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Maternal sensitivity in early childhood and body mass index in adolescence: A population-based study on the role of self-regulation as a mediator

Patricia Bravo [a,c], Rodrigo Cárcamo [b,g], Susana Santos [a,e,h,i], Ank Ringoot [d,f], Marinus H. van IJzendoorn [a,d], Manon H.J. Hillegers [a], Pauline W. Jansen [c,d,*]

[a] The Generation R Study Group, Erasmus MC-University Medical Center Rotterdam, Rotterdam, the Netherlands
[b] Facultad de Psicología, Universidad de Magallanes, Punta Arenas, Chile
[c] Department of Child and Adolescent Psychiatry/Psychology, Erasmus MC, University Medical Center Rotterdam, the Netherlands
[d] Department of Psychology, Education and Child Studies, Erasmus University Rotterdam, the Netherlands
[e] Department of Pediatrics, Erasmus MC – Sophia Children's Hospital, University Medical Center Rotterdam, Rotterdam, the Netherlands
[f] Faculty of Psychology, Open University of the Netherlands, Heerlen, the Netherlands
[g] Facultad de Psicología, Universidad San Sebastián, Sede Valdivia, Chile
[h] EPIUnit - Instituto de Saúde Pública, Universidade do Porto, Rua das Taipas, Porto, Portugal
[i] Laboratório para a Investigação Integrativa e Translacional em Saúde Populacional (ITR), Universidade do Porto, Rua das Taipas, Porto, Portugal

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ABSTRACT

Maternal sensitivity has been implicated in various aspects of child health and development, including overweight. However, long-term effects, the role of paternal sensitivity and the explanatory pathways are unclear. This study examined whether maternal sensitivity in early childhood is prospectively associated with adolescent body mass index and whether children's self-regulation mediates this relation. Data from 540 children and their mothers were available from a large cohort study in the Netherlands. Maternal sensitivity was assessed at child ages 1, 3, and at 4 years paternal sensitivity was also included. Children's self-regulation skills were observed at age 3, eating behaviour was assessed at 10 years, and child BMI was measured at 13 years. Longitudinal structural equation modelling was applied. The cross-sectional association between maternal sensitivity and child self-regulation was significant, while lower levels of self-regulation and higher levels of food responsiveness and restrained eating predicted a higher child BMI at 13 years. Furthermore, a direct association of paternal sensitivity at 4 years with BMI at 13 years was found, but only in girls. Maternal sensitivity was not directly associated with child BMI after adjusting for covariates. Our findings showed the importance of self-regulation in the early years for subsequent weight development. Nevertheless, as self-regulation could not explain the relationship between parenting and child weight, research should focus on the contribution of other contextual factors, such as feeding styles and the social environment, to this relationship.

1. Introduction

It is broadly acknowledged that overweight in children has multiple consequences for development and health (Chu et al., 2018; Rankin et al., 2016). Given that the foundations for a healthy weight are already laid in early childhood, it is important to identify early predictors of a trajectory towards a high body mass index (BMI) (Wu, Dixon, Dalton, Tudiver, & Liu, 2011). For young children, the most important context is the caregiving environment. Parents are the primary caregivers in the first few years of life, shaping behaviours and habits of young children in various ways (Patrick, Hennessy, McSpadden, & Oh, 2013; Powell, Frankel, & Hernandez, 2017; Rhee, Lumeng, Appugliese, Kaciroti, & Bradley, 2006). In addition, studies have found that the emotional quality of the mother-child relationship is associated with obesity risk in young children (Anderson & Keim, 2016) and also prospectively throughout middle and late childhood (Jansen, Giallo, Westrupp, Wake, & Nicholson, 2013). Various studies support the relevance of different parenting styles for children's weight development and obesogenic behaviours (Parletta, Peters, Owen, Tsiros, & Brennan, 2012; Patrick et al., 2013; Sleddens, Gerards, Thijs, De Vries, & Kremers, 2011), with most

* Corresponding author. Department of Child and Adolescent Psychiatry/Psychology, Erasmus University Medical Center, PO Box 2040, 3000, CA, Rotterdam, the Netherlands.
E-mail address: p.w.jansen@erasmusmc.nl (P.W. Jansen).

