Mediators of socioeconomic differences in overweight and obesity among youth in Ireland and the UK (2011–2021): a systematic review

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Abstract

Background: By 2025, adult obesity prevalence is projected to increase in 44 of 53 of European-region countries. Childhood obesity tracks directly onto adult obesity, and children of low socioeconomic position families are at disproportionately higher risk of being obese compared with their more affluent peers. A previous review of research from developed countries identified factors mediating this relationship. This systematic review updates and extends those findings specifically within the context of Ireland and the United Kingdom.

Objective: The aim of this systematic review is to summarise peer-reviewed research completed in Ireland and the United Kingdom between 2011–2021 examining mediators of socioeconomic differentials in adiposity outcomes for youth.

Design: An electronic search of four databases, Ovid MEDLINE, Embase, Web of Science and EBSCOhost was conducted. Quantitative studies, published in the English language, examining mediators of socioeconomic differentials in adiposity outcomes in youth, and conducted in Ireland and the United Kingdom between 2011–2021 were included. An appraisal of study quality was completed. The systematic review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

Results: Following screening, a total of 23 papers were eligible for inclusion. Results indicate socioeconomic differentials for Ireland and the United Kingdom follow similar patterns to other developed countries and have similar mediating factors including early life and parent-level factors. However, this review identified additional factors that mediate the relationship, namely access to green space and favorable neighborhood conditions. Identifying these factors present further opportunities for potential interventions and confirm the requirement for tailored and appropriate research and interventions for Ireland and the United Kingdom.

Conclusion: This review identified several modifiable factors that should be considered when planning interventions aimed at reducing socioeconomic differentials in adiposity among youth in Ireland and the United Kingdom. Support was found for interventions to be made as early as possible in an at-risk child’s life, with the prenatal and preschool...
Background
As a leading cause of preventable morbidity and mortality globally, obesity (OB, adult Body Mass Index (BMI) ≥ 30 kg/m²) is now classified as a modern-day health crisis [1], with adverse health and economic implications for individuals and society [2, 3]. A recent report projected that by 2025, OB prevalence would increase in 44 of the 53 World Health Organisation (WHO) European-region countries studied. Of these, Ireland is projected to have the highest, with 43% of the population obese, while the lowest (Italy) is projected to have 13% [4]. Addressing the rise in OB is a recognised priority in the Irish [5] and the United Kingdom (UK) [6] health care systems; however, the development of effective policy responses is dependent on the knowledge of what risk factors are associated with OB, the stage at which those risk factors are most potent, and which interventions are most effective for the at-risk cohort.

A high percentage of adult OB has its roots in childhood, with OB status persisting as the child matures: 55% of obese children will be obese in adolescence, and 80% of those obese in adolescence will remain obese entering adulthood [7]. It is generally recognised that one of the most effective routes to establishing long-term, sustainable change in the OB profile of a population is to address OB in early life [8]. Currently, with 25% of Irish youth [5], and 33% of UK children [6] classified as overweight (OW, BMI 25–30 kg/m²) or OB, it is critical that effective interventions be identified to address the child-to-adult pattern of OB [5, 9].

Recently, the prevalence of OB in children of economically-advanced countries has been seen to plateau, but OB continues to rise among children of low socioeconomic position (SEP) families leading to increasing differentials in risk of OB between SEP groups [3, 10–16]. In Ireland and the UK, there is evidence to suggest that differentials in the risk of OB by SEP begin as young as age three, are well established by age five, and widen with age [16–18]. A recent analysis of UK longitudinal data suggests SEP differentials in childhood BMI outcome first became evident in the UK in 2001, since when they have persisted and widened [12].

Understanding what factors might mediate the association between low SEP and adiposity in youth is vital in order to inform policy development. A recent systematic review summarised evidence from research undertaken in Organisation for Economic Co-operation and Development (OECD, with 38 member countries including the United States of America (USA) and Australia) countries of mediators that contribute to differentials in SEP and adiposity among youth. Reporting on over 28 studies that took place between 1990 and 2016, a number of modifiable risk factors were identified, including early life experience (particularly breastfeeding, early weaning, and maternal smoking in pregnancy); child dietary behaviours (particularly consumption of sugar-sweetened beverages and breakfast-eating patterns); child sedentary activity (particularly television viewing and computer use); and maternal BMI [19]. While these findings are informative at an OECD level, there is wide heterogeneity in the culture and living conditions experienced by youth of OECD countries, making the relevance of outcomes informative at a specific region or country (e.g. Ireland) unclear.

To date, there has been no systematic or scoping review of studies examining the area of SEP differentials in OB outcomes in the youth of Ireland and the UK. This review was undertaken to present an updated and comprehensive review of all existing research published between 2011–2021, reporting on factors that mediate or contribute to the relationship between SEP and adiposity and OB in youth in Ireland and the UK. The aims of this review were to potentially inform future policy discussions, and to identify any research gaps which might require further investigation.

Methods
The review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [20]. The protocol of this systematic review has been registered and is available on the Open Science Framework [21].

Studies reported in peer-reviewed journals were included if they had employed quantitative methods, were conducted in Ireland and/or the UK, were published in the English language between the years 2011 and 2021, reported on mediators of the association between at least one indicator of SEP and at least one indicator of adiposity, and had a study cohort aged 18 years or under.
Studies employing qualitative methodology were excluded, as was grey literature, studies where analytic methods were not clearly reported, studies conducted among clinical populations, studies employing ethnicity as an indicator of SEP, studies assessing underweight or stunting as an outcome measure, and/or studies assessing birthweight as an outcome measure.

With the aid of an experienced information specialist, the following bibliographic databases were interrogated (with a limitation of a date range of 2011 and August 4th 2021): Ovid MEDLINE, Embase, Web of Science and EBSCOhost. The search strategy was based on that employed by Gebremariam et. al. [19], with the purpose of extending and extrapolating from their earlier review while targeting Ireland and the UK only. The search was conducted on August 5th 2021.

An example of the final search strategy for one of the databases (Ovid MEDLINE®) is presented in Appendix 1.

The articles were reviewed in two phases. For the first level of screening (title and abstract), the database search results were imported into Rayyan [22], a web-based software for managing systematic reviews. Five researchers (TB, NL, SH, DM, AO) worked in independent pairs to screen articles for inclusion or exclusion, based on title and abstract only. Screening was conducted blind, with any discrepancies resolved by discussion with the larger group. Duplicates were identified and removed prior to discussion.

