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ORIGINAL RESEARCH

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Associations between dietary patterns, eating behaviours, and body composition and adiposity in 3-year-old children of mothers with obesity

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Summary

Background: The relationships between eating habits, behaviours, and the development of obesity in preschool children is not well established.

Objective: As children of mothers with obesity are themselves at risk of obesity, we examined these relationships in a cohort of 482 three-year-old children of mothers with obesity from the UK Pregnancy Better Eating and Activity Trial (UPBEAT).

Method: Dietary patterns were derived using factor analysis of an 85-item food frequency questionnaire (FFQ). Eating behaviours were assessed using the Children's Eating Behaviour Questionnaire (CEBQ). Measures of body composition included age-specific BMI cut-offs, WHO *z* scores, sum of skinfolds, waist and arm circumferences, and body fat percentage. Using adjusted regression analysis, we examined associations between dietary patterns, eating behaviours, and measures of body composition.

Results: Three distinct dietary patterns were defined: "healthy/prudent," "African/Caribbean," and "processed/snacking." The "processed/snacking" pattern was associated with greater odds of obesity; OR 1.53 (95% CI, 1.07-2.19). The "African/Caribbean" and the "healthy/prudent" patterns were associated with a lower arm circumference (β = −0.23 cm [−0.45 to −0.01]) and sum of skinfolds (β = −1.36 cm [−2.88 to −0.37]), respectively. Lower enjoyment of food and food responsiveness, and greater slowness in eating and satiety, were associated with lower arm and waist circumferences, WHO *z* scores, and obesity (all $P < .05$).

Conclusion: In children of mothers with obesity, those who had higher scores on a "processed/snacking" dietary pattern had greater odds of obesity. In contrast,

Abbreviations: ALSPAC, Avon Longitudinal Study of Parents and Children; BIA, bioelectrical impedance analysis; BMI, body mass index; CEBQ, Children's Eating Behaviour Questionnaire; FFQ, food frequency questionnaire; IOTF, International Obesity Task Force; UPBEAT, UK Pregnancy Better Eating and Activity Trial; SWS, Southampton Women's Survey; WHO, World Health Organization.

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slowness in eating was associated with lower measures of body composition. These novel findings highlight modifiable behaviours in high-risk preschool children which could contribute to public health strategies for prevention of childhood obesity.

KEYWORDS

childhood obesity, dietary patterns, eating behaviours, maternal obesity

1 | INTRODUCTION

Recent figures from the National Child Measurement Programme in England suggest that nearly a quarter of preschool children were overweight or had obesity,[1] with one in 40 children being affected by severe obesity. Obesity in early life is a predictor for adolescent and adulthood obesity,[2-4] with a recent meta-analysis of 37 studies reporting that children classified as having obesity using body mass index (BMI) were five times more likely to have obesity as adults compared with their healthy weight counterparts.[5] Worldwide, there is intense focus on reducing rates of childhood obesity.[6,7] The UK government recommend creating healthier food environments in schools, local areas, and providing parents with information on healthy food choices for their families with the aim of halving rates of childhood obesity by 2030.[6]

Several studies have independently suggested a relationship between eating behaviours[8-11] or dietary intake[12,13] and body composition in childhood. Associations between weight status in early life and food approach eating behaviours, such as food responsiveness and emotional overeating and consumption of energy dense foods, have consistently been reported. Longitudinal studies suggest that eating habits and food choices established in childhood are likely to persist into adulthood.[14-18] Therefore, the early years provide a unique opportunity to develop and establish healthy eating habits and behaviours.

Since current guidelines for prevention of childhood obesity recommend identification of populations at risk and early engagement,[6,7] we have addressed relationships between dietary habits and behaviours and childhood adiposity in children born to mothers with obesity. As recently reported by ourselves in a contemporary cohort,[19] and previously in many mother-child cohort studies, children of mothers with obesity are at high risk of developing obesity themselves.[20]

The primary aims of this study were to investigate (a) associations of childhood dietary patterns with measures of body composition and (b) associations between child's eating behaviours and measures of body composition in the 3-year-old children born to mothers from inner-city settings and ethnically diverse backgrounds (UK Pregnancy Better Eating and Activity Trial [UPBEAT]). The role of socio-economic deprivation in these relationships was also examined.

2 | METHODS

UPBEAT was a multicentre randomized controlled trial which explored the effect of an intensive 8-week antenatal diet and physical activity intervention in 1555 women with a BMI ≥ 30 kg/m^2.[21] The intervention focused on improving insulin sensitivity through reducing dietary glycaemic load, saturated fat intake, and increasing physical activity in comparison with standard antenatal care. The participants were from UK inner-city settings of ethnic diversity and high socio-economic deprivation. Details of the intervention inclusion and exclusion criteria have been published previously.[21,22] Research Ethics Committee approval was obtained in all participating centres, UK Integrated Research Application System; reference 09/H0802/5 (South East London Research Ethics Committee). All participants provided written informed consent.

