Parent-related mechanisms underlying the social gradient of childhood overweight and obesity: A systematic review

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Abstract

Background Low socioeconomic status (SES) is a significant risk factor for childhood overweight and obesity (COWOB) in high income countries. Parents to young children buffer and accentuate social and cultural influences, and are central to the development of this disease. An understanding of the parent-related mechanisms that underlie the SES - COWOB relationship is needed to improve the efficacy of prevention and intervention efforts.

Objective A systematic review of relevant literature was conducted to investigate the mechanisms by which levels of SES (low, middle and high) are associated to COWOB, by exploring mediation and interaction effects.

Method Six electronic databases were searched yielding 5155 initial records, once duplicates were removed. Studies were included if they investigated COWOB, SES, parent-related factors, and the multivariate relationship between these factors. Thirty studies were included. Factors found to be mediating the SES-COWOB relationship or interacting with SES to influence COWOB were categorised according to an ecological systems framework, at child-, parent-, household- and social-system level factors.

Results High parent BMI, ethnicity, child-care attendance, high TV time (mother and child), breastfeeding (early weening), food intake behaviours and low birth weight potentially mediate the relationship between SES and COWOB. Different risk factors for COWOB in different SES groups were found. For low SES families, parental obesity and maternal depressive symptoms were strong risk factors for COWOB; whereas long maternal working hours and a permissive parenting style were risk factors for higher SES families. None of the studies investigated parental psychological attributes such as attitudes, beliefs, self-esteem, etc. as potential mechanisms/risk factors.

Conclusions Families from different SES groups have different risk and protective factors for COWOB. Prevention and intervention efforts may have improved efficacy if they are tailored to address specific risk factors within SES.

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Childhood overweight and obesity (COWOB) has reached epidemic proportions around the world (World Health Organization, 2013). Attempts to reduce COWOB have ranged from individual interventions (e.g., behavioural counselling) (Campbell & Hesketh, 2007) to public policies (e.g., environmental changes within schools) (Bleich et al., 2013). However, these programs have had only moderate success in reducing rates (Bleich et al., 2013; Campbell & Hesketh, 2007). Lack of success could be due to a narrowed focus on factors identified through cross-sectional bivariate studies exploring the disease and its risk factors (Boonpleng et al., 2013; Cockrell & Foster, 2013; Davison & Birch, 2001). A broader approach exploring the multiple pathways towards the development of COWOB might better inform tailored interventions (Brown et al., 2010; Cockrell & Foster, 2013) and subsequently improve their efficacy.

One of the most commonly identified factors associated with COWOB, and indeed many other health problems, is socioeconomic status (SES) (Shrewsbury & Wardle, 2008; Sobal & Stunkard, 1989); consequently, many researchers control for SES rather than examine it (Adler et al., 1994). SES can be considered to reflect the context in which a child lives; it represents their social standing, ability to participate in society and access to material and social resources (American Psychological Association, 2013; Australian Bureau of Statistics, 2006). However, the mechanisms through which SES has its influence on child weight are still unclear (Shrewsbury & Wardle, 2008; Sobal & Stunkard, 1989).

In 1989, Sobal and Stunkard published findings of their review of 144 studies exploring the relationship between SES and overweight and obesity in adults and children; the studies were published between 1933 and 1982. Approximately equal numbers of studies found a negative association between SES and COWOB for girls (40%; n=13) and boys (32%; n=11). They concluded that the relationship in high income countries is complex and required further exploration (Sobal & Stunkard, 1989). Shrewsbury and Wardle conducted a subsequent review of 45 cross-sectional

studies published between 1990 and 2005 in high income countries only (Shrewsbury & Wardle, 2008). Forty-two percent of studies ($n = 19$) reported a negative association between SES and COWOB. Shrewsbury and Wardle recommended further research to “understand the mechanism by which parental education and other indicators of SES independently and collectively influence [child feeding and physical activity]” (Shrewsbury & Wardle, 2008, p. 282). Zarnowiecki, Dollman and Parletta (2014) conducted a systematic review of the associations between predictors of children’s dietary intake and SES. Predictors of children’s dietary intake were found to vary among different SES groups (Zarnowiecki et al., 2014). Given that weight status in pre-adolescence (up to approximately 8-years-old) is a reliable predictor of weight status in adolescence and adulthood (Guo et al., 2002; Whitaker et al., 1997) identification and modification of factors influencing early childhood weight gain (i.e., in children to eight years of age) may have the greatest impact in reducing overweight.

Bronfenbrenner’s Ecological Systems Theory (EST) (Bronfenbrenner, 1979) is useful to conceptualise the factors that may mediate the relationship between SES and COWOB, or interact with SES to influence COWOB. The theory situates the child at the centre of nested ecological systems, where bi-directional interactions occur between systems, and changes in one system can directly or indirectly affect child outcomes (Bronfenbrenner, 1979). Four systems are proposed based on research purporting that families/parents buffer and accentuate social and cultural influences, and are central to the development of COWOB (Davison et al., 2012). These systems are: the child-system (the immediate factors that contribute to child weight status), the parent- system (factors related to the important role of parents as the child’s primary socialising agent), the household- system (factors that represent the climate within which parent-child interactions take place, e.g. migrant-status) and the social-system (SES), collectively referred to as socio-ecological factors. The bi-directional interactions that occur between systems indicate that all systems are important but the parent system is of greatest interest because of its potential to enact change.

The overall aim of the present systematic review was to explore the parent-related mechanisms by which categories of SES (low, middle and high) are associated with COWOB in children to age 8 years, and to frame this within EST (i.e., to include available child, household and social system factors within this literature). To our knowledge, no previous systematic review has focused on identifying and understanding the associations between COWOB and SES category. The scope of the review is limited to multifactorial **analyses** (both cross-sectional and prospective designs) in order to explore possible mediation and interaction effects of the relationship between SES categories and COWOB. Where there was evidence to support directionality (**i.e., that SES influenced the association between COWOB and other factors or that other factors influenced the association between COWOB and SES**), the term moderation was tentatively used to describe the finding.

The research questions that informed this systematic review were:

1. What do studies reveal about potential mediators of the relationship between SES and COWOB?
2. What do studies reveal about the factors that interact with SES to influence COWOB?
3. What are the relative strengths and limitations of studies designed to understand the effect of SES on COWOB and what recommendations can be made for future research?

Method

Six electronic databases were searched: Psycinfo, Medline, CINAHL, Academic Search Complete, Scopus and Web of Knowledge. A lateral search of reference lists of included papers was also undertaken.

Search Strategy

The search was conducted in February 2016, with no restrictions on the publication date for articles. The search terms included word variations of three key research areas: parental/parenting factors, SES and CWOB. Search strings were created by combining related terms (in the columns) using OR, and connecting concepts using AND (see Table 1). Where available, subject heading terms were included in the search strings, however not all databases contained this option.

Inclusion criteria

Figure 1 illustrates the search strategy, inclusion and exclusion criteria at each step and number of studies included. In brief, the inclusion criteria required that studies involved children 0-8 years and from high income countries (as established by the International Monetary Fund classification system) (International Monetary Fund, 2013; Nielsen, 2011). These studies must have investigated CWOB, SES, parent-related/socio-ecological factors, and the multivariate relationship between these factors. To acknowledge the bidirectional influences of social, household, child and parenting/parental factors on CWOB, factors reflecting all four socio-ecological levels reported within the included studies are also summarised in this paper. However it was not the purpose of this paper to provide a comprehensive review of the child, household and social system factors. A total of 28 studies from the initial search and two studies from a lateral search were included in the review (with a total of 30), and 5127 studies were excluded. The earliest included study was published in 2003. The socio-ecological factors were assigned to the four systems according to the definitions stated earlier and where there was uncertainty surrounding the allocation to a system, assignment was discussed by PM and MH to reach consensus.

