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Title: Socioeconomic status and changes in appetite from toddlerhood to early childhood**.**

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Abstract

Understanding the mechanisms through which deprivation predisposes a child to increased obesity risk is key to tackling health inequality. Appetite avidity is a key driver of variation in early weight gain. Low socioeconomic status (SES) can be a marker of a more ‘obesogenic’ food environment which may encourage the behavioural expression of appetite avidity. The objective was to test the hypothesis that children of lower SES demonstrate increases in appetite avidity from toddlerhood to five years. Data were from the Gemini twin birth cohort, with one twin per family selected at random. Parents completed the Child Eating Behaviour Questionnaire (CEBQ) to assess appetitive traits at 16 months and five years. SES was defined using a weighted composite measure comprising seven key correlates. Linear regression models examined the cross-sectional and prospective associations between SES and appetite from 16 months to 5 years, controlling for appetite at 16 months, sex, birth weight and parental BMI. Cross-sectionally, lower SES was significantly associated with higher food responsiveness (β = -.09 ±.024), higher enjoyment of food (β = -.13 ±.024), lower satiety responsiveness (β =.09 ±.024), and lower food fussiness (β =.09, ±.024) at 16 months. At age 5, lower SES was significantly associated with higher food responsiveness (β = -.10 ±.032), higher desire to drink (β = -.22 ±.031) and higher emotional overeating (β = -.10 ±.032). Prospectively, lower SES predicted greater increases in two key weight-related appetitive traits, from 16 months to 5 years: emotional overeating (β = -.10 ±.032; p<.01) and food responsiveness (β = -.09, ±.030; p<0.01). The results indicate that appetite may be a behavioural mediator of the well-established link between childhood deprivation and obesity risk.

Keywords: Socioeconomic status, Child Eating Behaviour Questionnaire, Appetite, Childhood, Inequalities

Abbreviations: CEBQ, Child Eating Behaviour Questionnaire; SES, Socioeconomic status; BST, Behavioural Susceptibility Theory; BMI, Body Mass Index; SDS, Standard deviation scores; IMD, Index of Multiple Deprivation.

Introduction

Childhood obesity is a significant public health issue, and an important challenge for government and healthcare systems worldwide (PHE, 2015). There has been a consistent upward trend in rates of overweight and obesity in the UK since 2006, with 34.3% of children aged 10-11 classified as overweight or obese in 2017/18 (NHS, 2018). Excess bodyweight in childhood tracks into adolescence and significantly increases risk of cardiovascular disease, type 2 diabetes mellitus, and depression (Knai, Lobstein, Darmon, Rutter & McKee, 2012). The rise in obesity prevalence has been attributed to environmental changes that promote both the consumption of highly palatable, energy dense, convenience foods and physical inactivity (Rosenkranz & Dzewaltowski, 2008). There is a clear socioeconomic gradient to childhood obesity; in the UK, children from the most deprived areas are twice as likely to be classified as having overweight or obesity as those from the least deprived (Boodhna, 2014; PHE, 2018). Even in the first year of life, socioeconomic disadvantage has also been strongly linked to increased risk of obesity in adulthood (Gilman et al., 2018), which suggests the 'obesogenic' nature of the early environment may contribute to health outcomes in later life (Knai et al., 2012; Claassen, Klein, Bratanova, Claes, & Corneille, 2019). The gap in health inequalities between the richest and poorest within society are ever-expanding (Stamatakis, Wardle, & Cole, 2010). It is important to identify the mechanisms underlying the relationship between socioeconomic status (SES) and childhood overweight/obesity to inform interventions aiming to reduce social inequalities in health.

Despite the ubiquity of the 'obesogenic' environment in wealthy countries, not everyone develops overweight or obesity, and variation in weight status is observed even at the level of the nuclear family. Behavioural susceptibility theory (BST) provides a biopsychosocial framework which seeks to explain why some of this variation occurs (Carnell & Wardle, 2007). BST proposes that obesity results from a combination of genetic susceptibility to overeating and exposure to an 'obesogenic' food environment that promotes excess consumption (Llewellyn & Fildes, 2017; Llewellyn & Wardle, 2015). Central to this theory is the hypothesis that inherited individual differences in appetite act as behavioural mediators of an individual's genetic susceptibility to the 'obesogenic environment' (Carnell & Wardle, 2007; Llewellyn, van Jaarsveld, Johnson, Carnell, & Wardle, 2010; Llewellyn & Wardle, 2015). Twin studies have shown appetitive traits to be highly heritable (Carnell & Wardle, 2008; Llewellyn et al., 2010) and related to rate of weight gain in infancy and early childhood (Parkinson, Drewett, Le Couteur, & Adamson, 2010; Quah et al., 2015; Silje Steinsbekk & Wichstrøm, 2015; van Jaarsveld, Boniface, Llewellyn, & Wardle, 2014; van Jaarsveld, Llewellyn, Johnson, & Wardle, 2011). 'Food approach' traits characterise a more avid appetite and a greater interest in food, and include food responsiveness, enjoyment of food, emotional overeating and desire to drink; these traits have been consistently associated with higher weight in childhood. 'Food avoidance traits' characterise a smaller appetite and a lower interest in food, and include satiety responsiveness, slowness in eating, emotional undereating and food fussiness; these have been consistently associated with lower weight in children (Carnell & Wardle, 2008; Llewellyn, van Jaarsveld, Johnson, Carnell, & Wardle, 2011; Steinsbekk, Llewellyn, Fildes, & Wichstrom, 2017; Steinsbekk & Wichstrom, 2015; van Jaarsveld et al., 2011). In accordance with BST, recent research has also demonstrated that the heritability of weight is significantly higher in children living in more obesogenic home environments compared to those from less obesogenic home environments (86% vs 39%), indexed according to structural and social characteristics of the food, physical activity and media environment within the home. This study demonstrated that children with greater genetic susceptibility to obesity are at greater 'risk' of developing obesity when they grow up in environments that nurture the behavioural expression of an avid appetite (Schrempft, van Jaarsveld, Fisher, & et al., 2018).

