. Using IOTF BMI cutoffs [59], they found no association between neighborhood condition, an index of objective measures of neighborhood deprivation, and obesity risk.

Household and Individual-Level Metrics of SEP and Childhood Obesity

There were 16 studies that assessed the relations between household and/or individual-level metrics of SEP and obesity prevalence among children in the UK. Among them, there were 15 different household-level and individual-level SEP metrics assessed as determinants of obesity. Eleven studies assessed the relation between head-of-household occupational social class and obesity prevalence [29, 42, 49–51, 60–65]. Seven assessed the relation between maternal education and obesity prevalence [50, 51, 55, 61, 63, 66, 67]. Four studies assessed the relation between parental employment and obesity risk [51, 55, 68]. Three each assessed relationships between household income [55, 65, 66] or receiving free school meals [50, 51, 68] and obesity prevalence. Two studies considered the number of people in the household as a determinant of obesity [29, 50]. Other household and individual metrics of SEP included material deprivation score [41], paternal education [50], number of parents in the household [55], household benefits receipt [50], access to a vehicle [68], and household overcrowding [68].

Occupational Social Class

The literature about the relation between head-of-household occupational social class and obesity risk generally suggests that low social class is associated with higher risk for obesity. Among studies that utilized this SEP metric, 7 found that social class was inversely associated with obesity risk [29, 49, 50, 60–63]. For example, among a nationally representative sample of children between 4 and 18 years of age from throughout the UK, Jebb and colleagues [49] found an inverse relationship between social class and obesity (according to IOTF BMI cutoffs [59]), with a significantly higher prevalence of obesity in social classes IV and V than in classes I–III (6.5 vs. 2.7%, p = 0.003).

One study found that head-of-household occupational social class was positively associated with obesity risk [51], Chinn and Rona [29] assessed trends in triceps skin folds

among 20,703 English and 4,094 Scottish 4.5- to 12-year-old children between 1972 and 1990. They found that among boys in England, non-manual paternal social class was associated with higher increases in triceps skin folds than manual social class, but they found the opposite among girls as well as among both boys and girls in Scotland.

However, 3 studies found no association between head-of-household social class and obesity risk [42, 64, 65]. For example, Saxena and colleagues [64] found no association between the exposure and obesity (using IOTF BMI cutoffs [59]) among 5,689 children aged 2–20 years sampled in the 1999 Health Survey for England.

Maternal Education

The literature about the relation between maternal education and childhood obesity suggests that low maternal education is an important predictor of childhood obesity. Among 7 studies that assessed this relation, four found a significant inverse association between maternal education and the outcome of interest [50, 51, 61, 66, 67]. For example, one study by Semmler and colleagues [67] found that, although there was no significant difference in increase in overweight (BMI > 91st percentile according to UK 1990 reference data [58]) or obesity (BMI > 98th percentile of UK 1990 reference data [58]) between 1998/1999 and 2005/2006 by maternal education among 333 twin children in a 7-year longitudinal study in England and Wales, at last follow-up (age 11 years) 29% of low SEP children were obese compared to 17% of high SEP children ($p < 0.05$). 86% of children who were obese in low SEP families remained obese at follow-up compared to 41% of children who were obese in high SEP families ($p < 0.05$). Both findings were statistically significant.

One study found a positive association between maternal education and childhood obesity risk. Duran-Tauleria and colleagues [50] found that in adjusted models, increasing maternal education was predictive of higher weight-for-height and higher risk for overweight (weight-for-height > 75% percentile, according to UK 1990 reference data [58]).

There were two studies that found no association between maternal education and childhood obesity [55, 63]. Hawkins and colleagues [55] found no association between maternal education and overweight or obesity (according to IOTF BMI cutoffs [59]) among 13,188 3-year-old singleton children. Rona and Chinn [63] found similar results assessing the relation between maternal age at completion of education and triceps skin folds and weight-for-height among 9,815 children aged 5–11 years in Scotland and England.

Parental Employment

Four studies assessed relationships between parental employment and obesity risk among children [50, 51, 55, 68]. Among 13,188 3-year-old singleton children, Hawkins and colleagues [55] found that, while maternal employment itself was not associated with overweight (IOTF BMI cutoffs [59]), children of mothers working 21 h/week or greater had 1.23 higher odds (95% CI 1.10–1.37) of overweight. Similarly, Duran-Tauleria and colleagues [50] found that higher working hours among mothers were associated with higher weight-for-height among English, Scottish, and inner-city samples aged 5–11 years. Another study among 2,482 children in East London found that parental unemployment was associated with lower risk for overweight (IOTF BMI cutoffs [59]) compared to parental employment [68]. Similarly, in a 1982–1983 study of 13,073 5- to 11-year-old children , paternal employment was predictive of higher weight-for-height than paternal unemployment [51].