Quality assessment of scientific evidence

In accordance with the PRISMA guidelines (Moher et al., 2009), each of the studies that met the inclusion criteria was subjected to a critical evaluation process which assessed the quality of the

evidence and risk of bias. A scoring system adapted from Cohen et al.'s (Cohen et al., 2013) review was used to assess bias, as determined by sample size, response rate, characteristics of the study population, and methodology (measurement, statistical analyses and interpretation methods). A detailed explanation of the scoring system and allocation of points can be found in the supplement table 1. The highest possible score was eight. In addition to this, an assessment of mediation was conducted. Determining mediation can be a challenging task as the researcher must infer mediation from observations using theoretical reasoning and/or empirical and statistical data (MacKinnon et al., 2007). In order to assess the confidence of this inference, mediation was assessed according to Baron and Kenny's (1986) "causal steps approach". Studies were scored against the four criteria: 1) A significant relation of the independent variable (IV) to the dependent variable (DV) is required; 2) A significant relation of the IV to the hypothesised mediator variable (MV) is required; 3) The MV must be significantly related to the DV when both the IV and MV are predictors of the DV, 4) The coefficient relating the IV to the DV must be larger (in absolute value) than the coefficient relating the IV to the DV in the regression model with both the IV and MV in it. Each criteria was appointed a score of 0 if the information was not reported at all, 0.5 if the information was reported but without numerical evidence or 1 if all information was reported. Hypothesised MVs with scores of 3-4 were taken to represent strong evidence of a mediation effect, MVs with scores of 2-3 were considered to represent moderate evidence of a mediation effect and MVs with scores of less than 2 represent weak evidence.

Results

Table 2 summarises information about each study, including the sample demographics, sample size, study design and measures. The 30 included studies were conducted in North America ($n = 14$), Europe ($n = 10$), Australia ($n = 4$), and Asia ($n = 1$), including one study with samples from both North America and Europe. The studies were a mixture of cross-sectional ($n = 15$), longitudinal

($n = 12$), and mixed designs ($n = 3$). The assessment of study quality suggested low risk of bias in all studies and so all studies were included in the review (see Supplementary Table 1).

Child weight status was classified according to the International Obesity Taskforce (IOTF)(Cole et al., 2000) standards, US Centres for Disease Control (CDC)(Centers for Disease Control Prevention) standards, and non-standardised country-specific BMI-for-age reference charts; two studies reported both IOTF and CDC standards and one did not report the classification system. Maternal education was the most commonly used proxy measure for SES ($n=19$), followed by household income ($n=16$), composite score ($n=3$) and occupational prestige ($n= 2$); with some studies exploring multiple proxies within their studies. Twenty studies were assessed for mediation effects, their scores are reported in tables 3 and 4.

Child-system factors. Table 3 presents the fourteen studies that explored child-system factors; children's birth weight, TV watching, eating behaviours and breastfeeding in relation to their influences on the SES-COWOB relationship. Low birth weight was investigated in 10 studies; seven studies reported evidence of varying strengths to suggest low birth weight as a mediator of the SES-COWOB relationship (Balistreri & Van Hook, 2011; Cho et al., 2009; Demment, 2014; Gibbs & Forste, 2014; Klebanov et al., 2014; Layte et al., 2014; Strauss & Knight, 1999) while three studies reported findings with varying strengths of evidence for no mediation (Beyerlein, 2010; Gopinath, 2012; Jansen et al., 2013). TV viewing was investigated in five studies and while evidence of a mediation effect was found in all five studies, the quality of the mediation analyses were weak (Beyerlein, 2010; Cho et al., 2009; Dubois, M., 2006; Ebenegger et al., 2011; Moraes, 2012; Veldhuis et al., 2013). The mediating influence of children's eating behaviours were also unclear as two studies reported strong evidence to suggest breakfast omission had a mediating influence (Moraes, 2012; Veldhuis et al., 2013), while another two studies reported insufficient information to determine whether mediation had occurred or not (Dubois et al., 2006; Ebenegger et al., 2011)). Finally, breastfeeding (early weening) was investigated in three studies and all found support for a

mediation effect; two reported strong evidence (Gibbs & Forste, 2014; Layte et al., 2014), while the third contained weak evidence (Beyerlein, 2010).

In addition to mediation effects, one study explored possible interaction effects involving child sex, SES and COWOB (Balistreri & Van Hook, 2011). Child sex moderated the relationship between SES and child weight trajectories. Both low levels of parental education and baseline income were predictors of preschool girls being 'always overweight' or 'gradual overweight' (i.e., gradual increase in weight) (Balistreri & Van Hook, 2011). In preschool boys, parental education was the only predictor of gradual increase in weight, but both parental education and baseline income were weak predictors of 'always overweight' (Balistreri & Van Hook, 2011).

Parent-system factors. The fourteen studies that explored parent-system factors are presented within Table 4. There was evidence to suggest that parent weight status and maternal TV viewing potentially mediate the SES-COWOB relationship, ambivalent evidence for mother's age, and there was evidence to suggest that smoking during pregnancy and currently, feeding styles, depressive symptoms and alcohol consumption do not mediate the SES COWOB relationship. Results involving high parent weight status strongly supported it as a mediator of the SES-COWOB relationship (Bingham, 2013; Demment, 2014; Dubois et al., 2005; Gibbs & Forste, 2014; Hancock, 2014; Jansen et al., 2013; Layte et al., 2014; Moraeus, 2012; Veldhuis et al., 2013; Waters et al., 2014). Only one study reported results that potentially reject parent weight status as a mediator (Dubois & Girard, 2006). High duration of maternal TV viewing was investigated in one study and had moderate evidence to suggest it was a mediator also (Veldhuis et al., 2013). There was contradictory evidence for the influence of mother's age as one study indicated potential mediation (Gibbs & Forste, 2014) whilst another rejected this (Layte et al., 2014). Smoking during pregnancy was investigated in three studies; there was weak evidence to suggest smoking during pregnancy mediated the SES-COWOB relationship (Beyerlein, 2010), with stronger evidence to suggest that it did not mediate the relationship (Dubois & Girard, 2006; Gopinath, 2012). Factors that did not

mediate the SES-COWOB relationship were current maternal smoking (Gibbs & Forste, 2014), parental feeding styles (Wehrly et al., 2014), depressive symptoms (Gibbs & Forste, 2014) and alcohol consumption (Layte et al., 2014); these were all tested in one study each.

Three variables that interacted with SES were identified. In low SES families there was evidence that parental weight status (healthy-weight/obese) (Semmler et al., Ashcroft et al., 2009) and presence of maternal depressive symptoms (Morrissey & Dagher, 2014) were important risk factors. SES appeared to moderate the prospective association between parental weight status and children's BMI (Semmler et al., 2009). Collapsed across SES, children with healthy-weight parents showed similar changes in BMI regardless of SES, and children of obese parents showed a significant increase in BMI over a seven year period compared to children of healthy weight parents. However children of obese parents in low SES families showed significantly greater BMI increase compared to their counterparts in high SES families (Semmler et al., 2009). Having an obese parent was deleterious to the weight of children, particularly in low SES families where maternal depressive symptoms were also found to have greater influence. Maternal depressive symptoms were associated with COWOB in families of low and high SES but longer duration of maternal depressive symptoms accounted for more variance in low SES families than high (Morrissey & Dagher, 2014). Note that these results were found in single high and low quality studies and require replication.