Obesity risk may be greater among children from more deprived backgrounds because the environments they are exposed to encourage the behavioural expression of appetite avidity (Caldwell & Sayer, 2019). SES differences at both the neighbourhood level (e.g. density of takeaway outlets, access to green spaces) and individual level (e.g. education, income) are associated with the types of foods readily available to children and the overall quality of their dietary intake (Claassen, Klein, Bratanova, Claes, & Corneille, 2019; Giskes et al., 2009; Stamatakis et al., 2010). Additionally, certain parental feeding practices, mealtime structure and stress/chaos within the home have been shown both to vary by SES and relate to children's appetite and obesity risk (Black, Moon, & Baird, 2014; Patrick & Nicklas, 2005). Recent work by Boswell, Byrne, and Davies (2018) revealed that psychosocial factors such as parental stress predicted higher child food cue responsiveness; with parental stress higher in low income households. It is hypothesised that parental stress may drive changes in the hypothalamic-pituitary-adrenal (HPA) axis that regulates appetite, thus resulting in the secretion of appetite-stimulating glucocorticoids and hedonic neural processes that may increase reward responsiveness to more palatable food cues (Boswell et al, 2018; Torres & Nowson, 2007). Furthermore, lack of structure around meal times, which is a common in low SES households, has been associated with lower enjoyment of food and lower satiety responsiveness in children (Finnane, Jansen, Mallan, & Daniels, 2017; Jansen, Williams, Mallan, Nicholson, & Daniels, 2018).

Despite the clear, and widening, social gradient in health outcomes, research is being hampered by a lack of consensus regarding the best way to measure SES (McLaren, 2007). Childhood SES is most frequently captured using a single indicator such as household income or parental education. The measures chosen vary between studies and are often used interchangably, which can be problematic as each individual measure taps into a different phenomenon and individual measures do not capture the complexity of SES sufficiently. This highlights the importance of utilising comprehensive composite measures of SES that incorporate individual, household, and neighbourhood level factors.

Rationale

Understanding how childhood deprivation increases risk of excess weight gain is key to tackling health inequalities, but little is known about the specific mechanisms through which

SES increases obesity risk in early life. No previous studies have explored the link between appetitive traits and SES, and how variation in SES relates to the development of appetite in early childhood. We developed a comprehensive measure of SES and examined for the first time the cross-sectional and longitudinal associations between SES and a range of appetitive traits from 16 months to 5 years of age, using data from Gemini, a large population-based birth cohort of 2400 British families with twins born in 2007. We hypothesised that young children from more deprived families will develop a more avid appetite over time, which puts them at increased risk of obesity.

Methods

Sample

Participants were from the Gemini study, a longitudinal birth cohort of families with twins born in England and Wales between March and December 2007. In total, 2,402 families with monozygotic (identical) and dizygotic (non-identical) twins (n = 4804) consented to take part (van Jaarsveld, Johnson, Llewellyn, & Wardle, 2010). Figure 1 shows the distribution of Gemini families across the north and south of England and Wales. The geographical distribution of enrolled families mirrors that of the UK population (Wijlaars, Johnson, Jaarsveld, & Wardle, 2011). One twin from each family was selected at random for inclusion in the analyses to avoid clustering effects of twins in families. Participants in the present study were individual children with complete data on all variables included in the analysis (n = 941). Ethical approval was granted by the UCL Ethics Committee. Written informed consent was provided by Gemini families.

