Testing the direction of effects between child body composition and restrictive feeding practices: results from a population-based cohort

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ABSTRACT

Background: Parental restrictive feeding (i.e. limiting food intake of children) has been linked to childhood overweight. However, the directionality of the causal pathway remains unknown.

Objective: The objectives of this study were to examine the bidirectional association of maternal restrictive feeding with children's weight and body composition across childhood, and to explore a possible mediating role of maternal concern about child weight.

Design: Data were available for 4689 mother-child dyads participating in Generation R, a prospective birth cohort in the Netherlands. At ages 4 and 10 years, restrictive feeding was assessed with the parent-reported Child Feeding Questionnaire and children's BMI was measured. At age 6 years, Fat Mass Index (FMI) and Fat Free Mass Index (FFMI) were measured with Dual-energy X-ray absorptiometry (DXA). Both directions of the relation between restriction and child body composition were examined with multivariable linear regression analyses and cross-lagged modeling. Mediation analyses were performed to examine concern about child weight (mother-reported at child age 10 years) as a potential mediator.

Results: Higher child sex- and age-adjusted BMI SD scores (zBMI) at age 4 years predicted more restrictive feeding at age 10 years, adjusted for confounders and restrictive feeding at age 4 years (B=0.15, 95%CI: 0.11, 0.18). Both zFMI and zFFMI at 6 years were also positively associated with restrictive feeding at 10 years. Maternal concern about child weight partially mediated these associations from child body composition to restrictive feeding (e.g. for zBMI at 4 years: $B_{indirect}$ = 0.10, 95%CI: 0.07, 0.13). There was no temporal association from restrictive feeding at 4 years to child zBMI at 10 years after adjustment for baseline zBMI.

Conclusions: The continued use of restrictive feeding practices at age 10 years appeared to be primarily a response of mothers to an unhealthy weight of their child rather than a cause of children's overweight. Guidelines discouraging restrictive feeding for preventing childhood overweight should therefore be reconsidered.

INTRODUCTION

Parents have an important influence on children's food intake which in turn affects weight development.[1] Parents can regulate food intake by using different feeding strategies, including restrictive feeding. With this strategy, parents attempt to regulate and limit the types and amount of food that children eat.[2]

It has been postulated that restrictive feeding is a risk factor for overweight,[3] as it may hamper the development of a healthy self-regulation of food intake, and therefore lead to overeating when foods are freely available. Also, the attractiveness of restricted foods may increase, as shown in experimental studies.[4,5] Cross-sectional studies confirmed that restrictive feeding was associated with greater snack and sugar-sweetened beverage intake[6,7] and higher child weight,[8-11] but longitudinal studies found no temporal associations in the general population.[12-17] A longitudinal association of more restriction with higher BMI was only found in specific samples of children with low inhibitory control[18,19] or a predisposition to obesity,[20-23] in African-American children[24] and in girls.[23]

An alternative explanation for the reported cross-sectional findings is that parents use restrictive feeding in response to their child's eating behavior and overweight.[3,25] Parents are generally sensitive to their children's hunger and satiety cues, and adapt their feeding strategies when needed.[26] Thus, if children develop obesogenic eating habits or excess weight, parents may limit the availability of high-fat or high-sugar products in their homes, and set rules about snacking. However, this hypothesis was examined only a few times with contradicting findings. A longitudinal study in a U.K. cohort found no evidence for this hypothesis,[12] while in the Dutch Generation R and Portuguese Generation XXI cohorts, associations between child weight and later restriction were found.[27,28] It can be speculated that parental concern about children becoming overweight might drive the restriction of children's food intake. Indeed, results of Webber et al.[29] supported this hypothesis, by showing that the cross-sectional association between parental restriction and BMI in children aged 7 to 9 years was mediated by parental concern about child weight. However, because of the cross-sectional design of this study, temporality and causality of the associations could not be determined.

The inconclusive findings of studies so far highlight the need for longitudinal research with repeated assessments of both restrictive feeding and BMI to better understand the positive, cross-sectional association reported previously.[8-11] This study aimed to examine the direction of effects between restrictive feeding and child adiposity in a large prospective cohort in the Netherlands. We previously reported on the feeding - BMI association when children were 2 to 6 years old using only one assessment of restrictive feeding at age 4 years.[27] We now report on repeated measures of both restriction and child BMI at ages 4 and 10 years, enabling us to examine bi-directionality. We also examined more precise measures of body composition (fat and fat free mass) and the role of maternal concern about child weight.

METHODS

Study design and population

This study was embedded in the Generation R Study, a population-based cohort from fetal life onwards, which was described previously in detail.[30] In brief, all pregnant women living in Rotterdam, the Netherlands with an expected delivery date between April 2002 and January 2006 were invited for participation by health care workers during pregnancy and shortly after birth of their child (participation rate: 61%). The study was approved by the Medical Ethics Committee of the Erasmus Medical Center, Rotterdam and written informed consent was obtained from all participating children and their parents. Data used for the current study were prospectively collected at multiple time points. At the age of 4 years, restrictive feeding was measured by postal questionnaire and BMI data was retrieved from the Municipal Health Centers. At the age of 6 years, children visited our research center where body composition was measured. At 10 years of age, children visited the research center for the second time for body composition measures and at the same time point, feeding practices were measured by postal questionnaire.