Only one type of factor was identified as being an important risk factor in higher SES families, parenting style. Four studies investigated the interaction between parenting styles, SES and child weight status (Kakinami, 2015; Lane et al., 2013; Rodenburg, 2011; Topham et al., 2010). The odds of children being obese increased over threefold with increasing permissive parenting style in high SES families (Topham et al., 2010). Conversely, permissive parenting tended to protect children in low SES families, but the trend only approached significance (Topham et al., 2010). The SES-dependent relationship between permissive parenting and COWOB was supported with longitudinal data from a second study (Lane et al., 2013), where high income predicted a greater likelihood of

permissive parenting style, and permissive parenting style predicted early and sustained childhood overweight (Lane et al., 2013). There was no difference in child BMI between authoritarian and permissive parenting styles of mothers from low SES (Lane et al., 2013; Topham et al., 2010). Other parenting styles such as authoritarian or negligent parenting were identified as risk factors for children not living in poverty (Kakinami, 2015) but these findings were not supported in a fourth study that investigated authoritative, permissive, authoritarian, rejecting and neglecting parenting styles. A positive association between rejecting parenting and child BMI was found but the relationship was not moderated by parent's education level (Rodenburg, 2011). Taken together, these findings suggest that parenting styles are an important risk factor for CWOB in higher SES families, but further research is needed to clarify the influence of the different styles.

Household-system factors. Nine studies explored the multivariate relationship between household-system factors, SES and CWOB; these included family's ethnicity/migrant-status (terms used interchangeably), single-parent households, parents' employment status and child-care attendance (Gibbs & Forste, 2014)(see Table 4). Eight studies investigated ethnicity with six studies finding moderate-strength evidence to suggest that ethnicity was a mediator of the SES-CWOB relationship (Dubois et al., 2005; Ebenegger et al., 2011; Gibbs & Forste, 2014; Layte et al., 2014; Strauss & Knight, 1999; Waters et al., 2014), whereas two studies reported strong (Klebanov et al., 2014) and weak (Gopinath, 2012) evidence to reject ethnicity as a mediator. Regular child-care attendance was investigated in only one study where there was moderate strength evidence to suggest it was potential mediator of SES (Gibbs & Forste, 2014). The impact of single-parent households and employment status were investigated in three studies (Gibbs & Forste, 2014; Strauss & Knight, 1999; Veldhuis et al., 2013) and one study (Veldhuis et al., 2013) respectively; all studies reported moderate strength evidence to reject a mediation effect occurring.

Ethnicity and maternal work hours were found to interact with SES. African-American and Hispanic children in low SES had lower rates of CWOB than Anglo-Saxon children (Martinson et al.,

2012) which suggests a cultural protective factor. A similar protective trend was found in UK-born children with Hispanic, Asian (Pakistani, Bangladeshi and Indian), Caribbean and African mothers, compared to Anglo-Saxon children. No cultural/ethnic patterns were reported in higher SES families (Martinson et al., 2012). In another study conducted in Hawaii; collapsed across SES, children from Samoan, Native-Hawaiian, Filipino and Hawaiian-Asian mixed were at higher risk of COWOB compared to “white” children, and children of Asian culture were at lower risk (Novotny, Oshiro, & Wilkens, 2013). Lower SES (measured as low education level) increased the odds of COWOB in children of Samoan background but decreased the risk for other ethnic groups (Novotny et al., 2013). Ethnicity was found to interact with SES such that children in low SES families were at risk depending on their ethnic background, whereas maternal employment was found to interact with SES, such that children in high SES families were at greater risk of COWOB. For every 10 hours a mother worked (**per week**), children from high SES families were *more* likely to be overweight than children from low SES families (**Anderson et al., 2003**; Hawkins et al., 2008), suggesting that greater number of working hours was a risk factor for childhood overweight in high SES families only.

Social-system factors. One paper investigated the mediating effect of neighbourhood poverty on the relationship between SES (measured as household income) and COWOB, and found that after two years of age, neighbourhood poverty accounted for a significant proportion of the variation in weight trajectory between poor and non-poor families (Klebanov et al., 2014). However, because neighbourhood poverty was operationalised by the fraction of families with annual incomes under \$10,000 this mitigation would be expected.

Discussion

The systematic review was driven by three research questions and each question is addressed in turn below.

1. What do studies reveal about potential mediators of the relationship between SES and COWOB?

Although SES provides a useful way of representing the nexus of factors that often contribute to poor health and psychosocial outcomes (Adler et al., 1994), it can be tempting to reify SES which distracts attention from the mechanisms that underlie it and are of actual interest (Bradley & Corwyn, 2002). This review identified a number of potential factors that mediate the SES-COWOB relationship. Child's birth weight and parents' weight status received the most empirical attention and support but most other factors were only tested in one or two studies which make it difficult to draw strong conclusions.

Child-system factors potentially mediating the effect of SES on COWOB were high TV time, breastfeeding (early weaning), poor food intake behaviours and low birth weight. Parent-system factors were high TV time, smoking and high weight status, and the household-system factors were non-Anglo-Saxon ethnicity and less child-care attendance. These factors help explain the association between SES and COWOB and direct attention to parental behaviours. No studies explored the influence of parent attitudes, personality, knowledge, values or health behaviours as potential mediators of SES and should be studied as potentially modifiable risk and protective factors in future.

The risk factors of parental sedentary behaviour and overweight suggest children are exposed to an unhealthy home environment which sets children on a trajectory to overweight and obesity. This is consistent with Zarnowiecki et al.'s findings where parents of low SES were less likely to model health eating behaviours (2014). Moreover, the risk factor of low birth weight suggests that this unhealthy environment was in place prenatally, given evidence that low birth weight is associated with several unhealthy behaviours such as smoking and alcohol consumption (Spiegler et al., 2013). An unhealthy early childhood home environment may explain why regular child-care attendance was found to protect infants from COWOB. Pre-school aged children consume more energy dense foods

while outside of child-care centres, than recommended (Robson, 2015), as food provisions and activities are more likely to be monitored by regulatory health bodies (Slining, 2014). Possible explanations for the mediating role of ethnicity are offered in terms of migrant status, level of education, rejection of professional qualifications (i.e., discrimination), language barriers, health literacy and access to resources (i.e., acculturative stress) (El-Sayed et al., 2011). Further investigation into the relationship between SES, ethnicity and COWOB is required. Only one study explored the mediating effects of social-system factors (Klebanov et al., 2014) but the social level factor (neighbourhood poverty) was not independent of their measure of SES (household income).

Risk factors identified at the child-, parent-, and household-system support the development of interventions that target parents/family. Such interventions could be delivered via Maternal and Child Health and Ante-natal classes to improve health knowledge and priorities. Interventions designed to work across multiple levels, such as the INFANT program (Campbell et al., 2008) have potential to be sustainable and effective (Swinburn & Wood, 2013).

2. What do studies reveal about the interaction influences that involve the socio-ecological factors, SES and COWOB?

Six factors were found to interact with SES to influence COWOB. Low household income predicted weight gain in preschool girls but not boys, whereas parental education predicted weight gain in both boys and girls. The moderating effect of child sex on SES-COWOB suggests that there is something about maleness that offers some protection for boys from obesogenic influences in low SES. For example, it is possible that gender-related factors such as high activity levels of boys (Riddoch et al., 2004; Trost et al., 2002) offset some disadvantage associated with low household income for boys, but factors associated with parental education (e.g., health literacy) (Chari et al., 2014) impact boys and girls equally. It is also apparent that factors associated with culture buffer the influence of SES on COWOB. In low SES, children of African-American, Hispanic and Asian

backgrounds were of reduced risk of COWOB compared to children of Samoan and Anglo-Saxon cultures. In poverty-stricken families children were more likely to be overweight if they were Anglo-Saxon than African-American or Hispanic. The mechanisms underlying these cultural influences need further exploration.