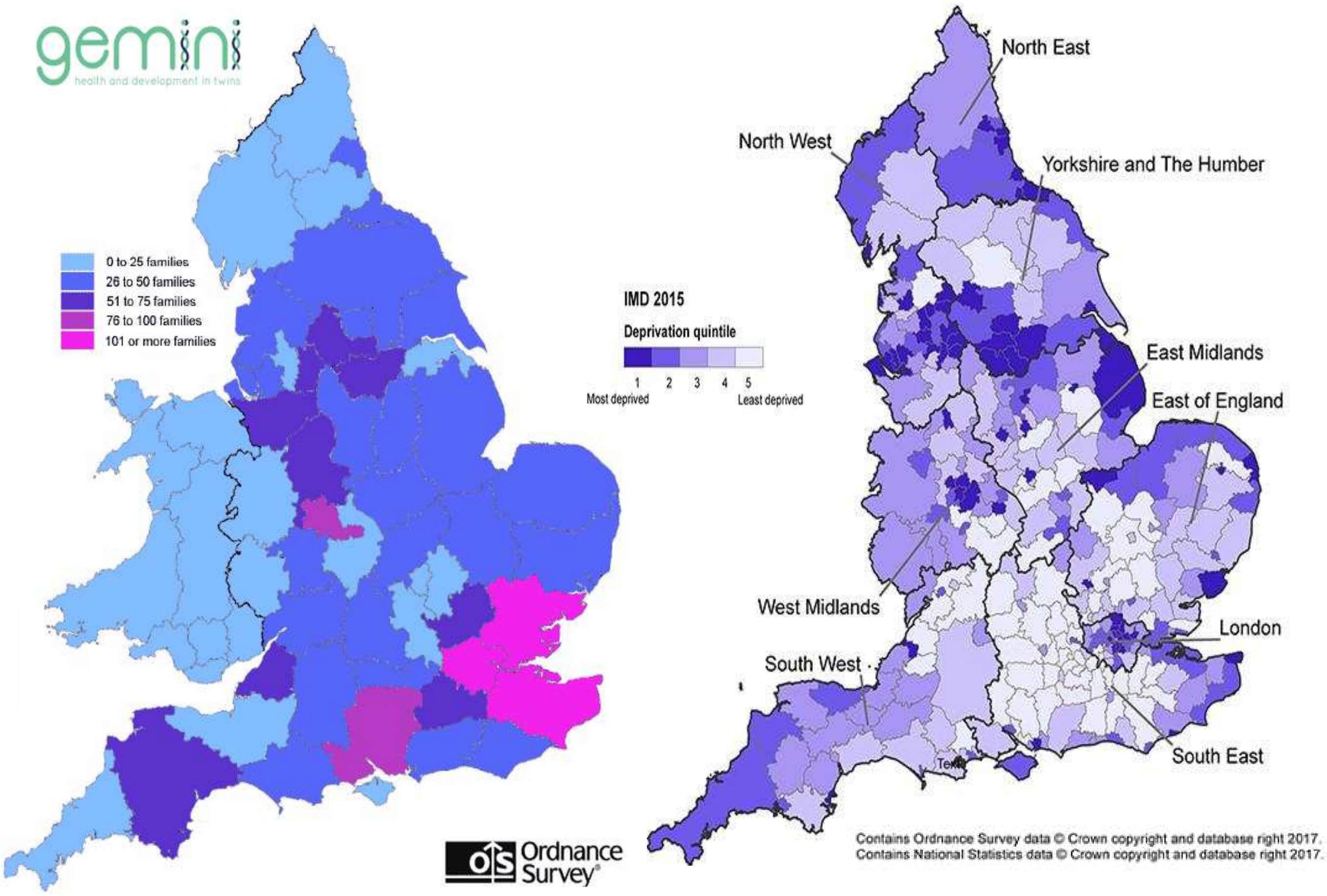

Figure 1. Distribution of Gemini Twins across the United Kingdom shown in the map on the left (adapted from van Jaarsveld et al., 2010), while the map on the right shows the level of deprivation within the United Kingdom based on the index of Multiple Deprivation (Reproduced with permission from the Department for Communities and Local Government, 2015).

Measures

Following recruitment, parents were asked to complete and return a series of postal-questionnaires at key developmental timepoints. These analyses used data collected at baseline when the twins were 8 months old, 16 months and 5 years.

Appetitive traits

Child appetite was assessed at 16 months and five years using the child eating behaviour questionnaire (CEBQ) and the CEBQ-T (toddler version of the CEBQ). The CEBQ is a parent-reported psychometric measure of eight appetitive traits, which consists of 35 items, rated using a 5-point Likert scale (1=Never to 5=Always) (Wardle, Guthrie, Sanderson, & Rapoport, 2001). Each of the eight CEBQ scales examines a different aspect of appetitive behaviour. Satiety Responsiveness (SR) measures a child's sensitivity to internal cues of 'fullness' (5 items e.g. 'My child gets full up easily'). Food Responsiveness measures a child's drive to eat in response to external food cues (5 items e.g. 'Given the choice, my child would eat most of the time'). Enjoyment of Food (EF) assesses a child's subjective pleasure from eating (4 items, e.g. 'My child loves food'). Desire to Drink (DD) measures a child's wanting for beverages (3 items, e.g. 'My child is always asking for a drink'). Emotional Overeating (EOE;4 items, e.g. 'My child eats more when worried') and Emotional Undereating (EUE; 4 items, e.g. 'My child eats less when s/he is tired') assess the extent to which a child eats (more or less) in response to emotional stressors. Slowness in Eating (SE) refers to the speed of meal consumption (4 items, e.g. 'My child eats slowly'). Finally, Food Fussiness (FF) examines a child's pickiness about the flavour and texture of foods they are willing to eat (6 items, e.g. 'My child refuses new foods at first'). The CEBQ-T is a slightly modified version of the CEBQ (Wardle et al., 2001), that has been adapted for toddlers. The majority of CEBQ and the CEBQ-T items are identical, except for small changes to the wording of items in the EOE and SR subscales of the CEBQ-T (see appendix 1). Two scales, EUE and DD, were removed from the CEBQ-T as during the piloting of this questionnaire, mothers reported that their toddlers did not engage in these behaviors (Herle, Fildes, van Jaarsveld, Rijsdijk, & Llewellyn, 2016).

Demographic information

Parents reported the sex, date of birth and birth weight (kg) of their twins in the baseline questionnaires. Mothers consulted their child's health records (completed by health professionals but held by the mother) when reporting birthweight and any subsequent weight measurements available at completion of the baseline (8 months) and 16 months questionnaires. Electronic weighing scales and height charts were sent to all families when the twins were aged two years to collect parent reported anthropometric measurements every 3 months. Height (m) and weight (kg) data at 16 months and 5 years (60 months) (missing data was replaced with nearest available data ±3 months) were used to calculate weight and BMI standard deviation scores (SDS), adjusted for age, sex and gestational age based on British 1990 growth reference data (Cole, 1996; Freeman et al., 1995). Paternal and maternal BMI (kg/m^2) data were also self-reported at baseline. Missing data for maternal BMI was replaced with imputed values using the Expectation Maximisation method (Dempster, Laid, & Rubin, 1997).

SES

At baseline, parents provided information about multiple indicators of SES including; highest maternal educational qualifications, current occupation (both parents), total annual household income, postcode, home ownership status, number of bedrooms in the home, and number of cars.

Occupation was used to calculate each household's National Statistics Socioeconomic Class (NS-SEC) using the simplified method in which occupation is attributed a four-digit Standard Occupation Classification 2000 (SOC2000) code, using the Computer Assisted Structured Coding tool (Cascot). For individuals with two jobs, the highest NS-SEC score was used. The parent or carer with the highest NS-SEC score was defined as the household reference person (HRP) and their score was used to represent the household NS-SEC score. NS-SEC scores were organised in 8 categories: 1 = 'Never worked or long-term unemployed', 2 = 'Routine occupation', 3 = 'Semi-routine', 4 = 'Lower supervisory/technical occupation', 5 = 'Small employers and own account workers', 6 = 'Intermediate occupations', 7 = 'Lower managerial and professional occupations', 8 = 'Large employers and higher managerial and higher professional occupations'. Further information about the classification of occupations with the NS-SEC are published elsewhere (Office for National Statistics, 2019). It was possible to attribute an NS-SEC score to 2394 (99.7% of cohort) households. Higher scores represented a household with higher SES.

Home ownership status was classified according to the Census 2001 and was used as an indicator of SES. Families were asked to state their home ownership status based on the following categories; 1 = ‘Own without mortgage’, 2 = ‘Own with mortgage’, 3 = ‘Rent privately’ and 4 = ‘Rent from local authority’. The numerical codes were reverse scored to ensure higher scores represented higher SES.