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evidence regarding mothers' parenting practices, as fathers were often not included in research. In the current study, we aim to determine whether maternal and paternal sensitivity in early childhood predict BMI in adolescence and if emotion regulatory skills mediate this association.

Among all parenting practices, parental sensitivity reflects one of the most fundamental aspects of parent-child interaction, influencing the child's physical, psychological, and cognitive development (Meins, Fernyhough, Fradley, & Tuckey, 2001). It has been shown that poor quality of the early maternal-child relationship can impair emotional and cognitive development and also may affect physical characteristics such as weight development (Deans, 2020). For instance, less sensitive mothers had infants who gained more weight in the first year of life (Worobey, Lopez, & Hoffman, 2009). Additionally, a study reported that children of authoritarian mothers (low sensitivity combined with high expectations for self-control) had the greatest odds of later overweight (Rhee et al., 2006). It has been suggested that the association is conditional on child sex, as parenting may impact BMI more in girls than boys, increasing the odds of overweight in girls (Wendland et al., 2014).

There are several mechanisms through which parental sensitivity may be associated with children's weight development. A prominent potential explanation comes from various studies showing that the quality of the caregiver-child relationship is associated with the development of emotional and regulatory skills in children (Carreras, Carter, Heberle, Forbes, & Gray, 2019; Kohler-Dauner et al., 2019; Leerkes, Blankson, & O'Brien, 2009; Song & Trommsdorff, 2016). Maternal sensitivity may influence children's weight development by affecting children's, particularly girls', capacity for self-regulation (Anderson, Gooze, Lemeshow, & Whitaker, 2012; Song & Trommsdorff, 2016). In turn, children with self-regulation difficulties early in life have a significantly higher BMI in early adolescence (Duckworth, Tsukayama, & Geier, 2010; Francis & Susman, 2009; Graziano, Kelleher, Calkins, Keane, & Brien, 2013; Tsukayama, Toomey, Faith, & Duckworth, 2010). This may reflect a direct effect, but previous studies indicated that general regulatory skills could also influence eating behaviour, in which a maladaptive regulation strategy may lead to poor regulation of food consumption and overeating to modulate negative affect (Evers, Stok, & de Ridder, 2010; Graziano, Calkins, & Keane, 2010), resulting in excessive weight gain. Additionally, both general and food-specific parenting, for instance by non-sensitive, controlling feeding practices, may lead to restrained eating in offspring, which could ultimately frustrate the ability to self-regulate offspring's own eating (Birch & Fisher, 1998; Kral & Rauh, 2010). Adolescents are especially prone to restrained eating when they have an avid appetite or relatively high BMI (Snoek, Engels, Van Strien, & Otten, 2013; Snoek, van Strien, Janssens, & Engels, 2008). So far, however, a comprehensive model including parenting, children's self-regulation, eating behaviour, and BMI has not been studied.

Thus, while previous research suggested an association between maternal sensitivity and child BMI in the preschool and school period, little is known about the long-lasting impact later in adolescence and the pathways explaining how parenting influences children's food consumption or BMI via children's emotion regulation. Moreover, since studies focused mostly on maternal parenting, the role of fathers remains unclear. Therefore, the first aim of the study was to examine the association of maternal sensitivity in early life with BMI in adolescence and investigate whether this association is mediated by children's self-regulation and inclination towards (emotional) overeating. The second aim was to investigate whether the association between parental sensitivity in both mothers and fathers and child BMI depends on child gender. In line with previous theoretical and empirical work, we hypothesized that both lower maternal and paternal sensitivity levels predict a higher BMI in adolescents, with stronger associations in girls than boys.

2. Methods

2.1. Design

This study was embedded in the Generation R Study, a prospective cohort from fetal life onwards (Kooijman et al., 2016). Pregnant women living in the study area in Rotterdam, the Netherlands, with an expected delivery date between April 2002 and January 2006 were invited to participate. The study was approved by The Medical Ethical Committee of the Erasmus Medical Center. Written informed consent was obtained from all participants in the study.