In low SES families, parental obesity (Semmler et al., 2009) and maternal depressive symptoms (Morrissey & Dagher, 2014) were strong risk factors for COWOB, and older maternal age was a protective factor. Different factors predicted COWOB in higher SES; these were permissive parenting style (Lane et al., 2013; Topham et al., 2010), and long maternal working hours (Hawkins et al., 2008). Risk factors for middle SES families were not identified. Families of low SES are more likely to be characterised by limited resources and an abundance of chronically stressful conditions (Taylor & Seeman, 1999). For these families, engaging in health promoting behaviours may not be a priority (due to lack of knowledge, lack of time, perceived barriers and/or perceived benefits; competing stressors) and consequently the physical and mental health status of all family members can be negatively influenced (Taylor & Seeman, 1999). Older parents may offset this effect because they are more likely to have financial security and educational attainment (Martin, 1994), and feel more prepared to fulfil the parenting roles required (Barnes et al., 2013). In high SES, a higher level of formal education can inform more effective ways of establishing and maintaining good health. Indeed, the evidence suggests that having higher education can even off-set the well-established risk for COWOB that is associated with having obesogenic parents. However, in spite of their higher levels of education, high SES families are not immune to COWOB. The mechanisms that explain this association have yet to be explored rigorously; this is clearly an area of research that warrants more attention.

3. What are the relative strengths and limitations of studies designed to understand the effect of SES on COWOB and what recommendations can be made for future research?

The major limitation of studies exploring mediation effects were that factors were analysed simultaneously and individual coefficients were not reported, hindering the identification of individual mediators. Furthermore, the parent subsystem was understudied, especially the psychological attributes of parents that might mediate poor health behaviours. The investigation of psychological processes such as attitudes, beliefs, self-efficacy, self-esteem, locus of control and how these interact with resources such as time, knowledge, income, etc. is an important area of investigation. How these factors differ between subgroups could provide important insight into the development of CWOBO. Furthermore, the measurement of SES varied between studies and power for assessing interaction effects is often poor, there is a need for future studies to replicate findings.

There are several limitations to this review; firstly the terms 'mediator' and 'moderator' were not used in the search criteria, but in our opinion this allowed the search to be all-inclusive. Secondly, this review excluded studies that had a restricted SES sample (e.g., only low SES), where important information regarding the relationship between low SES and CWOBO may have been missed. However, possible moderation effects of SES could not be tested in these studies and so they were not included. We cannot be certain that we found all the relevant studies. SES is a very common covariate of study, and there may have been studies that included a proxy measure for SES in their analyses, without reporting it in their key terms, title or abstract. Finally, this review does not include the biology of child obesity which is an important factor to understand along with the other socio-ecological factors.

In conclusion, SES cannot 'cause' OWOBO in children but it can be presented as though it holds some explanatory power. We believe that SES represents a confluence of family/parent-related factors that influence child overweight and obesity, and this review has made the first attempt to identify these from the existing literature. We hope that the findings of this review will encourage future researchers to replicate these studies in order to permit the (i) identification of candidates for intervention, and (ii) understanding of pathways through which these candidates

affect child health outcomes. Finally, the findings of this review suggest that there are different risk factors for COWOB in different SES groups (low and high).

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Key Messages:

- The mechanisms underlying the relationship between socioeconomic status and child overweight/obesity are poorly understood.
- Potential mediators of the relationship between SES and child overweight/obesity identified at the child, parent, and household level support a multi-level approach to reducing childhood obesity.
- The investigation of psychological processes as mediators of the relationship between overweight/obesity and SES is under-represented in the literature.
- Intervention strategies need to take into account the potential for having different factors influence overweight/obesity at different SES levels, further research is required.
- This review recommends greater emphasis on the identification of mediators and moderators of the relationship between SES and child overweight/obesity to inform the development of interventions.

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Table 1. Search terms and subject heading terms

	OR	AND OR	AND OR
Search terms	"environment* factors" SES disadvantag* socio*economic background rich* poor* neighbo* education income occupation*	psychosocial "parent* attitude" "parent* knowledge" "parent* beliefs" "parent* practice" maternal paternal caregiver	"child* obesity" "child* over weight" "weight gain" "fat child*" "child BMI" "child Body Mass Index"
Subject heading terms			
Psycinfo	"Socioeconomic Status"	"Parental Attitudes" "Parental Characteristics" "Parenting"	N/A
Medline	N/A	"Parenting"	"Pediatric obesity"
CINAHL	"Socioeconomic Factors"	"Parenting" "Parental Attitudes" "Parental Behavior" "Parent-Child Relations"	"Pediatric obesity"
Academic Search Complete	"SOCIOECONOMIC factors"	"PARENTING" "PARENTING -- Cross-cultural studies" "PARENTING -- Psychological aspects" "PARENTAL influences"	N/A
Scopus	N/A	N/A	N/A
Web of Knowledge	N/A	N/A	N/A

Table 2. Studies investigating mediation and interaction effects

Twenty studies investigating potential mediation effects					
a. First author (date of publication) b. Country c. Quality score	Main study aim	d. Sample size e. Sample mean age f. Sample demographics g. Study design h. Statistical Analysis	COWOB class. system	Socioeconomic status proxy	Variables
a. Balistreri (2011) b. USA c. 7.5	To identify trajectories of childhood overweight, and to measure the association between social/economic factors with trajectory membership.	d. 13,970 e. T1: Kindergarten T2: First grade T3: Third grade T4: Fifth grade and T5: Eighth grade f. Early Childhood Longitudinal Study-Kindergarten Cohort (ECLS-K). 25% come from an immigrant family. 89% of children had one parent with at least high school degree. g. Longitudinal h. Mixture Models identified 3 trajectories: 'Normal weight', 'Gradual onset', 'Always' overweight' Multinomial logistic regression	CDC	Parental education No high school, high school degree, some college or college Annual household income at T1	<ul style="list-style-type: none"> • Child's birth weight
a. Beyerlein (2010) b. Germany c. 7.5	To assess the possible differences in associations of several risk factors by subgroups of children's BMI distribution.	d. 9698 e. 5-6 years f. School-entry health examination in Bavaria, Southern Germany 1999-2002. 27.9% of parents had elementary or less education. g. Cross-sectional h. Quantile regression	WHO	Parental education Low education (neither mother nor father achieved O-level/GCSE)	<ul style="list-style-type: none"> • Child's birth weight • High television viewing: >2h day • Breastfeeding: Ever breastfeed? Yes vs. No • Mother smoking during pregnancy
a. Bingham (2013) b. Portugal c. 7	To update the prevalence of overweight and obesity in Portuguese children and to explore the influence and risks of socio-demographic factors and behavioural factors.	d. 17,136 e. 3-10 years f. Portuguese nationally representative sample g. Cross-sectional h. Logistic regression	IOTF	Parental education Primary (4 years), 6, 9, 12 years, University (>12 years)	<ul style="list-style-type: none"> • Parent BMI
a. First author (date	Main study aim	d. Sample size	COWOB	Socioeconomic status	Variables