At the age of 10 years, 8548 children and parents were invited to participate in an assessment, of whom 5862 children visited the research center for detailed follow-up measures. Children were excluded from the current analyses when they had missing data at 10 years on BMI (n=176) or maternal feeding practices (n=997), resulting in a study sample of 4689 children and their mothers. Missing data on BMI (n=2046), body composition (n=394) and feeding practices (n=1226) from previous waves and missing data on covariates were dealt with using multiple imputation (Supplementary Figure 8.1). A comparison of the study sample (n=4689) with excluded participants (n=3858) showed that the study population included more girls (p=0.01), and more children with a Dutch background (p<0.01) and higher family income (p<0.01).

Measures

Maternal restrictive feeding and concern about child weight

Restrictive feeding practices were measured when children were 4 and 10 years old with the use of the restrictive feeding subscale of the Child Feeding Questionnaire (CFQ). This subscale measures how much a parent controls his/her child's food consumption by restricting eating and by using food as reward for good behavior. Research has demonstrated adequate validity and reliability of the English language version,[31] which had been translated into Dutch by using the standard forward-backward translation method. When the children were 4 years old, mothers reported on their own use of restrictive feeding practices regarding the study child (89% mother-report). The subscale consists of 8 items, e.g. "If I did not guide or regulate my child's eating behavior, he/she would eat too many of his/her favorite foods" and "I offer my child his/her favorite food in exchange for good behavior". All item responses were rated on a five point scale, from "1. disagree", indicating no restriction, to "5. agree" indicating high restriction. Sum scores were calculated when at least 6 items were answered (62 mothers had 1 or 2 items missing). Internal consistency in our study population was considered as acceptable (Cronbach's α = 0.73). At the age of 10 years, mothers reported again on the CFQ restriction subscale (Supplementary Table 8.1). Two items of the original subscale were omitted due to space limitations in the questionnaire. Sum scores were calculated when mothers (98% mother-report) answered at least 5 items (69 mothers had 1 item missing). When children were 10 years old, mothers additionally reported on a shortened version of the CFQ subscale 'concern about child weight'. This two-item scale (originally three-item scale) assesses a mother's concern about her child becoming overweight, with the following items: "How concerned are you about your child having to diet to maintain a desirable weight?" and "How concerned are you about your child eating too much when you are not around?" Answers were given on a five-point scale ("1. not concerned at all" to "5. extremely concerned") from which a sum score was calculated. Internal consistencies on both shortened scales were very acceptable (Restriction, Cronbach's α = 0.74; Concern about child weight, Cronbach's α= 0.79), and similar to the internal consistency of the original full scales.[31]

Child BMI and body composition

At the age of 4 years, children's height and weight were measured by trained staff at the municipal Child Health Centers as part of routine health care. At the age of 10 years, participating children were invited to our research center where their growth characteristics were obtained. Height was measured with a stadiometer (Holtain Limited, Crosswell, Crymych, UK) to the nearest 0.1 cm, and weight was measured to the nearest 0.1 kg using an electronic scale (Seca 888, Almere, The Netherlands). At both ages, sex and age adjusted BMI (kg/m^2) standard deviation scores (zBMI) were calculated by using the Dutch reference growth curves (http://www.growthanalyser.org).[32]

At the age of 6 years, height was measured with a stadiometer (Holtain Limited, Crosswell, Crymych, UK) and children's body composition was assessed at our research center by trained staff using the Dual-energy X-ray absorptiometry (DXA) scanner (iDXA, GE-Lunar, 2008, Madison, WI, USA). While children were lying down in horizontal position, without shoes and metal objects, total and regional body fat mass, lean mass and bone mass were measured. From this, Fat Mass Index (FMI) was calculated as fat mass (kg)/ height $(m)^2$, and Fat Free Mass Index (FFMI) was calculated as fat-free mass (kg)/ height $(m)^2$. Sex- and age specific standard deviation scores (zFMI and zFFMI) were calculated for the total study population with body composition data available.

Covariates

The following covariates were considered as possible confounders in the association between restrictive feeding and child BMI: child's age, sex, ethnicity, birth weight, duration of breastfeeding, maternal education level, household income, maternal BMI and maternal depression and anxiety symptoms. Children's sex and birth weight were derived from medical records filled out by obstetricians and community midwifes. In prenatal questionnaires, the country of birth of both biological parents was assessed, from which child ethnicity was derived. Maternal educational level was also obtained by prenatal questionnaire. Maternal anxiety symptoms and depressive symptoms were obtained with two subscales of the validated Brief Symptom Inventory (BSI) when children were 3 years old.[33] Duration of breastfeeding was based on repeated questionnaires in the first year of children's lives. Information on household income was obtained by questionnaire when the children were 6 years old. Maternal weight and height were measured during the 6-years visit of the children from which maternal BMI was calculated as kg/m^2.

