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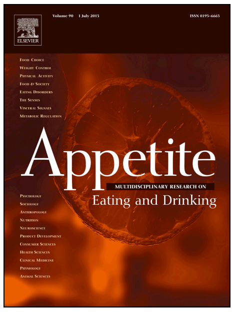

Prospective associations between parental feeding practices used in toddlerhood and preschool children's appetite vary according to appetite avidity in toddlerhood

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Abstract

Parental feeding practices are a key modifiable component of children's food environments. Evidence suggests that certain feeding practices may differentially influence children's eating behaviour or weight, depending on the child's temperament (e.g. emotionality). Building on this work, we tested the hypothesis that feeding practices during toddlerhood influence children's developing eating behaviours differently, depending on their appetite avidity (which is characterised by a larger appetite and greater interest in food). Data were from Gemini, a population-based cohort of British twin children born in 2007. Parental feeding practices were assessed at 15-months, and child appetite at 15-months and 5-years, using validated psychometric measures (n=1858 children). Complex samples general linear models examined prospective associations between PFPs at 15-months and child appetitive traits at 5-years, adjusting for clustering of twins within families and for the corresponding child appetitive trait at 15-months, difference in age between timepoints, child sex, gestational age, and socioeconomic status. Moderation analyses revealed that pressuring a child to eat led to greater increases in emotional overeating from 15-months to 5-years, only for children with high (1 SD above the mean: $B=0.13$; $SE\pm=0.03, p<0.001$) or moderate emotional overeating (mean: $B=0.07 \pm 0.03, p<0.001$) in toddlerhood. Greater covert restriction predicted greater reductions in emotional overeating and food responsiveness from 15-months to 5-years, only for children with high emotional overeating (1 SD above the mean: $B= -0.06 \pm 0.03, p=0.03$) and low food responsiveness (1 SD below the mean: $B= -0.06 \pm 0.03, p=0.04$) in toddlerhood. These findings are consistent with the hypothesis that children with a more avid appetite in toddlerhood are differentially affected by parental feeding practices; caregivers of toddlers may therefore benefit from feeding advice that is tailored to their child's unique appetite.

Key words: Child, Appetite, Parental feeding practices, Eating, Avid

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1. Introduction

Early childhood is a key period for the development of eating behaviours, appetite regulation and risk of obesity (Ramirez-Silva et al., 2021). Parental feeding practices (PFPs) are hypothesised to play a role in shaping children's eating behaviours and appetite (Carnell et al., 2014; Carnell & Wardle, 2007b; Musher-Eizenman & Holub, 2007; Russell et al., 2018) during this period. Individual differences in appetite are observable from early infancy, and Behavioural Susceptibility Theory (BST) postulates that variation in appetite avidity influences how much children eat in response to environmental cues and opportunity (Llewellyn & Fildes, 2017; Wardle & Carnell, 2009). In turn, these differences in eating behaviour result in some children being more vulnerable to developing obesity than others (Llewellyn & Fildes, 2017; Wardle & Carnell, 2009).

Appetite avidity, which is characterised by a larger appetite and greater interest in food, is influenced by both genetic and environmental influences, from early life. PFPs are a key modifiable component of a young child's food environment (Daniels et al., 2014), and have the potential to exacerbate or minimise the expression of a child's appetitive traits over time. For example, using food to reward a child who is more responsive to foods may further increase their responsiveness to the rewarded food, particularly if the rewarded food is highly palatable. As such, they have been the focus of several obesity prevention strategies (Gomes et al., 2021; Ruggiero et al., 2021). In particular, a large RCT that targeted PFPs in infancy and toddlerhood (NOURISH, which aims to support parents to recognise and respond to their child's hunger and satiety cues, and to use responsive feeding practices such as positive role modelling, providing structure, avoiding coercive or emotional feeding, further details are provided elsewhere Daniels et al., 2013) showed that children whose parents modified their feeding practices had better appetite regulation and a healthier relationship with food in early childhood (Daniels et al., 2014), suggesting that PFPs play a causal role in the development of children's eating behaviour. Early childhood therefore offers a unique window of opportunity for intervention (Blake-Lamb et al., 2016), after which appetite and eating behaviours have moderate stability and track from early to late childhood (Ashcroft et al., 2007).

However, evidence from longitudinal studies has shown that parents also adapt their feeding practices in response to their child's weight status and appetite (Kininmonth et al., under review; Steinsbekk, Belsky, & Wichstrom, 2016). Parents of a child with a more avid appetite (for example, a child who is more food responsive or less satiety responsive) are more likely to use controlling or nonresponsive feeding practices such as restriction to try to control their food intake (Carnell et al., 2014; Webber et al., 2010). These, and other, feeding practices have been cross-sectionally and prospectively associated with variation in children's appetitive traits, with reciprocal (Steinsbekk, Belsky, & Wichstrøm, 2016) as well as parent- and child-driven relationships observed (Harris et al., 2016; E. Jansen et al., 2018; Kininmonth et al., under review; Mallan et al., 2018).

Evidence also suggests that children may be differentially affected by PFPs, depending on their unique characteristics. Experimental and prospective research has demonstrated that the relationship between nonresponsive feeding practices such as restriction and children's eating behaviours or BMI varies as a function of a child's inhibitory control (Anzman & Birch, 2009; Rollins et al., 2014; Rothbart et al., 2001). For example, exposure to more parental restriction led to greater increases in BMI over time (Anzman & Birch, 2009) and eating in the absence of hunger during experimental protocol (Rollins et al., 2014), only for those with low inhibitory control. These findings suggest that some children may be more influenced than others, positively or negatively, by certain PFPs. Furthermore, research has shown that child temperament also shapes which PFPs children are exposed to, with more emotional children being less likely to experience restriction or to accept attempts to have their food intake reduced (Farrow et al., 2018). One characteristic that has not yet been studied in relation to PFPs is children's appetitive traits. Children may be differentially affected by PFPs depending on their appetite avidity in early life. For example, a child with a greater tendency to emotionally overeat in early life may be more susceptible to a parent who uses food to comfort their child if upset (emotional feeding) and these nonresponsive feeding practices may be more likely to be effective, but in turn they may nurture greater increases in their emotional overeating over time compared to a child with fewer emotional overeating tendencies in the first place.