of publication) b. Country c. Quality score		e. Sample mean age f. Sample demographics g. Study design h. Statistical Analysis	Class. system	proxy	
a. Cho (2009) b. Korea c. 6	To investigate the relationship between socio economic status and childhood adiposity in Korea.	d. 429 e. 7.9 years f. Well-educated, middle class: 80% of mothers and 87.4% of fathers graduated from university g. Cross-sectional h. Logistic regression	1998 Growth Chart for Korean Children (2-18 years)	Parental education Low = ≤ high school High = ≥ college Total household income Low = < 4 million won High = ≥ 4 million won	<ul style="list-style-type: none"> • Child sex • Child age • Child's birth weight • Screen time: time watching TV or using computer (games or internet). <90 min/day vs. ≥ 90 min/day. Excluding time in school activities • Eating fresh vegetables: ≤6 times/week vs. daily) • Fruit: ≤6 times/week vs. daily • Fast-food: <1 time/week vs. ≥ 1 time/week • Moderate physical activity: ≤2 time/week vs. ≥ 3 time/week • Parent BMI
a. Demment (2014) b. USA c. 5.5	To examine the associations between changes in family income status, early-life risk factors, and body mass index (BMI) z-score trajectory from age 2 to 15 years.	d. 595 e. 2-15 years f. Bassett Mothers Health Project g. Longitudinal h. Logistic regression	WHO	Household income trajectory Movement in and out of low-income	<ul style="list-style-type: none"> • Child's birth weight • Maternal overweight/obesity
a. Dubois (2005) b. Canada c. 7.5	To analyse the socio-economic factors related to breakfast eating, and the association between breakfast eating and childhood overweight.	d. 1549 e. 4.5 years f. Quebec Longitudinal Study of Child Development. Nationally representative sample. g. Cross-sectional h. Logistic regression	CDC IOTF	Mother's education No high school High school Diploma College education Household annual income <\$20000 vs. \$20000 – \$39999 vs. \$40000 - \$59999 vs. ≥\$60000	<ul style="list-style-type: none"> • Child sex • Breakfast eating: eating breakfast everyday vs. not everyday • Smoked during pregnancy • Number of overweight/obese parents • Ethnicity: non-immigrant / immigrant
a. First author (date of publication) b. Country	Main study aim	d. Sample size e. Sample mean age f. Sample demographics	COWOB Class. system	Socioeconomic status proxy	Variables

c. Quality score		g. Study design h. Statistical Analysis			
a. Dubois (2006) b. Canada c. 6.5	To examine a broad range of factors that may simultaneously contribute to childhood overweight in a population-based cohort of children followed from birth to 4.5 years, to determine which factors exert the most influence in early life.	d. 1450 e. 4-5 years f. Quebec Longitudinal Study of Child Development (QLSCD) g. Longitudinal h. Logistic regression	CDC	Household income Less than \$20000, \$20-\$39999, \$40-\$59999, \$60000+	<ul style="list-style-type: none"> • Parent BMI
a. Ebenegger (2011) b. Switzerland c. 5.5	To assess the independent contributions of parental migrant status and educational level on childhood adiposity and eating habits.	d. 542 e. 5.2 years f. 71% had a migrant parent, 37% had at least one parent of low education level. g. Cross-sectional h. Mixed linear regression and logistic regression	Swiss National Percentiles, 1989	Parental education Low = ≤9 years of formal education High = > 10 years of formal education	<ul style="list-style-type: none"> • Eating habits: daily frequency of consumption of water, caloric beverages, fruit, vegetables, fatty foods, sweet foods, omission of breakfast, meals in front of television, snacks in front of the television • Parent migrant status: place of birth
a. Gibbs (2014) b. USA c. 7.5	To examine the impact of infant feeding practices in child obesity and identify the mechanisms that link SES with child obesity	d. 8030 e. 9 months to 2 years f. Early Childhood Longitudinal Study (ECLS-B) g. Longitudinal h. Logistic regression	IOTF CDC WHO	Composite score Family SES was measured by a composite scale consisting of household income, parental education and occupational prestige created by the National Center for Educational Statistics.	<ul style="list-style-type: none"> • Child sex • Child's birth weight • Unhealthy infant feeding practices: predominant breastfeeding, predominant formula feeding, and fed both breast milk and formula in first 6 months • Maternal BMI: Self report height and weight • Mother's age at child's birth • Current smoking; Yes or No • Maternal depression: Abbreviated form of the Center for Epidemiologic Studies Depression Scale • Day care attendance: Regular attendance, Yes or No • Ethnicity: White, black, Hispanic, other.
a. First author (date of publication) b. Country c. Quality score	Main study aim	d. Sample size e. Sample mean age f. Sample demographics g. Study design	COWOB class. system	Socioeconomic status proxy	Variables

		h. Statistical Analysis			
a. Gopinath (2012) b. Australia c. 7.5	To examine associations between socio-economic, familial and perinatal factors with overweight/obesity in 6- and 12-year-old schoolchildren.	d. 4094 e. 6 years (results from 12 year olds not reviewed) f. Sydney Childhood Eye Study g. Cross-sectional h. Logistic regression	IOTF	Parent education University or less than university	<ul style="list-style-type: none"> • Child's birth weight: low: ≤ 2499g, normal: 2500-4000g, high: ≥ 4001g • Smoking during pregnancy • Ethnicity: White, East Asian, South Asian, Middle Eastern or Others/Mixed
a. Hancock (2014) b. Australia c. 7	To examine the longitudinal relationships between maternal protectiveness and child overweight and obesity.	d. 2596 e. 4-5 years f. Longitudinal Study of Australian Children (LSAC), nationally representative sample g. Longitudinal h. Regression	IOTF	Household income <\$599, \$600-\$999 per week, \$1000-\$1999 per week, and >\$2000 per week.	<ul style="list-style-type: none"> • Parent BMI
a. Jansen (2013) b. Australia c. 7	To determine the timing and strength of the association between SES and children's BMI in the pre- and primary school years, and to examine SES differences in overweight trajectories across childhood	d. 4949 e. T1: 4-5 years, T2: 10-11 years f. Longitudinal Study of Australian Children (LSAC), nationally representative sample g. Longitudinal h. Latent class analysis identified three main trajectories: stable-normal, late-onset overweight, persistent overweight/obese, resolving overweight. Multinomial logistic regression	IOTF	Composite score Equivalised annual family income, years and education and current or most recent occupational status.	<ul style="list-style-type: none"> • Child's birth weight • Parental BMI: Self-reported non-overweight, overweight, obese
a. Klebanov (2014) b. USA c. 5.5	To examine the BMI trajectories of children in early childhood, as a function of ethnicity and poverty	d. 985 e. T1: 2 years, T2: 6.5 years f. Infant Health and Development program – oversample of African-American and families at or below the poverty threshold g. Longitudinal h. Multilevel modelling	BMI only, no classification system reported	Adjusted annual household income Poverty = < families of three (\$8700 USD), four (\$11,200) and five (\$13,300) person-families	<ul style="list-style-type: none"> • Child's birth weight • Ethnicity: African-American, Hispanic-American, Anglo-American <p>Neighbourhood poverty: the fraction of families with annual incomes under \$10,000</p>
a. First author (date of publication) b. Country c. Quality score	Main study aim	d. Sample size e. Sample mean age f. Sample demographics g. Study design h. Statistical Analysis	COWOB class. system	Socioeconomic status proxy	Variables

a. Layte (2014) b. Ireland c. 7.5	To examine the extent to which child and lifestyle factors explain social class inequalities in the risk of obesity at three years	d. 11, 134 e. T2: 3 years f. Nationally representative sample of Irish children and their families g. Longitudinal & Cross-sectional h. Logistic regression	IOTF	Household social class Number of parents actively employed	<ul style="list-style-type: none"> • Child's birth weight • Child dietary quality: low, medium and high • Daily TV time: <hour daily, <2h daily, 2+ hours daily • Breastfeeding: none, < 3 months, < 6 months, and 6+ months • Maternal BMI • Maternal age (years) • Antenatal smoking: average number of cigarettes smoked daily during pregnancy • Alcohol consumption during pregnancy: quantity consumed within a week • Maternal nationality: Irish, UK, other European Union, African or other.
a. Moraeus (2012) b. Sweden c. 7	To examine the influences of societal and individual characteristics of children and their parents, on the prevalence of overweight and obesity.	d. 3636 e. 7-9 years f. Nationally representative sample of school children in Sweden g. Cross-sectional h. Regression	IOTF WHO	Parent education >12 years, 10-12 years, ≤9 years	<ul style="list-style-type: none"> • TV watching: ≥2 hrs/day • Breakfast on the day of study • Parent BMI
a. Strauss (1999) b. USA c. 6.5	To examine the role of race, marital status, maternal education, and family income, as well as standardised measures of the home environment in the development of childhood obesity	d. 2913 e. T1: 0-8 years, T2: 6-14 years f. National Longitudinal Survey of Youth (NLSY). Oversample of black and Hispanic children, however data was weighted to reflect a nationally representative sample. g. Cross-sectional and Longitudinal h. Logistic regression	CDC	Maternal education Number of years Household income Low, middle and high based on the nationally weighted 15 th and 85 th percentiles of the total sample Parental occupation Coded according to the 1970 US Census Bureau codes	<ul style="list-style-type: none"> • Child sex • Child's initial weight-for-height z-score • Ethnicity: African-American, Hispanic, Anglo-American • Maternal BMI • Maternal marital status (% single) HOME-SF cognitive and emotional scores: measure of the cognitive and emotional stimulation in the household
a. First author (date of publication) b. Country	Main study aim	d. Sample size e. Sample mean age f. Sample demographics	COWOB class. system	Socioeconomic status proxy	Variables

