Predictors and patterns of eating behaviors across childhood: Results from The Generation R Study

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ABSTRACT

Introduction: Only a few studies have prospectively examined stability of eating behaviors in childhood. These argue that eating behaviors are fairly stable from early childhood onwards, but knowledge on individual patterns across childhood is lacking. Here, we examined patterns of eating behaviors from ages 4 to 10 years in a population-based sample and aimed to identify parental and early-life predictors of these patterns.
Methods: Participants were 3514 children from The Generation R Study with repeated assessments of the Child Eating Behavior Questionnaire at ages 4 and 10 years. Patterns of emotional overeating, food responsiveness, enjoyment of food and satiety responsiveness were studied with person-centered Latent Class Growth Analysis with the aim to identify sub-groups of children with distinct eating behavior patterns. Using univariate multinomial logistic and linear regression, parental and early life predictors of eating behavior patterns were examined.
Results: We identified three patterns of emotional overeating (stable low (n=2240); moderately increasing (n=1028); strongly increasing (n=246)) and five patterns of food responsiveness (stable low (n=2343); high decreasing (n=238); moderately increasing (n= 679); strongly increasing (n=141); stable high (n=113)) from 4 to 10 years. For enjoyment of food and satiety responsiveness a similar pattern was identified for all children. Obesogenic eating behavior patterns were associated with a higher birth weight and BMI, emotional and behavioral problems, maternal overweight/obesity and controlling feeding strategies.
Discussion: This study suggests that children develop distinct patterns of emotional overeating and food responsiveness across childhood. Parental and early life predictors, particularly a higher weight status and psychiatric problems, are potential correlates of the development and maintenance of unhealthy eating behavior patterns across childhood. This knowledge might help identifying children at risk of developing obesogenic eating behaviors.

INTRODUCTION

Appetite-related eating behaviors influence food preferences, patterns of energy intake and are closely linked to weight status.[1,2] Several factors are likely to contribute to the development of eating behaviors, including genetic predisposition, in utero programming of appetite, first food experiences and the family environment.[3-9]

Previous studies suggest that eating behavior traits are already established in the first years of life and remain stable thereafter. A study among young children indicated that eating behaviors, such as food responsiveness, emotional overeating, satiety responsiveness and enjoyment of food were already stable (i.e. individual ratings of this behavior were consistent over time) and continuous (i.e. group ratings were consistent and similar over time) from 2 to 5 years of age.[10] Recently, a weak correlation for emotional overeating (r=0.25) was reported in a twin study within the same age span.[11] Further, the level of eating in the absence of hunger, loss of control in eating and overeating remained comparable after 6 months, 1 and 2 years of follow-up.[12-14] Yet, these studies included small sample sizes[10,12-14] - except for the twin study comprising 3784 children[11] -, had follow-up periods of maximum 3.5 years,[11] and one was performed in girls only.[12] Only one study with a follow-up period of seven years was performed: Ashcroft et al. examined stability and continuity of eating behaviors in 322 children aged 4 to 11 years and reported moderate correlations between the two ages on different obesogenic eating behaviors, ranging from r=0.44 for food responsiveness to r=0.46 for satiety responsiveness.[15] These moderate to low correlations across childhood suggest that there is also potential individual variation in eating behaviors over time. Identifying patterns of eating behaviors across childhood and its early life predictors might help detect potential targets for prevention and intervention in developing unhealthy eating behavior.

The aim of the present study was to examine patterns of obesogenic eating behaviors in a large, population-based sample of children aged 4 to 10 years, by using Latent Class Growth Analysis. This is a person-centered and data-driven approach to identify and cluster subgroups of children with homogenous response patterns. This is a different methodology than previously used, as studies generally examined the correlation between variables at different time points, without consideration of individual differences.[16] Exploratory analyses were conducted to identify potential early life and parental predictors of eating behavior patterns across childhood.

METHODS

Study design and population

This study was embedded in the Generation R Study, a population-based prospective birth cohort from fetal life onward, described previously in detail.[17] In brief, all pregnant women living in Rotterdam, the Netherlands, with an expected delivery date between April 2002 and January 2006 were invited (participation rate of 61%). Written informed consent was obtained from all participants and The Medical Ethical Committee of the Erasmus Medical Center approved the study. Full consent for the postnatal phase was obtained for 7294 children and their parents (74% of those originally enrolled). Children were included in the current sample for analyses when they had information available on eating behavior at the age of 4 years and again 10 years, resulting in a study sample of 3514 children (Supplementary Figure 2.1).

We compared children who were lost to follow-up (n=966 with missing eating behavior at the age of 10 years) with children included in the sample for analyses (n=3514). Those who were lost to follow-up were more often boys (52.7% versus 49.1%, p=0.046) and of non-western ethnic background (34.0% versus 19.4%, p<0.001) but were similar in their weight status at 3.5 years of age (9.0% overweight/obese versus 7.8% overweight/obese, p=0.261). Mothers of children who were lost to follow-up were more often low educated (23.3% versus 10.3%, p<0.001) and overweight/obese than mothers of children included in the study sample (38.4% versus 32.5%, p=0.001).