Postcodes at baseline were used to assign each household with an Index of Multiple Deprivation (IMD) score. IMD is commonly used to measure the level of deprivation in each local area in England and Wales. IMD is calculated based on seven different measures of local deprivation, including Employment, Education, Living Environment, Income, Crime, Health deprivation, Disability, and Barriers to housing and services. These domains are then used to attribute a weighted overall IMD score for each local area, with higher IMD scores representing higher level of deprivation. IMD scores could be assigned to 2,378 households based on their postcode, and these were subsequently categorised into 5 quintiles of deprivation (NPEU Tools, 2010). Quintiles were classified as follows: 1 = ‘score ≤8.49 (least deprived quintile)’, 2 = ‘8.5 -13.79’, 3= ‘13.8 - 21.35’, 4 = ‘21.36 - 34.17’, 5= ‘≥ 34.18 (most deprived quintile)’. These were then reverse scored so that 1 = ‘most deprived’ and 5 = ‘least deprived’.

Annual household income was assessed with the following question ‘What is the total household income (before tax deduction)?’. Responses were categorized into 12 bands, starting at 1 = *‘Up to £15k’*, up to 12 = ‘More than 90k+’.

Mothers were asked to report the highest educational qualification achieved. Response options ranged from 1 = *‘No qualifications’* to 7 = *‘Postgraduate qualification (*e.g. M*aster’s* or *PhD)’.*

These components of social class were then used to create a weighted composite measure of SES (Figure 2).

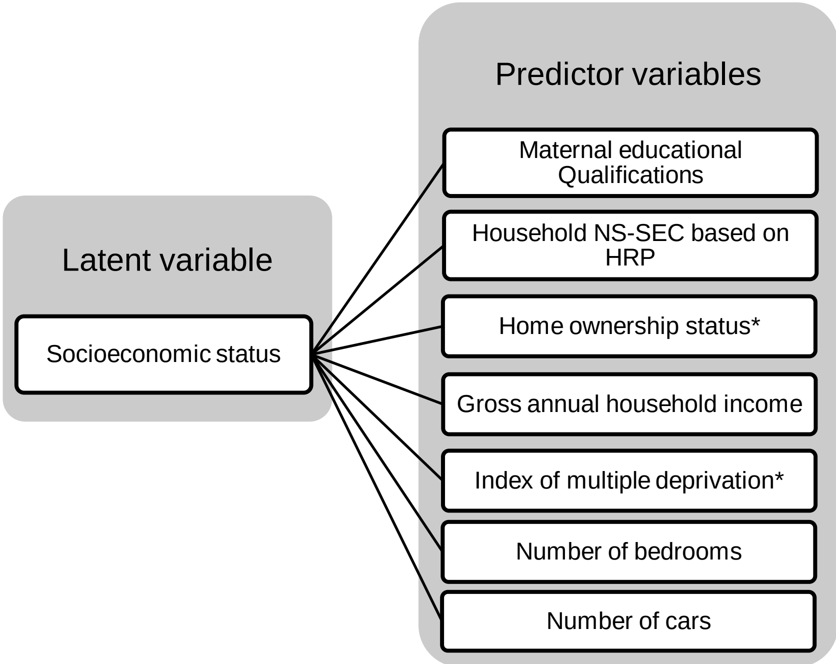

Figure 2: The indicators of socioeconomic status that were included within the composite measure of SES (*item reverse scored).

Statistical analyses

Statistical analyses were conducted using SPSS v25 (IBM Corp, Armonk, NY) . Principal component analysis (PCA) was conducted on the 7 correlates with direct oblimin to ascertain the number of latent variables that should be included in the composite measure. The weighted SES composite scores were generated using principal components analysis (PCA).

Multiple linear regression models examined cross-sectional associations between SES (independent variable) and each appetitive trait at 16 months (6 traits) and five years (8 traits) (dependent variables), controlling for sex, birthweight and parental BMI (mean BMI of both parents). Separate regression models were run for each appetitive trait. Multiple linear regression models were also used to model associations between SES (independent variable) and change in each appetite trait from 16 months to five years (dependent variable), controlling for appetite at 16 months, sex, birthweight and parental BMI (average of maternal and paternal BMI).

Results

Characteristics of the sample are shown in Table 1. Gemini was largely representative of twin births in England and Wales in 2007 in terms of the distribution of sex and zygosity (Jaarsveld, Johnson, Llewellyn, & Wardle, 2010), and sex and zygosity were similar at 16 months and 5 years to baseline. At baseline, Gemini mothers were slightly older than the national average; 33.6y compared to 29.5y nationally (Jaarsveld et al., 2010).

Table 1: Characteristics of the Gemini study sample (n = 2402 twins[1])

Characteristics	**Mean (±SD) or N (%)**
Sex [n (%)]	
Male	1194 (49.7)
Female	1208 (50.3)
Zygosity [n (%)]	
Monozygotic	749 (31.2)
Dizygotic	1616 (67.3)
Unknown	37 (1.5)
Weight SDS at birth (n = 2318)	-0.52 ± 1.11
Weight SDS at 16 months (n = 1584)	-0.09 ± 1.12
BMI SDS at age 5 (n = 929)	-0.04 ± 0.95
Maternal age (in years) at twins' birth (n = 2396)	33.6 ± 5.2
Maternal BMI at baseline (n =2338)	25.10 ± 4.76
Maternal BMI at baseline	
Desirable weight	1361 (56.7)
Overweight	723 (30.1)
Obese	317 (13.2)
Parents BMI at baseline (n = 2401)	25.75 ± 3.3
Parents BMI at baseline	
Healthy weight	1108 (46.1)
Overweight	1039 (43.3)
Obese	254 (10.6)
Ethnicity	
White British	2089 (87.0)
Non-White	311 (12.9)
Not Known	2 (0.1)
NS-SEC classification[2]	
High	1515 (63.1)
Middle	407 (16.9)
Low	472 (19.7)
Not Known	8 (0.3)

[1]Only one twin per household is presented in this table. Zygosity was unknown for 37 pairs, due to inconsistent questionnaire results and no DNA available.
[2]Classified based on the Office for National Statistics Socioeconomic Classification (NS-SEC) and grouped into high (higher and lower managerial and professional occupations), middle (intermediate occupations, small employers and own account workers) and low (lower supervisory and technical occupations, (semi)routine occupations, never worked and long-term unemployed). In comparison to the average statistics for the UK population, Gemini has a higher percentage of high SES families, (63.1% vs 49%) and less low SES families (19.7% vs 33%). Figures on National Statistics from Health Survey for England 2007 (Health and Social care Information Centre, 2008).