The intervention had no effect on the primary outcomes of gestational diabetes and large for gestational age infants. However, it was effective at improving maternal dietary intake, reducing gestational weight gain, and sum of skinfolds and increasing self-reported physical activity by 36 weeks gestation (all $P \leq .04$). In the infants at 6 months of age, we have reported that the intervention was associated with a reduction in a measure of adiposity;[23] as a cohort analysis in these infants, we have also shown positive associations between measures of appetite, assessed by the Baby Eating Behaviour Questionnaire, and body fat percentage, weight, and growth.[24]

Between August 2014 and October 2017, participants in the UPBEAT study were invited to attend a 3-year post delivery visit with their children. The study design and protocol of the follow-up were approved by the NHS Research Ethics Committee (UK Integrated Research Application System; reference 13/LO/1108). The children were included in this analysis if they had (a) attended the follow-up visit at 3 years of age; (b) had eating behaviour and food frequency questionnaires completed by the main caregiver; and (c) had body composition data recorded during the 3-year visit. Children were excluded if they were suffering from severe illness or if they were born before 34 weeks gestation.

2.1 | Child variables

2.1.1 | Food frequency questionnaire

The child's diet was assessed using an 85-item food frequency questionnaire (FFQ). The list of food and drink items were compiled from the 80-item validated Southampton Women's Survey FFQ.[25] In addition, three questions were extended to include culturally appropriate options, eg, "Rice-boiled & fried" extended to "Rice-boiled & fried jollof, rice and peas." Five extra food items were included which were culturally appropriate for the non-white ethnic subgroups in the UPBEAT cohort (black—including Afro Caribbean and African) (Table S1). The FFQ asked how often in the last 3 months the child had consumed each item with response options including never, less than once per month, one to three times per month, number of times per week (1-7), or more than once per day. If the item was consumed more than once a day, the number of times was recorded. Food and drink items consumed more than once a week which were not included in the FFQ were recorded as additional items. Type of milk consumed as a drink or added to cereal and sugar added to drinks and cereal was also collected.

Dietary patterns of the children were derived using factor analysis. Food and drink items listed in the FFQ were categorized into 39 groups based on similar nutritional composition. On the basis of frequency consumption, three items recorded as additional foods were also included: porridge/shredded wheat, fast food (McDonalds, Burger King, and KFC), and cereal bars (Table S1). Factor analysis with orthogonal varimax rotation was performed to derive the patterns using the children's weekly standardized frequency of each of the 39 food groups. The number of factors retained was chosen using the scree plot of eigenvalues. Within each factor, food groups with a factor loading coefficient ≥ ±0.22 were chosen (Table S2); this cut-off was selected so that each dietary pattern had equal distribution of food groups. Food groups with a factor loading coefficient ≥ ±0.32 were considered to have a strong association with that factor. Derived dietary pattern labels were selected based on foods with the highest factor loadings (≥±0.32).

2.1.2 | Children's Eating Behaviour Questionnaire

The Children's Eating Behaviour Questionnaire[26] (CEBQ) is a validated parent-reported psychometric method to assess child's eating style and behaviour.[27] The questionnaire consists of 35 items divided into eight eating behaviours, further subdivided into food approach and food avoidance questions rated on a 5-point Likert scale (Never = 1, Rarely = 2, Sometimes = 3, Often = 4, Always = 5). Seven questions were reverse scored. Food approach behaviours include food responsiveness, emotional overeating, enjoyment of food, and desire to drink; food avoidance behaviours were satiety responsiveness, slowness in eating, emotional undereating, and food fussiness. Higher scores indicate a higher level for the respective eating style.

2.1.3 | Anthropometric measures and body fat percentage

The outcomes of interest for the offspring were measures of body composition and adiposity assessed by sum of skinfold thicknesses (addition of triceps, bicep, subscapular, suprailiac, and abdominal skinfolds, measured in triplicate by trained research staff using children's Holtain skinfold callipers), mid-upper arm and waist circumferences, body fat percentage assessed by ImpediMed Imp SFB7 bioelectrical impedance analysis (BIA) and weight, height, and BMI *z* scores derived using the World Health Organization (WHO) reference data.[28] Childhood obesity was defined by International Obesity Task Force (IOTF) sex-specific centiles (boys obesity = 98.9th centile and girls obesity = 98.6th centile).[29]

2.2 | Maternal variables

We also addressed relationships between maternal social and demographic variables (maternal age at trial entry, ethnicity, socio-economic status, years in full-time education, and early-pregnancy BMI) and offspring eating habits.

