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Prospective associations of age at complementary feeding and exclusive breastfeeding duration with body mass index at 5–6 years within different risk groups

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Summary

Background: Children with overweight or obesity are at risk for developing obesity in adulthood. Certain maternal characteristics, such as ethnicity, education, body mass index (BMI) or neighbourhood, are determinants for childhood overweight risk. There are large variations in how mothers differing in these characteristics feed their infants. Therefore, associations of age at complementary feeding, exclusive breast feeding duration with childhood overweight may differ in these groups. Understanding these associations would be essential to develop overweight prevention strategies.

Objectives: The objective of this study is to study the associations of age at complementary feeding, exclusive breastfeeding duration with BMI-standard deviation score (SDS) at 5–6 years within risk groups.

Methods: Using data from the Amsterdam Born Children and their Development study, a population-based birth cohort (n = 4495), we formed groups of children at varying risk of overweight according to maternal characteristics of ethnicity, education, pre-pregnancy BMI and neighbourhood. Linear and logistic regression analyses were conducted.

Results: Complementary feeding after 5 months of age was associated with lower BMI-SDS in children of mothers of Dutch ethnicity (B: −0.12; 95% CI: −0.21, −0.04), medium-level education (−0.19; −0.30, −0.08), normal BMI (−0.08; −0.16, −0.01) and high-risk neighbourhood (−0.16; −0.29, −0.02). Compared with exclusive breastfeeding for <3 months, exclusive breastfeeding for ≥6 months was associated with lower BMI-SDS in groups of medium-level education (−0.28; 0.44, −0.11), normal BMI (−0.18; −0.29, −0.08) and medium-risk (−0.18; −0.33, −0.04) and high-risk (−0.22; −0.42, −0.02) neighbourhoods.

Conclusions: Associations between infant feeding practices and childhood BMI may differ between risk groups, implying that overweight prevention strategies should be group-specific.

Keywords: Breastfeeding, BMI, childhood overweight, complementary feeding, weaning.

Introduction

Increasing evidence suggests that early life growth and development can have an influence on long-term health outcomes. Overweight (including obesity) during childhood is a risk factor for later obesity and obesity-related diseases, such as coronary heart disease.(1,2) As obesity in adulthood is also associated with several other comorbidities and is difficult to reverse, it is thus important to maintain normal weight trajectories during childhood.(3) It has been estimated that in 2020, 60 million preschool children worldwide will have overweight.(4) Although some developed countries have reported recent stabilization in the prevalence of childhood overweight,(5) inequalities in the prevalence of overweight between certain groups, such as different socioeconomic and ethnic populations, seem to be growing.(6,7) In the Netherlands, an overall decrease in overweight has been observed in children of Dutch origin, whereas

the rates for children of Moroccan or Turkish origin are still increasing, from as early as 2 years of age.(7) This suggests that current intervention strategies may not be effective for all groups. Thus, there is a strong rationale to investigate early determinants for overweight in groups at varying risk of overweight.

Certain characteristics of the mother, such as ethnicity,(8) education,(9) body mass index (BMI)(10) or neighbourhood,(11) predict a child's risk of becoming overweight. Underlying determinants for overweight may be different for children whose mothers differ in these characteristics, being partly (epi)genetical and behavioural, related to dietary habits or physical activity. Infant feeding practices, i.e. (exclusive) breastfeeding and age at complementary feeding, have been suggested to have a moderate protective effect on childhood overweight.(12,13) However, conflicting evidence exists, and residual confounding remains an issue in these studies. Many previous studies have conducted analyses within a single population, correcting for certain factors such as education and ethnicity. Yet, there are considerable differences in how mothers of different education or ethnic backgrounds feed their infants.(14,15) This suggests that maternal factors should be considered as potential effect modifiers, rather than confounders. Consequently, associations between exclusive breast feeding duration and timing of complementary feeding may be different across populations. Such findings could suggest that interventions to target overweight that focus on infant feeding practices may have limited impact in certain groups. Furthermore, understanding potential differences in these associations between certain populations could aid the development of group-specific strategies to prevent overweight.