For the second level of screening (full text), all papers were transferred to an Excel spreadsheet allowing separate analysis for both included and excluded studies. For included studies, a second review, based on full text, was completed. Again, working in pairs, any discrepancies were resolved by discussion with the larger group, with resulting articles included in the final analysis. Excluded papers were coded for reason of exclusion. Additional papers were identified by examining references of the papers found through the initial search. Screening steps and outcomes are presented in Fig. 1.

All remaining papers underwent data extraction, with information being collated in an Excel spreadsheet based on those items extracted by Gebremariam et. al. [19]. The following items were charted: title; authors; journal; volume; issue; year; pages; type of paper; country conducted; indicator of adiposity; indicator of body weight; indicator of SEP; mediating factors (e.g. child diet, maternal BMI,

![Fig. 1 Flowchart indicating steps followed in literature search](image-url)
smoking etc.); time period conducted; population (e.g. infant, child, adolescent, youth); ethnicity; n (% female); methods; mediated relationship (including direction of the association); methods used to assess mediation (name of model used); mediation results; main findings; comments and further work.

A critical appraisal of each journal article was completed using an adapted version of the Liverpool Quality Assessment Tool [23] and the Effective Public Health Practice Project Quality Assessment Tool [24]. Categories of techniques employed for each study were assessed and totalled, generating an overall quality score ranging from 'strong' to 'moderate' to 'weak'. Techniques included: Selection Procedures (assessing selection bias and validity of methods); Baseline Assessment (assessing differences between selected groups); Outcome Assessment (assessing dropouts and withdrawals); Analysis (assessing confounding variables and statistical methods); and Impact (assessing the study's applicability to this review).

Results

The initial search returned 1184 articles, which reduced to 749 once duplicates were removed. Of these, 636 were excluded following review of title and/or abstract. A full text review took place for 113 articles, following which 93 were excluded. Full data extraction was conducted on 20 articles from the original search and an additional three papers identified by checking reference lists of the included articles. A total of 23 papers were included in the final review [17, 25–46]. See Fig. 1.

Tables 1 and 2 describe the studies included in this review. The majority of the studies used UK data (n = 21), while only 10% (n = 2) used data from Ireland. Most of the studies were longitudinal in design (n = 18), with the remaining (n = 5) cross-sectional (Table 1).

As children develop and grow, BMI changes considerably, necessitating the use of centile curves with variable cut-offs to denote OW and/or OB – each calculated by sex for different ages. Cut-off values are available using the British 1990 reference (UK90) published by the Child Growth Foundation [47, 48–51], the US Centers for Disease Control (CDC) charts [52], the International Obesity Task Force (IOTF) [53, 54], and the World Health Organisation (WHO) BMI-for-age cut-offs [55]. IOTF cut-off points were used to define OW and OB from BMI measures in the majority of studies (n = 16) [17, 25–31, 35, 38, 39, 41–45], with n = 3 using UK90 cut-off points [34, 37, 46], and one using both methods [29]. Both IOTF and WHO criteria were used in one study [43] while CDC cut-offs (with no references given) were used for one study [37]. One study did not employ cut-offs [40].

Table 1 also summarises indicators of SEP used: single indicators of SEP were employed in 14 studies [17, 25–28, 31–34, 39, 41, 42, 44, 45]. The remaining nine studies used a combination of measures to identify SEP [28, 29, 35–38, 40, 43, 46].

Table 2 details potential mediators examined and combinations of mediators used. Potential mediators of socioeconomic differences in adiposity were broken down into categories: early life factors n = 9; child screen time n = 6; child diet n = 6; parent-level factors n = 6; child health and behaviours n = 6; geographical factors n = 4; household-level factors n = 3; ethnicity n = 4; adverse childhood events n = 1; child height n = 1; and school-level factors n = 1. Table 3 provides a summary of variables in each category.

Mediators of the association between socioeconomic position and adiposity

Mediators of the association between deprivation scores and adiposity

Of the fourteen (61%) studies using single indicators of SEP, deprivation scores were used in five. The positive association between deprivation scores and prevalence of childhood OW, OB, and/or OW and OB, was mediated by: parent-level factors [41]; child health behaviours [41]; geography [41, 46]; household-level factors [45]; ethnicity [44]; and school-level factors [32]. Deprivation-based SEP differentials differed by sex and were reported to widen between the ages of four to five years and 10–11 years for most ethnic groups (the largest disparity seen in White children and the smallest seen in Black African children).

Mediators of the association between maternal education and adiposity

The association between maternal education and increased risk of adiposity was mediated by early life factors of maternal pre-pregnancy OW and maternal smoking during pregnancy [25]; Adverse Childhood Events (ACE) in the first five years of life [26]; screen time, with five or more hours a day of screen time being associated with a 1.7 fold increased risk of OB [27]; and parenting-level factors, with bedroom TV availability identified as the most important parenting pathway followed by informal meal settings [34].