RCTs have shown that PFPs are modifiable; therefore, understanding the relationships between PFPs and children's appetite and how they interact is important. However, as far as we are aware, no longitudinal studies in large representative cohorts have yet examined if relationships between PFPs and children's appetite vary as a function of a child's appetite avidity in early life. Therefore, the purpose of this study was to establish if longitudinal associations between PFPs and children's appetite traits vary according to children's appetite avidity in toddlerhood. We hypothesise that nonresponsive feeding practices in toddlerhood are associated with greater increases in appetite avidity from toddlerhood to early childhood, for those children who have high appetite avidity in toddlerhood. We also hypothesise that responsive feeding practices in toddlerhood will be associated with reductions in appetite avidity for those children who are more food responsive.

2. Methods

2.1 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 and completed baseline questionnaires when their children were on average 8.2 (±SD 2.2) months old. The recruitment of the sample has been described in detail elsewhere(van Jaarsveld et al., 2010). Data used in this study are from baseline, 15 months, and five years. Of the 2402 families who completed the baseline questionnaire, 1931 families (80.4%) completed the 15 months questionnaire, and 1087 families (45.3%) completed the five years questionnaire. This study sample comprised 929 families with complete data on PFPs and child appetite (1858 children; 955 [51.4%] female). The twins' primary caregiver provided written informed consent for their family to participate in the study. Ethical approval was granted by the University College London Committee for the Ethics of non-National Health Service Human Research. The Gemini dataset was used as it is one of the most comprehensive and largest UK-based longitudinal birth cohorts with repeated measures of weight, height, a wide range of eating behaviours, PFPs and sociodemographic characteristics, from early life, that was available to the authors which allowed the research question to be addressed.

2.2 Measures

2.2.1 Parental feeding practices

Eight PFPs were reported by the primary caregiver when their children were 15 months and 5 years old using measures of PFPs (Table S1) (Birch et al., 2001; Musher-Eizenman & Holub, 2007; Ogden et al., 2006; Wardle et al., 2002). Items were rated using a five-point Likert scale from 'never' (1) to 'always' (5). The eight scales included three nonresponsive (Instrumental feeding, Emotional feeding, Pressure to eat) and five responsive PFPs (Covert restriction, Control over meals/snacks, Monitoring, Encouragement to eat healthy foods, Modelling of healthy eating). 'Instrumental feeding' measures caregivers' use of food as a contingency for healthy food consumption or good behaviour (4 items; e.g., *'I use puddings as a bribe to get my child to eat his/her main course'; 15 months:α=0.50*). 'Emotional feeding' measures caregivers' use of food to manage or control a child's negative emotions (5 items; e.g. *'I give my child something to eat to make him/her feel better when s/he is feeling upset'; 15 months:α=0.85*). The 'pressure to eat' scale measures caregivers' attempts to coerce the child to eat more (5 items; e.g. *'My child should always eat all of the food I give him/her'; 15 months:α=0.65*). 'Covert restriction' measures the extent to which parents restrict their child's access to foods, supposedly without their child knowing (4 items; e.g. *'I avoid buying unhealthy foods and bringing them into the house'; 15 months:α=0.69*). The 'Parent control' scale examines the extent to which caregivers exert control over what and when their child eats meals and snacks (5 items; e.g. *'I decide how many snacks my child should have'; 15 months:α=0.58*). 'Encouragement to eat' assesses caregivers use of positive reinforcement to encourage their child to eat food, particularly healthy foods (5 items; e.g. *'I encourage my child to eat a wide variety of foods'; 15 months:α=0.59*). 'Monitoring' assesses the extent to which caregivers keep track of their child's high fat/sugary food consumption while in their own or others' care (3 items; e.g. *'I keep track of the high fat foods that my child eats'; 15 months:α=0.72*). 'Modelling' assesses the extent to which caregivers model healthy eating to their children (4 items; e.g. *'I model healthy eating for my child by eating healthy foods myself'; 15 months:α=0.80*). A mean score was calculated for each of the scales for each twin if responses were available for most items within a scale (2/3 for monitoring, 3/4 for modelling, instrumental feeding and covert restriction, and 3/5 items for remaining scales). If participants had completed all items for that scale, all items were used to generate the mean scale score. Most participants had completed all items for each scale. Between 0.3-1.7% of the analysis sample (6-21 participants) had missing data for 1 item and 0.1% of sample (2 participants) had missing data for 2 items for emotional feeding.

2.2.2 Child appetitive traits

Child appetite was assessed at five years using the Children's Eating Behaviour Questionnaire (CEBQ) (Wardle et al., 2001) and at 15 months using the CEBQ-T (toddler version of the CEBQ). The CEBQ is a parent-reported psychometric measure of eight appetitive traits (seven eating behaviour traits and one drinking behaviour trait), which consists of 35 items, rated using a 5-point Likert scale (1=Never to 5=Always). It has been validated using behavioural measures of food intake and has good internal and test-retest reliability (Carnell & Wardle, 2007a; Wardle et al., 2001). Five of the seven eating behaviour scales were selected for this study, on the basis that they were robustly associated with measures of adiposity in a recent meta-analysis (Kininmonth et al., 2021). The five selected scales included three food approach traits which characterise a more avid appetite and greater interest in food (Food Responsiveness, Enjoyment of Food, Emotional Overeating) and two food avoidant traits which characterise a less avid appetite and lower interest in food (Satiety Responsiveness, Slowness in Eating). Food Responsiveness (FR) 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'; 15 months:α=0.76, 5 years:α=0.81*). Enjoyment of Food (EF) assesses a child's subjective pleasure from eating (4 items, e.g. *'My child loves food'; 15 months:α=0.85, 5 years:α=0.86*). Emotional Overeating (EOE) assesses the extent to which a child eats more in response to emotional stressors (4 items, e.g. *'My child eats more when worried'; 15 months:α=0.82, 5 years:α=0.77*). Satiety Responsiveness (SR) measures a child's sensitivity to internal cues of 'fullness' (5 items e.g. *'My child gets full up easily'; 15 months:α=0.75, 5 years:α=0.76*). Slowness in Eating (SE) refers to the speed of meal consumption (4 items, e.g. *'My child eats slowly'; 15 months:α=0.66, 5 years:α=0.79*). A mean score was calculated for each subscale was only calculated for participants who had completed the majority of items for that scale (3/4 for EOE, EF, SE and 3/5 for FR and SR). If participants had completed all items for that scale, then all items were used to generate the mean scale score. Most participants had completed all items for each scale. Between 0.1-1.2% of the analysis sample had missing data for 1 item.