Statistical analyses

Restrictive feeding and concern about child weight measures were transformed into standardized scores (z-scores) for effect-size comparison purposes. The association between child zBMI or body composition with restrictive feeding was studied in both directions using multiple linear regression analyses. First, the crude association was tested, and in a second step, covariates were included in the model. Covariates were only included if they influenced the feeding-BMI association by more than 5%. As a result, maternal education, maternal anxiety symptoms and duration of breastfeeding were not included in the models. As a third step, the association between restrictive feeding at 4 years and child zBMI at 10 years was additionally adjusted for zBMI at baseline (4 years), in order to examine whether restrictive feeding predicted the change in zBMI. Likewise, the association between child zBMI at 4 years and restrictive feeding at 10 years was additionally adjusted for restrictive feeding at baseline (4 years) to examine whether BMI predicted change in restrictive feeding. Interaction effects with sex were studied for all the above associations by adding an interaction term to the models. A sensitivity analysis was performed to study whether children in different weight categories respond differently to maternal restriction. Child zBMI at age 4 years was categorized according to BMI status (underweight, normal weight and overweight/obese). Subsequently, a stratified multivariable linear regression was performed to examine the association between maternal restrictive feeding at age 4 years and child zBMI at 10 years.

A cross-lagged modeling approach was used to further investigate the association between child zBMI and restrictive feeding. In this type of path analysis, all associations are accounted for each other, confounding factors, stability effects and cross-sectional correlations, and, stepwise, the mutual prospective associations between restrictive feeding and child zBMI. In order to find the best-fitting model, we first tested the stability model, that only included the stability paths and cross-sectional associations, with confounders regressed at the two baseline assessments (model 1). Next, we included the lagged association from restrictive feeding at 4 years to zBMI at 10 years (model 2) in the stability model, and in a separate model the lagged association from child zBMI at age 4 to restrictive feeding at age 10 years (model 3). Finally, both lagged associations were entered in the full model simultaneously (model 4). The best-fitting model was chosen based on model improvement tested with the Satorra-Bentler χ^2-difference test for maximum likelihood estimation.[34] By using this method, the created models are not judged on the overall model fit since the aim is not to best predict the outcomes, but rather to examine which of the models with alternative pathways provide the best fit to the data.

In a final analysis, we examined the possible mediating role of parental concern about child weight in the association between child zBMI and restrictive feeding. With mediation analysis, we estimated the direct effect of child zBMI on restrictive feeding, as well as the indirect effect via parents' concern about child weight. Similar mediation analyses were conducted with zFMI and zFFMI at the age of 6 years as predictors of restrictive feeding at 10 years. All mediation models were adjusted for confounders.

Multiple imputation (full conditional specification) was used to account for missing values in the predictors and confounders in the multiple regression analyses. Information on all variables included in the study as well as child zBMI at ages 1, 2, 3, 4, 6, 11 and 14 months, and at age 1.5, 2, 2.5, 3 and 6 years, and other CFQ subscales at age 4 years were used to estimate imputations. Analyses were based on pooled results of 20 imputed data sets. For the cross-lagged and mediation analyses, Full Information Maximum Likelihood (FIML) was used to deal with missing values. When only including children with data available on all predictors and outcomes (n=2268), we found similar results as observed in the imputed data. Multiple linear regression analyses were performed with SPSS version 21.0 (IBM Corp, Armonk, NY, USA), and the cross-lagged- and mediation analyses were performed with Mplus, version 7.11 (Muthén & Muthén, Los Angeles, CA, USA).

RESULTS

Non-imputed characteristics of the study sample are shown in Table 8.1. Most children were Dutch (65.1%), and grew up in families with a household income of 1600-4000 euros per month (49.8%). Mothers' average BMI was 25.3 kg/m^2. Maternal restrictive feeding declined over time, with a mean item score of 2.97 (SD=0.77) when children were 4 years old, towards a mean item score of 2.46 (SD=0.92) when children were 10 years old.

Table 8.1. Characteristics of the study sample (n = 4689)[a]

Child characteristics	**n**	**Values**
Sex, % male	4689	49.5%
Age at 10-years visit in years, mean (SD)	4689	9.76 (0.29)
Ethnicity, %		
Dutch	3022	65.1%
Other Western	411	8.9%
Non-Western	1208	26.0%
Birth weight (standardized score), mean (SD)	4642	−0.05 (1.01)
BMI (kg/m^2) at 4 years, mean (SD)	2643	15.80 (1.31)
BMI (kg/m^2) at 10 years, mean (SD)	4689	17.38 (2.53)
FMI (kg/m^2) at age 6 years, mean (SD)	4295	3.92 (1.22)
FFMI (kg/m^2) at age 6 years, mean (SD)	4295	11.93 (0.89)
Maternal characteristics		
Maternal BMI (kg/m^2), mean (SD)	4347	25.34 (4.74)
Household income, %		
Low, <1600€ per month	504	12.4
Medium, 1600-4000€ per month	2023	49.8
High, >4000€ per month	1538	37.8
Maternal depressive symptoms (score), mean (SD)[b]	3354	0.12 (0.29)
Restrictive feeding at 4 years (mean item score), mean (SD)	3463	2.97 (0.77)
Restrictive feeding at 10 years (mean item score), mean (SD)	4689	2.46 (0.92)
Concern about child weight at 10 years (mean item score), mean (SD)	4689	1.24 (0.55)