2.2. Study population

The current study was conducted in a subsample of children of Dutch national origin who participated in the Generation R Focus Cohort. In total, 1,106 enrolled in this Focus cohort (see Fig. 1 for a flow chart). Maternal sensitivity was observed during lab visits at child ages 1 and 3 years. Children's self-regulation skills were also observed at 3 years, using measures of ability to Delay Gratification, Compliance, and Task Persistence. Data from both visits was available for 715 children and their mothers. At 13 years, participants visited our research center again to obtain data on BMI. For 175 participants, the BMI measurement was not done at 13 years. The final sample included all children with information on at least one maternal sensitivity observation, one self-regulation measure and the BMI measurement at 13 years, which were available in 540 children. Finally, in order to address the second aim of this study, a sample including sensitivity of both parents was observed; data on paternal and maternal sensitivity at 4 years and child BMI at 13 years was available for 582 children.

Non-responding families (n = 566) had younger mothers at baseline (31.1 versus 31.9 years old, $t(1,104) = 3.38$, $p < .01$) with more often a low educational level χ^2 (1, N = 1,104) = 20.92, $p <. 01$, but with similar levels of high family income χ^2 (1, N = 913) = 861, $p = .35$ as families included in the analyses. There were no differences between responders and non-responders in maternal sensitivity at 1 or 3 years, in any of the self-regulation variables, eating behaviours variables, nor BMI at 13 years (e.g. 19.6 versus 19.2, $t(750) = -1.64$, $p = .10$).

2.3. Measures

2.3.1. Observed maternal and paternal sensitivity

During the lab visit at child age 1-year, maternal sensitivity was observed during 5 min of free play. Maternal sensitivity was coded from DVD recordings with the Ainsworth's 9-point rating scales for *Sensitivity* and *Cooperation* (Ainsworth, Bell, & Stayton, 1974). The intraclass correlation (ICC) for intercoder agreement was .79 for Sensitivity and .69 for Cooperation (n = 24). In the study sample, the Sensitivity and Cooperation scales correlated strongly (r = .84). A mean sensitivity score was created by standardising the two scores and computing the average.

Additionally, at 3 years, maternal sensitivity was observed when mother-child dyads performed two 3-min tasks that were too difficult for the child: building a tower and an etch-a-sketch task. Maternal sensitivity was coded for each task from DVD recordings with the revised Erickson 7-point rating scales for *Supportive Presence* and *Intrusiveness* (Egeland, Erickson, Clemenhagen-Moon, Hiester, & Korfmacher, 1990). The two tasks were independently coded by 13 coders, who were extensively trained and regularly supervised. Total ICCs for the sub-scales were .75 on average for the tower task (range .73 - .77, $n = 53$) and .79 on average for the etch-a-sketch task (range .65 - .93, $n = 55$). The Supportive Presence scale correlated weakly between both tasks ($r = .23$), just as the Intrusiveness scale ($r = .34$). An overall sensitivity score was created by reversing the Intrusiveness scales, standardising the scores on the sub-scales, and creating an average over both subscales and both tasks (Lucassen et al., 2015).