Measures

Child eating behaviors

Child eating behavior was assessed twice using the same measure, when children were 4 and 10 years old. At both time points, mothers reported on their child's eating behavior with the Child Eating Behavior Questionnaire (CEBQ). The CEBQ is a 35-item instrument developed by Wardle et al. in 2001 and assesses variation in eating behaviors among children using seven subscales.[18] In this study, four subscales were included, namely: Food responsiveness, enjoyment of food, emotional overeating and satiety responsiveness. Food responsiveness is a 5- item subscale reflecting the child's sensitivity to external food cues (e.g. "Given the choice, my child would eat most of the time"), enjoyment of food is a 4-item subscale (e.g. "My child loves food"), emotional overeating consists of 4 items (e.g. "My child eats more when he/she is upset"), and lastly, satiety responsiveness is a combined subscale of 9 items covering satiety responsiveness and slowness in eating. The satiety responsiveness and slowness in eating scales are sometimes examined as separate constructs, and sometimes combined. Here, we used the combined scale, because slower eating speed has been considered as a response to internal satiety cues during

food intake. We and others used this combined scale before, which has been validated against observed behavioral assessments of food intake [2,3,19,20] (e.g. "My child gets full up easily"). Answering options ranged from 1. "never" to 5. "always", and mean item-scores per subscale were calculated, allowing for 25% missing answers per subscale. The CEBQ has well-established psychometric properties, including good test-retest reliability, internal consistency and concurrent validity with actual/observed eating behavior.[19,21,22] At both time points, the subscales showed high reliability in the study sample: At 4 years Cronbach's α for emotional overeating= 0.85, food responsiveness= 0.84, enjoyment of food= 0.89 and satiety responsiveness= 0.81. At the age of 10 years, Cronbach's α for emotional overeating= 0.92, food responsiveness= 0.86, enjoyment of food =0.87 and satiety responsiveness= 0.85.

Parental and child early life predictors

Several child early life- and parental characteristics were considered as potential predictors of eating behavior patterns across childhood, since they have been linked with eating behavior before.[4,6,23] Information about child date of birth, sex and birth weight were obtained from midwife- or hospital registries. Birth weight SD scores were calculated adjusted for gestational age, according to Niklasson et al.[24] Child ethnicity was based on country of birth of both parents, as assessed with a prenatal questionnaire. In postnatal questionnaires, mothers reported at 2 months, 6 months and 12 months on whether they breastfed their infant. If mothers reported that they had stopped breastfeeding, they were asked how old their infant was when they stopped breastfeeding. At the age of 3 years, mothers and fathers separately completed the Child Behavior Checklist (CBCL/1.5-5), a 99-item questionnaire including a range of child emotional and behavioral problems rated on a three-point Likert scale (0. "Not true", 1. "Somewhat true, sometimes true", 2. "Very true, often true").[25] We included the two broadband scales in our study: Emotional problems (i.e. internalizing behavior), consisting of the subscales Emotionally reactive, Anxious/Depressed, Withdrawn and Somatic Complaints (36 items); and behavioral problems (i.e. externalizing behavior) consisting of the subscales Attention Problems and Aggressive Behavior (24 items). Sex and age adjusted T-scores were calculated based on a normative sample using the program ASEBA PC. The derived T-scores were subsequently standardized (presented in SD scores). The Dutch translation of the CBCL has shown to be valid and reliable.[26] The two broadband scales showed good reliability within our sample (Cronbach's α emotional problems= 0.81, behavioral problems= 0.89). At 3.5 years of age, children visited the Municipal Health Centers where their height and weight were measured without shoes or heavy clothing by staff assistants, from which sex- and age adjusted BMI scores were calculated and weight status was determined according to the cut-off points of Cole et al.[27]

Mothers reported on their educational level in a prenatal postal questionnaire. During their visit in the first trimester of pregnancy, mother's and father's height and weight were measured at the Generation R research center by trained research assistants. BMI was calculated and categorized into underweight-normal weight (BMI<25.00) or overweight/obesity (BMI≥25.00). Maternal glucose and insulin levels were derived from non-fasting serum blood samples collected during the first trimester of pregnancy, with an average of 13 weeks gestation. When children were 3 years old, mothers and fathers each reported on their psychopathology symptoms using a shortened version of the Brief Symptom Inventory (BSI). The BSI is a validated self-report questionnaire originally including 53 items with 8 subscales, and response options ranging from 0. "Not at all" to 4. "Extremely".[28] The Dutch translation of the BSI showed high validity and good reliability.[29] With the shortened version, 4 subscales were assessed: Depression, Anxiety, Hostility and Interpersonal Sensitivity. The standardized mean score of all items was calculated and showed good reliability for both mothers and fathers (Cronbach's α mother= 0.89, father= 0.88). Finally, when children were 4 years old, mothers reported on their own feeding practices using the validated Child Feeding Questionnaire including the subscales Monitoring (3 items), Restriction (8 items) and Pressure to eat (4 items).[30] Answering options ranged from 1. "Never" to 5. "Always", and mean item scores were calculated per subscale. The reliability of these subscales in our sample were moderate to high (Cronbach's α for monitoring = 0.91, restriction= 0.72 and pressure to eat=0.65).

Statistical analysis

First, sample characteristics and correlations between eating behavior subscales at ages 4 and 10 years were examined. Then, patterns of eating behavior were determined for each subscale separately by Latent Class Growth Analysis (LCGA) in Mplus 7.0.[31] With LCGA, distinct groups of children can be identified based on response patterns at ages 4 and 10 years. This is a person-centered, data-driven approach that can be used with repeatedly measured outcomes where the latent classes reflect groups of children with similar response patterns over time. This way, heterogeneity in developmental patterns of eating behaviors can be determined, while the within-class variation is constrained to zero. This method was considered suitable for this study, because the goal was to identify differences between classes and not variation within classes.[32]

First, we identified a single class growth curve model including all children. From there, we increased the number of classes by one each time until we found the best-fitted model with x number of classes for each eating behavior subscale. Optimal model fit was determined by the following criteria: the lowest Bayesian Information Criterion (BIC), the highest Entropy (measurement of accuracy for the classification of each individual into a latent class, with >0.80 indicating adequate classification), at least 5% of all individuals in one class, high posterior probabilities for each class and a significant Bootstrapped

Likelihood Ratio Test (BLRT), comparing the current model with the model with one class less. For each class, an intercept (reflecting the baseline level at age 4 years) and a slope was obtained.[16,33]

After patterns of eating behavior were determined, we examined associations between predictors and eating behavior patterns in SPSS 21.0 (IBM statistics). Given that we aimed to characterize the groups of children with specific eating behavior patterns and were not examining any causal relations, we only present univariate analyses. For food responsiveness and emotional overeating (with 5 and 3 identified classes, respectively) we used univariate multinomial logistic regression analyses to examine associations between early-life predictors and subsequent eating behavior patterns (in both subscales, "stable low" was chosen as the reference group). For enjoyment of food and satiety responsiveness a single pattern was observed, and therefore, we used univariate linear regression analyses to examine the association between early life predictors and the slope (similar to the delta) between the two time points. We used the Benjamini and Hochberg False Discovery Rate (FDR) procedure to correct for multiple comparisons. We listed the values of $d \times i/n$ in which d is the significance threshold of 0.05, n is the number of tests and i is the test number along with the obtained and sorted p-value. When the p-value is smaller than $d \times i/n$, it is declared significant.[34] Finally, we repeated our analyses with parental and early-life predictors after excluding siblings (19.6%) to check whether results were not driven clustering within families. Associations for siblings might be similar for factors such as sociodemographic and parental conditions, and could potentially create an overestimation of the observed associations when siblings had a similar eating behavior pattern.