[a] Data was missing for child ethnicity (n=48), birth weight (n= 47), child BMI at age 4 years (n=2046), child body composition at age 6 years (n=394), maternal BMI (n=342), household income (n=624), maternal depressive symptoms (n=1335), and restrictive feeding at age 4 years (n= 1226).
[b] Maternal depressive symptoms were derived from the Brief Symptom Checklist (BSI).
FMI: Fat Mass Index, FFMI: Fat Free Mass Index

Cross-sectionnaly, maternal restrictive feeding had a stronger association with child zBMI at the age of 10 years (B= 0.24, 95%CI: 0.21, 0.27), than at the age of 4 years (B= 0.10, 95%CI: 0.06, 0.14) (not tabulated). In Table 8.2, the confounder-adjusted longitudinal relations between child zBMI, body composition, restrictive feeding and maternal concern about child weight as obtained with linear regression analyses are shown. Only confounder adjusted results are presented, as together, the confounders, child ethnicity, birth weight, household income, and maternal BMI and depressive symptoms, hardly affected effect sizes. A higher level of restrictive feeding at the age of 4 years was associated with a higher child zBMI at 10 years (B=0.05, 95%CI: 0.01, 0.10). However, this association attenuated to null after adjusting for child zBMI at 4 years. In contrast, a higher child BMI at 4 years was related to more restrictive feeding at age 10 years, even after

Table 8.2. Associations between child BMI, body composition, restrictive feeding and concern about child weight (n = 4689)[a]

Outcomes at age 10 years	Predictors	B (95% CI)	p-value
Child zBMI	Restrictive feeding (4y)	0.05 (0.01, 0.10)	0.03
	Restrictive feeding (4y)[b]	0.00 (−0.04, 0.05)	0.88
Restrictive feeding	Child zBMI (4y)	0.18 (0.14, 0.21)	<0.01
	Child zBMI (4y)[c]	0.15 (0.11, 0.18)	<0.01
	Child zFMI (6y)	0.25 (0.22, 0.29)	<0.01
	Child zFFMI (6y)	0.13 (0.10, 0.16)	<0.01
Concern about child weight	Restrictive feeding (4y)	0.10 (0.05, 0.14)	<0.01
	Child zBMI (4y)	0.29 (0.25, 0.32)	<0.01
	Child zFMI (6y)	0.56 (0.53, 0.60)	<0.01
	Child zFFMI (6y)	0.19 (0.16, 0.22)	<0.01

[a] Values are linear regression coefficients derived from multivariable linear regression analyses. Restrictive feeding and concern about child weight sum scores were transformed into z-scores. All models are adjusted for child ethnicity, birth weight, maternal depressive symptoms, maternal BMI, and household income. Effect sizes of unadjusted associations did not materially differ from the confounder adjusted effect sizes and are therefore not presented. zBMI, sex-and age-adjusted BMI SD scores; zFFMI, sex-and age-adjusted fat-free mass index SD scores; zFMI, sex-and age-adjusted fat mass index SD scores.
[b] Additionally adjusted for zBMI at age 4 y.
[c] Additionally adjusted for restrictive feeding at age 4 y.

adjustment for restrictive feeding at age 4 years (B=0.15, 95%CI: 0.11, 0.18). zFMI and zFFMI were also prospectively associated with restrictive feeding practices, of which the association for zFMI was stronger (e.g., zFMI: B=0.25, 95%CI: 0.22, 0.29). More maternal restrictive feeding at 4 years of age was associated with more maternal concern about child weight at the age of 10 years (adjusted B=0.10, 95%CI: 0.05, 0.14). Furthermore, a higher zBMI at 4 years and zFMI and zFFMI at 6 years were each prospectively associated with more maternal concern about the child's weight (e.g. zFMI: adjusted B=0.56, 95%CI: 0.53, 0.60). The association between child zBMI, zFMI and zFFMI with maternal concern about child weight, was stronger for girls than for boys; e.g. per 1 z-score increase in BMI, maternal concern increased by 0.33 z-score for girls (95%CI= 0.28, 0.38), and by 0.21 z-score for boys (95%CI= 0.19, 0.28). No other sex differences were found for any associations we examined. The association between maternal restrictive feeding at age 4 years and zBMI at age 10 years did not differ by child weight status at age 4 years since restriction was not associated with future zBMI in either of the weight status categories (Supplementary Table 8.2).