Mediators of the association between parental/family level factors and adiposity

For 9-year old children in Ireland, the majority of SEP inequalities in childhood OB were explained by parental health and maternal BMI, which when added to other parental health traits (such as smoking and drinking habits) was as large, or a larger contributor to OB/OW inequalities than any other group of factors.
| Author (year) and country | Sample Characteristics (n, age (SD), % female) | Study design & instruments | Indicator of body weight (including measurement method and categorisation, descriptives) | Indicator of socioeconomic position | Mediators | Quality Score |
|--------------------------|-------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------|----------------------------------|-----------|---------------|
| Cetateanu et al., 2014, UK [46] | 2007–08: n = 973,073 and 2008–09: n = 1,003,849 and 2009–10: n = 1,026,366, age: 4–5 years, 10–11 years | Cross-sectional, data from census, ONS and GIS (NCMP) | Objectively measured wgt and hgt, defining BMI > = 85th and <= 95th percentile as OW and obesity as > 95th percentile using UK90 BMI references | IDACI (measuring relative deprivation including income, employment, education, skills and trainings, health and disability, crime, barriers to housing and services, and living environment), and area SEP | Geography (food environment characteristics: counts of fast food, other unhealthy food, mixed food outlet) | Strong |
| Goisis et al., 2016, UK [39] | n = 11,965, age: 5 years and n = 93,84, age: 11 years, 48.4% female | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measured wgt and hgt, defining OW/OB using IOTF criteria; Sample average: 20% OW, 5.8% OB | Family income | Early life (maternal prenatal smoking, breastfeeding duration, weaning), child health behaviours (physical activity, child sedentary behaviour, active play with parent, sleep time, mode of travel to school), screen time (television and computer), child diet (breakfast, fruit and sugar drink consumption), parent-level (maternal BMI) | Moderate |
| Goisis et al., 2019, UK [31] | n = 11,331, age: 7 years, 49.5% female | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measured wgt and hgt, categorized into non-overweight, OW/OB using IOTF cut-offs | Family income | Ethnicity, early life (maternal prenatal smoking, breastfeeding duration, weaning), child health behaviours (sport/exercise, active playing with parent, regular bedtime), Screen time/media exposure (television and computer use), child diet (breakfast, fruit, sugar drinks), parent-level (maternal overweight/obese at time of survey, parenting: meals eaten with parent) | Moderate |
| Laverty et al., 2021, UK [40] | n = 8,432, age: 7, 11 and 14 years, 51.3% female | Longitudinal, home visit interviews (PCG and child) (MCS) | Objectively measured wgt and hgt, used to calculate BMI and % BF | Family income, occupational social class | Child health behaviour (mode of travel to school) | Strong |
| Author (year) and country          | Sample Characteristics (n, age (SD), % female) | Study design & instruments | Indicator of body weight (including measurement method and categorisation, descriptives) | Indicator of socioeconomic position | Mediators | Quality Score |
|-----------------------------------|------------------------------------------------|----------------------------|---------------------------------------------------------------------------------------|-----------------------------------|-----------|---------------|
| Layte et al., 2014, Ireland [17] | n= 9,057, age: birth, 9 months and 3 years, 49% female | Longitudinal, home visit interviews (PCG) and health records (GUI) | Birthweight: taken from health professions birth records converted to z scores. Age 9 months: objectively measured wgt converted to z scores. Age 3: objectively measured wgt and hgt, categorized into OW/OB using IOTF cut-offs | Household social class (Irish Central Statistics office) | Early life (maternal prenatal smoking and alcohol consumption, duration of breastfeeding, weaning); child diet (dietary quality index); screen time/media exposure (television and DVD use) | Moderate |
| Lu et al., 2020, UK [43]          | n= 15,996, age: 3, 5, 7, 11 and 14 years, 48.3% female | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measured wgt and hgt, defining OB and OB using both IOTF and WHO criteria; OW & OB: 28.5% (IOTF), 35% (WHO) | Maternal education, family income | Ethnicity | Moderate |
| Martinson et al., 2012, UK and USA [37] | US sample: FFS, n= 2,990, age 1, 3, 5 and 9 years; UK sample: MCS, n= 6,816, age 3, 5, 7 and 9 years | US: Longitudinal, parental hospital and home visit interviews. (FFS) UK: Longitudinal, home visit interviews (PCG) (MCS) | US sample: BMI calculated from wgt and hgt at ages 3 and 9; UK sample: Objectively measured wgt and hgt, BMI calculated from wgt and hgt at ages 3 and 7; BMI categorised using CDC guidelines with 85th percentile designating OW | Maternal education, family income | Ethnicity; Parent-level factors (age mother immigrated (under/over 18 years)) | Moderate |
| Massion et al., 2016, UK [25]     | n= 11,764, age: 11 years, 48% female | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measured wgt and hgt, defining OW/OB using IOTF criteria; 28.8% OW at age 11 | Maternal education | Early life factors (maternal pre-pregnancy weight, maternal prenatal smoking, BW, caesarean delivery, breastfeeding duration, weaning) | Strong |
| Mireku et al., 2020, UK [45]      | n= 11,714, age: 14 years, 47.6% female | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measured wgt and hgt. BMI used to classify OW and OB using IOTF cut-offs: 8.0% OB, 27.2% OW | Area of deprivation | Household-level (income (equivalised)) | Moderate |
| Noonan et al., 2016, UK [41]      | n= 194, age: 9–10 years, 55.1% female | Cross-sectional, data from NSPO, in-school interviews (child), parental questionnaires (via school) | Objectively measured wgt and hgt, used to calculate BMI and BMI z-scores. Normal weight and OW/OB defined using IOTF. 26% OW/OB | IMD (family income, employment, health education, housing, environment, crime) | Geography (home and neighbourhood environment (including crime and aesthetics)); child health behaviour (physical activity); parent-level (child bedroom TV) | Moderate |
| Author (year) and country | Sample Characteristics (n, age (SD), % female) | Study design & instruments | Indicator of body weight (including measurement method and categorisation, descriptives) | Indicator of socioeconomic position | Mediators | Quality Score |
|--------------------------|-----------------------------------------------|----------------------------|---------------------------------------------------------------------------------|---------------------------------|-----------|---------------|
| Noonan, 2018, UK [28]    | n = 10,736, age: 9 months-14 years, 49.5% female | Longitudinal, home visit interviews (PCG and child) (MCS) | Objectively measured wgt and hgt, categorized into non-overweight, OW/OB using IOTF cut-offs; OW 26.6%, OB 7.4% | Family income | Child diet (fruit, veg, sugary drink, and fast food consumption) | Moderate |
| Noonan et al., 2018, UK [30] | n = 3,717, age: 7 years, 51% female | Longitudinal, home visit interviews (PCG), physical activity assessment (MCS) | Objectively measured wgt and hgt, categorized into normal OW OB using IOTF criteria; 17% OW, 14% OB | Maternal education and area deprivation | Child health behaviours (physical activity) | Moderate |
| Oude Groeniger et al., 2020, UK [27] | n = 11,413, age: 7–14 years, 47% female | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measured wgt and hgt, defining OB using IOTF criteria; 8% OB at age 14 | Maternal education | Screen time/media exposure (television viewing and computer use) | Strong |
| Parkes et al., 2016, UK [34] | n = 2,957, age: 46, 70 and 94 months, 48.4% female | Longitudinal, in-home interviews (PCG) (GUS) | Objectively measured wgt and hgt, at 46, 70 and 94 months used to derive standardised BMI z-scores using UK90 British growth reference data | Maternal education | Parent-level (parenting: main meal while watching TV, meals eaten in non-dining/food preparation area (e.g. bedroom), child-bedroom TV), Child diet (skip breakfast, fruit, veg, crisps, sugar drinks, sweets, and chocolate consumption) | Strong |
| Samani-Radia et al., 2011, UK [29] | n = 2,298, age: 5–14 years, 45.6% female | Cross-sectional, in-school surveys, LEA data | Objectively measured wgt and hgt, categorized into non-overweight, OW/OB using IOTF cut-offs and % BF cut-offs using UK90 growth reference data categorizing overweight and obese | Environment (poorer urban/inner city London area with a high density of social housing) and income characteristics defined at school-level (% of children receiving free school meals) | Child height | Moderate |
| Schalkwijk et al., 2017, UK [38] | n = 6,467, age: 9 months, 3, 5 and 7 years, 49.7% female | Longitudinal, home visit interviews (PCG) observational assessment (interviewer) (MCS) | Objectively measured wgt and hgt, defining OB using IOTF criteria; defining normal, 19.9% OW/OB at 7 years | Parental education, family income | Geography (greenspace, access to garden, condition of neighbourhood) | Strong |
| Author (year) and country | Sample Characteristics (n, age (SD), % female) | Study design & instruments | Indicator of body weight (including measurement method and categorisation, descriptives) | Indicator of socioeconomic position | Mediators | Quality Score |
|--------------------------|------------------------------------------------|---------------------------|---------------------------------------------------------------------------------|-----------------------------------|-----------|---------------|
| Silverwood et al., 2016, UK [36] | $n=16,628$, age: 6–9 weeks, 21–24 and 39–42 months, and 48 months, 48.4% female | Longitudinal, census and SIMD data, child health records (CHSP Pre-School). (SLS) | Length/height, weight and age derived from CHSP preschool records at 6–8 weeks, 8–9 weeks, 21–24 months, 39–42 months and 48 months. Predicted BMI at age 4.5 years derived from predicted hgt and wgt values with OW at age 4.5 defined using Cole (2000) standard definition | Maternal education, Scottish IMD, family income | Early life (BW) | Moderate |
| Straatmann et al., 2020, UK [26] | $n=63,066$, age: 14 years | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measured wgt and hgt, defining OW/OB using IOTF criteria; 24.6% OW/OB | Maternal education | ACE (verbal and physical maltreatment, parental divorce, drug use, alcohol use, maternal mental illness, domestic violence) | Strong |
| Strugnell et al., 2020, UK [44] | $n=23.5$ million, age: 4–5 years, 10–11 years, 49% female | Cross-sectional, school records (NCMP) | Objectively measured wgt and hgt. IOTF growth reference used to classify OW and OB | IDACI (measuring relative deprivation including income, employment, education, skills and trainings, health and disability, crime, barriers to housing and services, and living environment) | Ethnicity | Weak |
| Stuart et al., 2016, UK [35] | $n=96,999$, age: 3, 5, 7, 11 years, 50.7% female | Longitudinal, home visit interviews (PCG) (MCS) | Objectively measure wgt and hgt, categorized into OW/OB using IOTF cut-offs | Parental income, parental education, persistent poverty indicator | Early life (maternal prenatal smoking, breastfeeding (never), low BW, high BW) | Strong |
| Townsend et al., 2011, UK [32] | $n=396,171$, age: 4–5 years, 48% female and $n=392,344$, age: 10–11 years, 48% female | Longitudinal, data from NCMP, CWI scores via the DCLG, FSM via school census data from DCSF (NOMP) | Objectively measured wgt and hgt, resulting in z-scores using UK90 growth reference (Cole 1995, 1998) | CWI (a composite score of seven domains: material well-being, health, education, crime, housing, environment, children in need) | School-level deprivation: FSM (% of children receiving free school meals) | Strong |
| Author (year) and country | Sample Characteristics (n, age (SD), % female) | Study design & instruments | Indicator of body weight (including measurement method and categorisation, descriptives) | Indicator of socioeconomic position | Mediators | Quality Score |
|--------------------------|-----------------------------------------------|-----------------------------|--------------------------------------------------------------------------------------|-----------------------------------|-----------|---------------|
| Walsh et al., 2015, Ireland [42] | n = 8,599, age: 9 years, 45.1% female | Cross-sectional, home visit interviews (PCG and child) (GUI) | Objectively measured wgt and hgt, defining OB and OW/OB using IOTF cut-offs. 5.3% OB, 24.1% OW/OB | Family income | Geography (urban/rural, proximity to recreational facilities); household-level (home owner); parent-level (age of parents, parent BMI, current smoker, child bedroom media); early life (maternal prenatal smoking and alcohol consumption, breastfeeding (ever), BW); child health behaviour (frequency of exercise, hospital nights, doctor visits); screen time (TV, computer and video games); child diet (sugar drinks, crisps, chips, junk food) | Strong |
| Wijlaars et al., 2011, UK [33] | n = 2,394, age: birth-3 months, 50.5% female | Longitudinal, questionnaire (PCG), child health records (Gemini study) | Health professions record of infant weight used to calculate weight standard deviation scores at birth and 3 months based on UK90 growth reference data | NS-SEC (based on occupation, maternal education qualifications) | Early life (maternal prenatal smoking, breastfeeding duration, wearing), parent-level (BMI) | Moderate |