RESULTS

Descriptive characteristics of the study sample are reported in Table 2.1. Of all included children, 19.4% had a non-western background and 7.8% of the children were overweight or obese at the Municipal Health Center visit (mean age=3.5 years). During the first trimester of pregnancy, 32.5% of the mothers and 46.5% of the fathers were overweight or obese. Mean item scores on each eating behavior subscale per time point are presented in Supplementary Table 2.1.

Patterns of eating behavior from 4 to 10 years

Patterns of eating behavior from 4 years to 10 years are presented for each eating behavior subscale separately in 3514 participants (Figure 2.1). The number of patterns (latent classes) depended on model fit, which can be found in Supplementary Table 2.2.

Table 2.1. Descriptive characteristics of the study sample

Child characteristics	**Total n**	**Percentage, mean (SD) or median [IQR][a]**
Age at 4 years questionnaire, mean (SD)	3514	4.05 (0.09)
Age at 10 years questionnaire, mean (SD)	3514	9.70 (0.28)
Sex, % girls	3514	50.9%
Child ethnicity, %	3507	
Dutch	2504	71.4%
Other Western	322	9.2%
Non-Western	681	19.4%
Birth weight in grams, mean (SD)	3499	3449 (562)
Weight status category at last CB visit, % overweight/obese	3251	7.8%
Emotional problems t-score at 3 years, median [IQR][b]	3246	43.00 [12.00]
Behavioral problems t-score at 3 years, median [IQR][b]	3246	43.00 [11.50]
Duration of breastfeeding in months, mean (SD)	2870	4.73 (3.90)
Parental characteristics		
Maternal education level, %	3392	
Low (No education - high school)	350	10.3%
Medium (Lower vocational education)	923	27.2%
High (Higher vocational education and university)	2119	62.5%
Maternal pre-pregnancy BMI, % overweight/obese	3128	32.5%
Paternal BMI, % overweight/obese	2681	46.5%
Maternal glucose level during first trimester of pregnancy, mmol/L, mean (SD)	2435	4.38 (0.86)
Maternal insulin level during first trimester of pregnancy, pmol/L, median [IQR]	2433	106.80 [152.02]
Maternal psychopathology symptoms SD score, median [IQR][c]	3231	0.10 [0.19]
Paternal psychopathology symptoms SD score, median [IQR][c]	2821	0.05 [0.14]
Maternal feeding practices, mean item score[d]		
Monitoring	3499	4.47 (0.74)
Restriction	3507	2.97 (0.77)
Pressure to eat	3513	3.09 (0.97)

[a] Values are percentages for categorical variables, means (standard deviations) for continuous normally distributed variables and medians (interquartile ranges) for continuous, non-normally distributed variables. [b] Mother-reported with the Child Behavior Checklist. [c] Psychopathology symptoms were assessed with the Brief Symptom Inventory. [d] Maternal feeding practices were assessed with the Child Feeding Questionnaire, mean item scores range from 1 to 5.

Three patterns of emotional overeating were identified according to optimal model fit criteria. We identified a "stable low" pattern of emotional overeating, including 2240 children (intercept=1.36, slope=−0.31). Further, 1028 children increased by 0.49 points

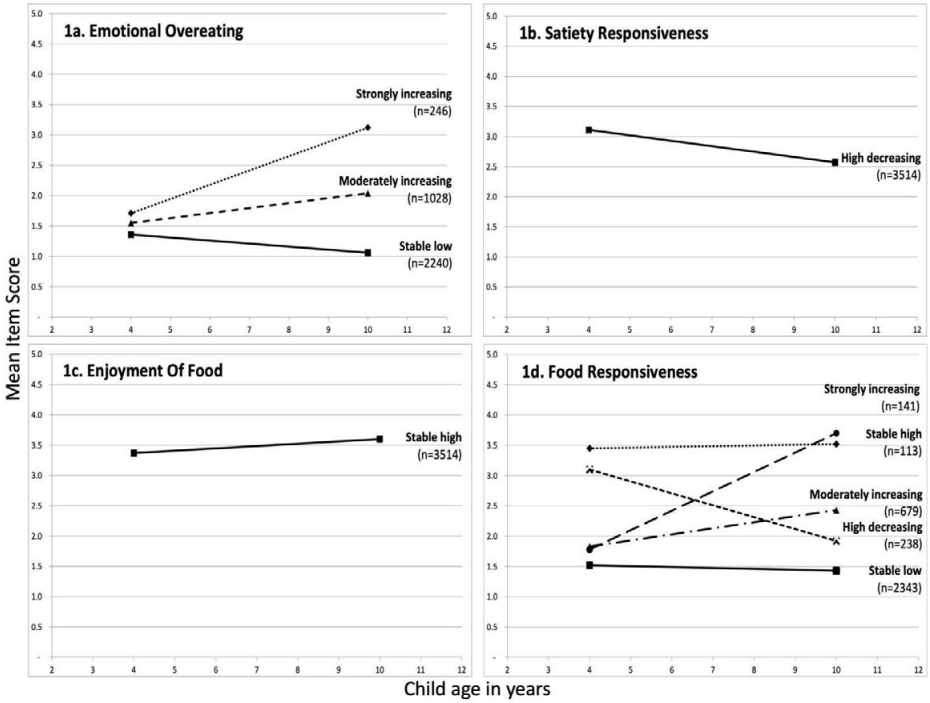

Figure 2.1. Latent Class Growth Trajectories of eating behavior subscales in children aged 4 to 10 years

on mean item score from 4 to 10 years (intercept=1.55) and were classified as "moderately increasing". Lastly, 246 children increased by 1.41 points on mean item score (intercept=1.71), showing a "strongly increasing" response pattern for emotional overeating.