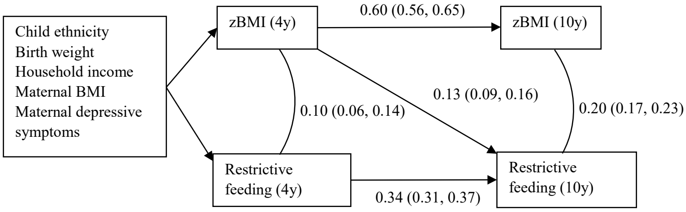

Figure 8.1. The lagged model of associations between restrictive feeding and child BMI from age 4 to 10 years (n=4689). Values represent standardized linear regression coefficients (95% CI's) derived from path analysis and adjusted for covariates.

The best-fitting lagged model of associations between restrictive feeding and child zBMI is shown in Figure 8.1. This model included only lagged effects from a higher child zBMI at 4 years towards more restrictive feeding at 10 years (model 3) (B= 0.13 95% CI: 0.09-0.16). The stability paths showed moderate stability over time for both child zBMI and parental restrictive feeding. The reversed path (from restriction to zBMI, model 2) had a less fit and adding both paths (model 4) was not a significant addition to model 3. The other models, model fit indices and results of the Satorra-Bentler χ^2-difference test are presented in Supplementary Table 8.3 and Supplementary Figures 8.2A-C.

In a final step, we examined whether maternal concern about child weight mediated the association from body composition to restrictive feeding that we observed in the cross-lagged model (Figure 8.2A-C). Figure 8.2A shows that the relation between child zBMI at 4 years and restrictive feeding at 10 years was mediated by maternal concern about child weight ($B_{indirect}$ =0.10, 95% CI: 0.07, 0.13). Likewise, Figures 8.2B and 8.2C show that the relation of child zFMI and zFFMI with restrictive feeding at 10 years was also mediated by maternal concern about child weight status. However, the mediation effect of maternal concern about child weight was significantly larger for child zFMI than for zFFMI, as indicated by non-overlapping confidence intervals (for zFMI, $B_{indirect}$ =0.20, 95%CI: 0.18, 0.22; for zFFMI, $B_{indirect}$ =0.08, 95 CI%: 0.06, 0.09).

DISCUSSION

The findings from this large population-based study showed that children's higher zBMI and fat mass at ages 4 and 6 years prospectively predicted more use of restrictive feeding by mothers when the children were 10 years old, while in general, the use of restrictive feeding declined over the childhood years. This indicates that restrictive feeding is primarily a response of mothers to children's excess weight, largely - as shown in our analyses - because mothers are concerned about their child's weight. Our results do not

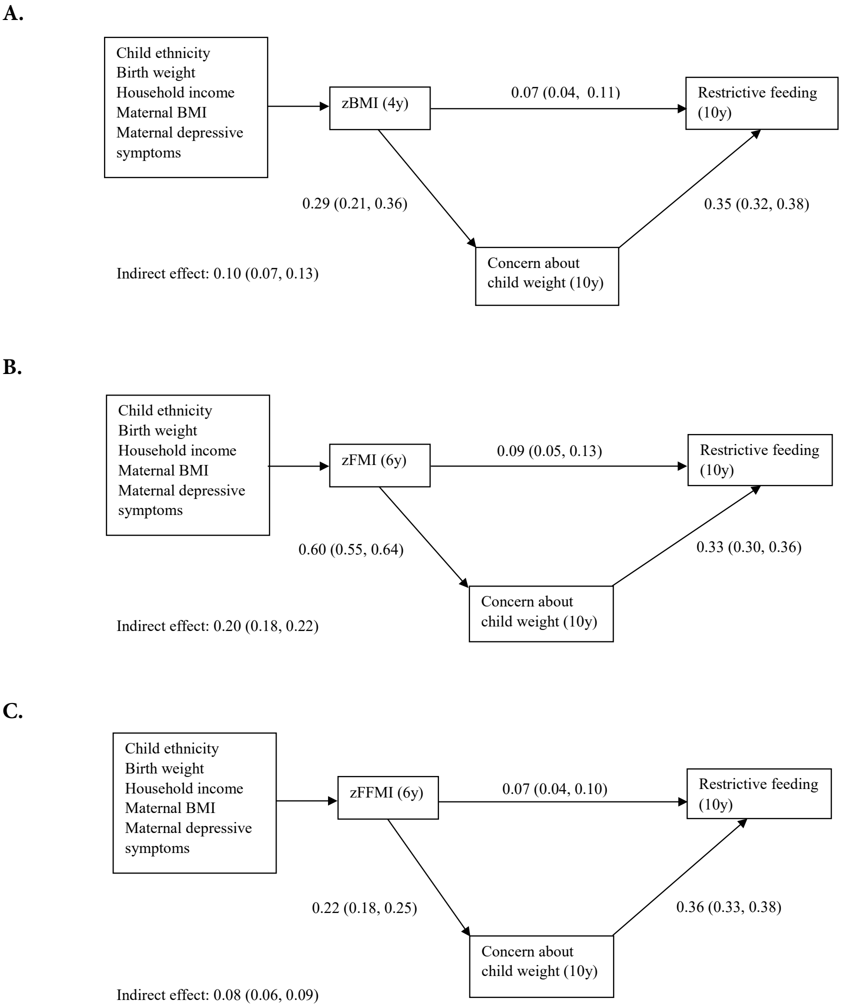

Figure 8.2A-C. Mediation models between child body composition, concern about child weight and restrictive feeding (n = 4689).