2.2.1 | Statistical analysis

In this secondary analysis of the UPBEAT study, there was no effect of the intervention on offspring eating patterns or behaviours; therefore, the data were treated as a cohort. Demographic results were expressed as mean ± standard deviation, median, and interquartile range or percent and number as appropriate. Depending on the outcome of interest, unadjusted and adjusted linear, logistic or quantile regression were used. Unadjusted regression (model 1) was performed to analyse the relationship between maternal social and demographic factors and dietary patterns at age 3 years, followed by adjusted regression (model 2) to investigate the relationship of the derived dietary patterns and the eight CEBQ subscale scores with the nine measures of body composition at age 3 years. For model 2, confounding variables were selected due to their association with dietary intake and body composition and included the minimization variables from the main trial (maternal BMI at trial enrolment, parity, and ethnicity), smoking status at baseline, maternal age, years spent in full-time education, infant birthweight, child's age at follow-up, sex, and randomization arm. Coefficients or odds ratios were presented with 95% confidence intervals. Data were analysed using Stata software, version 15.0 (StataCorp, College Station, Texas).

3 | RESULTS

Figure 1 shows a flow chart of participants through the study. Five hundred fourteen children (33.0% of the original UPBEAT cohort) were followed up at age 3 years (3.5 ± 0.28 years). Four hundred ninety (95%) provided complete dietary data (FFQ and CEBQ), eight children were excluded as they were either born ≤34 weeks gestation or were suffering from severe illness; therefore, the study population comprised 482 children. Data for the majority of measures of anthropometry had less than 5% missingness except for BIA (20%) and sum of skinfolds (23%). Of the 482 included children, 243 (50%) were female and 234 (49%) were born to mothers who were randomized to the UPBEAT intervention arm. Mean maternal age was 31.2 ± 5.2 years; 68% were white, 23% were black African/Caribbean, and 9% were from Asian or other ethnic backgrounds. Seventy-six percent were from the index of multiple deprivation quintiles 4 and 5 (most deprived). One hundred sixty-five of the children (34%) were overweight or had obesity, and 6% were morbidly obese (defined using the IOTF sex-specific centiles[29]). For the WHO *z* scores, the average height-for-age, weight-for-age, and weight-for-height were above the mean of the reference population 0.38 ± 1.1, 0.83 ± 1.0, and 0.90 ± 1.0, respectively (Table 1).

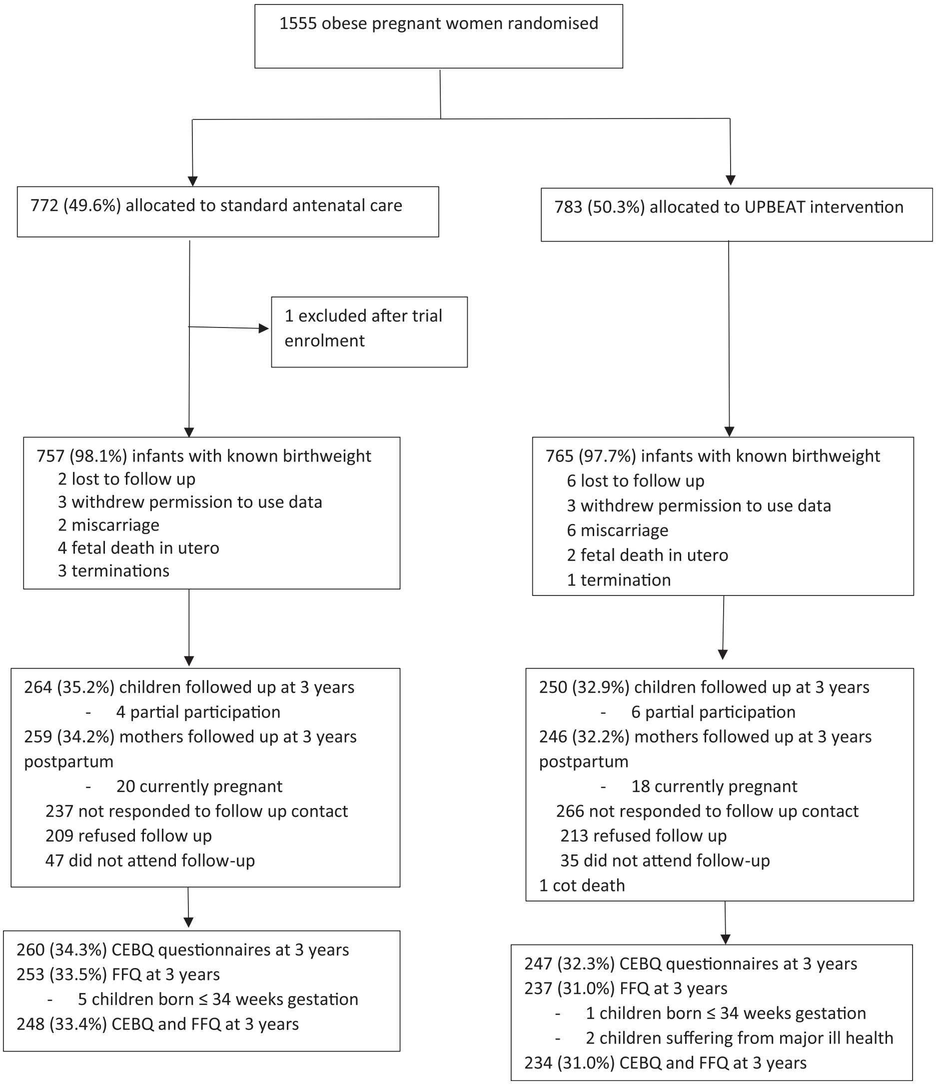

FIGURE 1 Consort diagram of participants enrolled in the UK Pregnancy Better Eating and Activity Trial (UPBEAT) at 3 years post-partum