For food responsiveness, we found five distinct patterns among children. Most children (n= 2343) had a stable low pattern of food responsiveness, from a mean score of 1.52 at 4 years to a mean item score of 1.43 at 10 years ("stable low"). Further, 238 children had a high mean item score at age 4 years and a lower score at 10 years (intercept=3.10, slope=−1.19, "high decreasing"). Next, 679 children increased by 0.60 points on mean item score (intercept=1.83) from 4 to 10 years ("moderately increasing"), while 141 children increased in food responsiveness by 1.92 points on mean item score (intercept=1.72; "strongly increasing"). For 113 children, we observed a "stable high" food responsiveness pattern across childhood (intercept=3.45, slope=0.07).

For enjoyment of food and satiety responsiveness, BIC and BLRT indicated the possibility of more than one class, while entropy in both cases suggested that a one class-solution should be preferred. Inspection of the two- and three class solutions for enjoyment of food and satiety responsiveness showed that patterns were added parallel to the one class pattern, which suggested that there was no clear distinction in the developmental course of these behaviors. Moreover, the entropy did not meet the threshold of 0.80. Therefore,

Table 2.2. Univariate multinomial logistic regressions between predictors and patterns of emotional overeating

Early life predictors	Total n	Patterns of Emotional overeating		
		Stable low OR (95% CI)	Moderately increasing OR (95% CI)	Strongly increasing OR (95% CI)
Child characteristics				
Sex – girls	3514	*Reference*	1.24 (1.07, 1.44)*	0.99 (0.76, 1.29)
Ethnicity[a]	3507			
Other western		*Reference*	1.14 (0.88, 1.47)	0.85 (0.51, 1.41)
Non-western		*Reference*	1.21 (1.00, 1.46)	1.33 (0.97, 1.84)
Birth weight SD score	3499	*Reference*	0.94 (0.87, 1.01)	1.13 (0.99, 1.29)
BMI at age 3.5 years – Overweight/obese[b]	3251	*Reference*	1.62 (1.23, 2.13)*	2.11 (1.37, 3.23)*
Emotional problems t-score at 3 years, SD score[c]	3246	*Reference*	1.15 (1.06, 1.24)*	1.40 (1.22, 1.61)*
Behavioral problems t-score at 3 years, SD score[c]	3246	*Reference*	1.17 (1.08, 1.26)*	1.28 (1.12, 1.47)*
Duration of breastfeeding, per month	2870	*Reference*	1.01 (0.99, 1.03)	0.99 (0.95, 1.02)
Parental characteristics				
Educational level[d]	3392			
Medium		*Reference*	0.96 (0.81, 1.14)	0.97 (0.71, 1.33)
Low		*Reference*	1.06 (0.82, 1.36)	1.19 (0.77, 1.83)
Maternal pre-pregnancy BMI – Overweight/obese	3128	*Reference*	1.18 (1.00, 1.39)	1.38 (1.04, 1.84)
Paternal BMI – Overweight/obese	2681	*Reference*	0.98 (0.83, 1.16)	1.24 (0.91, 1.70)
Maternal prenatal glucose level, mmol/L[e]	2435	*Reference*	1.01 (0.91, 1.12)	1.10 (0.91, 1.31)
Maternal prenatal insulin level, log pmol/L[e]	2433	*Reference*	1.03 (0.94, 1.14)	1.10 (0.92, 1.30)
Maternal total psychopathology symptoms SD score	3231	*Reference*	1.07 (0.99, 1.17)	1.17 (1.03, 1.33)*
Paternal total psychopathology symptoms SD score	2821	*Reference*	1.08 (0.98, 1.18)	1.14 (0.98, 1.32)
Maternal feeding practices, mean item score				
Monitoring	3499	*Reference*	0.82 (0.75, 0.91)*	0.74 (0.63, 0.86)*
Restriction	3507	*Reference*	1.37 (1.24, 1.51)*	1.33 (1.12, 1.59)*
Pressure to eat	3513	*Reference*	1.02 (0.95, 1.10)	1.11 (0.97, 1.28)

[a] Reference group for ethnicity = Dutch. [b] Child BMI was assessed at the Municipal Child Health Center visit, mean age 3.5 years (SD= 0.5). [c] Mother –reported, results were comparable with father–reported sum scores of emotional and behavioral symptoms. [d] Reference group for maternal educational level= High. [e] Maternal glucose and insulin levels were assessed during the first trimester of pregnancy and adjusted for the number of weeks of gestation. * Significant after FDR procedure.

we preferred the one-class pattern for both subscales. For all participants, scores of enjoyment of food increased slightly over time (intercept=3.37, slope=0.23) while for satiety responsiveness, mean item scores decreased by 0.55 points (intercept=3.11).

Parental and early life predictors

Table 2.2 shows the relationship between predictors and patterns of emotional overeating (stable low = reference group). Girls had 1.24 times higher odds of having a moderately increasing emotional overeating pattern compared to boys (95% CI= 1.07, 1.44). Furthermore, children with overweight or obesity at the age of 3.5 years were two times more likely to be classified in the moderately increasing or a strongly increasing emotional overeating pattern compared to underweight/healthy weight children (e.g. $OR_{\text{strongly increasing}}$ = 2.11, 95% CI= 1.37, 3.23). Emotional and behavioral problems at 3 years of age were associated with moderately increasing or strongly increasing emotional overeating patterns across childhood (e.g. for behavioral problems: $OR_{\text{strongly increasing}}$ = 1.28, 95% CI=1.12, 1.47). Parental predictors of offspring emotional overeating patterns were also identified: offspring of mothers with more psychopathology symptoms were more likely to have a strongly increasing emotional overeating pattern (OR= 1.17, 95% CI =1.03, 1.33). More maternal monitoring of food intake was associated with less emotional overeating, while restrictive feeding was associated with higher odds of developing a moderately or strongly increasing emotional overeating pattern ($OR_{\text{high increasing}}$ = 1.33, 95% CI =1.12, 1.59).