Therefore, the objective of this study was to examine the associations of age at complementary feeding and exclusive breastfeeding duration with BMI-standard deviation scores (SDSs) at 5–6 years of age within groups of children at varying risk of overweight. We based our selection of risk groups on several maternal characteristics that are associated with childhood overweight,(8–11) including pre-pregnancy BMI, education level, ethnicity and neighbourhood. We hypothesized that the associations between infant feeding practices and BMI in childhood may differ between the risk groups.

Methods

Participants

Data were obtained from the Amsterdam Born Children and their Development (ABCD) study, a large Dutch prospective birth cohort in the city of Amsterdam.(16) Between January 2003 and March 2004, all pregnant women (n = 12 373) living in Amsterdam were invited to participate in this study by completing a pregnancy questionnaire (Fig. S1). Of these women, 8266 women completed the questionnaire (at 12–14 weeks of pregnancy), and 7863 women gave birth to live singleton infants. Weight and height data for a total of 4495 children at 5–6 years of age were obtained either from the Youth Health Care (YHC) (n = 3404) or from the ABCD health check (n = 1091). Participants with missing data on age at complementary feeding or duration of exclusive breastfeeding were excluded, leaving n = 4133 for age at complementary feeding and n = 4080 for duration of exclusive breastfeeding.

Risk groups

From the available data, we formed several risk groups based on four maternal characteristics: pre-pregnancy BMI, maternal education level, ethnicity and neighbourhood (Table SII). Data on pre-pregnancy BMI (weight and height data), education level, ethnicity and neighbourhood (in the city of Amsterdam) were all self-reported by the mother. All maternal data were obtained through the pregnancy questionnaire. Pre-pregnancy BMI was calculated from the weight and height data and categorized as follows: normal weight (including underweight) BMI $<$25 kg m^{-2}; overweight 25–29.9 kg m^{-2}; or obese $\geq$30 kg m^{-2}. Education level was defined as years of education after primary school: low (0–5 years of education); medium (6–10 years); or high ($>$10 years).(17) Ethnicity was defined as the country of birth of the mother or her mother (to include first-generation and second-generation immigrants), categorized as Dutch, Turkish, Moroccan or Surinamese.(18) Numbers in groups of other ethnicities were too small for separate analyses. Neighbourhood was defined as the area of residence in Amsterdam (based on four digit postal code) where the mother was living at the time of completing the questionnaire. Neighbourhoods were categorized according to previously reported prevalence of child overweight (including obesity) at 5 years in Amsterdam as following: low (reported prevalence of child overweight in the area $<$15%), medium (15–20%) or high risk of overweight ($>$20%).(19)

Measurements

Infant feeding practices

Information on age at complementary feeding and duration of exclusive breastfeeding were collected

prospectively during the YHC evaluations, which parents are routinely invited to complete for their children at 1–4, 6, 7.5, 9 and 11 months of age.(20) To complete missing data, information on infant feeding was also obtained with a questionnaire administered when children were 5 years of age (23.7% of the data for age at complementary feeding and 19.9% for exclusive breastfeeding). These data have been reported to be reliable by means of an intra-class correlation coefficient, showing sufficient validity.(20) Age at complementary feeding was defined as the child's age (in months) at which other foods and beverages were introduced to the previously exclusively breastfed or formula-fed infant. For the current analysis, this was categorized as either <5 or ≥5 months. We also performed sensitivity analysis using 6 months as a cut-off for complementary feeding age; this showed only slight changes in the estimates in comparison with using a 5-month cut-off. The duration of exclusive breastfeeding was defined as duration of breastfeeding (in months) without any other milk, solids or fluids. The following categories were used: <3, 3–5.9 and ≥6 months. Duration of any breastfeeding was defined as non-exclusive breastfeeding duration, categorized as <3, 3–5.9 and ≥6 months.