3.1.1. | Dietary pattern analysis

Factor analysis identified three dietary patterns in the children, summarized in Figure S1 with the full list of factor loadings shown in Table S2. The first dietary pattern was labelled "healthy/prudent" due to high loadings (≥0.32) on brown bread, boiled and baked potatoes, rice and pasta, fish, vegetables, beans and pulses, fruit (fresh, tinned, and dried), and nuts. The second dietary pattern was characterized as a diet high in white bread, crisps and savoury snacks, roast potatoes (including chips), processed foods, quiche and pizza, confectionary, desserts, cakes, biscuits, and low and high sugary drinks, and this pattern was termed "processed/snacking." The third pattern, "African/Caribbean," was characterized by yam/cassava/plantain, red meat, chicken and turkey, soups (including African and Caribbean soups) and rice/pasta, fish, and offal and was low in cheese, yoghurts, and spreads.

3.1.2. | Maternal demographics

In a univariate analysis (model 1), different maternal social and demographic characteristics were associated with the three childhood dietary patterns. A higher number of years in full-time education and a higher maternal age were associated with the child having a higher score on a healthy/prudent dietary pattern. Fewer years in full-time education, lower maternal age, and having a white mother were associated with the child having a higher score on a processed/snacking dietary pattern. Having a black mother and a greater deprivation defined by index of multideprivation were associated with the child having a high score on an African/Caribbean dietary pattern (Table S3, all $P < .05$).

3.1.3. | Dietary patterns and anthropometric measures and body fat percentage

In the adjusted regression model (model 2), the healthy/prudent dietary pattern was associated with a −1.76 cm (95% confidence interval, −3.30 to −0.14, $P = .03$) lower sum of skinfolds. The processed/snacking pattern was associated with a higher odds of obesity ([BMI ≥ 30 kg/m^2], defined using the IOTF gender-specific cut-offs[29]) (OR = 1.53 [1.07 to 2.19] $P = .04$). The African/Caribbean pattern was associated with a lower arm circumference (−0.23 cm

TABLE 1 Maternal and offspring demographics of the analysed sample (n = 482)

Maternal Demographics	Mean (SD)/ Median (IQR)/N (%)	
Prepregnancy		
Age, y		31.2 (5.2)
Ethnicity	White	329 (68)
	Black	110 (23)
	Asian	20 (4)
	Other	23 (5)
Years in full-time education		15.0 (2.8)
Maternal BMI,[a] kg/m^2		34.7 (32.5-37.9)
Nulliparous		229 (50)
Index of multiple deprivation quintiles[b]	1 (least deprived)	30 (6)
	2	31 (6)
	3	55 (12)
	4	172 (36)
	5 (most deprived)	191 (40)
Maternal antenatal and neonatal demographics		
Mother assigned to UPBEAT Intervention		234 (49)
Gestational diabetes mellitus[c]		116 (25)
Birthweight, g		3499 (499)
Large for gestational age > 90th centile[d]		61 (12)
Small for gestational age < 10th centile[d]		34 (7)
Child 3-y follow-up demographics		
Age, y		3.5 (0.28)
Female		243 (50)
Mother living with a partner		387 (80)
Mother a current smoker		47 (9)
Mode of infant feeding at 4 mo	Breastfed	135 (52)
	Formula fed	105 (41)
	Mixed fed	18 (7)
BMI *z* score[d]	472	0.88 (1.0)
Height-for-age *z* score[d]	477	0.38 (1.1)
Weight-for-age *z* score[d]	477	0.83 (1.0)
Weight-for-height *z* score[d]	472	0.90 (1.0)
International Obesity Task Force gender-specific cut-offs BMI categories[e]	Underweight (<18.5 kg/m^2)	15 (3)
	Healthy (18.5-24.9 kg/m^2)	292 (62)
	Overweight (25.0-29.9 kg/m^2)	125 (26)
	Obese (30.0-34.9 kg/m^2)	14 (3)
	Morbidly obese (≥35.0 kg/m^2)	26 (6)
Sum of skinfolds,[a, f] mm	371	41.3 (34.0 to 50)
Percentage body fat, %	382	22.3 (6.5)
Arm circumference, cm	462	17.7 (1.8)
Waist circumference, cm	466	53.0 (4.3)

Abbreviations: BMI, body mass index; IQR, interquartile range.
[a]Median (interquartile range).
[b]Scores were calculated for the region of residence, by fifths of the population. UK-wide scores were developed from English and Scottish data relating to employment and income domains.
[c]Gestational diabetes diagnosed using the International Association of Diabetes in Pregnancy Group's criteria at 24 to 28 weeks gestation.
[d]World Health Organization (2007) *z* score.
[e]IOTF international cut-off as BMI references.
[f]Sum of triceps, biceps, subscapular, suprailiac, and abdominal skinfold thicknesses (mm).