Household Income

Three studies also assessed the relation between household income and obesity risk [55, 65, 66]. Only one study found an association: Stamatakis and colleagues [65] found that

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household income adjusted for family size was associated with lower odds of obesity (using IOTF BMI cutoffs [59]) in fully adjusted models among data from the National Studies of Health and Growth in 1974, 1984 and 1994, and the 1996–2003 Health Surveys for England. Among 13,188 3-year-old singleton children, Hawkins and colleagues [55] found no association between household income and overweight (IOTF BMI cutoffs [59]) in bivariate models, although there was a tendency toward overweight among lower income households ($p = 0.11$). Matijasevich and colleagues [66], in a study of just under 7,000 children in Avon, reported a non-significant ($p < 0.06$) association between household income and overweight among boys, and no association among girls.

Free School Meals

Three studies also assessed the relation between receiving free school meals and risk for childhood obesity. They found no association between free school meals and obesity risk [50, 51, 68]. For example, Taylor and colleagues [68] showed no association between receiving free school meals and overweight or obesity (using both IOTF BMI cutoffs [59] and 1990 UK reference data [58]) among 2,482 11- to 14-year-old children in East London. However, it is important to note that two of the extant studies are derived from data older than 15 years, and one is limited to a highly diverse sample in East London, and therefore may not accurately reflect the relation between receiving free school meals and childhood obesity risk in the UK. Moreover, because free school meals in the UK are allocated based on household income, adjusting for other socioeconomic metrics in multivariable models of this relation may be methodologically questionable, although this was done in each of the studies reviewed here.

Household Size

Two studies considered the number of people in the household as a determinant of obesity [29, 50], with conflicting findings. One study [50] found in fully adjusted models that larger family size was protective against overweight (weight-for-height above the 75th percentile according the UK 1990 reference data [58]). Alternatively, Chinn and Rona [29] found that a higher number of children in the family was associated with higher mean triceps skin fold increase between 1972 and 1990 among English boys, but found the opposite among Scottish boys, and English and Scottish girls.

Miscellaneous

Other household and individual metrics of SEP that were studied as predictors of childhood obesity included material deprivation [41], paternal education [50], number of parents in the household [55], household benefits reception [50], access to a vehicle [68], and household persons per room [68]. Of these, material deprivation [41] number of parents in the household [55], and access to a vehicle [68] were associated with any outcome of interest.

Emerson [41] studied the relation between an individual metric of material deprivation (using the number of consumer durable goods deemed 'essentials' not present in the household) and obesity risk (using IOTF BMI cutoffs [59]), and found that greater exposure to material deprivation was associated with obesity risk. Hawkins and colleagues [55], among 13,188 singletons from the Millennium Cohort Study, found that lone-parent status was associated with overweight (using IOTF BMI cutoffs [59]) risk in fully adjusted models. Taylor and colleagues [68], in a study of almost 2,500 East London children aged 11–14 years, found that family access to a vehicle was associated higher risk for obesity (according to IOTF BMI cutoffs [59]) among girls, and higher risk for overweight (according to UK 1990 reference data [58]) among boys compared to having no access to a vehicle.

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Discussion

A comprehensive review of the peer-reviewed literature regarding socioeconomic inequalities in childhood obesity in the UK between 1980 and 2010 found that both area-level and household/individual-level metrics of SEP are associated with childhood obesity in the UK. In particular, three of the most common area-level indices of SEP in the epidemiologic literature, the Index of Multiple Deprivation, the Townsend Deprivation Index [56], and the Carstairs Deprivation Index [57], were reliable predictors of childhood obesity in the UK (although they did not predict obesity in all studies). We also found that common household and individual-level metrics of childhood SEP, including head-of-household social class and maternal education were reliable determinants of childhood obesity in the UK (although they did not predict obesity in all studies). Some other associated household and individual-level metrics, including household income, free school meals, and paternal employment, were not independently associated with childhood obesity after adjustment for income levels. This indicates the importance of supporting analyses with appropriate conceptual casual frameworks that specify the production of inequalities in obesity across levels and therefore guide the construction of analytic models when exploring the roles of socioeconomic predictors of childhood obesity at the area level, household level, and individual level.