Outcome

The primary outcome was the child's BMI-SDS at age 5–6 years. For this, weight and height data were obtained from the YHC registry or the ABCD health check, which was conducted by trained research assistants. Height was measured to the nearest millimetre with a Leicester portable height measure (Seca, Hamburg, Germany), and weight was measured to the nearest 100 g with a calibrated Marsden M-4102 scale (Oxfordshire, UK).(16) BMI was calculated from the height and weight data as weight in kilograms divided by the square of height in metres. BMI scores were converted to age-adjusted and sex-adjusted SDSs relative to WHO 2007 growth standards(21) using the Growth Analyser 3.0 (Dutch Growth Research Foundation, Rotterdam, The Netherlands). We also obtained odds ratios (ORs) for overweight, for which children were dichotomized into having either 'no overweight' or 'overweight' (including obesity) according to sex-specific and age-specific BMI cut-off values defined by the International Obesity Task Force.(22)

Statistical analysis

Differences in mean BMI-SDS (continuous outcome) at 5–6 years between the risk groups were tested using ANOVA. The ORs for overweight (dichotomous outcome) for each risk group were obtained using logistic regression analyses. Risk groups with lowest overweight prevalence were used as the reference group. First, we examined the associations between age at complementary feeding and duration of exclusive breastfeeding with BMI-SDS by unadjusted linear regression analyses, using BMI-SDS as a continuous outcome. Second, we used logistic regression analyses using dichotomized BMI cut-off values to examine the associations with overweight. We conducted stratified analyses (planned a priori the basis of previous literature)(8–11) according to each risk group (ethnicity, education, BMI and neighbourhood). Interaction between exclusive breastfeeding duration and age at complementary feeding was tested by adding a product term of these two variables to the main linear regression model.(23) Additional adjusted linear regression models were performed (Tables SII and SIII) to assess the robustness of the crude analyses. In model 2, analyses were adjusted for the other risk group variables to test whether the associations were confounded by other maternal characteristics. In model 3, analyses were adjusted for birth weight SDS (age-adjusted and sex-adjusted relative to the WHO 2006 growth standards)(24) and in the analysis of age at complementary feeding, adjusted for duration of any breastfeeding.(12) These adjustments were made instead of model 2 covariates. Results are presented as B, OR and 95% CI using the following reference groups: age at complementary feeding <5 months and exclusive breastfeeding <3 months. Statistical analyses were conducted using SPSS, version 23.0 (SPSS Inc., Chicago, IL, USA).

Results

Body mass index-standard deviation scores and overweight according to risk groups

In all risk groups, mean BMI-SDS was significantly higher than in the reference group (Table 1). The largest contrasts in mean BMI-SDS within the risk groups were found for ethnicity and pre-pregnancy BMI, with the highest BMI-SDS values for Turkish children (mean BMI-SDS: 0.80; SD: 1.3) and children of mothers with obesity (0.75; 1.3). Children of Turkish ethnicity had a greater than sixfold risk of overweight (OR: 6.38; 95% CI: 4.71, 8.64) compared with children of Dutch ethnicity. Children from mothers with obesity had a greater than fourfold risk (OR 4.06; 95% CI: 3.09, 5.33) compared with children from mothers with normal BMI.

Table 1 BMI-SDS, overweight and ORs for overweight at 5–6 years of age according to risk groups

Maternal characteristics	% (*N*)	BMI-SDS mean (SD)	Overweight % (*N*)	OR for overweight (95% CI)
Ethnicity				
Dutch	58.0 (2607)	0.13 (0.9) (ref)	7.8 (203)	(ref)
Turkish	6.9 (238)	0.80 (1.3)***	35.0 (83)	6.38 (4.71, 8.64)***
Moroccan	8.5 (384)	0.57 (1.1)***	23.2 (89)	3.57 (2.71, 4.71)***
Surinamese	6.6 (298)	0.26 (1.2)*	16.8 (50)	2.40 (1.71, 3.35)***
Education level				
Low	20.0 (892)	0.47 (1.2)***	21.5 (191)	3.49 (2.76, 4.42)***
Medium	37.1 (1656)	0.23 (1.1)***	13.3 (220)	1.96 (1.57, 2.45)***
High	42.9 (1916)	0.04 (0.9) (ref)	7.3 (139)	(ref)
Pre-pregnancy BMI				
Normal	76.4 (3424)	0.07 (1.0) (ref)	9.3 (317)	(ref)
Overweight	16.8 (754)	0.52 (1.1)***	19.9 (150)	2.44 (1.97, 3.02)***
Obese	6.8 (305)	0.75 (1.3)***	29.3 (89)	4.06 (3.09, 5.33)***
Neighbourhood				
Low risk	27.2 (1221)	0.10 (0.9) (ref)	7.5 (91)	(ref)
Medium risk	43.8 (1966)	0.19 (1.1)*	12.7 (249)	1.8 (1.40, 2.30)***
High risk	29.1 (1305)	0.29 (1.2)***	16.7 (218)	2.5 (1.93, 3.23)***

*$p < 0.05$. ***$p < 0.001$.
BMI-SDS, body mass index-standard deviation score; ORs, odds ratios.