TABLE 2 Associations between offspring dietary patterns at age 3 years of age and body composition

		Healthy		Processed and Snacking		African and Caribbean	
		Coefficient/Odds Ratio[e] (95% CI)		Coefficient/Odds Ratio[e] (95% CI)		Coefficient/Odds Ratio[e] (95% CI)	
BMI *z* score[a, d]	472	−0.01 (−0.12 to 0.09)	*P* = .82	0.06 (−0.04 to 0.16)	*P* = .23	−0.08 (−0.21 to 0.04)	*P* = .20
Body fat percentage, %	382	−0.10 (−0.92 to 0.71)	*P* = .80	0.66 (−0.10 to 1.43)	*P* = .09	−0.64 (−1.41 to 0.48)	*P* = .33
Height-for-age *z* score[a, d]	477	0.02 (−0.08 to 0.13)	*P* = .65	0.02 (−0.08 to 0.12)	*P* = .69	0.07 (−0.05 to 0.21)	*P* = .24
Height-for-weight *z* score[a, d]	472	−0.02 (−0.12 to 0.08)	*P* = .72	0.08 (−0.01 to 0.18)	*P* = .09	−0.08 (−0.21 to 0.04)	*P* = .18
Weight-for-age *z* score[a, d]	477	−0.01 (−0.12 to 0.09)	*P* = .75	0.05 (−0.04 to 0.15)	*P* = .28	−0.007 (−0.13 to 0.12)	*P* = .91
Arm, cm	462	−0.1 (−0.29 to 0.08)	*P* = .28	0.15 (−0.03 to 0.33)	*P* = .10	−0.23 (−0.45 to −0.01)	*P* = .04
Waist, cm	466	0.06 (−0.39 to 0.51)	*P* = .79	0.10 (−0.33 to 0.52)	*P* = .66	−0.45 (−0.98 to 0.08)	*P* = .09
Sum of skinfolds,[b] mm	371	−1.76 (−3.30 to −0.14)	*P* = .03	0.63 (−1.59 to 2.86)	*P* = .57	−0.89 (−3.12 to 1.33)	*P* = .43
Obese (IOFT cut-off)[c, d]	472	1.07 (0.73 to 1.56)	*P* = .70	1.53 (1.07 to 2.19)	*P* = .002	0.61 (0.37 to 1.01)	*P* = .056

Note: Children were excluded if they were born ≤34 weeks gestation or suffering from major ill health.
Abbreviations: BMI, body mass index; IOTF, International Obesity Task Force, gender-specific BMI cut-offs.
[a]Z scores calculated using the WHO growth standards (2007).
[b]Sum of triceps, biceps, subscapular, suprailiac, and abdominal skinfold thicknesses (mm).
[c]Odds ratio.
[d]Was not adjusted for infant sex or age at follow-up.
[e]Adjusted for maternal ethnicity, socio-economic status, smoking and BMI at baseline (15-18 weeks gestation), years spent in full-time education, maternal age, parity, infant birthweight, age at follow-up, sex, and randomization arm.

[−0.45 to −0.01], *P* = .04) (Table 2). No other dietary pattern-body composition associations were found.

3.1.4. | Eating behaviour and body composition

There were no differences in the CEBQ scores according to gender or mode of infant feeding (Tables S4 and S5). For the food approach scales, following adjustment for confounders, lower enjoyment of food, and food responsiveness were associated with lower arm and waist circumferences, weight-for-age, weight-for-height, and BMI *z* scores and obesity (all $P < .006$, Figures 2 and 3). For the food avoidance scales, greater slowness in eating and satiety responsiveness were associated with a lower BMI *z* score, a lower odds of obesity, weight-for-age, weight-for-height, and height-for-age *z* scores and arm and waist circumferences (all $P < .009$, Figures 2 and 3). Food fussiness was associated with a lower BMI, odds of obesity, and weight-for-height *z* score (all $P < .002$, Figures 2 and 3). Emotional undereating was not associated with any measures of body composition or adiposity; emotional overeating was only associated with weight-for-height *z* score ($P = .02$). Body fat percentage and sum of skinfolds were not associated with any of the eating behaviour subscales (data not shown).

Grouping the children by BMI class, an obese BMI (IOTF BMI centile cut-off equivalent to ≥30 kg/m^2) vs healthy, after adjustment for confounders, the children with obesity showed higher food approach scales scores for food responsiveness ($P = .001$), enjoyment of food ($P = .02$), and desire to drink ($P = .03$). In contrast, the food avoidance scale, slowness in eating, and satiety responsiveness ($P < .008$) were inversely associated with obesity (Table 3, Figure S2).