Values were derived from mediation analyses and represent linear regression coefficients (95% CI's), adjusted for covariates. Model fit indexes were considered as sufficient to good (Comparative Fit Index: 0.83, 0.98, 0.86, and Root Mean Squared Error of Approximation: 0.051, 0.025, 0.054, for figures A, B, C, respectively). FMI: Fat Mass Index, FFMI: Fat Free Mass Index.

support the hypothesis that restrictive feeding is a risk factor for childhood obesity, since restriction did not predict a change in zBMI.

The finding that a higher zBMI in early childhood predicted more restrictive feeding six years later is in line with a child-responsive model. Apparently, mothers are sensitive to their child's weight status and adapt their feeding practices accordingly, probably with the intention to reduce children's food intake and improve health and well-being.[29] This result is in line with results from a Portuguese longitudinal study,[28] and also corresponds with research on other controlling feeding practices, which showed that parents use more coercive feeding strategies when their child is very thin.[27,35]

Besides supporting the child-responsive hypothesis, our results also extend previous findings by using detailed measurements of body composition. Only very few longitudinal studies examined body composition beyond BMI in relation with restrictive feeding in either direction, and showed inconsistent results.[12,16,24] Our analyses with specific body composition measures showed that fat mass was more predictive of restrictive feeding than fat free mass. This suggests that parents respond differently in their feeding practices when children are chubby or have a rather large frame.

Mothers' concern about child weight appeared as an important mediator in the association between child weight and restriction. This is an important extension of previous cross-sectional findings of Webber et al.,[29] who observed that parental concern about child weight mediated the cross-sectional association between child BMI and restriction. Beyond Webber's research, this specific mediation pathway was not studied before. However, related research on part of the pathways showed that mothers who are concerned about their child becoming overweight are more likely to restrict intake of unhealthy foods by their children.[36] Furthermore, Keller et al.[37] found that the android/gynoid body fat ratio in children, a measure of fat distribution around the belly and hip area, explained 47% of the variance in parental concern about child weight. Together, these findings suggest that parental concern about their child's body weight is an important driver of feeding behavior, although it did not fully explain the relation between child weight and restriction. Additional explanatory mechanisms might include parents' potential concerns about dietary intake and general health of children, which may also drive parents' control over children's food-intake.

Our study found no evidence for restrictive feeding at the age of 4 years influencing weight development, similar to other longitudinal studies in the general population.[12-17] However, this contrasts with longitudinal studies among children at-risk for overweight and with experimental studies.[4,5,18-24] Together these findings might imply that there is a direct effect of restrictive feeding on eating behavior, but that at the longer term, restrictive feeding is only a risk factor for overweight among those who are susceptible to overweight. However, our findings could not confirm this since the (lack of) effect of restriction was similar for children who were underweight, normal weight or overweight/

obese at age 4 years. A possible reason why parental restriction does not influence weight status at the age of 10 years might be that during this school-age period, children start eating more outside of their homes with peer influences and food availability at school and sports facilities becoming more important influences. This might also explain the decline of maternal restrictive feeding over time, as observed in our study. Mothers of heavier children, however, might maintain greater restriction in later childhood because they have concerns about their child's weight, while during early childhood mothers might have other reasons to restrict their child's eating, as indicated by a less strong cross-sectional association at the age of 4 years.

As stated before, in the general population, the influence of restrictive feeding on child BMI seems absent, although future research is needed to unravel whether this accounts for all aspects of restrictive feeding. The CFQ restriction scale that was used in our study only measures overt control (i.e., controlling food intake by directly influencing child eating),[38] but not covert control (controlling food intake in a way that cannot be detected by a child, e.g. not bringing snacks in the house). These aspects of control may have differential associations with child BMI[39,40] and are potentially also differentially associated with maternal factors, such as sociodemographics and BMI. Moreover, an in-depth examination of the level of restriction is needed, since mild restriction of unhealthy foods might be beneficial for a child with overweight, whereas more intrusive and extreme restriction might have adverse effects.[38]