Abbreviations: ACE Adverse Childhood Experience, ALSPAC Avon Longitudinal Study of Parents and Children (UK), BF Body fat, BMI Body Mass Index, BW Birth weight, CI Confidence Interval, CHSP Pre-School Child Health System Programme Pre-School (UK), CFM ChildWellbeing Index (UK), DCLG Department of Communities and Local Government (UK), DCSF Department for Children, Schools and Families (UK), FFS Fragile Families and Child Wellbeing Study (US), FSM Free School Meals, GIS Geographic Information System (UK), GUI Growing Up in Ireland (Ireland), GUS Growing up in Scotland (UK), Hgt height, HSE Health Survey for England (UK), IDACI Income Deprivation affecting Children Index (UK), IMD Index of Multiple Deprivation (UK), IOTF International Obesity Task Force, LEA Local Education Authority (UK), MCS Millennium Cohort Study (UK), NCMP National Child Measurement Programme (UK), NS-SEC National Statistics Socioeconomic Class index (UK), NSPD National Statistics Postcode Directory (UK), OB Obese, OECD Organisation for Economic Co-operation and Development, ONS Office for National Statistics (UK), OW Overweight, PCG Primary Care Giver, SD Standard Deviation, SEP Socioeconomic position, SIMD Scottish Index of Multiple Deprivation (UK), SLS Scottish Longitudinal Study (UK), TV Television, Wgt weight
| Study | Mediated relationship (direction of the association) | Method used to Assess Mediation [name of model used] | Mediation Results* |
|-------|----------------------------------------------------|----------------------------------------------------|--------------------|
| Cetateanu & Jones [46] | Association btw deprivation and (a) OB (+) and (b) OW/OB (+) for: (1) 4–5 year olds (-) (2) 10–11 year olds (-) | Preacher and Hayes indirect effect method | (1) No mediating effect in the 4–5 year old group (2) For the older cohort, availability of fast food outlets and other types of unhealthy food outlets partially mediated the association btw deprivation and OB and OW/OB by between 1 and 2%. No mediation was found for the availability of mixed food outlets |
| Goisis et al. [39] | Association btw family income and risk of: (1) OB at age 5 (-) (2) OW at age 11 (-) (3) OB at age 11 (0) (4) Upward movement across weight categories from age 5 to age 11 (–) | Assessment of attenuation/reduction of regression coefficients upon inclusion of mediators | (1 and 4) Physical activity, TV use, bedtime, fruit intake, sweet drink intake and maternal BMI skipping breakfast did most to attenuate inequalities. Other factors including maternal smoking during pregnancy, breastfeeding duration and time of weaning also played a role in mediation (2 and 3) Fruit, sweet drink, and breakfast intake did most to attenuate inequalities, with other factors (see 1 and 4) playing a smaller role |
| Goisis et al. [31] | Association btw family income and OW/OB | Logistic regression models | Poorer White children are at higher risk of OW/OB than higher-income White children (RRR 1.13; 95% CI: 1.02 to 1.25). This SEP differential is reversed for children from Black Caribbean/African backgrounds and non-existent for Indian and Pakistani/Bangladeshi backgrounds. In contrast to White children, lower income children from all other ethnic backgrounds are less likely to be OW/OB at age 7 than their more advantaged counterparts |
| Laverty et al. [40] | Association btw household income group and occupational social class with: (1) BMI (2) % BF | Longitudinal (panel) regression models | (1) Switching to active travel was associated with a −0.32 kg/m² BMI (95% CI −0.58 to −0.06) among those in the lowest household income group compared with a −0.11 kg/m² among the highest group (−0.24 to 0.03) (2) Switching to active travel was associated with a −0.71% BF (95% CI −1.47% to 0.05%) among the lowest household income group compared with a −0.55% BF (−1.01 to −0.09%) among those in the highest income group |
| Layte et al. [17] | Association btw social class (baseline professional class) and: (1) rapid growth from birth to 9 months (2) rapid grow from 9 months to 3 years (3) rapid OB at 3 years | Assessment of attenuation/reduction of regression coefficients upon inclusion of mediators | (1) Breastfeeding and age at weaning most important for non-manual class. Antenatal smoking and alcohol consumption most important for manual and unclassified classes. The model with all mediators reduced coefficients by an average of 76% (2) Child diet, TV viewing and maternal BMI led to highest reductions in all classes. Lower maternal BMI and lower levels of TV viewing mediated lower odds of rapid weight gain (3) Child diet, TV viewing and maternal BMI led to highest reductions in coefficients in all classes. All mediator groups had some contribution |
| Study | Mediated relationship (direction of the association) | Method used to Assess Mediation [name of model used] | Mediation Results* |
|-------|----------------------------------------------------|--------------------------------------------------|-------------------|
| Lu et al. [43] | (1) Association btw poverty and higher BMI in children (2) Association btw maternal education and higher BMI in children | Mixed-effects fractional polynomial and multinomial regression modelling | (1) Poverty was associated with higher BMI in children of White and South Asian origins, widening with age to 0.75 kg/m² (95% CI, 0.59–0.91) and 0.77 kg/m² (0.26–1.27) at 14 years for the White and South Asian groups, respectively. A reverse income-BMI association in children of Black (African-Caribbean) origin was found with the poverty group having a lower BMI (−0.37 kg/m² [−0.71 to -0.04]) at 5 years and −0.95 kg/m² [−1.79 to −0.11] at 14 years (2) Similar patterns (see (1)) presented with maternal education and obesity at 14 years |
| Martinson et al. [37] | Association btw SEP and child OW | Multivariate logistic regression models | Low SEP children with non-White native- and foreign-born mothers are at lower risk of OW. Low SEP children with white immigrant mothers are at an increased risk of OW |
| Massion et al. [25] | Association btw maternal education and childhood OW at age 11 | Assessment of attenuation/reduction of RR on inclusion of mediators (Barron and Kenny) | Early life risk factors (maternal pre-pregnancy OW, maternal smoking during pregnancy) reduced the RR from 1.72 (95% CI 1.48 to 2.01) to 1.47 (1.26–1.71) |
| Mireku & Rodriguez [45] | Association btw deprivation and (a) OW, OB and (b) %BF | Linear regression models and log-binomial models | When stratified by geographic-level deprivation, the family income gradient in the risk of OB for moderately affluent (2nd, 3rd or 4th quintile deprivation) neighbourhoods was non-significant. However, family income gradient in the risk of OW/ OB persisted for the most (RR 5.5 (95% CI 1.0–17.2, p < 0.05) and least (2.4 (1.0–5.8, p < 0.05) deprived quintiles of geographic-level deprivation |
| Noonan et al. [41] | Association btw area deprivation and child BMI and waist circumference | Linear regression analyses | A significant inverse association was seen between neighbourhood aesthetics and high deprivation group’s BMI ($\beta = -0.29$, $p < 0.01$) and waist circumferences ($\beta = -0.27$, $p < 0.01$) |
| Noonan [28] | Association btw poverty and childhood OW/OB | Adjusted logistic and multinomial logistic regression analyses | Adolescents living in poverty compared to those not living in poverty reported more frequent consumption of sweetened drinks and fast food, and less frequent consumption of fruits and vegetables (OR = 1.92–3.61; $p < 0.001$). Difference in weight status and dietary intake outcomes for girls in poverty were greater (OR = 1.55–3.62; $p < 0.001$) compared to boys (OR = 1.39–3.60; $p < 0.001$) |