4 | DISCUSSION

This study uniquely explores associations between dietary patterns and eating behaviours with BMI and measures of adiposity in 3-year-old children born to mothers with obesity from high social deprivation and ethnically diverse backgrounds.

Children with obesity had higher scores on a processed/snacking dietary pattern defined as a diet high in confectionary, crisps, processed foods, cakes, and biscuits and greater food approach and less food avoidance eating behaviours. Dietary intake and body composition analyses in children have hitherto focused on specific food groups, such as sugar-sweetened beverages,[30] high sugar/fat snacks,[31] or fruit and vegetable intake.[32] However, dietary patterns reduces dietary data into fewer variables by combining highly correlated food groups; therefore, they may better define an individual's habitual diet as they attempt to describe the whole diet rather than description of specific nutrients or foods.[33] Whilst several studies have addressed relationships between dietary patterns and obesity in older children,[34] we are unaware of previous reports addressing dietary patterns and adiposity in 3-year olds even though at this age the children may already be on a trajectory to development of later life obesity.[35] Arguably, prevention at this age through appropriate dietary intervention may have particular gain in terms of prevention of adult obesity, as previous studies have reported that dietary patterns track from early childhood to later life.[36] A report of dietary patterns in the UK ALSPAC cohort of children described “healthy,” “traditional,” and “processed” dietary patterns in children at 3 years of age,[37] whilst the healthy and processed patterns are similar to the present study; other differences may reflect ethnic diversity of the UPBEAT cohort. Comparison in relations to body composition is not possible as the ALSPAC study did not include measurement of

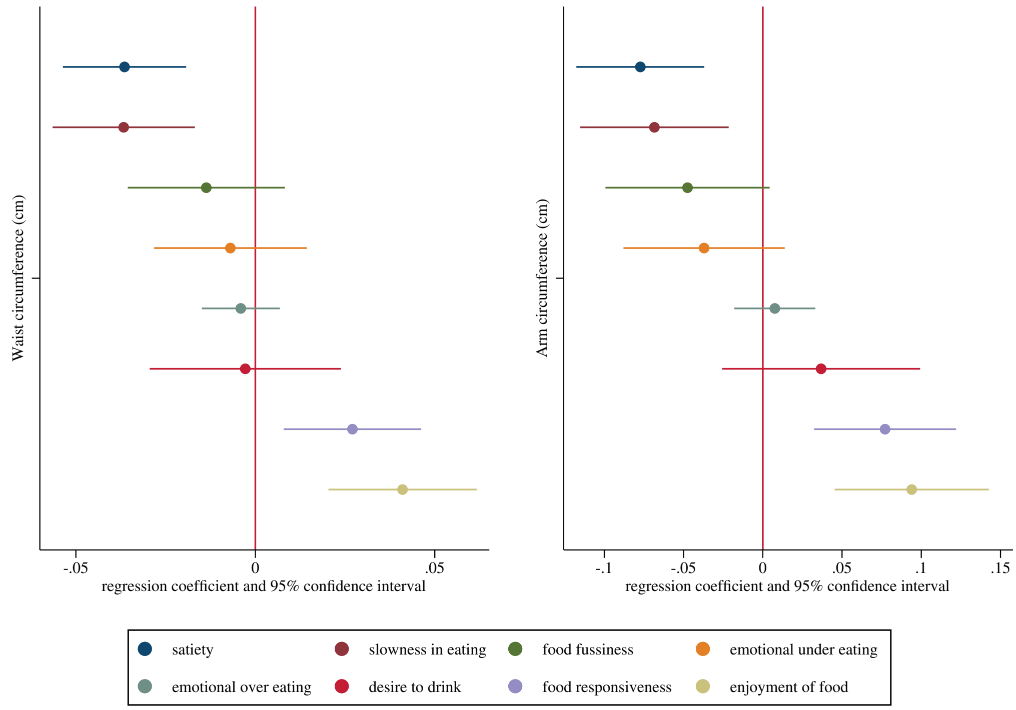

FIGURE 2 Associations between measures of the Children's Eating Behaviour Questionnaire (CEBQ) and waist and arm circumferences in children at 3 years of age