c. Quality score		g. Study design h. Statistical Analysis			
a. Van Den Berg (2013) b. Netherlands c. 6	The objective of this study is first to examine the relation of maternal education and growth velocity during the first year of life and early childhood (1–5 years).	d. 1684 e. 1-5 years f. Dutch ethnicity population-based cohort study – Amsterdam Born Children and their Development Study g. Longitudinal h. Regression and path analysis	Dutch reference standards	Maternal education <6 years, 6-10 years, >10 years	<ul style="list-style-type: none"> • Child's birth weight • Introduction of solid foods: <4 months, 4-6 months, >6 months • Smoking during pregnancy • Breastfeeding duration: <1 month, 1-3 months, 3-6 months, >6 months • Maternal BMI • Maternal age •
a. Veldhuis (2013) b. Netherlands c. 6.5	To examine the association between overweight and SES among 5 year old children	d. 5582 e. 5 years old f. Ethnically homogenous group "Dutch" ethnicity. g. Cross-sectional h. Multinomial logistic regression. (A percentage change of >5% in ORs is considered relevant for an educational level subgroup.)	IOTF	Maternal education Low = < high school Middle = completed high school High = ≥ university	<ul style="list-style-type: none"> • Child TV watching: ≤ 2 hrs/day vs. >2hrs/day • Breakfast consumption: daily, <7days/week • Employment status: full-time, part-time or not employed • Single parenting: Two-parent families, single-parent family or otherwise specified • Maternal weight status: no overweight, overweight and obese • Maternal TV watching: ≤ 2 hrs/day vs. >2hrs/day
a. Waters (2008) b. Australia c. 5	To examine the relationship between overweight/obesity in children, socioeconomic status and ethnicity/cultural background.	d. 2685 e. 4-13 years f. 48.3% had a parent born overseas g. Cross-sectional h. Logistic regression	CDC IOTF	Parent education ≤Grade 10, 11/12 or technical qualification, or university	<ul style="list-style-type: none"> • Parent BMI • Ethnicity: Country/Area of birth
a. Wehrly (2014) b. USA c. 6.5	To explore the relationship between measures of parental control in child feeding and child body composition	d. 243 e. 4.8 years f. The majority of parents reported a monthly household income less than \$3000 (49.8%) and were of White-non Hispanic background (44.6%) g. Cross-sectional h. Hierarchical multiple regression	CDC	Monthly household income Above or below the poverty line according to the U.S. Department of Human Health and Human services guidelines	<ul style="list-style-type: none"> • Parental feeding style: pressure to eat and restriction subscales from the Child Feeding Questionnaire

Eleven studies investigating potential interaction effects					
a. First author (date of publication) b. Country c. Quality score	Main study aim	d. Sample size e. Sample mean age f. Sample demographics g. Study design h. Statistical Analysis	COWOB Class. System	Socioeconomic status indicator/s	Variables
a. Anderson (2003) b. USA c. 8	To determine whether a causal relationship exists between maternal employment and childhood weight problems.	d. 6283 e. 3-11 years (stratified into 3-5 and 6-11 years) f. National Longitudinal Survey of Youth (NLSY) g. Longitudinal h. Econometric techniques	CDC	Household income Income quartiles since birth Maternal education Less than high school, high school or > some college	• Mother's employment: Never worked, mother worked <35 hrs/week since birth, mother worked ≥35 hrs/week since birth
a. Balistreri (2011) b. USA c. 8.5 (Also reported in mediation table)	To identify trajectories of childhood overweight, and to measure the association between social/economic factors with trajectory membership.	d. 13,970 e. T1: Kindergarten T2: First grade T3: Third grade T4: Fifth grade and T5: Eighth grade f. Early Childhood Longitudinal Study-Kindergarten Cohort (ECLS-K). 25% come from an immigrant family. 89% of children had one parent with at least high school degree. g. Longitudinal h. Mixture Models identified 3 trajectories: 'Normal weight', 'Gradual onset', 'Always' overweight' Multinomial logistic regression	CDC	Parental education No high school, high school degree, some college or college Annual household income at T1	• Sex of child
a. First author (date of publication) b. Country c. Quality score	Main study aim	d. Sample size e. Sample mean age f. Sample demographics g. Study design h. Statistical Analysis	COWOB Class. System	Socioeconomic status proxy	Variables
a. Hawkins (2008) b. UK c. 8	To examine the relationship between maternal employment and childhood overweight	d. 13,113 e. 3 years old f. 89% white mothers, 31% in managerial or professional occupations, and 14% were single mothers g. Cross-sectional h. Logistic regression	IOTF	Maternal Socio economic circumstances: Office for National Statistics Maternal Education Highest academic	• Maternal employment hours: average hours per week)

				qualification attained	
				Household Income reported in bands	
a. Kakinami (2015) b. Canada c. 8	To assess the effect of parenting style on the risk of childhood obesity, and to determine whether poverty was a moderator of the association.	d. 37,577 e. 2-11 years (stratified into 2-5 and 6-11) f. Cross-sectional g. National Longitudinal Survey of Youth (NLSY) h. Logistic regression	WHO	Household income Poverty defined as annual household income below the Statistics Canada cut-off	<ul style="list-style-type: none"> Parenting style: Authoritative (responsive and demanding), Authoritarian (not responsive but demanding), Permissive (responsive but not demanding) and Negligent (not responsive and not demanding)
a. Martinson (2012) b. USA & UK c. 7	To compare obesity between children of native and foreign-born mothers.	d. 9206 e. USA- T1:1 year, T2:3 years, T3: 5 years & 9 years UK- T1: 3 years, T2: 5 years & T3: 7 years f. Fragile Families and Child Wellbeing Study (FFS) in USA and Millennium Cohort Study (MCS) in UK –oversample of ethnic minorities. g. Cross-sectional & Longitudinal h. Multivariate logistic regression	CDC	Maternal Education High (some university) or low (no university) Low household income Bottom 30 percent of the income distribution adjusted for family size	<ul style="list-style-type: none"> Ethnicity: Mother's birthplace Hispanic, African-American, White-American, Asian, Caribbean and African In the US, native-born black and Hispanic mothers are more likely to be obese than native-born white mothers. In England, there is less variation in maternal obesity
a. First author (date of publication) b. Country c. Quality score	Main study aim	d. Sample size e. Sample mean age f. Sample demographics g. Study design h. Statistical Analysis	COWOB Class. System	Socioeconomic status proxy	Variables
a. Morrissey (2014) b. USA c. 5.5	To examine whether the association between maternal depressive symptoms and child obesity is moderated by parent education level	d. 6500 e. T1: 9 months, T2: 2 years, T3: 4 years, T4: 5.5 years f. Early Childhood Longitudinal Study-Birth Cohort (ECLS-B) g. Longitudinal h. Linear probability modelling	CDC	Parental education at T1 Neither parent graduated high school, at least one parent has a high school degree, at least one parent graduated from college	<ul style="list-style-type: none"> Maternal depressive symptoms (modified version of the Centre for Epidemiologic Studies Depression Scale at each wave)
a. Novotny (2013) b. Hawaii (USA)	To examine the prevalence of	d. 8839 e. 6 years	CDC	Neighbourhood SES Neighbourhood	<ul style="list-style-type: none"> Ethnicity: White, Asian, Filipino, native Hawaiian, Samoan, Hawaiian-Asian, other