Developing the SES composite measure

Correlations between each of the individual indicators of social class ranged from r=0.16 (maternal education and number of cars) and r=0.57 (NS-SEC and gross annual income) but tended to be low to moderate in size indicating that each measure is tapping into a separate component of SES (**Error! Reference source not found.**). The Kaiser-Meyer-Olkin (KMO) revealed that the sample was adequate to run the PCA (KMO = .82). PCA revealed all seven SES indicators loaded well onto a single factor (all had factor loadings >0.4) and all were therefore included in the final composite measure. Household annual income (0.77) and household NS-SEC (0.75) loaded highest and were given the highest weightings in the composite measure. These were followed by maternal education (0.56), home ownership status (0.54), IMD score (0.49), number of bedrooms (0.46) and number of cars (0.43). Weightings were attributed to individual components of the composite based on their factor loadings. These weighting were combined with the raw values and used to calculate the weighted SES composite using the following equation: SES composite = (household annual income*.22) + (household NS-SEC * .22) + (maternal education*.18) + (home ownership status*.18) + (IMD score*.08) + (number of bedrooms*.06) + (number of cars*.06). Internal reliability for the composite measure was high (Cronbach α = .72) and was not improved by removing any individual indicator.

Full details of the associations between CEBQ measured appetitive traits and the individual and composite SES measures are shown in Supplemental table 1**.**

Cross-sectional associations between SES and appetite

Table 2 shows the results from the cross-sectional multiple linear regression models, which explored associations between the composite measure of SES and each of the CEBQ appetitive traits at 16 months and five years, while controlling for child sex, birth weight and parental BMI. At 16 months, lower SES was significantly associated with higher Food

Responsiveness (standardised $\beta = -.09 \pm .02$, $p = 0.001$), higher Enjoyment of Food (standardised $\beta = -.13 \pm .02$, $p > 0.001$), lower Satiety Responsiveness (standardised $\beta = .09 \pm .02$, $p = 0.001$) and lower Food Fussiness (standardised $\beta = .09$, $\pm .02$ $p > 0.001$), but the effect sizes were small. Overall, the ΔR^2 revealed that the model including the SES composite explained between 0.6-1.6% of the variance in appetitive traits at 16 months.

At five years, lower SES was associated with higher Desire to Drink (standardised $\beta = -.22 \pm .03$, $p < 0.001$), higher Food Responsiveness (standardised $\beta = -.10 \pm .03$, $p = 0.002$), and higher Emotional Overeating (standardised $\beta = -.10 \pm .03$, $p = 0.002$) but was no longer associated with Enjoyment of Food, Satiety Responsiveness or Food Fussiness. Effect sizes were small. Overall, the ΔR^2 revealed that the model including the SES composite explained between 0.9-4.5% of the variance in appetitive traits at 5 years.

Table 2. Linear regression examining cross-sectional associations between appetitive traits and SES at 16 months (n = 1784[a]) and 5 years (n = 976[b]) – adjusted models[1].

Appetitive traits at 16 months	SES composite					
	Mean	**(SD)**	***Standardised β ± SE***	**p**	**Adjusted R^2**	**ΔR^2**
FR	**2.28**	**(0.76)**	**-.09 ± .02**	**<0.001****	**.013**	**.006**
EF	**4.18**	**(0.62)**	**-.13 ± .02**	**<0.001****	**.007**	**.016**
EOE	1.64	(0.59)	-.01 ± .02	0.85	.003	.002
SR	**2.68**	**(0.62)**	**.09 ± .02**	**<0.001****	**.019**	**.006**
SE	2.49	(0.65)	.05 ± .02	0.03	.022	.002
FF	**2.19**	**(0.71)**	**.09 ± .02**	**<0.001****	**-.002**	**.006**
Appetitive traits at 5 years						
FR	**2.37**	**(0.75)**	**-.10 ± .03**	**0.002***	**.015**	**.009**
EF	3.89	(0.68)	-.02 ± .03	0.47	.006	.00
EOE[b]	**1.56**	**(0.50)**	**-.10 ± .03**	**0.002***	**.008**	**.01**
SR	2.84	(0.62)	.03 ± .03	0.42	.033	.033
SE	2.90	(0.77)	-.01 ± .03	0.79	.025	.024
FF	2.75	(0.83)	.00 ± .03	0.92	.001	.000
EUE[b]	2.66	(0.84)	-.01 ± .03	0.88	-.003	-.004
DD	**2.43**	**(0.89)**	**-.22 ± .03**	**<0.001****	**.028**	**.045**

Note. [1]Adjusted for sex, birth weight, and parental BMI. * p < 0.01; **p< 0.001
[a] N for each appetitive trait at 16 months (FR n = 1784; EF n = 1784; FF n = 1787; SR n = 1788; SE n = 1785; EOE n = 1784)
[b] N for each appetitive trait at 5 years (EF n = 974; FR n = 978; SE n = 978; EUE n=967; EOE n = 966)
Adjusted R^2 variance explained by the model including only the covariates (sex, birth weight, parental BMI). ΔR^2 variance explained by model including covariates (sex, birth weight, parental BMI) and SES composite.
Abbreviations: FR=Food Responsiveness; EF=Enjoyment of Food; FF=Food Fussiness; EOE=Emotional overeating; SE=Slowness in Eating; SR=Satiety responsiveness; EUE=Emotional undereating; DD=Desire to drink

Prospective associations between SES and appetite

Prospectively, lower SES predicted greater increases in two appetitive traits that characterise greater appetite avidity from 16 months to 5 years; EOE (standardised β = -.10 ± .032) and FR (standardised β = -.09, ± .030; both p<0.01) (see **Table 3**). The effect sizes were small. Overall, the ΔR^2 revealed that the model including the SES composite explained 0.7-1% of the variance in appetitive traits.

Table 3. Linear regression model examining longitudinal associations between SES and change in appetite from 16 months to 5 years (n = 941[a]).