In Table 2.3, associations of predictors with patterns of food responsiveness are presented ("stable low" = reference group). Children with a higher birth weight and a higher weight status at 3.5 years had higher odds of a high decreasing, increasing or stable high food responsiveness pattern. For instance, overweight or obese children had 9.53 higher odds of having a stable high food responsiveness pattern compared to underweight/normal weight children (95% CI= 6.03, 15.07). Additionally, more behavioral problems were associated with more food responsiveness across childhood ($OR_{\text{strong increasing}}$ = 1.58, 95% CI= 1.30, 1.91). Offspring of mothers with a high BMI had higher odds of developing unhealthy food responsiveness patterns, as well as offspring of mothers who practiced more restriction and less pressure to eat in their feeding strategies. Paternal BMI was not consistently associated with more food responsiveness, nor were maternal and paternal psychopathology symptoms.

Associations of parental and early life predictors with the change in enjoyment of food and satiety responsiveness from 4 to 10 years are shown in Table 2.4. A higher birth weight, being overweight or obese and more maternal monitoring were associated less change in enjoyment of food (e.g. for overweight/obese at 3.5 years, B= −0.13, 95% CI = −0.23, −0.04) than a lower birth weight, underweight/normal weight and less maternal monitoring. Relatively high levels of emotional problems of the child and of maternal restriction were associated with more change in enjoyment of food from 4 to 10 years. For

Table 2.3. Univariate multinomial logistic regressions between predictors and patterns of food responsiveness

Early life predictors	Total n	Patterns of Food responsiveness				
		Stable low OR (95% CI)	High decreasing OR (95% CI)	Moderately increasing OR (95% CI)	Strongly increasing OR (95% CI)	Stable high OR (95% CI)
Child characteristics						
Sex – girls	3514	*Reference*	1.08 (0.82, 1.41)	1.02 (0.86, 1.21)	1.03 (0.74, 1.45)	1.67 (1.13, 2.47)*
Ethnicity[a]	3507					
Other western		*Reference*	0.78 (0.46, 1.33)	1.18 (0.88, 1.57)	0.97 (0.53, 1.80)	0.78 (0.37, 1.63)
Non-western		*Reference*	1.35 (0.98, 1.85)	0.90 (0.72, 1.13)	1.23 (0.82, 1.86)	1.11 (0.69, 1.77)
Birth weight SD score	3499	*Reference*	1.21 (1.06, 1.39)*	1.15 (1.05, 1.25)*	1.28 (1.08, 1.52)*	1.43 (1.18, 1.72)*
BMI at age 3.5 years – Overweight/obese[b]	3251	*Reference*	5.62 (3.83, 8.24)*	2.03 (1.44, 2.87)*	5.09 (3.14, 8.23)*	9.53 (6.03, 15.07)*
Emotional problems t-score at 3 years, SD score[c]	3246	*Reference*	1.10 (0.95, 1.27)	1.12 (1.02, 1.23)	1.09 (0.91, 1.32)	1.13 (0.92, 1.38)
Behavioral problems t-score at 3 years, SD score[c]	3246	*Reference*	1.38 (1.20, 1.59)*	1.32 (1.21, 1.45)*	1.58 (1.30, 1.91)*	1.53 (1.24,1.88)*
Duration of breastfeeding, per month	2870	*Reference*	1.03 (0.99, 1.07)	1.00 (0.98, 1.02)	0.96 (0.92, 1.01)	1.02 (0.96, 1.07)

Table 2.3. Univariate multinomial logistic regressions between predictors and patterns of food responsiveness (*continued*)

Early life predictors	Total n	Patterns of Food responsiveness				
		Stable low OR (95% CI)	High decreasing OR (95% CI)	Moderately increasing OR (95% CI)	Strongly increasing OR (95% CI)	Stable high OR (95% CI)
Parental characteristics						
Educational level[d]	3392					
Medium		*Reference*	1.00 (0.73, 1.37)	0.92 (0.75, 1.13)	0.97 (0.65, 1.45)	0.78 (0.49, 1.25)
Low		*Reference*	1.49 (0.98, 2.26)	1.21 (0.91, 1.61)	1.29 (0.74, 2.24)	1.55 (0.88, 2.72)
Maternal pre-pregnancy BMI – Overweight/obese	3128	*Reference*	0.88 (0.64, 1.20)	1.29 (1.06, 1.56)*	1.96 (1.37, 2.79)*	1.86 (1.24, 2.80)*
Paternal BMI – Overweight/obese	2681	*Reference*	1.03 (0.76, 1.39)	1.37 (1.12, 1.67)*	1.48 (1.01, 2.18)	1.54 (0.98, 2.41)
Maternal prenatal glucose level, mmol/L[e]	2435	*Reference*	0.86 (0.71, 1.04)	1.05 (0.93, 1.18)	1.07 (0.85, 1.35)	0.91 (0.68, 1.20)
Maternal prenatal insulin level, log pmol/L[e]	2433	*Reference*	1.18 (0.99, 1.40)	1.02 (0.91, 1.14)	1.02 (0.97, 1.50)	1.01 (0.77, 1.31)
Maternal total psychopathology symptoms SD score	3231	*Reference*	1.05 (0.90, 1.22)	1.17 (1.07, 1.28)*	0.95 (0.76, 1.20)	1.19 (1.00, 1.42)
Paternal total psychopathology symptoms SD score	2821	*Reference*	1.03 (0.88, 1.21)	1.04 (0.94, 1.16)	0.93 (0.73, 1.19)	1.12 (0.91, 1.37)
Maternal feeding practices, mean item score						
Monitoring	3499	*Reference*	1.00 (0.83, 1.20)	0.96 (0.85, 1.07)	0.88 (0.71, 1.09)	1.01 (0.79, 1.32)
Restriction	3507	*Reference*	2.53 (2.08, 3.08)*	1.39 (1.23, 1.56)*	1.44 (1.14, 1.81)*	2.63 (2.00, 3.47)*
Pressure to eat	3513	*Reference*	0.68 (0.59, 0.78)*	0.84 (0.77, 0.92)*	0.74 (0.62, 0.88)*	0.44 (0.36, 0.53)*