c. 7.5	childhood overweight and obesity in 5 - 8 year olds, with adjustment for important covariates.	f. Nationally representative sample of Hawaiian children and their families. 13.6% white, 9.4% less than university educated. g. Cross-sectional h. Mixed Logistic Models		education level based on 2000 Census. High school or less, some college, associate degree or greater than associate degree	mixed, other
a. Rodenburg (2011) b. Netherlands c. 6	To explore whether the potential association between parenting and child weight is moderated by socio-demographic variables	d. 1665 e. 8 years f. IVO Nutrition and Physical Activity Child cohort (INPACT study) g. Cross-sectional h. Linear regression	1997 National Growth Study	Parental education Low (primary school and lower secondary), medium (higher secondary and university prep), or high (higher vocational education and university)	• Parenting styles (22 item instrument by Steinberg et al.): Authoritative, Permissive, Authoritarian, Rejecting (low support, low behavioural control, high psychological control), and Neglecting.
a. Semmler (2009) b. UK c. 4.5	To test if SES moderates the association between parental weight and changes in BMI from childhood to early adolescence.	d. 333 e. T1: 2 years, T2: 4 years, T3: 11 years f. Twin children of families with obese parents and socio-demographically matched families with normal-weight parents g. Longitudinal h. Analysis of variance, controlling for gender, age at follow-up, zygosity, and clustering in twin pairs.	1990 British Norms	Maternal education: lower SES (GCSE or less) vs. higher SES (A level or above)	• Mother's measured BMI
a. First author (date of publication) b. Country c. Quality score	Main study aim	d. Sample size e. Sample mean age f. Sample demographics g. Study design h. Statistical Analysis	COWOB Class. System	Socioeconomic status proxy	Variables
a. Topham (2009) b. USA c. 5	To test the moderating influence of two risk factors, maternal depression and SES on the ass bw authoritarian and permissive parenting styles and child obesity	d. 176 e. 6.85 years f. 78% white mothers, 15.4% less than college educated, 13.6% were single mothers g. Cross-sectional h. Multiple Logistic Regression	CDC	Household income Four-factor Hollingshead index based on Parental education and Maternal Occupation	• Parenting style (Parenting Styles and Dimensions Questionnaire) Authoritarian Permissive
a. Lane (2013)	To examine the impact	d. 917	CDC	Household Income:	• Parenting style (Method prescribed by Rhee et

b. USA c. 6.5	of socio economic status and psychosocial predictors on trajectories of childhood adiposity.	e. 24 months to 11 years old f. Diverse study sample: 24% minorities, 11% mothers with < high school education and 14% single mothers g. Longitudinal h. Growth mixture models		Not adjusted for costs of living based on geographical location or family size	al.): Permissive, Authoritative, Authoritarian and Neglectful
Note: SES = Socioeconomic Status; COWOB = Child Overweight and Obesity; CDC = Centres for Disease Control standards; IOTF = International Obesity Taskforce standards; WHO = World Health Organisation standards.					

Table 3. Child-system factors identified within multivariate analyses of the SES-COWOB relationship

First Author	Age	Design	Analyses	SES proxy							
				Education	Income	Occupation	Composite	TV watching	Breakfast consumption	Birth weight	Breastfeeding
Balistreri	3-5 y.	L	Mixture models	•	•					✓ ⁽¹⁾	
Beyerlein	5-6 y.	CS	Quantile Regression	•				✓ ⁽¹⁾		? ⁽¹⁾	✓ ⁽¹⁾
Cho	7-8 y.	CS	Regression	•	•			? ⁽⁰⁾		✓ ⁽⁰⁾	
Demment	2-15 y.	L	Regression		•					✓ ⁽⁴⁾	
Dubois (1)	4-5 y.	CS	Regression	•	•				? ^(2.5)		
Ebenegger	5.2 y.	CS	Regression	•					? ^(2.5)		
Gibbs	2 y.	L	Regression				•			✓ ⁽³⁾	✓ ⁽⁴⁾
Gopinath	6 y.	CS	Regression	•						✗ ⁽³⁾	
Jansen	4-5 y.	L	Regression				•			✗ ⁽²⁾	
Klebanov	2 y.	L	Mixture models		•					✓ ⁽³⁾	
Layte	3 y.	CS & L	Regression			•		✓ ⁽²⁾		✓ ⁽³⁾	✓ ⁽³⁾
Moraeus	7-9 y.	CS	Regression	•				✓ ⁽²⁾	✓ ⁽⁴⁾		
Strauss	0-8 y.	CS & L	Regression	•	•	•				✓ ⁽²⁾	
Veldhuis	5 y.	CS	Regression	•				✓ ⁽³⁾	✓ ⁽³⁾		

Note: CS = Cross-sectional; L = Longitudinal; • type of SES proxy used; ✓ support of partial mediation ; ✗ no mediation; () mediation score out of 4. Measurement details can be found in Table 2.

Table 4. Parent- and household-system factors identified within multivariate analyses of the SES-COWOB relationship

				SES																
				Education	Income	Occupation	Composite	Parent BMI	Parent age	Current smoking	Antenatal smoking	Antenatal alcohol	Depressive symptoms	Employment status	TV watching	Feeding style	Marital status	Ethnicity	Child Care	Neighbourhood poverty
First Author	Age	Design	Analyses																	
Beyerlein	5-6 y.	CS	Quantile Regression	•							✓ ₍₁₎									
Bingham	3-10 y.	CS	Regression	•				✓ _(2.5)												
Demment	2-15 y.	L	Regression		•			✓ ₍₄₎												
Dubois (1)	4-5 y.	CS	Regression	•	•			✓ _(2.5)			✗ ₍₃₎						✓ ₍₂₎			
Dubois (2)	4-5 y.	L	Regression		•			✗ ₍₃₎												
Ebenegger	5.2 y.	CS	Regression	•													✓ _(2.5)			
Gibbs	2 y.	L	Regression				•	✓ ₍₃₎	✓ ₍₃₎	✗ ₍₃₎			✗ ₍₂₎			✗ ₍₃₎	✓ ₍₃₎	✓ ₍₃₎		
Gopinath	6 y.	CS	Regression	•							✗ ₍₃₎						✗ ₍₄₎			
Hancock	4-5 y.	L	Regression		•			✓ _(1.5)												
Jansen	4-5 y.	L	Regression				•	✓ ₍₂₎												
Klebanov	2 y.	L	Mixed Models		•												✗ ₍₄₎		✓ ₍₂₎	
Layte	3 y.	CS & L	Regression			•		✓ ₍₂₎	✗ ₍₂₎		✓ ₍₃₎	✗ ₍₂₎					✓ ₍₂₎			
Moraes	7-9 y.	CS	Regression	•				✓ ₍₄₎												
Strauss	0-8 y.	CS & L	Regression	•	•	•											✗ ₍₃₎	✓ ₍₂₎		
Veldhuis	5 y.	CS	Regression	•				✓ ₍₃₎						✗ ₍₃₎	✓ ₍₃₎		✗ ₍₃₎			
Waters	4-13 y.	CS	Regression	•				✓ ₍₃₎										✓ ₍₃₎		
Wehrly	4.8 y.	CS	Regression		•											✗ ₍₃₎				
Note: CS = Cross-sectional; L = Longitudinal; • type of SES proxy used; ✓ support of partial mediation ; ✗ no mediation; () mediation score out of 4. Measurement details can be found in Table 2.																				