| Noonan & Fairclough [30] | (1) Association btw individual-level SEP (maternal education) and childhood OW/OB (2) Association btw area-level SEP and childhood OW/OB | Adjusted linear and multinomial logistic regression analysis | Individual-level and area-level SEP were independently related to OW/OB. Higher rates of OW/OB among deprived children were not due to physical inactivity |
| Study                        | Mediated relationship (direction of the association)                                                                 | Method used to Assess Mediation [name of model used] | Mediation Results*                                                                 |
|------------------------------|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|----------------------------------------------------------------------------------|
| Oude Groeniger et al. [27]   | Association between maternal education and childhood OB                                                              | Causal mediation analysis                            | At age 14, between 13 and 18% of relative inequalities in childhood OB were reduced if maternal education differences in screen media exposure at age 7 and 11 were eliminated |
| Parkes et al. [34]           | Association btw maternal education and child BMI trajectory slope (-)                                               | Path analysis                                        | Indirect effect of SEP via all mediators (0.16) comprised 89% of the total effect of SEP level on BMI outcome. Pathway to BMI slope from maternal education through parenting (informal meal setting) and then unhealthy diet accounted for 68% of the significant indirect pathways. The main indirect pathway involving parenting was via the effect of child bedroom TV, with smaller effects of informal meal setting and less positive mealtime interaction. An effect of unhealthy diet (which in turn affected BMI) which did not got through parenting was also seen |
| Samani-Radia & McCarthy [29] | Association btw geographical location deprivation, family income and childhood OB and % BF                           | Chi-square tests                                     | Children from lower incomes were significantly shorter, heavier and higher % BF, with a higher BMI for their age compared with those from a higher income background. A shorter height-for-age of the lower income group children may contribute to the income group divisions |
| Schalkwijk [38]              | Association btw parental education, family income and childhood OW/OB                                                | Logistic regression models                           | Among low SEP households, lack of garden access and less green space was associated with OW/OB; among higher SEP, poor neighbourhood condition influenced the probability of OW and OB: OR, 95% CI 1.38 (1.12–1.70), 1.38 (1.21–1.70) respectively |
| Silverwood et al. [36]       | Association btw maternal education, area deprivation and weekly household income with OW/OB                           | Traditional (Baron & Kenny) and counterfactual-based mediation analyses (bootstrapping to assess significance) | Higher BW in low SEP is associated with increased inequalities in OW |
| Straatmann et al. [26]       | Association btw maternal education and OW/OB at age 14                                                             | Counterfactual mediation analyses                    | For OW/OB, 19% of the total effect of socioeconomic conditions was mediated through all ACEs investigated |
| Strugnell et al. [44]        | Association btw income deprivation and childhood OW/OB (1) 4–5 year olds; (2) 10–11 year olds                       | Multivariable logistic regression models             | For OW/OB, 19% of the total effect of socioeconomic conditions was mediated through all ACEs investigated (1 and 2) Ethnicity has an independent influence on OW/OB for both groups (4–5 and 10–11 year olds), with the distribution between most and least advantaged widening for most ethnic groups between ages 4–5 and 10–11 years. (2) For the 10–11 year olds, SEP differentials were found to differ by sex and by ethnicity with the largest disparity reported for White children, and the smallest seen in Black African children. Comparing boys in the least deprived and most deprived groups, the difference was 12% among White British boys and 18% for Any Other White Backgrounds, compared with 11% for Indian boys, 5% for Pakistani boys and 2% for Black African boys |
| Study                        | Mediated relationship (direction of the association)                                                                 | Method used to Assess Mediation [name of model used]                                                                 | Mediation Results*                                                                 |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Stuart & Panico [35]         | Association btw parental income, parental education and a persistent poverty indicator with (1) OW (2) OB             | Multinomial logistic regression models                                                                               | High BW (RRR: 2.16, \( p < 0.05 \)), not being breastfed (RRR: 1.33, \( p < 0.05 \)) and mother smoking during pregnancy (RRR: 1.96, \( p < 0.001 \)) mediated some educational gradient (but not income gradient) between the OB and normal weight group. SEP does not uniformly impact BMI trajectories, and different indicators of disadvantage capture different trajectories. For SEP inequalities, the OW group was mostly characterized by low parental income, whereas the OB group was mostly characterized by low parental education. |
| Townsend et al. [32]         | Association btw area deprivation and BMI                                                                                | Cross-classified multilevel regression models                                                                      | Longer time spent in school with a high percentage of children receiving FSM (poorer schools) affected the association found between BMI and low SEP. Deprivation explains a greater proportion of the variance in BMI for older compared with younger children, perhaps reflecting the impact of deprivation as children age, highlighting the widening of health inequalities through childhood. |
| Walsh & Cullinan [42]        | (1) Association btw household income and childhood OB and OW/OB (2) Inequality in OW/OB (based on concentration indices) | Prediction of inequality gradient using regression                                                                  | Parental occupation and education contributed to OB (41.16%) and OW/OB (44.18%) inequalities; parental health (maternal BMI and maternal smoking during pregnancy) contributed OB (3.7%) and OW/OB (84.1%) inequalities. Child variables had a low impact on observed inequalities—mainly via TV viewings and bedroom TV. |
| Wijaars et al. [33]          | (1) Association btw parental occupation (NS-SEC Index) and 3-month weight (-), weight gain btw birth and 3 months (-) and rapid weight gain (-) (2) Association btw maternal education and 3-month weight (-), weight gain between birth and 3 months (-) and rapid weight gain (-) | Assessment of attenuation/reduction of regression coefficients upon inclusion of mediators (bootstrapping to assess significance) | (1) Breastfeeding duration attenuated the association btw parental occupation and 3-month weight by 66%; weight gain by 62%; and odds of rapid growth by 53% (2) Breastfeeding duration attenuated the association btw maternal education and 3-month weight by 88%; weight gain by 82% and odds of rapid growth by 64%. No mediating effect was found for smoking during pregnancy, maternal and paternal BMI. |