Strengths of this study are its population-based longitudinal design and repeated measurements of both feeding and BMI, and objectively measured body composition. There are also limitations that should be discussed. First, as noted above, the restriction subscale of the CFQ only measures overt restriction, precluding any conclusions on covert restriction. Secondly, parental concern about child weight was measured in parallel with restrictive feeding practices at the age of 10 years, while restrictive feeding was not assessed when zFMI and zFFMI were measured. This limits our conclusions regarding directionality of the (mediating) pathways. Third, at the age of 10 years, the restrictive feeding and concern about child weight subscales were shortened. However, internal consistencies of the scales were very acceptable, and similar to the original full scales.[31] Furthermore, generalizability of the results might be limited since the non-response analysis showed differences between included and excluded parents and children. As reported, those who were lost to follow up relatively often came from non-Dutch families with a low household income, which are known risk factors for child overweight.[41] However, we assume that the influence of this differential drop-out is limited, because these factors were accounted for in the analyses and hardly affected the reported associations. Also, there were missing data on determinants and covariates of the included children. The findings with imputed data were, however, similar to findings including only children with full data on determinants and outcomes (data not shown). Finally, in our study, mothers reported on the use of restrictive feeding, whereas additional information from fathers could give more insight in the feeding strategies within families and the complementary effects of mothers and fathers.

In conclusion, our findings do not support the often assumed adverse effect that restrictive feeding causes excess weight gain in children. Instead, we found strong evidence that restrictive feeding is a response of mothers to their child having a relatively high zBMI or fat mass and that this response is largely driven by concerns of parents about child weight. Thus, restrictive feeding seems to reflect understandable intentions of parents who are worried that their child has an unhealthy weight. Current guidelines and recommendations in the context of childhood overweight, such as provided by Public Health England and the Dutch Center for Youth Health (Nederlands Centrum Jeugdgezondheid) generally discourage restrictive parenting in food-related situations. Instead, recommending that children need to regulate their own nutritional needs, supported by authoritative parenting methods.[38,42-44] This might need to be reconsidered, particularly if our findings are replicated in future studies.

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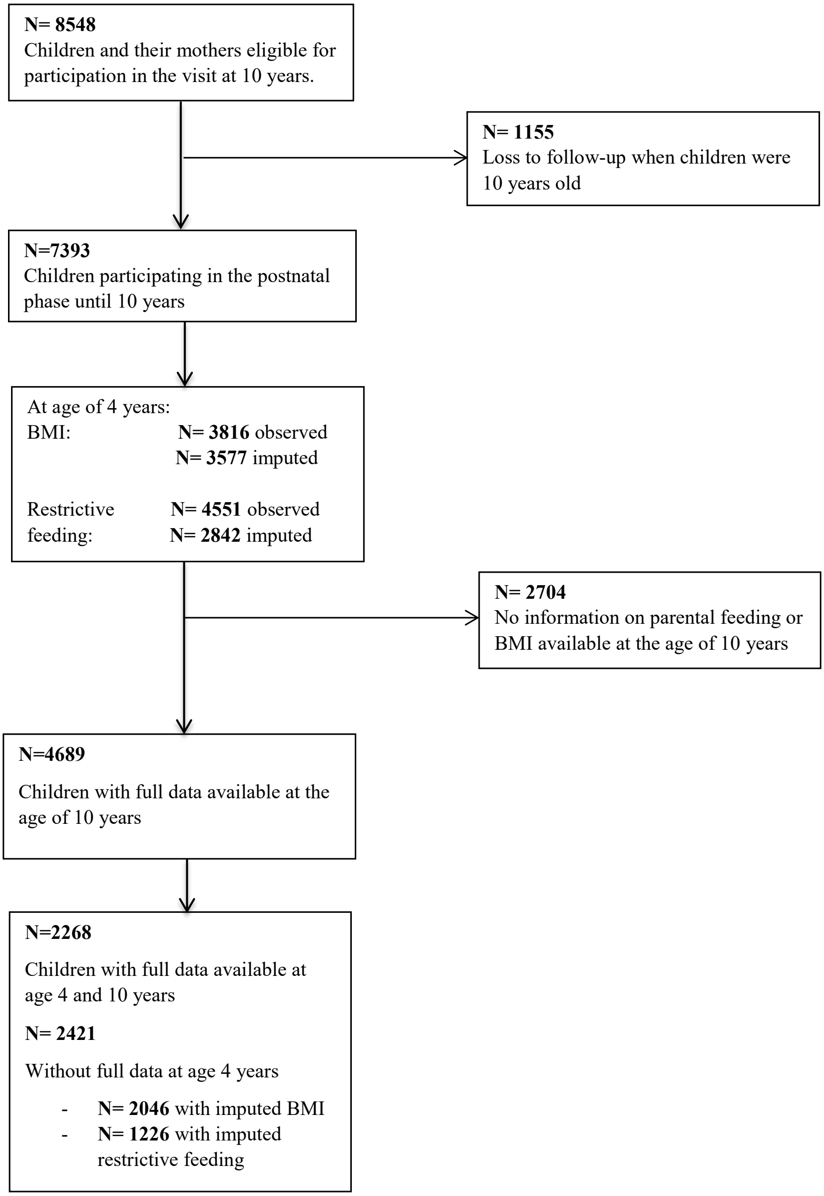
SUPPLEMENT



Supplementary Figure 8.1. Flowchart of the study sample.