Appetitive traits at 5 years	SES composite [1]				
	Standardised *β ± SE*	t	p	Adjusted R^2	**ΔR^2**
FR	**-.09 ± .03**	**-3.08**	**.002***	**.005**	**.007**
EF	.42 ± .03	1.36	.18	.001	.001
EOE	**-.10 ± .03**	**-3.18**	**.002***	**.006**	**.010**
SR	-.01 ± .03	-.26	.80	.013	.000

SE	-.01 ± .03	-.36	.72	.013	.000
FF	-.03 ± .03	-1.08	.28	.000	.000

Note. [a]**N for each appetitive trait (EF n = 938; EOE n = 929; FR n = 940; SR n = 941; SE n = 941; FF n = 941).**
[1]Adjusted for appetite at 16 months, sex, birth weight and parental BMI. * **p < 0.01; **p< 0.001.**
Adjusted R^2 variance explained by the model that includes covariates (sex, birth weight, and parental BMI). $\Delta \boldsymbol{R}^2$ variance explained by model including covariates (sex, birth weight, parental BMI) and SES composite.
Abbreviataions: FR=Food Responsiveness; EF=Enjoyment of Food; FF=Food Fussiness; EOE=Emotional overeating; SE=Slowness in Eating; SR=Satiety responsiveness; EUE=Emotional undereating; DD=Desire to drink

Discussion

To our knowledge, this is the first study to explore the cross-sectional and prospective associations between SES and appetite in early childhood. Our findings indicated that children from lower SES households exhibited appetitive traits that characterise a more avid appetite, with higher food responsiveness, higher enjoyment of food, lower food fussiness and lower satiety responsiveness at 16 months compared to high SES households. The cross-sectional association between lower SES and higher food cue responsiveness remained at five years. Additionaly, at 5 years lower SES was associated with higher emotional overeating and higher desire to drink. Prospectively, being from a lower SES predicted greater increases in two key weight-related appetitive traits that characterise a more avid appetite - food responsiveness and emotional overeating - from toddlerhood (16 months) into early childhood (5 years).

Individual differences in appetite emerge in early infancy, and while appetitive traits are shown to be relatively stable over time (Ashcroft, Semmler, Carnell, van Jaarsveld, & Wardle, 2007; Farrow & Blissett, 2012), children tend to become more appetitive as they approach adolescence. Gradual increases in food responsiveness, enjoyment of food and emotional overeating and decreases in satiety responsiveness and food fussiness have been reported between the ages of 4 and 11 (Ashcroft et al., 2007; Farrow & Blissett, 2012). In this study lower SES predicted greater increases in food responsiveness during childhood, suggesting children from more disadvantaged backgrounds are more susceptible to increases in food responsiveness compared to children of higher SES. Twin studies highlight that food responsiveness is highly heritable (Llewellyn & Fildes, 2017; Llewellyn et al., 2010), yet the behavioural expression of higher food cue responsiveness is only possible when the environment permits it (Wardle & Carnell, 2009). A child of lower SES is more likely to live in a higher risk ‘obesogenic’ environment, with greater exposure to unhealthy foods, less mealtime structure, less responsive feeding practices (e.g. parental use of food as reward, emotional feeding, and pressuring to eat) (Gross, Mendelsohn, Fierman, Racine, & Messito, 2012; Rodgers et al., 2013) and therefore greater exposure to environmental cues to eat

(Baumann, Szabo, & Johnston, 2017; Rodgers et al., 2013; Rudy et al., 2016). These environmental factors may help to explain the observed socioeconomic differences in appetite (Caldwell & Sayer, 2019), as well as increases in appetite avidity over the preschool years, as children gain autonomy and are increasingly able to interact with their environments.

Lower SES also predicted greater increases in emotional overeating, from toddlerhood (16 months) to early childhood (5 years). Unlike most other appetitive traits which have strong genetic underpinnings, individual variation in emotional overeating in childhood is largely explained by environmental influences (Herle, Fildes, Rijsdijk, Steinsbekk, & Llewellyn, 2018). The home environment may be more chaotic or stressful in deprived households, potentially due to greater financial instability, greater parental stress, food insecurity or less structure within the household, which may in turn increase the likelihood of a child using food as a mechanism to cope with higher levels of emotional distress (Boswell et al., 2018). Indicators of SES, such as income or maternal education, have also been associated with parental feeding styles or practices linked to the development of child overweight. It has been reported that parents of lower SES may be less likely to model healthy eating behaviours, be less responsive to child's cues of hunger and satiety in their feeding styles and may be more likely to use food as reward or to comfort compared to higher SES parents (Bauer, Hearst, Escoto, Berge, & Neumark-Sztainer, 2012; Braden et al., 2014; Cardel et al., 2012; Pinket et al., 2016; Rodgers et al., 2013). Parental feeding strategies such as using food as a reward to control behaviour (so-called 'instrumental feeding') and using food to soothe an upset or distressed child (so-called 'emotional feeding') have both been positively associated with emotional overeating (Jansen, Mallan, Nicholson, & Daniels, 2014; Steinsbekk et al., 2018). It is possible that parents of low SES are more likely to use food to pacify their children's emotional states, and that it is this parental behaviour that teaches a child to use food to cope with emotional distress (Demir & Bektas, 2017; Rodgers et al., 2013).

Findings also revealed children of lower SES were less satiety sensitive at 16 months. The extent to which parents adopt responsive feeding practices during milk feeding and weaning have been linked with an infant's ability to regulate their own appetite and may reduce risk of obesity (Brown & Lee, 2012; Brown & Lee, 2015; Carnell, Benson, Driggin, & Kolbe, 2014; DiSantis, Collins, Fisher, & Davey, 2011; Llewellyn et al., 2010; Paul et al., 2018). Differences in parental feeding practices have been observed across SES groups, with lower SES mothers less likely to be responsive to child's cues of hunger and satiety, and more likely to use strategies such as emotional feeding, restriction or pressuring to eat (Dubois & Girard, 2003; Gibbs & Forste, 2014; Gross et al., 2012). Such parental feeding styles may mediate the relationship between SES and satiety responsiveness observed in this study. However, as this relationship had disappeared by 5 years, these findings suggest no enduring link between SES and satiety responsiveness beyond the very early years.