Abbreviations: ACE Adverse Childhood Event, BF Body fat, BMI Body Mass Index, BW Birthweight, Btw between, CI Confidence Interval, FSM Free school meals, NS-SEC Index National Statistics Socioeconomic Class index (UK), OB Obesity, OR Odds Ratio, OW Overweight, RR Relative Risk, RRR Relative Risk Ratio, SEP Socioeconomic position, TV Television
A relatively low impact for child-level variables (including media use, bedroom TV, and fizzy drink consumption) was found [42]. For UK children and preteens (aged five and 11), childhood physical activity and diet were reported to be important in explaining the differentials in OW/OB outcomes [39]. For UK adolescents, dietary intake mediated the association found between SEP and OW/OB, particularly for girls [28].

Ethnicity also mediated the association, with White children from poor backgrounds shown to be at greater risk of OW/OB than White children from wealthier families. This effect was reversed for Black African/Caribbean children and was non-existent for children of Indian and Pakistani/Bangladeshi origin [31]. Within this, early life factors (including maternal smoking during pregnancy and duration of breastfeeding) and maternal health behaviours (including BMI, breastfeeding-eating habits, and level of physical activity) explained differences in the White ethnic group but had no effect on the Black Caribbean and African groups [31].

**Mediators of the association between NS-SEC- UK/Ireland and adiposity**

Using national statistics as SEP indicators, for studies in Ireland, the relationship was mediated by early childhood factors: maternal and antenatal lifestyle behaviours and screen time. Child diet and screen time had a greater effect than either early nutrition or maternal prenatal behaviours [17]. In the UK, the association remained significant after including early life factors (smoking during pregnancy) and parental BMI in the models and was attenuated by 68% when breastfeeding was included [33].

**Mediators of the association between school-level deprivation and adiposity**

One study defined SEP using school-level and neighborhood characteristics. Here, the association was found to be mediated by child height, with a shorter height-for-age of the ‘lower income’ group children contributing to the income group differentials. It should be noted that this study was “restricted to Caucasian children” [29].