Associations between age at complementary feeding and body mass index-standard deviation scores at 5–6 years

When compared with complementary feeding <5 months, complementary feeding <5 months was associated with 0.11 lower BMI-SDS at 5–6 years of age (Table 2). When stratified by risk group, a significant association was found in groups of Dutch ethnicity (B: −0.12; 95% CI: −0.21, −0.04), medium education (−0.19; −0.30, −0.08), normal BMI (−0.08; −0.16, −0.01) and high-risk neighbourhood (−0.16; −0.29, −0.02). In line with the linear regression, logistic regression analyses indicated a significantly lower risk for overweight in these groups when complementary feeding >5 months (except for the group with normal BMI, Table 2).

In the additional adjusted linear regression models 2 and 3 (Table SIII), adjustment for confounders somewhat attenuated the associations in several risk groups but did not drastically change the results.

Association between duration of exclusive breastfeeding and body mass index-standard deviation scores at 5–6 years

When compared with exclusive breastfeeding for <3 months, exclusive breastfeeding for ≥6 months was associated with 0.18 lower BMI-SDS at 5–6 years. A significant association was observed in groups of medium education (B: −0.28; 95% CI: −0.44, −0.11), normal BMI (0.18; −0.29, −0.08), medium-risk (−0.18; −0.33, −0.04) and high-risk neighbourhood (−0.22; −0.42, −0.02). Logistic regression analyses were in line with these results, indicating a lower risk for overweight when infants were exclusively breast fed for ≥6 months compared with <3 months except for the group from high-risk neighbourhoods (Table 3).

After additional adjustment for confounders, significant associations observed in the crude linear regression analysis remained, except in the group of low education (Table SIV).

There was no evidence of an interaction between age at complementary feeding and duration of exclusive breastfeeding ($p = 0.78$).

Discussion

In this large, population-based cohort study of 5- to 6-year-old children, we found that associations of age at complementary feeding and exclusive breastfeeding duration with BMI differed between groups at varying risk of overweight. Compared with complementary feeding before 5 months, complementary feeding after 5 months of age was associated with lower BMI and lower risk of overweight in groups of Dutch ethnicity, medium education, normal BMI and high-risk

Table 2 Crude linear and logistic regression analyses between age at complementary feeding and BMI-SDS and overweight at age 5–6 years by risk groups

	Linear regression		Logistic regression	
	B for BMI-SDS when complementary feeding ≥5 months	(95% CI)	OR for overweight when complementary feeding ≥5 months	(95% CI)
All	−0.11**	(−0.18, −0.04)	0.81*	(0.66, 0.99)
Ethnicity				
Dutch	−0.12**	(−0.21, −0.04)	0.71*	(0.52, 0.97)
Turkish	0.04	(−0.39, 0.48)	1.22	(0.59, 2.52)
Moroccan	−0.12	(−0.40, 0.16)	0.86	(0.48, 1.55)
Surinamese	−0.04	(−0.35, 0.26)	0.84	(0.43, 1.63)
Education level				
Low	−0.09	(−0.27, 0.09)	0.95	(0.66, 1.37)
Medium	−0.19**	(−0.30, −0.08)	0.62**	(0.45, 0.84)
High	0.02	(−0.08, 0.12)	1.33	(0.85, 2.11)
Pre-pregnancy BMI				
Normal	−0.08*	(−0.16, −0.01)	0.87	(0.66, 1.13)
Overweight	−0.17	(−0.34, 0.01)	0.77	(0.51, 1.15)
Obese	0.07	(−0.24, 0.38)	0.96	(0.55, 1.66)
Neighbourhood				
Low risk	−0.08	(−0.21, 0.04)	1.12	(0.65, 1.95)
Medium risk	−0.07	(−0.18, 0.04)	0.91	(0.67, 1.24)
High risk	−0.16*	(−0.29, −0.02)	0.70*	(0.50, 0.96)