[a] Reference group for ethnicity = Dutch. [b] Child BMI was assessed at the Municipal Child Health Center visit, mean age 3.5 years (SD= 0.5). [c] Mother –reported, results were comparable with father–reported sum scores of emotional and behavioral symptoms. [d] Reference group for maternal educational level= High. [e] Maternal glucose and insulin levels were assessed during the first trimester of pregnancy and adjusted for the number of weeks of gestation. * Significant after FDR procedure.

Table 2.4. Univariate associations of early life predictors with the change in enjoyment of food and satiety responsiveness from 4 to 10 years

Early life predictors	Total n	Δ Enjoyment of food B (95% CI)	Δ Satiety responsiveness B (95% CI)
Child characteristics			
Sex – girls	3514	0.04 (−0.01, 0.08)	0.02 (−0.02, 0.06)
Ethnicity[a]	3507		
Other western		−0.02 (−0.10, 0.07)	0.03 (−0.04, 0.11)
Non-western		0.04 (−0.02, 0.10)	0.03 (−0.03, 0.08)
Birth weight SD score	3499	−0.04 (−0.06, −0.01)*	0.03 (0.01, 0.05)*
BMI at age 3.5 years – Overweight/obese[b]	3251	−0.13 (−0.23, −0.04)*	0.07 (−0.01, 0.15)
Emotional problems t-score at 3 years, SD score[c]	3246	0.04 (0.02, 0.07)*	−0.04 (−0.06, −0.02)*
Emotional problems t-score at 3 years, SD score[c]	3247	0.03 (0.00, 0.05)	−0.03 (−0.05, −0.01)*
Duration of breastfeeding, per month	2870	−0.00 (−0.01, 0.00)	0.00 (−0.01, 0.01)
Parental characteristics			
Educational level[d]	3392		
Medium		−0.02 (−0.08, 0.04)	0.05 (−0.00, 0.10)
Low		−0.09 (−0.17, −0.01)	0.11 (0.04, 0.19)*
Maternal pre-pregnancy BMI – Overweight/obese	3128	0.02 (−0.04, 0.07)	0.03 (−0.02, 0.08)
Paternal BMI – Overweight/obese	2681	−0.01 (−0.07, 0.04)	0.02 (−0.03, 0.06)
Maternal prenatal glucose level, mmol/L[e]	2435	0.03 (−0.01, 0.06)	−0.01 (−0.04, 0.02)
Maternal prenatal insulin level, log pmol/L[e]	2433	0.03 (−0.00, 0.06)	−0.01 (−0.04, 0.02)
Maternal total psychopathology symptoms SD score	3231	0.01 (−0.02, 0.04)	−0.00 (−0.03, 0.02)
Paternal total psychopathology symptoms SD score	2821	−0.01 (−0.04, 0.02)	−0.02 (−0.05, 0.01)
Maternal feeding practices, mean item score			
Monitoring	3499	−0.07 (−0.10, −0.04)*	−0.01 (−0.04, 0.02)
Restriction	3507	−0.01 (−0.04, 0.02)	−0.01 (−0.04, 0.02)
Pressure to eat	3513	0.12 (0.09, 0.14)*	−0.08 (−0.12, −0.06)*

[a] Reference group for ethnicity = Dutch. [b] Child BMI was assessed at the Municipal Child Health Center visit, mean age 3.5 years (SD= 0.5). [c] Mother –reported, results were comparable with father–reported sum scores of emotional and behavioral symptoms. [d] Reference group for maternal educational level= High. [e] Maternal glucose and insulin levels were assessed during the first trimester of pregnancy and adjusted for the number of weeks of gestation.* Significant after FDR procedure.

satiety responsiveness we observed an overall decrease over time (slope=−0.55). Children of mothers with a low education level showed more change in their satiety responsiveness over time than children of mothers with high education (B= 0.11, 95% CI= 0.01, 0.05), while children with higher levels of emotional or behavior problems as well as those exposed to more maternal pressure to eat decreased more in their satiety responsiveness ($B_{\text{maternal pressure to eat}}$ = −0.08, 95% CI = −0.12, −0.06). Lastly, we found comparable results after excluding siblings from our study sample.

DISCUSSION

In this prospective cohort study with repeated measurements of eating behaviors, we showed individual differences in development of emotional overeating and food responsiveness from age 4 years to 10 years. With regards to enjoyment of food and satiety responsiveness, no distinct patterns were identified with all children showing a similar pattern of increasing and decreasing patterns for food enjoyment and satiety responsiveness, respectively. These findings suggest that emotional overeating and food responsiveness are dynamic behaviors in the first years of life and can change after pre-school age. Children's overweight and emotional and behavioral problems early in life were likely to temporally precede the development of more unhealthy eating behaviors, along with maternal feeding practices. Socio-demographic factors were not associated with eating behavior patterns.