**Mediators of the association between multiple socioeconomic markers and adiposity**

Trajectories of BMI varied by ethnicity, with poorer White children heavier than their non-poor peers, and the reverse seen for children of Black African-Caribbean origin: the poverty group had a lower mean BMI than the non-poor group [43]. Furthermore, low SEP children of non-White native and foreign-born mothers were found to be at lower risk of OW compared to children of White mothers. Children born to White immigrant mothers were associated with an increase in the risk of OW [37].

Lack of garden access and less green space increased the risk of OW/OB in lower educated households, while poor neighborhood conditions among higher educated households increased the probability of OW and OB [38]. It is of note that recommended physical activity levels were achieved by the low SEP group, suggesting that higher rates of OW and central OB among deprived children are not due to physical inactivity [30].
Switching to active travel had a greater reduction in both BMI and percentage body fat for those in the lowest household income group compared with those in the highest income group. Similarly, switching to active travel was associated with a greater reduction in lower body fat among those in the economically inactive NS-SEC group, compared with those in the managerial/professional NS-SEC group [40].

While higher birthweight in the more disadvantaged groups increased the SEP differentials found in OW/OB outcome at age four and a half [36], in the youngest age-group, outcomes differed by definition of SEP. Disadvantaged OW children were mostly characterised by low parental income, while disadvantaged OB children were mostly characterised by parental education. Factors in infancy and pregnancy did not mediate the relationship between lower income and OW, although high birthweight, maternal smoking during pregnancy, and not being breastfed mediated some of the educational differentials [35].

Summary of mediation findings
Table 4 presents studies by SEP indicator and factors examined. Factors assessed in three or more studies, with mediating effects documented in 60–100% of those studies were as follows: early life (seven [17, 25, 31, 33, 36, 39, 42] of nine studies); child diet (five [17, 28, 31, 34, 42] of six studies); parent-level factors (five [31, 33, 34, 41, 42] of six studies); child health behaviours (four [28, 40–42] of six studies); screen time (three [17, 27, 42] of six studies); geography (four [38, 41, 42, 46] of four studies); ethnicity (four [31, 37, 43, 44] of four studies); and household-level factors (three [37, 42, 45] of three studies). For school-level deprivation [32], childhood ACE [26], and child height [29], each was found to have a mediating effect; however, as each was examined in one study only, there is insufficient evidence to draw definitive conclusions.

Assessment of study quality
A critical appraisal of each journal article was completed by researchers working independently in pairs. Disagreements were resolved by discussion. An adapted version of the Liverpool Quality Assessment Tool [23] and the Effective Public Health Practice Project Quality Assessment Tool [24] were used to measure study quality. In looking at baseline assessment, all \( n = 23 \) studies were rated as having valid data collection tools, while 14 papers [17, 25, 26, 28, 30, 32, 34, 39–45] were considered strong for participant study completion (60–100%). Nine papers reported dropouts [17, 31, 32, 39–43, 46]. When analysing confounders, 13 studies [17, 25, 27, 28, 30–33, 38, 40, 42, 43, 46] had controlled for most, or some confounders. For all included studies, statistical methods were rated as appropriate for the study design. After several rounds of screening, all papers were scored highly for quality impact and considered applicable to the review. Overall scoring rated 10 studies of strong quality [25–27, 32, 34, 35, 38, 40, 42, 46], 12 of moderate quality [17, 28–31, 33, 36, 37, 39, 41, 43, 45], and one study of weak quality [44]. Table 2 reports the overall scoring for each individual study.

Discussion
This review summarises research completed in Ireland and the UK in the last ten years, examining factors that mediate or attenuate SEP differentials in adiposity for children aged 18 and younger. Factors were examined according to definitions of SEP, and studies were appraised for study quality. A number of statistical methods were used in the studies, with some referencing specific strategies for assessing and comparing mediator models [56, 57]. Most studies used regression modelling. Some models reported results for aggregated mediating factors, making it impossible to assess the effect of individual factors in isolation. A critical appraisal of each journal article found the majority (22/23) to be of strong or moderate quality, and all included studies were applicable to the review question.

In Ireland and the UK, SEP differentials are evident from as early as three and nine months of age respectively [17, 33], are seen to persist during childhood, and to widen during adolescence [43]. There is a more pronounced differential reported at age 11 compared to age five [39], particularly when considered by ethnic group [31, 43, 44]. For the younger age groups, factors outside the home have less of an effect; for example, the availability of fast food, and other unhealthy foods outlets, did not mediate for younger children, but were found to mediate the SEP differential at age 10–11 years [46]. Place-based factors, such as safe environments and neighbourhoods were shown to be beneficial and were associated with increased rates of child physical activity, including active travel to school. Furthermore, the duration of time that children and young people spend in more deprived neighbourhoods and schools is associated with more harmful outcomes [32, 38, 40, 41, 45].

This review highlights that for some ethnic minority children, there are differences in the pattern of SEP differentials in adiposity outcome. The risk of OB or OW associated with low SEP is higher for White children compared to all “other ethnic backgrounds” [31]. A widening of the SEP differential in early childhood was evident when examined by most ethnic groups [31, 43, 44]; however, one study reported a negative association between BMI and SEP for children of Black origin [43]. Low SEP children with non-White native-
foreign-born mothers were found to be at lower risk of OW compared with low SEP children of White immigrant mothers [37]. Additionally, early life factors (including smoking during pregnancy and duration of breastfeeding) explained differences in the White group, but had no effect on the Black, Caribbean, and African groups [31]. The role of ethnicity in the association between SEP and childhood OW/OB outcome was not considered in either of the Ireland-based studies included in this review; it was only considered in UK-based
research. This is of note as, according to the 2016 census, Ireland's population had doubled since 1950, and one in ten of the population had been born outside Ireland. The census reported an increase in the proportion of Irish nationals identifying as other than 'White Irish,' suggesting that research into what role ethnicity might play in the SEP/adiposity association would be beneficial when addressing this issue within the Irish context.

As with previous systematic reviews, this review found that early life factors were consistently identified as mediators in the SEP differentials in adiposity outcome. From three months through to 11 years of age, clear effects were seen for early life risk factors including maternal pre-pregnancy OW, breastfeeding duration, time of weaning, high birthweight, antenatal smoking, and alcohol consumption during pregnancy [17, 25, 31, 33, 35, 42]. One exception was found in a study employing family income as the SEP indicator; yet this same study repeated the analysis using education level as an SEP indicator and found early life factors (including high birthweight, maternal smoking during pregnancy, and not being breastfed) mediated the SEP differential [35]. This highlights the need for careful consideration of the measurement of SEP employed in the study design, and perhaps supports the use of multiple measures of SEP within a study.