*$p < 0.05$. **$p < 0.01$.
B represents change in body mass index-standard deviation score (BMI-SDS), and odds ratio (OR) represents odds for overweight when complementary feeding at 5 months or later (compared with complementary feeding <5 months).

neighbourhood. These associations, except for the group of normal BMI, were supported by logistic regression analyses and remained significant after adjusting for confounders. Furthermore, we found that when compared with exclusive breastfeeding for less than 3 months, exclusive breastfeeding for 6 months or longer was associated with lower BMI and lower risk of overweight at age 5–6 years in risk groups of medium education, normal BMI and medium-risk neighbourhood. Associations in groups of medium education and normal BMI remained significant after adjustment for confounders.

Previous studies on age at complementary feeding and overweight in childhood have reported inconsistent results.(12) These studies varied by several factors; categorization of age at complementary feeding, definition of the outcome (overweight/obesity) and timing of outcome measurement. Furthermore, most studies included different populations, such as mix of ethnicities, which were analysed as one population and corrected for certain factors such as ethnicity. Different associations between populations, as observed in the current study, could explain the inconsistencies in previous findings. Only one previous study examined differences in associations between age at complementary feeding and obesity between populations.(25) In this particular study, early (<3 months) complementary feeding was more strongly associated with childhood obesity in groups of White/European ethnicity and of higher income than in Black, Asian, middle-income or low-income groups. This seems to be in agreement with our findings of a stronger association in Dutch ethnicity than in other ethnicities. Also previous studies with Turkish children reported no association between age at complementary feeding and overweight in childhood or excess weight gain during infancy.(20,26)

A number of studies have reported a moderate protective effect of exclusive breastfeeding duration on overweight.(13,27,28) We observed that, compared with exclusive breastfeeding for less than 3 months, exclusive breastfeeding for 6 months or longer was associated (after adjustment for confounders) with lower BMI and lower risk of overweight at age 5–6 years in risk groups of medium education, Dutch ethnicity (indicated by logistic regression and adjusted linear regression models) and normal BMI. Similar to our study, studies in the USA and Sweden stratified

Table 3 Crude linear and logistic regression analyses between duration of exclusive breastfeeding and BMI-SDS and odds of overweight at age 5–6 years by risk groups

	Linear regression (reference group: <3 months)		Logistic regression (reference group: < 3 months)	
	3–5.9 months B (95% CI)	≥6 months B (95% CI)	3–5.9 months OR (95% CI)	≥ 6 months OR (95% CI)
All	−0.06 (−0.13, 0.01)	−0.18*** (−0.28, −0.09)	0.83 (0.67, 1.02)	0.58** (0.42, 0.81)
Ethnicity				
Dutch	−0.05 (−0.13, 0.03)	−0.10 (−0.21, 0.02)	0.83 (0.60, 1.14)	0.53* (0.31, 0.91)
Turkish	0.02 (−0.37, 0.341)	−0.06 (−0.60, 0.47)	1.12 (0.60, 2.12)	1.01 (0.42, 2.48)
Moroccan	0.14 (−0.17, 0.44)	−0.20 (−0.56, 0.16)	1.32 (0.71, 2.45)	1.20 (0.58, 2.50)
Surinamese	−0.05 (−0.47, 0.36)	−0.42 (−1.03, 0.18)	0.47 (0.16, 1.41)	0.25 (0.03, 1.95)
Education level				
Low	0.10 (−0.12, 0.32)	−0.25 (−0.52, 0.02)	1.20 (0.79, 1.83)	0.72 (0.40, 1.31)
Medium	−0.06 (−0.18, 0.06)	−0.28** (−0.44, −0.11)	0.84 (0.60, 1.17)	0.50* (0.28, 0.89)
High	0.03 (−0.06, 0.12)	−0.02 (−0.15, 0.10)	1.08 (0.74, 1.58)	0.65 (0.35, 1.20)
Pre-pregnancy BMI				
Normal	−0.05 (−0.13, 0.02)	−0.18** (−0.29, −0.08)	0.88 (0.67, 1.14)	0.52** (0.33, 0.82)
Overweight	0.13 (−0.06, 0.32)	−0.16 (−0.40, 0.09)	1.05 (0.68, 1.61)	0.73 (0.40, 1.33)
Obese	−0.06 (−0.42, 0.29)	0.02 (−0.48, 0.52)	0.83 (0.44, 1.57)	0.65 (0.25, 1.70)
Neighbourhood				
Low risk	−0.04 (−0.15, 0.07)	−0.11 (−0.27, 0.05)	0.90 (0.57, 1.42)	0.35* (0.14, 0.89)
Medium risk	−0.08 (−0.18, 0.03)	−0.18* (−0.33, −0.04)	0.73 (0.53, 1.00)	0.58* (0.36, 0.93)
High risk	−0.01 (−0.16, 0.14)	−0.22* (−0.42, −0.02)	1.08 (0.76, 1.54)	0.78 (0.46, 1.32)