2.2.3 Demographic information

Primary caregivers reported the sex, date of birth and birth weight (kg) of their twins in the baseline questionnaires. Primary caregivers 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 15 months questionnaires. Electronic weighing scales and height charts were sent to all families when the twins were aged two years to collect parent-reported height and weight measurements every 3 months. Weight (kg) data at 15 months and 5 years (60 months) were used. Standard deviation scores (SDS) for child weight (Weight-SDS) were calculated using the UK90 British growth reference data(Freeman et al., 1995), adjusting for age, sex, and gestational age. Weight gain (kg) was calculated by subtracting weight at 15 months from weight at 60 months. Paternal and maternal height and weight were also self-reported at baseline by the primary caregiver (for themselves and on behalf of their partner) and used to calculate BMI (kg/m^2).

Primary caregivers provided information about multiple indicators of socioeconomic status (SES), including: highest maternal educational qualification; current occupation (both parents); total annual household income; postcode; home ownership status; number of bedrooms in the home; and number of cars. Principal component analysis was used to create the SES composite score, which incorporated these seven indicators of SES. The seven indicators provided insights into individual, household and neighbourhood level factors to try to capture the complexity of SES. Higher composite scores reflect higher SES (scores ranged from 1.30-6.96). Further details about the creation of SES composite scores are described elsewhere (Kininmonth et al., 2020).

2.3 Missing data

Data were missing for the following covariates: parental BMI (n=2), children's weight at 15 months (n=725) and 5 years (n=1138), and gestational age (n=10). Missing data on covariates were handled using Multivariate Imputation by Chained Equations (MICE) package in R (Buuren, 2010), to ensure that the sample size was maximised for the analyses. All variables included in the study were used as predictors to enhance prediction of imputed estimates. We performed a maximum of 50 iterations to create 20 imputed datasets. Pooled statistics for the main analyses are shown in the results. Data were not imputed for parental feeding practices and child appetitive traits.

2.4 Statistical analysis

Complex samples general linear models (CSGLM) were used to examine associations between each PFP at 15 months (independent variable) and each child appetitive trait (CEBQ subscale) at 5 years (dependent variable), controlling for the corresponding child appetitive trait at 15 months, difference in age between timepoints, sex of child, gestational age, and SES. All analyses were conducted in R (R Core Team, 2018, 2020) (version 4.1.1) using the statistical package *Survey* (Lumley et al., 2021) which allows adjustment for clustering of twins within families. An interaction term between the PFP at 15 months (independent variable) and the child appetitive trait at 15 months (moderator) was included in models to test the hypothesis that the relationship between PFP at 15 months and child appetitive traits at 5 years varies according to children's appetite at 15 months (toddlerhood). Child appetitive traits and parental feeding practices were mean-centred in the interaction models to aid interpretation. Separate models were run for each parental feeding practice and each appetitive trait. An alpha level of 0.05 was used. No adjustment for multiple testing was made, and all results are presented in full, in line with the Gemini study policy.

2.3.1 Sensitivity analyses

Weight has been cross-sectionally and prospectively associated with both appetite and PFPs. Analyses were therefore rerun including weight gain as a main effect to allow the independent prospective association between parental feeding practices and appetite to be examined, after confounding from child weight gain was controlled for. Raw weight gain (kg) was used, rather than change in weight SDS, as evidence has suggested that raw weight gain is preferred when examining weight change over time (Cole et al., 2005). In addition, an interaction term between weight SDS at 15 months and PFPs at 15 months was included to ensure any interactions between PFPs and appetite were not just reflecting interactions between PFPs and weight. Finally, parental BMI at 15 months was included as a main effect as parental BMI is highly correlated with child BMI.

3. Results

The characteristics of the analysis sample are shown in **Table 1.** Compared to the total Gemini sample (n=2402 families), primary caregivers in this study were significantly older at their twins' birth (33.92 years vs 32.94), of significantly higher SES (4.63 vs 4.33), and had a significantly lower BMI (24.64 vs 25.10), although the sizes of the differences were small. These differences in SES (4.64 vs 4.30), maternal age at twins' birth (33.95 vs 32.78) and BMI (24.62 vs 25.32) were also observed when the analysis sample was compared to families with data at 15 months.

Table 1: Descriptive statistics for analysis sample with complete data at 15 months and 5 years (n=1858 twins, 929 families).

Sample characteristics	***Mean (SD) or N (%)***
Sex	
Female	955 (51.4%)
Gestational Age (weeks)	36.28 (2.45)
Maternal age at twin birth (years)	33.92 (4.59)
Age at 15 months (months)	15.62 (0.95)
Age at five years (years)	5.15 (0.13)
Weight SDS at 15 months	-0.09 (1.07)
Weight SDS at five years	-0.04 (0.89)
Weight gain (kg) from 15 months to five years	8.13 (1.60)
Parental BMI	25.5 (3.07)
SES composite score[1]	4.63 (1.24)
Appetitive traits at 15 months	
Food Responsiveness	2.23 (0.75)
Emotional Overeating	1.63 (0.58)
Enjoyment of Food	4.17 (0.62)
Satiety Responsiveness	2.68 (0.63)
Slowness in Eating	2.48 (0.65)
Parental feeding practices at 15 months	
Emotional feeding	2.01 (0.72)
Pressure to eat	2.22 (0.71)
Instrumental feeding	1.32 (0.46)
Restriction	3.07 (0.90)
Parent control	4.48 (0.45)
Monitoring	3.60 (1.03)
Encouragement	4.03 (0.62)
Modelling	3.40 (0.83)
Appetitive traits at 5 years	
Food Responsiveness	2.37 (0.73)

Emotional Overeating	1.56 (0.51)
Enjoyment of Food	3.88 (0.67)
Satiety Responsiveness	2.86 (0.62)
Slowness in Eating	2.83 (0.77)

[1]SES composite scores ranged from 1.30-6.96; lower scores on the composite reflect lower SES.