In the present study, being of lower SES was associated with lower Food Fussiness at 16 months. These findings contradict previous research suggesting fussy eating behaviours are more common in children from lower income households (Cardona Cano et al., 2015; Gibson & Cooke, 2017; Tharner et al., 2014). Fussy eating commonly emerges during early infancy and is characterised by rejection of novel foods (neophobia) and general pickiness around the flavours and textures a child is willing to eat (Dovey, Staples, Gibson, & Halford, 2008). Research has shown that repeated exposure to a specific food increases acceptance (Fildes, van Jaarsveld, Wardle, & Cooke, 2014; Gibson & Cooke, 2017; Turrell, 1998) and exposure to a wide variety of foods in infancy has been linked with greater dietary variety and reduced neophobia in childhood (Mallan, Fildes, Magarey, & Daniels, 2016). Children from more deprived backgrounds tend to be offered fewer fruits and vegetables (Trude et al., 2016), potentially reducing their opportunities for exposure and leading to narrower food preferences compared to children from more affluent households (Turrell, 1998). In this context, the finding of reduced food fussiness in children from lower SES backgrounds might seem counter-intuitive. However, qualitative research reveals lower income families are less likely to provide children with opportunities to try new foods, instead offering familiar and well-liked foods to avoid potential food waste (Daniel, 2016). This means opportunities for the behavioural expression of fussy eating may be reduced in lower SES households, likely causing parents to perceive and report lower levels of food fussiness in their children. In contrast, higher income families may offer a broader range of foods, particularly commonly rejected foods such as vegetables, and introduce novel foods more frequently, thereby providing ample opportunity for a child to express their fussy eating tendencies (Daniel, 2016). Again, SES differences in fussy eating were no longer present by the time the children were five years. This may be due to general increases in exposure to novel or disliked foods for all children, regardless of SES, as they gain autonomy and experience a broader range of foods both inside and outside the home.

Children from lower SES families exhibited higher desire to drink at age five; in line with previous research in low income families (Lora, Hubbs-Tait, Ferris, & Wakefield, 2016). Higher desire to drink has been associated with greater preference for, and increased consumption of, sugar sweetened beverages (SSB) and fruit juices (Sweetman, Wardle, & Cooke, 2008). Research suggests a socioeconomic gradient to SSB consumption, with individuals of lower SES consuming more of these types of drinks (Bolt-Evensen, Vik, Stea, Klepp, & Bere, 2018; De Coen et al., 2012; Hupkens, Knibbe, van Otterloo, & Drop, 1998).

Strengths and limitations

Strengths of this study include the large sample size, prospective analyses and the use of a composite measure of SES, which incorporates multiple indicators of socioeconomic position. These results are in line with previous studies which have highlighted the importance of using multiple correlates to measure SES (Marra, Lynd, Harvard, & Grubisic, 2011; Shrewsbury & Wardle, 2008). However, there are several limitations. Firstly, appetite was parent-reported, which may introduce measurement error due to the subjective nature of the assessment. However, the CEBQ has been shown to be valid reliable measure in diverse populations, with good correspondence to objective measures (Ashcroft et al., 2007; S. Carnell & Wardle, 2007; Domoff, Miller, Kaciroti, & Lumeng, 2015). Nevertheless, social desirability bias cannot be ruled out and may be particularly problematic if the level of bias varied by SES. Secondly, weights and heights for the twins' were also parent-reported, however previous research has shown high correspondence between parent- and researcher-measured heights and weights (Wardle, Carnell, Haworth, & Plomin, 2008). Thirdly, although our analyses adjusted for confounding variables, it is possible that residual confounding by other factors could remain. A fourth limitation is the use of the twin sample, as twins typically have lower birth weights compared to singletons (Estourgie-van Burk, Bartels, van Beijsterveldt, Delemarre-van de Waal, & Boomsma, 2006), meaning this sample may not fully represent the general population or variation across SES groups. However, there is no reason to believe the association between SES and appetite would be different for twins versus singletons. Finally, as is common with cohort studies the sample has a higher percentage of higher SES families (63.1% vs 49%) and fewer low SES families mid-high SES (19.7% vs 33%; Health and Social care Information Centre, 2008) thus, the true impact of SES on appetite may not have been fully captured in this population, which may be reflected in the modest ΔR^2 (0.9-4.5%) attributable to SES. Future analyses should be conducted in samples with greater variation in SES to see if relationships between SES and appetite are stronger in more diverse populations. Although the PCA analyses showed the SES composite was appropriate in this sample, an important next step is to ascertain whether the composite measure is stable in another cohort.

Conclusion

In summary, children growing up in lower SES households had greater increases in two key appetitive traits, food responsiveness and emotional overeating, from toddlerhood (16 months) to early childhood (age 5). These appetitive traits have been consistently positively associated with weight in childhood, which suggests that appetite may be a behavioural mediator of the well-established link between childhood deprivation and obesity risk. Further research is needed to understand how differences in SES relate to the behavioural expression of appetite avidity and how these differences in appetite may contribute towards excess weight gain in childhood.

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Appendix 1: Child Eating Behaviour Questionnaire-Toddler (CEBQ-T) item modifications

Appetitive traits	Child Eating Behaviour Questionnaire (CEBQ)	Child Eating Behaviour Questionnaire – Toddler Version
Emotional overeating	1. My child eats more when worried 2. My child eats more when annoyed 3. My child eats more when anxious	1. My child eats more when irritable 2. My child eats more when grumpy 3. My child eats more when upset
Satiety responsiveness	1. My child leaves food on his/her plate at the end of a meal	1. My child leaves food on his/her plate or in the jar at the end of a meal

Supplemental table 1. Demographic information for the multiple indicators of SES used within the composite measure of SES**.**