Strengths and limitations

Strengths of this study comprised its prospective population-based design including repeated measurements of eating behaviors, the comprehensive assessment of various important parental and child early life predictors, and a large sample size. There are, however, also limitations that should be discussed. First, both assessments of eating behavior were mother-reported. Maternal ratings of child eating behavior might be affected by her own beliefs about eating and weight status of the child. Having multiple informants, such as father- and child self-report, would be preferential. Yet, during this age period one might assume that the mother is the most accurate reporter and high correlations between observed food intake of the child and parental reported CEBQ scores were previously found.[19] Likewise, maternal mental well-being might also influence her ratings of her child's behaviors, and associations might therefore be the result of a divergent perception of the mother. However, associations of father-reported emotional and behavioral problems with (mother-reported) eating behaviors yielded similar results. Further, eating behavior was assessed only twice, while preferably, more time points were used to determine patterns of eating behavior. This way, also potential non-linearity of

the eating behavior patterns can be determined. Moreover, due to the observational and descriptive nature of this study, causal effects of the predictors cannot be proven. Finally, as non-Dutch children with lower socioeconomic backgrounds and a higher maternal BMI were relatively often lost to follow-up, generalizability of the results may be limited.

Patterns of eating behavior

A few previous studies reported on stability and continuity of eating behavior across childhood.[10-15] Ashcroft et al. (2008) concluded from the TEDS cohort that eating behaviors showed striking continuity throughout childhood with only obesogenic eating behaviors, such as emotional overeating and food responsiveness, increasing slightly over time.[15] We observed comparable correlations for each eating behavior subscale in The Generation R Study, except for emotional overeating (r=0.21 in Generation R versus r=0.45 in TEDS). Yet, we further explored individual stability by identifying groups of children based on a person-centered empirical approach, which to our knowledge, has not been done before. Importantly, we found distinct patterns of food responsiveness and emotional overeating throughout childhood, suggesting that – despite continuity and stability in most children – the developmental patterns may not be uniform.

Emotional overeating has been previously described as a learned behavior influenced by environmental factors and that develops over time, with shared environmental factors explaining 71% of the variance in 4-year old twins.[11,35] This fits our observation of relatively low scores with little variability between classes on emotional overeating at 4 years, which became more variable at the age of 10 years. Identified patterns revealed that, although the majority of children remained low in their emotional overeating, some children developed a tendency towards more eating in response to emotions across childhood.

Children developed distinct patterns in their sensitivity to external food cues. Seven percent of the children already scored relatively high on food responsiveness at pre-school age, suggesting that, unlike emotional overeating, some children already developed high levels of food responsiveness early in life. A part of these children (44%) decreased in their sensitivity to external food cues by the age of 10 years. Opposed to this, 23% of the children increased in their food responsiveness after the age of 4 years, probably in line with a gradual increase in exposure to food quantities. For both emotional eating and food responsiveness, future research is warranted to further monitor the developmental patterns of these eating behaviors, as preferably, the increasing trends stabilize.

We did not observe distinct patterns of enjoyment of food and satiety responsiveness from 4 to 10 years of age. Children's scores on enjoyment of food remained quite stable over time with mean item scores at 4 and 10 years being comparable to those of Ashcroft et al.[15] However, Farrow et al.[10] reported no significant correlation of enjoyment of food in children at ages 2 and 5 years. Given the age difference with our and Ashcroft's study,

perhaps children are still developing their food enjoyment very early in childhood, a period where picky eating is most prevalent and presumably affecting the pleasure of eating.[36]

Our results showed that, generally, children became slightly less sensitive to internal satiation cues over time. This rather small change fits the observation that heritability for satiety responsiveness appeared to be higher than other eating behavior dimensions, estimated at 63-72%.[37,38] Apparently, genes strongly influenced the internal regulation of satiety responsiveness and if expressed early in life, this results in a rather stable pattern over time which is only minimally influenced by environmental factors.

Parental and early life predictors

Although there is a strong genetic influence on appetite traits in children, this varies between the different eating behaviors, with 53% for enjoyment of food to 72% for satiety responsiveness. These heritability estimates suggest that a considerable amount of variability can be explained by environmental factors.[37] First of all, our results foremost suggest that children who are already overweight or obese by the age of 3.5 years have strikingly higher odds of developing more and more emotional overeating and food responsiveness over the next years, although not corrected for potential confounding. This indicates that children who are already on a high weight trajectory from early life onwards are prone to develop unhealthy eating behaviors. Only a few recent studies also have suggested that a higher weight status might precede subsequent unhealthy eating behaviors in childhood,[20,23,39,40] which was mainly due to an increase in fat rather than muscle mass.[41] Yet, a higher weight status early in life was associated with less increasing food enjoyment and less decreasing satiety responsiveness over time. Maternal overweight/obesity was correlated with patterns of increasing food responsiveness only. Previous studies showed that parental obesity was associated with a preference for high-fat food, and tendencies towards external eating, overeating and eating in the absence of hunger among offspring.[6,42-44] The latter is an appetitive trait comparable to food responsiveness and external eating in which children ignore their internal satiety feelings in response to the presence of food. Here, parental obesity was not associated with other eating behaviors across childhood than food responsiveness.

This is one of the first studies showing that emotional and behavioral problems might be important predictors of the development of obesogenic eating behaviors. As suggested here, children might react differently to their emotional and behavioral problems, by either more food approaching or more food avoidant behavior. As a 'natural' response, stress and anxiety can suppress appetite,[45] explaining higher scores of satiety responsiveness. Indeed, emotional problems have been previously associated with food avoidant behavior.[46] However, overeating has also been shown as a reaction to emotional and behavioral problems. A previous study observed that children aged 3.5-4 years with

emotional problems, conduct problems and peer problems, also showed more obesogenic eating behaviors.[47] Moreover, overweight children reporting loss of control over eating experienced more psychological distress.[48] Due to deficits in emotion-regulation and inhibition, some children possibly respond more to external food cues or emotional triggers, which can activate the brain-reward system, resulting in overeating.[4] Decreased self-regulation has been linked with childhood obesity.[49,50] Besides children's emotional and behavioral problems, maternal – but not paternal – psychopathology symptoms were associated with more emotional overeating and food responsiveness, which was also previously reported.[6] Maternal psychiatric problems were shown to affect controlling and emotional feeding practices,[51,52] a potential pathway towards overeating. Further, psychiatric problems and eating behavior traits might share genetic vulnerabilities, as it was previously reported that the phenotypic associations between depressive symptoms and disordered eating were due to common genetic factors.[53]