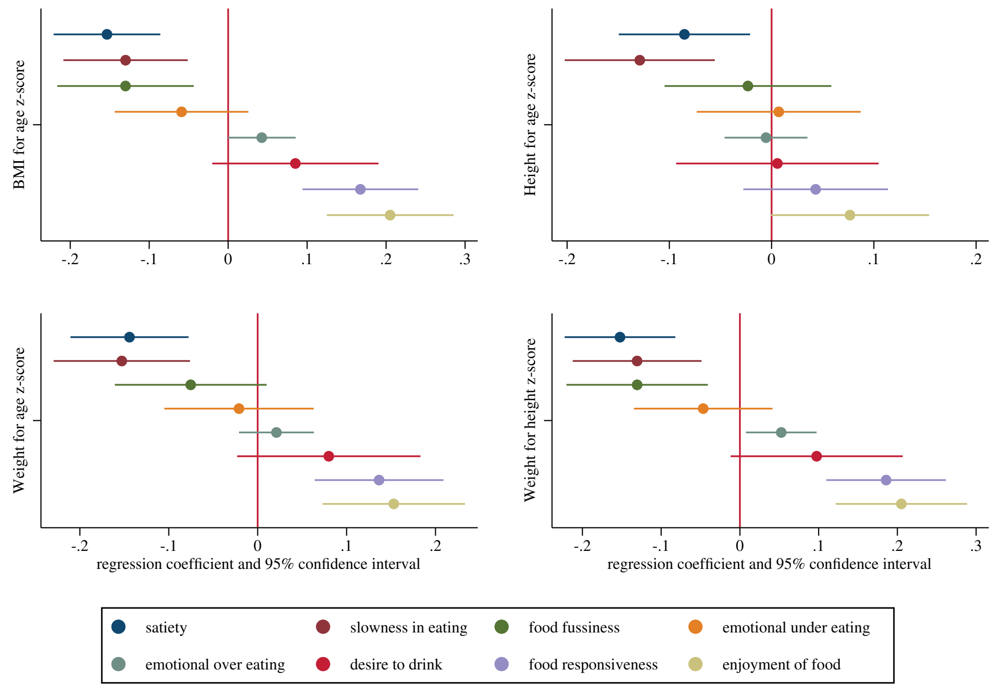

FIGURE 3 Associations between measures of the Children's Eating Behaviour Questionnaire (CEBQ) and the WHO *z* scores in children at 3 years of age

adiposity, although there was no association between dietary patterns at 3 years and BMI when measured at age 7 years.[38]

Our findings support those from the CHASE cohort who described that UK black/African 9- to 10-year-old children benefit from maintaining a traditional African/Caribbean diet. This was evident from the observed association of high scores on an African/Caribbean dietary pattern with a lower arm circumference despite the black women having a higher index of multideprivation. CHASE showed that a traditional African/Caribbean diet in late childhood was associated with an improved lipid profile, and compared with a white-European diet, the overall nutrient content was lower in total fats and higher in carbohydrates,[39] and lower in processed foods, which might explain the relationship with the lower measure of adiposity.

We have previously reported the maternal dietary patterns of 1023 women obtained during the UPBEAT study[40] in which four

TABLE 3 Adjusted association between offspring dietary patterns at 3-y of age and eating behaviour

	Underweight		Overweight		Obese	
	Coefficient (95% CI)		Coefficient (95% CI)		Coefficient (95% CI)	
Food approach scales	(n = 15)		(n = 125)		(n = 38)	
Food responsiveness	−0.25 (−0.68 to 0.18)	P = .25	0.27 (0.09 to 0.44)	P = .003	0.47 (0.19 to 0.74)	P = .001
Emotional overeating	−0.21 (−0.47 to 0.03)	P = .096	0.05 (−0.04 to 0.15)	P = .29	0.07 (−0.09 to 0.23)	P = .39
Enjoyment of food	−0.62 (−1.09 to −0.16)	P = .008	0.20 (0.02 to 0.399)	P = .02	0.34 (0.05 to 0.64)	P = .02
Desire to drink	0.20 (−0.40 to 0.81)	P = .508	0.10 (−0.14 to 0.35)	P = .418	0.42 (0.03 to 0.83)	P = .03
Food avoidance scales						
Emotional under eating	0.008 (−0.49 to 0.50)	P = .94	−0.07 (−0.27 to 0.13)	P = .48	−0.20 (−0.52 to 0.11)	P = .213
Slowness in eating	0.46 (0.005 to 0.93)	P = .047	−0.08 (−0.27 to 0.09)	P = .36	−0.40 (−0.70 to −0.11)	P = .007
Food fussiness	0.71 (0.22 to 1.21)	P = .005	0.02 (−0.18 to 0.22)	P = .83	−0.28 (−0.60 to 0.03)	P = .08
Satiety responsiveness	0.19 (−0.20 to 0.58)	P = .34	−0.21 (−0.37 to −0.05)	P = .009	−0.461 (−0.71 to −0.20)	P < .001

Note: Adjusted for maternal ethnicity, socio-economic status, smoking and BMI at baseline (15-18 weeks gestation), years spent in full-time education, maternal age, parity, infant birthweight, sex, age at follow-up, and randomization arm. Children were excluded if they were born ≤34 weeks gestation and suffering from major ill health.

distinct patterns were identified: "snacks," "processed," "fruit and veg," and "African/Caribbean." Whilst only three patterns were identified in this analysis of the diets of their children, they were broadly similar to those of their mothers 3 years previously, highlighting commonality of diet within families, as reported previously in the UK Southampton Women's Survey.[41]