3.1. Interactions: Do the prospective associations between parental feeding practices and child appetite vary according to appetite avidity in toddlerhood?

Moderation analyses were performed to establish if longitudinal associations between PFPs and children's appetite traits varied according to children's appetite avidity in toddlerhood.

Nonresponsive feeding practices

A significant interaction was observed between pressure to eat and emotional overeating (unstandardised Beta (B) = 0.09, SE±= 0.04, p=0.03). For children with high (1 SD above mean: B=0.13 ± 0.03, p<0.001) or moderate (mean: B=0.07 SE± 0.03, p<0.001) emotional overeating at 15 months, more pressure to eat at 15 months was associated with greater increases in emotional overeating from 15 months to 5 years (**Figure 1**). Each one unit increase in pressure to eat at 15 months was associated with a 0.13 increase in emotional overeating from 15 months to 5 years for children with high emotional overeating and a 0.07 increase for children with moderate emotional overeating at 15 months, holding all other variables constant. There was no significant relationship between pressure to eat and emotional overeating at 5 years for those children with low emotional overeating at 15 months.

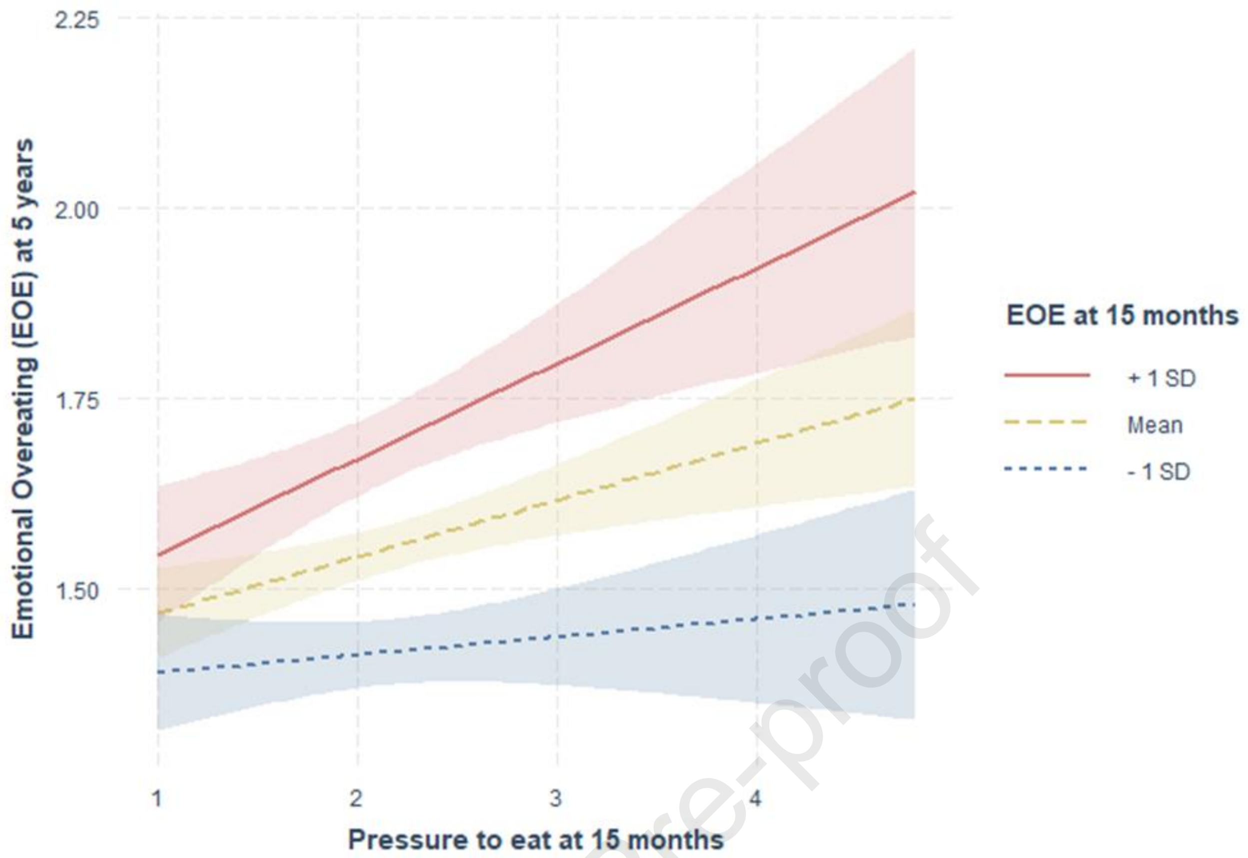

Figure 1: Simple regression slopes for moderation analysis between pressure to eat and emotional overeating (EOE). 1 SD above the mean represents high EOE, the mean value represents moderate EOE and 1 SD below the mean represents low EOE.

A significant interaction was observed between pressure to eat and slowness in eating (B= 0.08 SE±0.04, p=0.04; **Figure 2**). For children with high (1 SD above mean: B= 0.16 ± 0.04, p<0.001) or moderate (mean: B= 0.11 SE± 0.03, p<0.001) slowness in eating at 15 months, more pressure to eat at 15 months was associated with greater increases in slowness from 15 months to 5 years (in other words, slower speed of eating from 15 months to 5 years). Each one unit increase in pressure to eat was associated with a 0.16 increase in slowness in eating from 15 months to 5 years, for children with high slowness in eating and a 0.11 increase for those with moderate slowness in eating at 15 months. There was no significant relationship between pressure to eat and slowness in eating at 5 years for those children with low slowness in eating (quicker speed of eating) at 15 months (1 SD below mean: B= 0.06 SE± 0.04, p=0.13).