*$p < 0.05$. **$p < 0.01$. ***$p < 0.005$.
BMI-SDS, body mass index-standard deviation score; OR, odds ratio.

their analyses by maternal ethnicity and concluded that the protective effect of breastfeeding (any duration, non-exclusive) on overweight/obesity or BMI development was limited to children of White mothers and not observed in Blacks, Hispanics or non-Swedish immigrants.(29–32) One of these studies also examined a low-income population in which the effect was limited only to White children who were breastfed at least for 4 months and whose mothers did not smoke.(31) In our study, breastfeeding for 3–5.9 months was not significantly associated with lower BMI-SDS in the crude analyses in any of the risk groups. Results on exclusive breastfeeding duration for 6 months or longer showed a similar protective effect in most of the risk groups.

There are several possible explanations why we found differences in associations between age at complementary feeding or exclusive breast feeding duration with overweight between the risk groups. First, there may be other factors that play a more important role on development of overweight than age at complementary feeding or exclusive breastfeeding duration. One such factor might be diet quality and quantity, for which we lacked information.(33,34) We found that age at complementary feeding and exclusive breastfeeding duration was weakly associated with child's BMI in groups with Turkish ethnicity, high education or maternal obesity. Turkish parents have been reported to supplement breastfeeding with additional formula and to feed uncommon complementary foods such as sweetened yogurt, bread and confectionery compared with mothers of Dutch origin.(14) Furthermore, mothers with obesity have been found to provide higher proportions of 'adult' foods to their infants than mothers with normal weight.(35) The observed associations could also have been attenuated by differences in dietary practices during early childhood.(36) Second, absence of statistical significance for some associations could be also due to the limited number of participants in certain risk groups. Numbers in the groups of non-Dutch ethnicity (each group <10% of total population), and mothers with overweight (17%) or obesity (7%) were relatively small. Finally, we cannot exclude the possibility that the observed associations represent chance findings. Therefore, our results should be interpreted with caution.

The strength of our present study was the large population-based cohort, which included many non-Dutch participants, who were followed from early pregnancy until childhood. Unlike most previous studies, we conducted separate analyses within several

risk groups. Yet, some limitations should be addressed. First, as mentioned, our analysis may have lacked statistical power to detect a true effect in some of the risk groups. However, our sample sizes were larger than some previous studies.(12) Second, information on age at complementary feeding and breastfeeding was mainly prospectively collected during the regular YHC visits, but partly retrospectively collected at 5 years of age, which relied on parental recall. The reliability between the sources has been previously reported.(20)

To conclude, these results suggest that associations between infant feeding practices and BMI in childhood differ between risk groups, implying that strategies to prevent childhood overweight should be group-specific. Future studies should include higher numbers of participants from specific risk groups as well as information on both quantity and quality of the complementary foods.

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Conflicts of interest

O. S. and M. A.-B. are employees of Danone Nutricia Research.

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Supporting information

Additional Supporting Information may be found online in the supporting information tab for this article.

Figure S1. Selection of the study population
Table S1. Risk groups by age at complementary feeding (n = 4133) and duration of exclusive breastfeeding (n = 4080)
Table SII. Associations between age at complementary feeding and BMI-SDS at age 5–6 years by risk groups, linear regression, adjusted models
Table SIII. Associations between duration of exclusive breastfeeding and BMI-SDS at age 5–6 years by risk groups, linear regression, adjusted models