Note: CS = Cross-sectional; L = Longitudinal; • type of SES proxy used; ✓ support of partial mediation ; ✗ no mediation; () mediation score out of 4. Measurement details can be found in Table 2.

Supplementary Table 1. Assessment of quality of evidence

	Anderson (2003)	Balistreri (2011)	Beyerlein (2010)	Bingham (2013)	Cho (2009)	Demment (2014)	Dubois (2005)	Dubois (2006)	Ebenegger (2011)	Gibbs (2014)	Gopinath (2012)	Hancock (2014)	Hawkins (2008)	Jansen (2013)	Kakinami (2015)	Klebanov (2014)	Lane (2013)	Layte (2014)	Martinson (2012)	Moraes (2012)	Morrissey (2014)	Novotny (2013)	Rodenburg (2011)	Semmler (2009)	Strauss (1999)	Topham (2009)	Van Den Berg (2013)	Veldhuis (2013)	Waters (2008)	Wehrly (2014)
Sample size: 1 point for $n \geq 10,000$, 0.5 point for $1,000 \leq n \leq 10,000$ or 0 point if $n < 1000$ or not reported	1	1	0.5	0.5	0	0	0.5	0.5	0	0.5	0.5	0.5	1	0.5	1	0	0.5	1	1	0.5	0.5	0.5	0.5	0	0.5	0	0.5	0.5	0.5	0
Response rate: 1 point if response rate $\geq 70\%$, 0.5 if response rate 50-70% or 0 if response rate $< 50\%$ /not reported	1	0.5	1	0.5	0.5	0	1	0	1	1	1	0.5	1	0.5	1	1	0	0.5	0	0.5	0	1	0.5	0	1	0	0.5	0.5	0	0
Representative study population: 1 point if clearly stated, 0.5 point if clearly stated cohort but not necessarily externally valid to nation or 0 points if other/ not reported	1	1	1	1	0.5	0.5	1	1	0.5	1	1	1	1	1	1	0.5	1	1	1	1	1	1	1	0.5	1	0	1	0.5	0.5	0.5
Weight measured by a trained person: 1 point or 0 point if reported by parents	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BMI classification: 1 point if a standardised measure was used or 0 point for non-standardised country-specific BMI charts).	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	0	1	1	1
Statistical test conducted: 1 point if analysis allowed for assessment of statistically significant associations or 0 points otherwise	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Controlling for confounders: 1 point if controlled for any confounders or 0 if only did bivariate analysis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Specific age group or stratifying results by age group: 1 point if stratified results or specifically stated that a test had been done and age was not an effect modifier in the population studied or 0 points if did not discuss	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1
TOTAL	8	7.5	7.5	7	6	5.5	7.5	6.5	5.5	7.5	7.5	7	8	7	8	5.5	6.5	7.5	7	7	6.5	7.5	6	4.5	6.5	5	6	6.5	5	5.5

Table 3. Child-system factors identified within multivariate analyses of the SES-COWOB relationship

First Author	Age	Design	Analyses	SES proxy				TV watching	Breakfast consumption	Birth weight	Breastfeeding
				Education	Income	Occupation	Composite				
Balistreri	3-5 y.	L	Mixture models	•	•					✓ ⁽¹⁾	
Beyerlein	5-6 y.	CS	Quantile Regression	•				✓ ⁽¹⁾		? ⁽¹⁾	✓ ⁽¹⁾
Cho	7-8 y.	CS	Regression	•	•			? ⁽⁰⁾		✓ ⁽⁰⁾	
Demment	2-15 y.	L	Regression		•					✓ ⁽⁴⁾	
Dubois (1)	4-5 y.	CS	Regression	•	•				? ^(2.5)		
Ebenegger	5.2 y.	CS	Regression	•					? ^(2.5)		
Gibbs	2 y.	L	Regression				•			✓ ⁽³⁾	✓ ⁽⁴⁾
Gopinath	6 y.	CS	Regression	•						✗ ⁽³⁾	
Jansen	4-5 y.	L	Regression				•			✗ ⁽²⁾	
Klebanov	2 y.	L	Mixture models		•					✓ ⁽³⁾	
Layte	3 y.	CS & L	Regression			•		✓ ⁽²⁾		✓ ⁽³⁾	✓ ⁽³⁾
Moraes	7-9 y.	CS	Regression	•				✓ ⁽²⁾	✓ ⁽⁴⁾		
Strauss	0-8 y.	CS & L	Regression	•	•	•				✓ ⁽²⁾	
Veldhuis	5 y.	CS	Regression	•				✓ ⁽³⁾	✓ ⁽³⁾		

Note: CS = Cross-sectional; L = Longitudinal; • type of SES proxy used; ✓ support of partial mediation; ✗ no mediation; () mediation score out of 4. Measurement details can be found in Table 2.

First Author	Age	Design	Analyses	SES proxy				Parent BMI	Parent age	Current smoking	Antenatal smoking	Antenatal alcohol	Depressive symptoms	Employment status	TV watching	Feeding style	Marital status	Ethnicity	Child Care	Neighbourhood poverty
				Education	Income	Occupation	Composite													
Beyerlein	5-6 y.	CS	Quantile Regression	•							✓ ⁽¹⁾									
Bingham	3-10 y.	CS	Regression	•				✓ ^(2.5)												
Demment	2-15 y.	L	Regression		•			✓ ⁽⁴⁾												
Dubois (1)	4-5 y.	CS	Regression	•	•			✓ ^(2.5)			✗ ⁽³⁾							✓ ⁽²⁾		
Dubois (2)	4-5 y.	L	Regression		•			✗ ⁽³⁾												
Ebenegger	5.2 y.	CS	Regression	•														✓ ^(2.5)		
Gibbs	2 y.	L	Regression				•	✓ ⁽³⁾	✓ ⁽³⁾	✗ ⁽³⁾			✗ ⁽²⁾				✗ ⁽³⁾	✓ ⁽³⁾	✓ ⁽³⁾	
Gopinath	6 y.	CS	Regression	•							✗ ⁽³⁾							✗ ⁽⁴⁾		
Hancock	4-5 y.	L	Regression		•			✓ ^(1.5)												
Jansen	4-5 y.	L	Regression				•	✓ ⁽²⁾												
Klebanov	2 y.	L	Mixture Models		•													✗ ⁽⁴⁾		✓ ⁽²⁾
Layte	3 y.	CS & L	Regression			•		✓ ⁽²⁾	✗ ⁽²⁾		✓ ⁽³⁾	✗ ⁽²⁾						✓ ⁽²⁾		
Moraeus	7-9 y.	CS	Regression	•				✓ ⁽⁴⁾												
Strauss	0-8 y.	CS & L	Regression	•	•	•											✗ ⁽³⁾	✓ ⁽²⁾		
Veldhuis	5 y.	CS	Regression	•				✓ ⁽³⁾						✗ ⁽³⁾	✓ ⁽³⁾		✗ ⁽³⁾			
Waters	4-13 y.	CS	Regression	•				✓ ⁽³⁾										✓ ⁽³⁾		

Wehrly	4.8 y.	CS	Regression	•	✕ ₍₃₎
Note: CS = Cross-sectional; L = Longitudinal; • type of SES proxy used; ✓ support of partial mediation; ✕ no mediation; () mediation score out of 4. Measurement details can be found in Table 2.					

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