Similarly to dietary patterns, eating behaviours developed in early life track through childhood.[42] The validated CEBQ questionnaire has greatly facilitated studies of relationships between appetite traits and body composition.[18,26,43] Using this questionnaire, food responsiveness and enjoyment of food were associated with higher arm and waist circumferences, weight-for-age, weight-for-height, and BMI *z* scores and higher odds of obesity. In contrast, slowness in eating and satiety responsiveness were inversely associated with the same measures of body composition, suggesting that these traits are protective against an obesogenic environment. Importantly, slower eating is a modifiable eating style which may reduce excessive weight gain in childhood. The associations between enjoyment of food and food responsiveness and increased body composition and rates of obesity are consistent with previous studies, suggesting that children with overweight or obesity are more responsive to food cues,[44-46] but amongst these, the only report of children at a similar age to this study was from an Australian cohort of 2- to 5-year-old children, although the results were based on parent-reported measurements.[46]

In agreement with BASELINE, an observational study in 1189 two-year-old children from Ireland,[43] we did not find associations between emotional undereating/overeating and desire to drink and measures of body composition. This could be because the children were too young to display emotion in relation to eating habits. Although in older children, a similar lack of an association has been found.[47] This may imply that these three measures from the CEBQ do not have a major impact on body composition and adiposity compared with the other subscales.

The offspring of mothers with obesity are particularly at risk of obesity, and this is the first study to address dietary patterns and eating behaviours associated with obesity in such children. As previously described by ourselves[19] and others, there is a striking relationship between maternal obesity and offspring risk of obesity.[20,48] Whether this arises from shared familial environment, shared genes, the maternal in utero environment, or a combination of all three is not established. Animal models and some of the human cohort studies however have argued for a major contribution of in utero determinants through persistent effects on the developing fetus, including modification of the pathways of energy balance at the level of the hypothalamus.[49,50] This is supported by the recent finding of an association between perinatal methylation of the SLC6A4 gene implicated in appetite regulation and obesity in later childhood.[51] Whether the relationships between food approach and food avoidance variables with measures of childhood adiposity in these children are a direct result of the in utero environment cannot be established from this study, although future comparisons of the strength of these relationships within cohorts of children from mothers of a healthy BMI, with appropriate adjustment for confounders, could shed light on the aetiology of these relationships.

4.1.1. | Strengths and limitations

Strengths of the study include the rich UPBEAT dataset which provides comprehensive information on the eating habits and behavioural origins of early childhood obesity and multiple determinants of childhood body composition and adiposity. The sample of the mothers and their offspring included are ethnically diverse and of low socio-economic status. To our knowledge, this is the only study that has combined dietary patterns and eating behaviours in the same study of childhood obesity at any age. Limitations include loss to follow-up of the study population which may result in selection bias; however, there were no differences in the maternal population who completed the 3-year follow-up compared with those who did not, except for a higher proportion of white women returning for the 3-year visit. The CEBQ is a parent-reported measure and is subject to recall bias and the main caregiver's own interpretation of eating behaviours; however, the CEBQ is validated and previous trials have reported high internal validity. The dietary patterns, derived using factor analysis, involve a number of arbitrary decisions including consolidation of food items into groups, the number of factors to extract, rotation method, and naming of the factors. FFQs are also associated with recall bias from the child's main caregiver.[52] The measures of body composition utilized in this study have limitations. BMI standardized cut-offs, *z* scores, BIA, and sum of skinfolds which was used to define obesity and adiposity in the children are indirect measures of fat mass; future studies should consider validating measures of body composition with DEXA, which is widely recognized as a good measure of adiposity.[53] Lastly, our study was observational, so causality of the associations cannot be assumed.

In summary, we found that food approach eating behaviours and a diet high in processed and snacking foods were associated with obesity and measures of body composition at 3 years of age in children of mothers with obesity. Conversely slower eating, a "healthy/prudent" or a traditional "African/Caribbean" diet was associated with lower rates of obesity or adiposity. This study provides evidence for potentially modifiable determinants and adds credence to the view that promoting healthy food alternatives and eating behaviours should be considered for assimilation into public health strategies in high-risk children at risk of obesity in early life.

CONFLICT OF INTEREST STATEMENT

K.M.G. reports other from Nestle Nutrition Institute, grants from Nestec, outside the submitted work. In addition, K.M.G. has a patent Phenotype prediction issued, a patent Predictive use of CpG methylation issued, a patent Maternal Nutrition Composition pending, and a patent vitamin B6 in maternal administration for the prevention of overweight or obesity in the offspring issued. L.P. is part of an academic consortium that has received research funding from Abbott Nutrition and Danone. The other authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

The authors responsibilities were as follows: P.T.S., A.L.B., K.M.G., and L.P. conceptualized and designed the study. K.V.D., A.C.F., M.O.K., and P.T.S. drafted and carried out the analyses. K.V.D., A.C.F., M.O.K., and L.P. had overall responsibility for the manuscript. K.V.D., A.C.F., P.T.S., A.L.B., M.O.K., K.M.G., and L.P. critically reviewed the manuscript and approved the final manuscript as submitted.

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SUPPORTING INFORMATION

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