While there are relatively few prospective studies of the relation between SEP and obesity in other Western European countries, their findings are comparable to the small number of which we are aware in the UK. For example, in a prospective study of 341 children aged between 6 and 8 years in the south of Italy, Valerio and colleagues [69] demonstrated that children with less educated mothers had accelerated weight gain over a 3-year period relative to those with more educated mothers. A prospective study of a random sample of 9- and 10-year-old children in Copenhagen schools in Denmark [70] found that, while parental education and occupation did not predict obesity at 10 years follow-up after adjusting for childhood adiposity and gender, a metric of neighborhood-level deprivation predicted higher risk for overweight after adjustment for parental education and occupation. Similarly, in a prospective cohort of 10-year-old children in Sweden [71], low neighborhood-level social class was associated with higher obesity risk. By contrast, in a cohort of children in Southeast Sweden [72], neither maternal nor paternal education was associated with risk of childhood obesity at age 5 (using IOTF BMI cutoffs [59]).

Methodological Limitations of the Extant Literature

Although this review demonstrated important gradients in childhood obesity risk by metrics of SEP in the UK, there are several methodological limitations to the current literature about socioeconomic inequalities in childhood obesity that limit our understanding: i) there have been few studies that have simultaneously studied both area-level and household/individual-level determinants of childhood obesity, ii) there are no known studies that have utilized multilevel modeling or complex systems approaches to understand the relative influence of contextual and individual SEP on childhood obesity risk in the UK, iii) there is limited availability of longitudinal studies that have assessed life course and/or intergenerational SEP gradients in childhood obesity, iv) the extant literature has paid little attention to mechanisms underlying the relation between metrics of SEP and childhood obesity, and v) the multiplicity of SEP metrics used in analysis and the lack of adherence to comparable metrics limits comparisons of the literature across metrics.

The first two limitations pose foundational challenges to our understanding of socioeconomic inequalities in childhood obesity in the UK. First, the concept that individuals may

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interact with, and therefore be influenced by, their ecological contexts is fundamental in social scientific inquiry [73–76]. Studies about socioeconomic disparities in childhood obesity which only account for variation in the outcome of interest via individual or household metrics of SEP, of which there were 14 of 23 studies reviewed, may not account for ecological manifestations of poverty and their contributions to childhood obesity, yielding an imperfect understanding of the relation between SEP and childhood obesity.

Moreover, 7 of 23 studies reviewed assessed area-level metrics of SEP as determinants of obesity without including individual-level or household-level metrics of SEP. In the absence of individual-level SEP data, investigators often use area-level SEP metrics as proxies for individual SEP. However, area-level SEP metrics are encumbered by substantial measurement error, as not all individuals living in lower SEP areas will have low individual SEP metrics, and vice versa. Moreover, it is difficult to ascertain the mechanisms that relate area-level metrics of SEP to health outcomes of interest. On one hand, area-level SEP metrics can serve as proxies for individual SEP, thereby representing populations with concentrated individual-level poverty, and explaining relations between area-level metrics and outcomes of interest. Alternatively, it is possible that context itself, independent of individual-level SEP, can predict outcomes of interest [73].

Studies that simultaneously consider both individual and area-level factors as determinants of outcomes are most appropriate, given the following three barriers discussed above: i) Individuals may interact with, and therefore be influenced by, their ecological contexts [73–76]. ii) Area-level SEP variables may be poor proxies for individual-level SEP. iii) It is difficult to quantify the direct and indirect contributions of area-level metrics to outcomes of interest in epidemiologic analyses that do not include individual-level data. Epidemiologists, therefore, have begun, over the past 10 years, to conceptualize and analyze models of disease with such a multilevel understanding in mind [77] – a departure from traditional models of disease that focused on features of the individual or proxies thereof exclusively [78]. Multilevel models, which account for clustering within multilevel data, allow investigators to estimate the relations between exposures and outcomes of interest while adjusting for other exposures across levels of influence [73]. Multilevel thinking has allowed investigators to conceptualize and examine how factors operating at multiple levels of influence – characteristics of individuals, their families, contacts, neighborhoods, and societies – can shape, both individually and in cooperation, their health and disease risks [77]. Growing out of the multilevel conceptual paradigm as well as an understanding of the limitations of traditional predictive regression modeling, complex systems approaches feature stochastic modeling techniques that allow investigators to capture bi-directional, dynamic, and relational interactions between traditional ‘exposures’ and ‘outcomes’ at any level of analysis and influence [77]. These approaches, therefore, may be ideally suited to understand the causes, mechanisms, and consequences of socioeconomic disparities in childhood obesity in high-income contexts. Without simultaneous study of SEP metrics on multiple levels using multilevel or complex systems tools, it remains impossible to quantify the contributions of metrics of SEP at multiple levels to childhood obesity risk in this context.