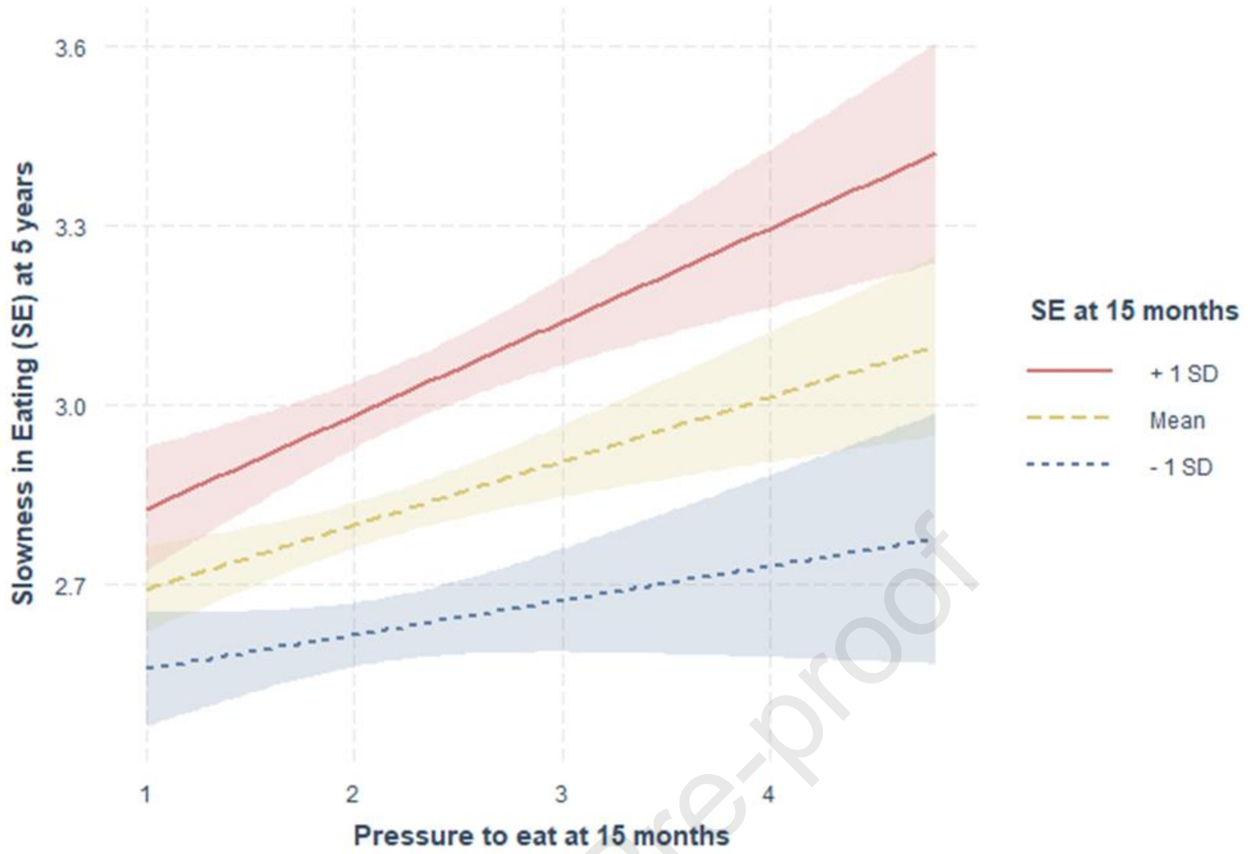

Figure 2: Simple regression slopes for moderation analysis between pressure to eat and slowness in eating (SE). 1 SD above the mean represents high SE, the mean value represents moderate SE and 1 SD below the mean represents low SE.

Responsive feeding practices

There was a significant interaction between covert restriction at 15 months and food responsiveness at 15 months in predicting food responsiveness at 5 years (B=0.07 SE± 0.03, p=0.017). For children with low food responsiveness at 15 months, greater covert restriction was associated with reductions in food responsiveness by 5 years (1 SD below the mean: B= -0.06 SE± 0.03, p=0.04; **Figure 3**), such that each one unit increase in covert restriction at 15 months was associated with a -0.06 reduction in food responsiveness from 15 months to 5 years, for children with low food responsiveness at 15 months. Whereas, for children with moderate (mean: B=0.00 SE± 0.02, p=0.88) or high food responsiveness at 15 months (1 SD above the mean: B=0.05 SE± 0.04, p=0.14), there was no relationship between covert restriction and food responsiveness at 5 years.