Exposure to controlling feeding practices, such as restricting the child's access to palatable foods and pressuring the child to eat more are suggested to negatively influence children's appetite-related eating behaviors: such parenting behaviors may encourage children to eat in response to external food cues rather than to their internal satiety cues.[3,54,55] This study adds to this hypothesis by showing that restricting the child to certain types of sugary or palatable foods is associated with patterns of increasing responsiveness to food as well as increasing emotional overeating from 4 to 10 years. However, monitoring food intake of the child was associated with a lower risk of emotional overeating, while no associations for monitoring were found with other eating behaviors. As shown in previous literature, pressuring the child to eat more has a counterproductive effect of more food avoidant and less food approaching behavior,[56-58] which is reflected in our findings with food responsiveness. However, pressure also increased enjoyment of food and decreased satiety responsiveness. Although we and previous studies suggest that maternal feeding strategies might negatively affect children's eating behaviors,[59,60] current observational research also suggests a more bi-directional nature,[61] with mothers increasing their controlling feeding strategies as a response to unhealthy eating behaviors and weight status of her children.[61-63] However, a recent review of experimental studies still concluded adverse effects in eating behaviors as a result of controlling feeding practices. Lastly, of the studied predictors, we found no associations for sociodemographic factors, breastfeeding duration, and diabetes indicators with eating behavior development, which is largely consistent with other studies.[6,23]

Conclusion

In conclusion, this study suggests that children may develop distinct patterns of emotional overeating and food responsiveness across childhood, while for enjoyment of food and satiety responsiveness a single pattern was observed for all children. Child early life pre-

dictors related to a higher weight status and emotional and behavioral problems, as well as maternal feeding practices are likely correlates of the development and maintenance of unhealthy eating behavior patterns across childhood. Our findings therefore help to identify children with a higher risk to develop unhealthy eating behaviors for whom targeted intervention strategies may be effective. Such interventions may, for instance, teach children alternative coping strategies to deal with stress and negative mood, which can replace the emotional eating strategy.

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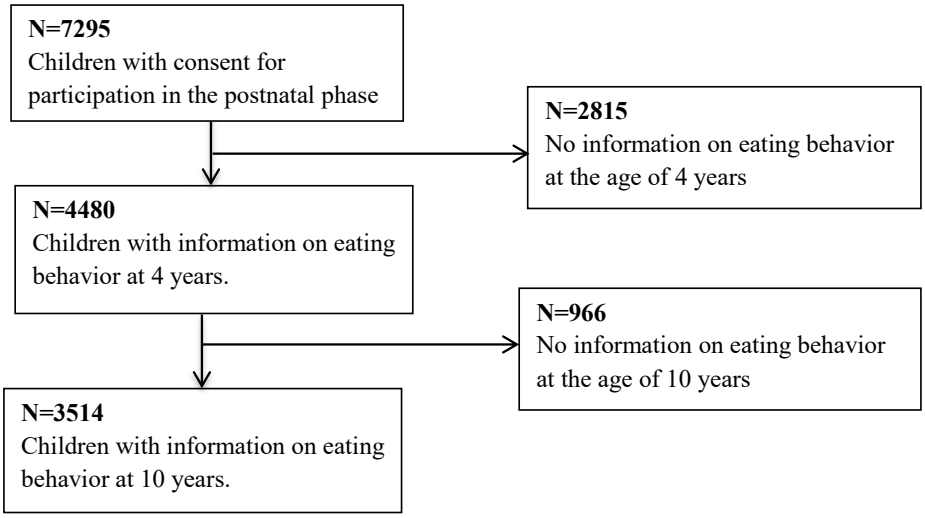
SUPPLEMENT



Supplementary Figure 2.1. Flowchart of the study sample

Supplementary Table 2.1. Difference in eating behavior between the age of 4 years and 10 years, n=3514

CEBQ subscale	Age 4 years Mean item score (SD)	Age 10 years Mean item score (SD)	r	*p* value
Emotional overeating	1.44 (0.60)	1.49 (0.66)	0.21	<0.001
Food responsiveness	1.77 (0.67)	1.83 (0.76)	0.37	<0.001
Enjoyment of food	3.37 (0.72)	3.60 (0.66)	0.46	<0.001
Satiety responsiveness	3.11 (0.62)	2.57 (0.65)	0.48	<0.001

*Spearman correlations for Emotional overeating and Food responsiveness, and Pearson correlation coefficients for Enjoyment of food and Satiety Responsiveness.

Supplementary Table 2.2. Fit indices of the LCGA procedure for each eating behavior subscale, n=3514

	BIC	Entropy	Lowest n in class	Lowest latent class posterior probability	BLRT[a] p-value
Food responsiveness					
1 class	15182.892	-	3514	-	-
2 classes	13826.470	0.900	425	0.906	0.0000
3 classes	13345.153	0.889	272	0.844	0.0000
4 classes	12981.769	0.885	101	0.848	0.0000
5 classes	12789.752	0.852	113	0.790	0.0000
6 classes	12642.179	0.859	47	0.818	0.0000
Enjoyment of food					
1 class	14802.462	-	3514	-	-
2 classes	14044.049	0.645	854	0.838	0.0000
3 classes	13893.865	0.687	137	0.803	0.0000
4 classes	13535.148	0.885	133	0.913	0.0000
Emotional overeating					
1 class	13352.870	-	3514	-	-
2 classes	12284.095	0.874	1101	0.938	0.0001
3 classes	10340.375	0.977	246	0.989	0.0000
4 classes	10364.869	0.982	0	0.000	1.0000
Satiety responsiveness					
1 class	13620.014	-	3514	-	-
2 classes	12806.113	0.619	1155	0.842	0.0000
3 classes	12631.093	0.571	586	0.737	0.0000
4 classes	12623.140	0.604	88	0.744	0.0000

[a] Bootstrapped Likelihood Ratio Test