A novel finding was the contribution of neighbourhood aesthetics and geographic-level deprivation to the SEP differentials for adiposity outcome. Furthermore, when SEP differentials (defined by family income) were examined by geographical-level deprivation, a u-shape association was seen with the family income effect dissipating for the moderately affluent areas but persisting for the most and least affluent areas. This suggests that moderately affluent areas may have ease of access to community amenities, while lower income families living in more affluent areas may be denied access to amenities by virtue of lack of public amenities or amenities being private or fee-based [45]. At age seven, higher BMI outcome for low SEP children in neighbourhoods with positive aesthetics were mediated by higher levels of physical activity, while evidence was found to indicate that individual-level and area-level SEP were independently related to adiposity outcomes. Surprisingly, in neighbourhoods with high aesthetics scores, higher physical activity reduced the SEP differential, suggesting that for this age, higher rates of OW and OB in the lower SEP group was not driven by physical inactivity [30, 41].

However, in comparison with early life factors, environment and ethnicity, the effect of child- and parent-level factors were less clear. Relatively few studies examined these factors in isolation. Child diet (including fruit intake, skipping breakfast, and sugar drink intake) and TV viewing contributed most to SEP differentials in younger children [17, 31, 34]. For children aged 14, the amount of screen time had the greatest effect on SEP differentials in OB outcome. While some studies reported high reductions in the SEP differentials when diet was considered [17, 34], others found less of an effect, reporting stronger effects for parent-level factors, such as allowing bedroom TV [42]. Indeed, some argued child diet should be considered an indirect effect of parenting [27].

As expected, the magnitude of an effect in the selected papers is related to the method used to classify adiposity (i.e. BMI, OW or OB). For instance, smoking during pregnancy, length of breastfeeding, and time of weaning are reported as having the greatest effect on the SEP association with OB, compared with OW [39]. In addition, different measures of disadvantage were found to capture different outcomes and were not interchangeable [42]. For example, high birthweight and maternal smoking in pregnancy mediated SEP differentials when SEP was measured using education, but not when using income [35]. This highlights that within this field, different measures of, and proxies for, adiposity (e.g. BMI, OB, OW) and SEP (e.g. level of maternal education, family income etc.) must be carefully considered when planning research and interpreting outcomes.

**Strengths and limitations**

Previous research has shown that as a measure of SEP, level of maternal education is used most often in childhood OB literature and is considered to be more stable than other measures throughout the child's upbringing [58, 59]. Notably, with increasing diversity in both Irish and UK populations, how maternal education is categorised must be considered, particularly in well-established datasets, such as the MCS and GUI. As an example, three of the four studies included in this review use the MCS categories of maternal education as an indicator of SEP. However, the MCS may miscategorise as many as 3% of the total sample or up to 10% of ethnic minority groups by providing an 'overseas qualification only' category which has no corresponding UK (or ISCED) education category [31]. It is therefore imperative that as new, more recent sweeps of important longitudinal datasets such as the MCS and GUI are interrogated, the measure of maternal education be adjusted for ethnicity. It is of note that Ireland has yet to publish research examining SEP differentials in terms of ethnicity, despite the ethnic composition of Ireland changing substantially in recent decades.

A strength of this review is that all studies used objectively measured child weight and height measurements. The majority (20/23 measurement points) were obtained using trained researchers and the balance using health
professionals (n = 2) and school records (n = 1). Objective anthropometric measures protect against the divergence seen between clinical and parental measures, particularly at the extremes of the weight spectrum (with parents less likely to classify children as over-, or under-weight) [60, 61]. However, this objectivity did not extend to measurements of mediating factors (including diet and levels of physical activity) and indicators of SEP. The majority of studies (19/23) relied on questionnaires or interviews for data collection, which risks error due to participant embarrassment or recall bias.

One limitation to the study is the over-representation of certain datasets in each country: the Millennium Cohort Study is the source for 13/21 (62%) studies in the UK, while the Growing Up in Ireland dataset is the source for both studies (100%) based in Ireland. While both the Millennium Cohort Study and the Growing Up in Ireland study are very robust data sources that are well validated and representative of their respective population, the over-reliance on these datasets in examining childhood outcomes for both the UK and Ireland should be considered.

Finally, this review was designed to examine studies of children up to the age of 18 years. Despite the search terms, of the 23 studies in the review, the oldest children featured were aged 14 years. This lack of studies for the older adolescent cohort identifies a clear gap in the literature and prevents examination of the reach or progression of the effect of mediators. Targeting this shortfall is needed to fully inform future intervention strategies to address the SEP differentials in adiposity outcomes.

Conclusion
Understanding what factors mediate the association between low SEP and adiposity is vital when planning interventions and considering policy development. This review identified several modifiable factors that confirm research undertaken in other OECD countries. Early life exposures, parenting practices, and school-level deprivation have been confirmed to be significantly associated with differences in adiposity outcomes. In addition, our review of the research for Ireland and the UK highlighted an important role for place-based factors (including neighbourhood safety and aesthetic characteristics). In keeping with previous OECD-wide reviews [19], our results are equivocal about the role of physical activity in the risk of OW and OB. This would suggest that more studies, ideally employing objective measures of activity, would be beneficial to further investigate this outcome.

Overall, our findings support many longitudinal studies showing the efficacy of targeted, early intervention programmes aimed at disadvantaged children and their families. Interventions designed to help mothers engage in beneficial health behaviours (e.g. maintaining a healthy weight, reducing smoking and/or drinking during pregnancy, increase rates and duration of breastfeeding), can improve outcomes for the child, mother and family, and can potentially address future risk of childhood OW and OB [25, 36, 62]. Indeed, the widening of SEP differentials seen as the child matures reinforces the need for these early, preventative interventions.

This review is particularly timely considering the dramatic widening of the deprivation gap evident in England’s National Child Measurement Programme of 2021. Since 2020, the SEP differential has almost doubled. Currently over 20% of five year old children living in the most deprived areas have OB, compared with under 8% of their more affluent peers [63]. In light of these figures, the relative paucity of research undertaken in Ireland and the UK examining mediators of SEP differentials for OB outcomes must be addressed urgently. Our findings suggest that while multi-country analyses provide an excellent overview, country- or area-specific research may produce more nuanced findings, which may better inform the development of policy responses and interventions.

Supplementary Information
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Additional file 1.

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Authors’ contributions
FC DS and SH conceived the systematic review. All authors screened studies and conducted data extraction and quality appraisal. FC prepared the manuscript. All authors reviewed and approved the final version of this manuscript.

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Availability of data and materials
The dataset generated and/or analysed in this review can be accessed by replicating the search criteria outlined in Appendix 1 within the following databases: Ovid MEDLINE, Embase, Web of Science and EBSCOhost. Search results are also available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.
Competing interests
The authors declare that they have no competing interests.

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