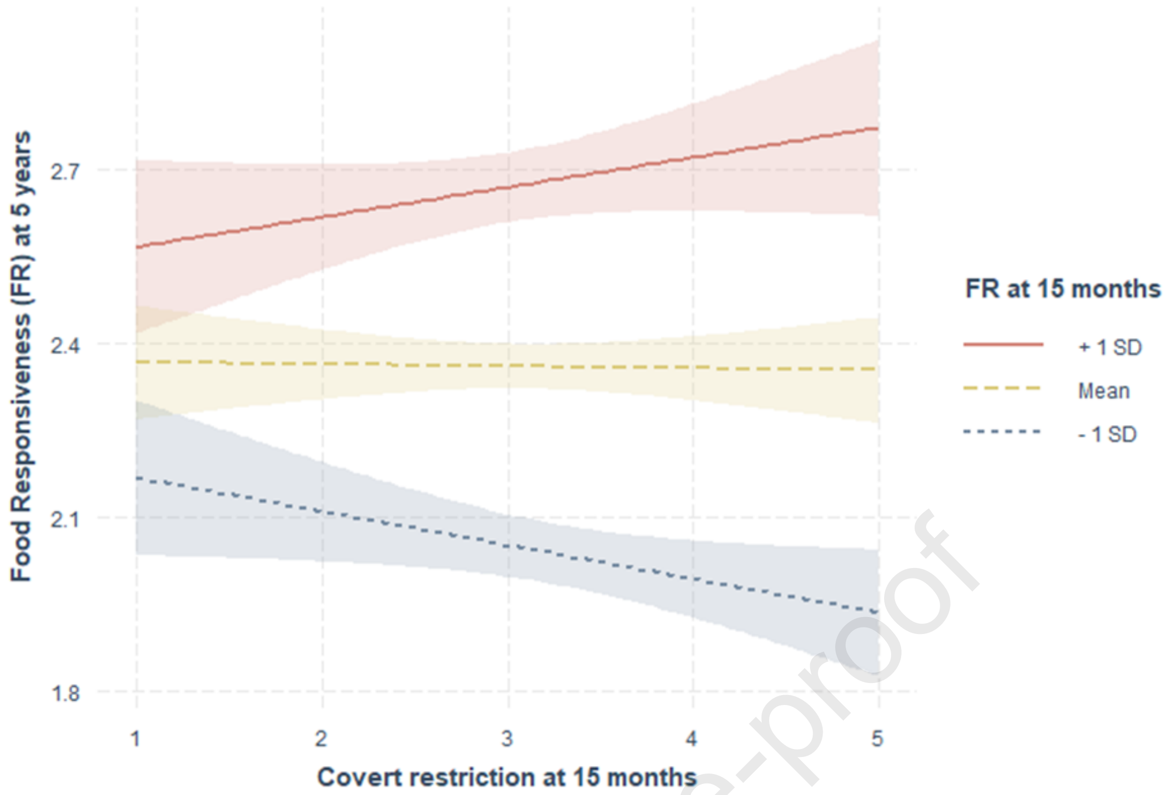

Figure 3: Simple regression slopes for moderation analysis between covert restriction and food responsiveness (FR). 1 SD above the mean represents high FR, the mean value represents moderate FR and 1 SD below the mean represents low FR.

There was also a significant interaction between covert restriction and emotional overeating at 15 months (B=-0.07 SE± 0.03, p=0.03). For children with high emotional overeating at 15 months, more covert restriction was associated with greater reductions in emotional overeating from 15 months to 5 years (1 SD above the mean: B = -0.06 SE± 0.03, p=0.03; **Figure 4**). Each one unit increase in emotional overeating was associated with a 0.06 reduction in emotional overeating from 15 months to 5 years, for children with high emotional overeating at 15 months. No significant relationship was observed between covert restriction at 15 months and emotional overeating at 5 years for children who had low (1 SD below the mean: B = 0.02 SE± 0.02, p=0.35) or moderate (mean: B=-0.02 SE± 0.02, p=0.22) emotional overeating at 15 months.

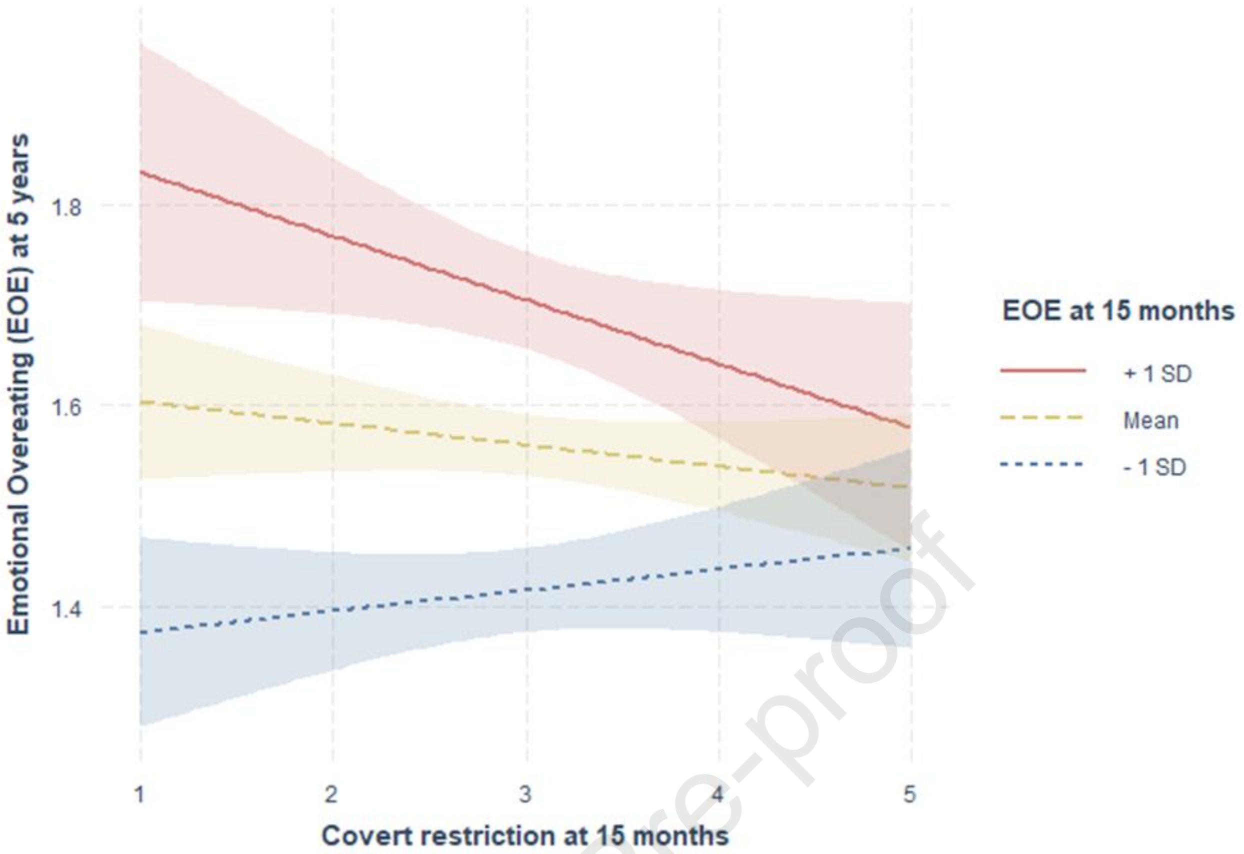

Figure 4: Simple regression slopes for moderation analysis between covert restriction and emotional overeating (EOE). 1 SD above the mean represents high EOE, the mean value represents moderate EOE and 1 SD below the mean represents low EOE.