Supplementary Table 8.1. Items of the CFQ restriction subscale

Item
1. I have to be sure that my child does not eat too many sweets (candy, ice cream, cake or pastries)
2. I have to be sure that my child does not eat too many high-fat foods
3. I have to be sure that my child does not eat too much of his/her favorite foods*
4. I intentionally keep some foods out of my child's reach
5. I offer sweets (candy, ice cream, cake, pastries) to my child as reward for good behavior
6. I offer my child his/her favorite foods in exchange for good behavior
7. If I did not guide or regulate my child's eating, he/she would eat too many junk foods*
8. If I did not guide or regulate my child's eating, he/she would eat too much of his/her favorite foods

*Item not included in the assessment at age 10 years

Supplementary Table 8.2. Associations between maternal restrictive feeding at 4 years and child zBMI at 10 years, stratified by child BMI category at 4 years (n= 4689)[a]

Restrictive feeding	Child zBMI at age 10 years	
	B (95% CI)	p-value
BMI category at age 4 years		
Underweight (n= 474)	−0.03 (−0.14, 0.09)	0.66
Normal weight (n= 3803)	0.03 (−0.02, 0.08)	0.22
Overweight (n= 412)[b]	−0.01 (−0.10, 0.09)	0.91

[a] Values are standardized linear regression coefficients derived from stratified multivariable linear regression analyses. Models were adjusted for child ethnicity, birth weight, maternal depressive symptoms, maternal BMI and household income. [b] Including obesity (n=59).

Supplementary Table 8.3. Model fit indices for the cross-lagged analyses between restrictive feeding and child BMI.

Model fit indexes	Model 1 (Stability model)	Model 2 (Stability model + lagged restriction → BMI)	Model 3 (Stability model+ lagged BMI → restriction)	Model 4 (Cross-lagged model)
χ^2 (df)	523.30 (16)***	526.24 (15)***	479.07 (15)***	484.09 (14)***
χ^2 Δ test, indicating difference from Model 1 (df)[a,b]	-	2.37 (1)	41.64 (1)***	44.71***
CFI	0.759	0.757	0.780	0.777
RMSEA	0.082	0.085	0.081	0.085

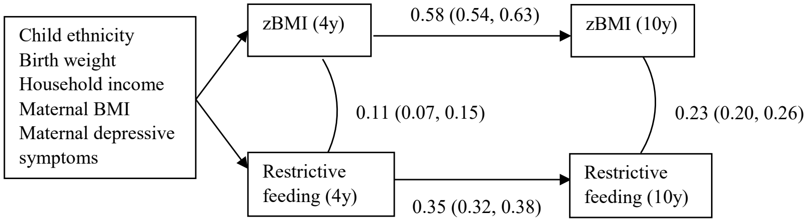
* p-value <0.05, ** p-value <0.01, *** p-value <0.001.

[a] Result of the Satorra-Bentler χ^2 difference test.

[b] Model 4 did not show an improved model fit over best-fitting Model 3, χ^2 difference 1.70, p-value:0.19.

CFI: Comparative Fit Index, RMSEA: Root Mean Squared Error of Approximation, df: degrees of freedom

A.



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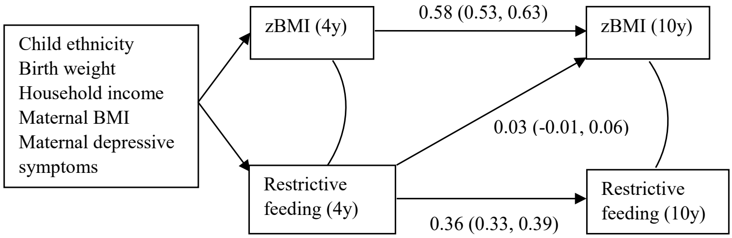
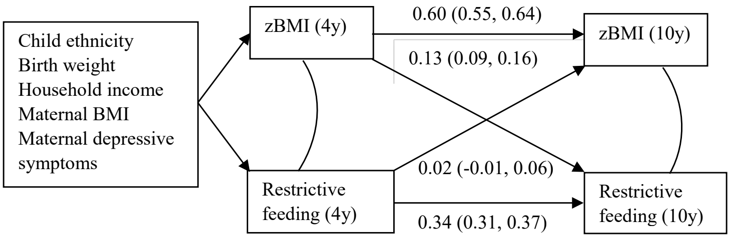


C.



Supplementary Figure 8.2A-C. The stepwise models of associations between child BMI and restrictive feeding from age 4 to 10 years (n=4689). Results of the lagged model of associations between restrictive feeding and child BMI from age 4 to 10 years. Values represent standardized linear regression coefficients (95% confidence intervals) derived from path analysis and adjusted for covariates. A: Stability model. B: Stability model + lagged association from restriction to child zBMI. C. Cross-lagged model.