Indicator of SES	N	%
Maternal Education qualificaition		
No qualifications	129	5.4
GCSE, CSE, O level	389	16.2
Vocational qual	374	15.6
A or AS level	258	10.7
HNC or HND	246	10.2
Undergrad	619	25.8
Postgrad	387	16.1
NS-SEC based on the HRP[1]		
Unemployed or never worked	15	.6
Routine occupation	13	.5
Semi-routine	358	15.0
Lower supervisory	86	3.6
Small employer and own account worker	122	5.1
Intermediate occupations	285	11.9
Lower managerial and professional occupations	743	31.0
Large employers and higher managerial and higher professional occupation	772	32.2
Number of bedrooms in household		
1	35	1.5
2	401	16.7
3	1154	48.1
4	585	24.4
5	166	6.9
6+	59	2.4
Number of cars per household		
0	144	6.0
1	814	33.9
2	1335	55.6
3	82	3.4
4	18	.8
5	4	.2
6	2	.1
Home ownership status		
Rent from local authority	189	8.0
Rent privately	275	11.6
Own with mortgage	1745	73.5
Own without mortgage	165	7.0
Index of multiple deprivation (quintiles)		
1 – most deprived	304	12.8
2	412	17.3
3	476	20.0
4	573	24.1
5 – least deprived	613	25.8
Annual household income (before tax deduction) (n = 2314)		
Up to £15k	202	8.7
£15-22.5k	257	11.1
£22.5-30k	320	13.8
£30-37.5k	285	12.3
£37.5-45k	254	11.0
£45-52.5k	223	9.6
£52.5-60k	178	7.7
£60-67.5k	122	5.3
£67.5-75k	104	4.5
£75-82.5k	71	3.1
£82.5-90k	46	1.9
More than 90k[1]	252	10.5

Note. SES = Socioeconomic status, HRP = Household reference person, NS-SEC = National Statistics Socioeconomic Class (NS-SEC). [1]The NS-SEC score for each household was classified based on the Household reference person (i.e. the person within the household that has the highest NS-SEC score). Further details published elsewhere (ONS, 2019).
[1] The annual household income upper limit is 100k.

Supplemental table 2: Pearson's Correlation Co-efficient correlations between individual SES indicators and composite measure of SES (baseline) and Child Eating Behaviour Questionnaire appetitive traits at 16 months and 5 years.

		Socioeconomic factor							Appetite at 16 months						Appetite at 5 years							
		IMD	Income	Tenure	NS-SEC	No. of bedroom	No. cars	Maternal Education	SR	FR	EF	EOE	FF	SE	SR	FR	EF	EOE	DD	FF	SE	EUE
	SES composite	**.481****	**.897****	**.522****	**.802****	**.435****	**.375****	**.683****	**.075****	**-.079****	**-.126****	-.005	**-.086****	.032	.005	**-.102****	-.017	**-.093****	**-.237****	.010	-.022	-.006
	IMD quintile	1.00	**.361****	**.228****	**.357****	**.257****	**.279****	**.243****	-.033	-.013	-.020	.035	.011	**-.054**	**-.076***	.021	**.066***	-.035	**-.085****	-.026	-.034	-.026
	Gross annual income	-	1.00	**.358****	**.572****	**.411****	**.273****	**.441****	**.057***	**-.066***	**-.10****	.002	**.061***	.029	.010	-.136	-.046	-.105**	**-.187****	.013	-.025	-.022
	Household tenure	-	-	1.00	**.439****	**.276****	**.341****	**.299****	**.070***	**-.075****	**-.070****	-.011	.047	.041	**.066***	-.121	-.009	-.070*	**-.155****	.006	.045	.017
Socioeconomic factors	NS-SEC based on HRP	-	-	-	1.00	**.237****	**.288****	**.482****	**.061***	-.056*	**-.081****	-.010	**.070****	.033	.022	**-.082****	-.014	-.063*	**-.167****	-.036	.022	.017
	Number of bedrooms	-	-	-	-	1.00	**.344****	**.177****	-.001	-.035	-.043	.000	.010	-.006	-.013	**-.091****	-.041	-.046	-.057	.023	-.030	-.016
	Number of cars	-	-	-	-	-	1.00	**.156****	-.023	.004	-.004	-.026	.004	-.007	-.024	-.020	.015	-.043	-.03	-.004	-.032	-.018
	Maternal education	-	-	-	-	-	-	1.00	**.099****	**-.068****	**-.146****	-.023	**.082****	.044	-.009	-.020	.013	-.034	-.248	.017	-.036	.009
	SR	-	-	-	-	-	-	-	1.00	**-.417***	**-.606****	**-.069****	**.443****	**.59****	**.40****	**-.214****	**-.278****	-.027	-.014	**.126****	**.228****	**.109****
	FR	-	-	-	-	-	-	-	-	1.00	**.370****	**.369****	**-.177****	**-.27****	**-.23****	**.43****	**.19****	**.25****	**.12****	-.04	**-.14****	.047
Appetite at 16 months	EF	-	-	-	-	-	-	-	-	-	1.00	**.071****	**-.604****	**-.46****	**-.29****	**.17****	**.41****	.020	.027	**-.25****	**-.21****	**-.06***
	EOE	-	-	-	-	-	-	-	-	-	-	1.00	.012	-.044	**-.10****	**.20****	**.08***	**.29****	**.07***	-.04	**-.07***	**.08****
	FF	-	-	-	-	-	-	-	-	-	-	-	1.00	**.34****	**.18****	.003	**-.28****	**.11****	.01	**.41****	**.18****	**.15****
	SE	-	-	-	-	-	-	-	-	-	-	-	-	1.00	**.26****	**-.12****	**-.22****	-.004	.040	**.11****	**.28****	.055
	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-.318	-.551	-.008	.045	**.40****	**.56****	**.28****
	FR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	**.38****	**.46****	**.29****	**-.10****	**-.23****	**.12****
	EF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	.061	.026	**-.54****	**-.43****	**-.12****
Appetite 5 years	EOE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	**.22****	**.072***	.026	**.42****
	DD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	.040	.008	**.15****
	FF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	**.268****	**.199****
	SE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	**.26****
	EUE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00

Note. SR = Satiety Responsiveness; FR = Food Responsiveness; EF = Enjoyment of Food; EOE = Emotional Overeating; FF = Food Fussiness; SE = Slowness in Eating. FF = Food Fussiness; EUE = Emotional Undereating; DD = Desire to Drink. *p < .01, **p<.001