Finally, there was no significant interaction between instrumental feeding and appetitive traits at 15 months. No significant interaction was observed between encouragement to eat and appetitive traits at 15 months, monitoring and appetitive traits at 15 months, emotional feeding and appetitive traits at 15 months, modelling and appetitive traits at 15 months or parent control and appetitive traits at 15 months. For completeness, a full description of the main effects and non-significant interaction terms are presented in the supplementary material (Table **S2-S9**).

3.3. Sensitivity analyses

The interactions described above were mirrored in the sensitivity analyses, except that the interaction between pressure to eat and slowness in eating did not remain ($B=0.04$ $SE\pm 0.04$, $p=0.338$) when including child weight gain and including an interaction term between child weight in toddlerhood and the feeding practice. This indicated that the interaction between pressure to eat and slowness to eat may be reflecting that parents may in fact be responding to their child's weight, as appetite is correlated with weight.

4. Discussion

This study aimed to establish, for the first time, if longitudinal associations between nonresponsive PFPs in toddlerhood and appetite in early childhood varied according to children's appetite avidity in toddlerhood. In this sample, the findings indicated that covert restriction and pressure to eat differentially affected the development of two key appetitive traits which characterise a more avid appetite – food responsiveness and emotional overeating - depending on children's appetite avidity in toddlerhood. Specifically, pressuring a child to eat when they do not wish to led to greater increases in emotional overeating from 15 months to 5 years, but only in those children with high or moderate emotional overeating tendencies in toddlerhood. We also hypothesised that responsive feeding practices would be associated with reductions in appetite avidity. In line with this hypothesis, we observed that greater use of covert restriction was associated with greater reductions in emotional overeating and food responsiveness from 15 months to 5 years, but only for those children with high emotional overeating tendencies and low food responsiveness in toddlerhood. These findings suggest that some children may be more susceptible than others to parental feeding practices, but that not all feeding practices are harmful and this should be considered when developing intervention strategies to support the development of children's healthy eating behaviours.

The present study identified that pressuring a child to eat predicted greater increases in emotional overeating from toddlerhood (15 months) to early childhood (5 years), but only for those children with high or moderate emotional overeating tendencies in toddlerhood. These findings suggest that some children (those with a more avid appetite) may be more susceptible to the effects of nonresponsive feeding practices such as pressure to eat than other children. Our findings extend previous cross-sectional research which has shown that exerting high levels of pressure to eat on a child is associated with higher emotional overeating in children aged 2 to 5 years old (Carper et al., 2000; Jansen et al., 2012) and 7-10 years old (Houldcroft et al., 2014). The findings of the current study point to specific parental feeding practices, such as emotional feeding and pressure to eat, as potentially modifiable behaviours that may nurture emotional overeating in early childhood, particularly for those children who are most susceptible to emotional overeating. We also observed that greater pressure to eat during toddlerhood (15 months) predicted slower speed of eating from toddlerhood to early childhood (5 years), but only for those children with slower speed of eating in toddlerhood. These findings are supported by previous cross-sectional research (Carnell et al., 2014; Haycraft & Blissett, 2012; Webber et al., 2010). Pressuring feeding practices may manifest in response to caregivers' fear that their child is eating insufficient amounts or variety of food (Haycraft & Blissett, 2012) or due to concerns about their child's weight status (Baughcum et al., 2001; Melbye & Hansen, 2015). Although well intentioned, pressuring feeding practices have been shown to lead to greater fussiness around food(Jansen et al., 2017) and lower intake of food at mealtimes (Galloway et al., 2006). Although, the interaction was no longer significant when adjusting for child weight, suggesting that the interaction between pressure and slowness in eating may be reflecting a relationship between pressure to eat and child weight. Nonetheless, pressuring a child to eat when they do not wish to appears to have a detrimental impact on the development of a child's eating behaviours. Such parental feeding practices may be important avenues to target as part of a tailored feeding intervention to support healthy development based on a child's appetitive traits.

One feeding practice that has been suggested to be beneficial for children's eating behaviours by providing structure and limits to guide a child is covert restriction (Brown et al., 2008; Ogden et al., 2006). Covert restriction is defined as "controlling a child's food intake in a way that *cannot* be detected by the child" (Nowicka et al., 2014; Ogden et al., 2006). Our findings suggest that this may only be true for less food responsive children. In this study, we observed that greater covert restriction in toddlerhood was associated with reductions in food responsiveness from 15 months to 5 years, but only for those children who were less food responsive. This may be because children who are less responsive to food cues may also be less likely to notice the changes to their food environment that occur as a result of covert restriction. As such, the less food responsive child's experience of this restriction is more likely to be genuinely covert, reducing the frequency of palatable food cues in the home food environment, and thus reducing opportunities to demonstrate food responsiveness over time. In contrast, children who are highly food responsive may be more aware of any changes in their food environment, therefore, despite the parents' best efforts, the restriction may not actually be occurring in a 'covert' manner, indicating that it may be harder to use covert restriction with a highly food responsive child. However, our findings suggested that covert restriction did not help nor have a detrimental effect on their responsiveness in highly food responsive children. Interestingly, we also observed that greater covert restriction in toddlerhood was associated with greater reductions in emotional overeating from 15 months to 5 years, but only for those children with high or moderate emotional overeating tendencies in toddlerhood. Covert restriction can be characterised by practices such as not buying unhealthy foods and bringing them into the house. Previous research has shown that emotional overeating is associated with increased consumption of energy-dense foods in the state of emotion (Nguyen-Michel et al., 2007; Sleddens et al., 2010). Therefore, it may be that by creating a home food environment which is not conducive to consuming energy-dense foods, through the use of covert restriction, reduces opportunities for children to consume such foods in response to their experiences of negative emotion, and thus, emotional eating behaviour is less likely to be reinforced. If such foods are less accessible in the home environment, it may also, indirectly, reduce the likelihood of parents using such foods to regulate children's emotions. Experiences of covert restriction did not significantly affect the development of emotional eating in those children who expressed low tendencies to emotional overeating at 15 months, suggesting that low levels of this trait in early life may be protective in terms of the development of later emotional eating, irrespective of the home food environment. In summary, our findings indicate that covert restriction does not appear to have a detrimental effect on appetite and may be beneficial in reducing emotional overeating in those children predisposed to this behaviour. As such, covert restriction may be a potential feeding practice that could be promoted to families.