The third methodological limitation is the limited availability of longitudinal studies that have assessed life course and/or intergenerational SEP gradients in childhood obesity in the UK. Increasingly, the life course approach has gained traction in social epidemiology. Defined by Ben-Shlomo and Kuh [79], the life course framework in epidemiology implies the assessment of long-term effects on disease risk from physical and social exposures throughout the life course. Life course approaches to the question of childhood obesity in the UK have been fruitful: for example, a study about the predictors of childhood obesity among a cohort of 7-year-old children in Avon [66] found that several exposures occurring before the age of 3, including parental obesity, early adiposity rebound, greater than 8 h/week spent

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watching television, and short sleep duration at age 3 were all significant predictors of obesity (>95th percentile of UK 1990 reference data [58]). Moreover, within this framework, evidence has suggested that maternal health and wellbeing, both before and during pregnancy, may influence the health and wellbeing of children. For example, studies have demonstrated that maternal smoking [80] and maternal obesity [81] during pregnancy may influence risk for childhood obesity. The paucity of longitudinal studies that have included and/or analyzed socioeconomic data from gestation and/or early childhood as determinants of obesity in later children in meaningful ways limits our understanding of the mechanisms by which SEP may influence childhood obesity risk in the UK.

Growing out of the paucity of longitudinal studies, the fourth methodological limitation to the extant literature about socioeconomic inequalities in childhood obesity in the UK is that the current literature has largely ignored mechanisms by which SEP may influence childhood obesity. For example, it has been shown that food insecurity may mediate the relation between poor SEP and risk for childhood obesity in other countries, as it may lead to binge eating cycles and energy-dense food consumption [82, 83]. To our knowledge, this feature of the relation between SEP and obesity among children in the UK remains unstudied. Studies that empirically assess mechanisms by which SEP may influence obesity risk in the UK are crucial for interventions designed to curb the childhood obesity epidemic in this context.

The fifth methodological limitation is that the multiplicity of SEP metrics used in analysis and the lack of adherence to comparable metrics limits comparisons of the literature across metrics. For example, the most regularly studied metric of SEP in the literature reviewed above was head of household social class, about which only 11 out of 23 studies collected and analyzed data. The next most considered metric was maternal education at 7 out of 23 studies. Because the nature of SEP metrics, their relation to childhood obesity, and the mechanism by which they may influence obesity among children may differ substantially, the lack of adherence to comparable metrics among studies assessing SEP differences in childhood obesity risk in the UK disrupts overall comparisons across studies and limits our ability to draw meaningful inference from the extant literature.

Limitations

The reader should keep in mind several limitations when interpreting the findings of this review. First, because we restricted the studies reviewed above to those published in the peer-reviewed literature, the articles we reviewed and the inferences we have drawn may be subject to a publication bias. Although our inclusion criteria were expansive and included data about many of the largest health surveys in the UK, our findings may not accurately reflect current knowledge about SEP and obesity in the UK. Second, our findings were organized by level of influence and then by metric of analysis. Our organization scheme could possibly have, in part, shaped the inferences we drew from the extant literature. Third, our findings were limited to studies about socioeconomic disparities in obesity risk among children in the UK. Therefore, it would be inappropriate to generalize our findings to other age groups in other national contexts.

Directions for Future Research

Five directions for future research emerge from this review. First, studies that assess SEP metrics at multiple levels of influence – area, household, and individual – are needed to understand the complex relation between SEP and childhood obesity risk.

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Second, these studies should utilize multilevel thinking during conception and multilevel and complex systems approaches during analysis so as to quantify SEP influences at multiple levels on childhood obesity risk. These studies could clarify the importance of contextual factors in shaping childhood obesity in the UK for researchers and policymakers alike.

Third, investigators interested in this area might consider studies that include data about maternal SEP during pregnancy as well as early life metrics of SEP among children so as to understand SEP determinants of childhood obesity in the UK throughout the life course.

Fourth, research about the mechanisms relating SEP and childhood obesity in the UK is needed so as to educate potential interventions against childhood obesity.

Fifth, consensus regarding metrics of SEP that are most fruitful in research about socioeconomic disparities in childhood obesity is needed, and researchers in this area should utilize these metrics primarily.

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