In this study, we observed that using food to control a child's emotions or behaviour, or having low levels of control over feeding during toddlerhood, are feeding practices which are all associated with increases in appetite avidity from toddlerhood to early childhood, irrespective of the child's appetitive traits in toddlerhood. Our findings support and extend previous cross-sectional research which has found that emotional feeding and instrumental feeding were associated with higher food cue responsiveness in children aged 3-5 years (Carnell et al., 2014) and higher emotional overeating (Rodgers et al., 2013; Tan & Holub, 2015). Evidence has suggested that these nonresponsive feeding practices may encourage a child to associate eating with cues other than hunger, thus increasing the likelihood of eating in the absence of hunger (Wardle et al., 2002) and increasing a child's preference for and wanting of the reward food (Birch et al., 1982), potentially leading to increased snacking (Sleddens et al., 2010) and poor regulation of energy intake throughout childhood. Importantly, our findings highlight that children were not differentially affected, indicating that these nonresponsive feeding practices have a negative impact on appetite development, regardless of children's appetite in toddlerhood. Furthermore, responsive feeding practices such as greater monitoring, encouragement to eat healthy foods were associated with greater enjoyment of food, irrespective of appetitive traits in toddlerhood. These findings suggest that greater monitoring and encouragement to eat healthy foods may be important responsive feeding practices that play a role in shaping a child's enjoyment of food. These findings should be taken into consideration when developing interventions to support the development of healthy eating behaviours.

4.2. Strengths and limitations

Strengths of this study include the large sample size, prospective analyses, and the use of multiple, well-established, validated psychometric measures of parental feeding practices and appetite (Carnell & Wardle, 2007a). Nonetheless, there are several limitations that should be acknowledged. Firstly, the sample are relatively homogenous in nature, with the majority identifying as White-British with a smaller representation of lower SES families compared to the general population, therefore the findings may not be representative of families from more deprived backgrounds or different cultural backgrounds. Factors such as time constraints, conflicting priorities, and frequent changes in contact information make it harder to retain lower SES families in longitudinal cohorts and as such the proportion of lower SES families in the Gemini cohort has decreased over time (Brannon et al., 2013; Cui et al., 2019). Parental feeding practices have been shown to differ by socioeconomic status and ethnicity (Cardel et al., 2012; Gross et al., 2012a), with lower SES linked to greater use of pressure to eat and restriction (Gross et al., 2012b). Furthermore, parents from ethnic minorities have been found to use more restriction and pressure to eat, compared to non-minority groups (Blissett & Bennett, 2012; Cardel et al., 2012; Gu et al., 2017). Therefore, greater variation in feeding practices may be present in more diverse samples with a wider range of socioeconomic status and ethnicity. Future research should aim to replicate the findings in more socioeconomically and ethnically diverse samples. In addition, it is also important to note that the internal consistency as indicated by the Cronbach's alpha was low (<0.7) for 'pressure to eat', 'instrumental feeding', 'parent control', 'encouragement to eat'. However, in recent years it has been highlighted that a Cronbach's alpha value between 0.6-0.8 is acceptable (Ursachi et al., 2015). Most scales, except 'instrumental feeding' met this criterion when rounding to one decimal place. The low internal consistency may indicate that the items in the scale are poorly related, or it could be due to low number of items in the scale. Despite the low internal reliability, this scale was included to enable the relationships between such feeding practices and child appetite to be examined, to further understanding in this area and provide opportunity for the findings to be replicated by other researchers. Another important limitation to discuss is the observational nature of this study which limits our ability to infer causal relationships. While the findings are consistent with our hypothesis that PFPs differentially affect the development of appetite, depending on the child's appetite in toddlerhood, more research in the form of a randomised controlled trial or an intervention-based study is required to test this hypothesis and establish causality.

4.3. Future directions and intervention

Notwithstanding these limitations, the findings of the current study point to specific parental feeding practices that could be targeted when developing intervention or preventative strategies to support the development of children's healthy eating behaviours and also suggest that caregivers may benefit from feeding advice being tailored to their child's unique appetitive traits. To date, only a few existing interventions have focussed on modifying parental feeding practices (Gomes et al., 2021) and even fewer have examined the influence of such modifications on children's appetite (Ruggiero et al., 2021). The NOURISH intervention has shown promising findings in this area, with reductions in non-responsive feeding practices (Ruggiero et al., 2021) and improvements in children's eating behaviours, such as reductions in food responsiveness and emotional overeating (Magarey et al., 2016). The findings of the current study suggest that interventions or preventative strategies could be further developed by tailoring feeding advice based on children's appetite avidity in early childhood. Additionally, current public health advice regarding managing children's eating is generic, ineffective and does not acknowledge the variability in children's appetite avidity. This lack of tailored feeding advice makes behaviour change very difficult for parents of children with a more avid appetite as they do not know the most appropriate way to manage their child's eating behaviours effectively. As such, future feeding advice should be tailored based on children's appetitive traits to help support parents of children with a more avid appetite. There is scope for the CEBQ to be adapted for use as a screening tool to characterise toddler or child appetite in order to provide tailored advice for parents.

5. Conclusion

This study highlights that children with more avid appetites in toddlerhood may be differentially affected by two parental feeding practices - covert restriction and pressure to eat - and as such feeding advice may need to be targeted according to a child's appetitive traits, as some children are more susceptible to certain feeding practices than others. The findings provide insight into the parental feeding practices that could be targeted when developing intervention or preventative strategies and suggest that advice may need to be tailored based on children's appetitive traits.

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Competing interests

The authors declare that they have no competing interests.

Data availability

Data described in the manuscript and analytic code can be made available upon request to the Gemini team. Please visit the Gemini website and complete a data request form (https://www.geministudy.co.uk/data-access). This will then be reviewed through the Gemini Executive Committee in accordance with the Gemini Data Access Policy.

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Ethical statement

Ethical approval was granted by the University College London Committee for the Ethics of non-National Health Service Human Research (Project ID Number: 1126/001). Written informed consent was provided by all Gemini families. All aspects of data collection and storage were in compliance with the standards specified by this body.