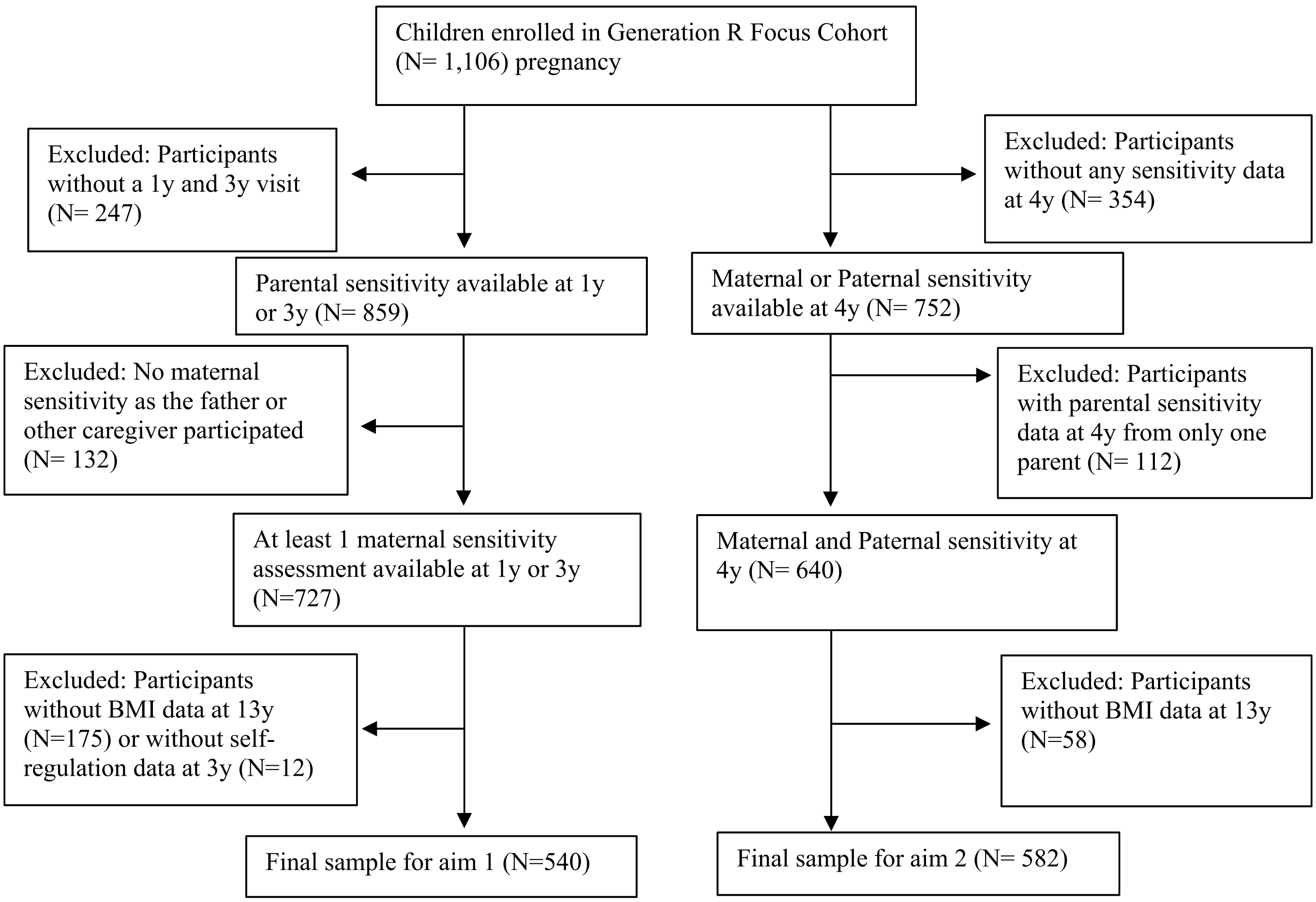

Fig. 1. Flowchart of sample selection.

Maternal and paternal sensitivity at child age 4 years was observed when mother/father-child dyads performed the same tasks (building a tower and an etch-a-sketch task) as during the 3-years visit. Similar Erickson 7-point rating scales for *Supportive Presence* and *Intrusiveness* (Egeland et al., 1990) were used. The Supportive Presence scale correlated weakly in both tasks ($r = .20$, for mothers; $r = .26$ for fathers), just as the Intrusiveness scale ($r = .28$, for mothers; $r = .31$ for fathers). Again, overall sensitivity scores were created, averaging both subscales and tasks for maternal and paternal sensitivity separately. Intercoder reliability was established in 40 cases. The average intraclass correlation coefficient for both tasks was .80 (range .63–.87) (Lucassen et al., 2015).

2.3.2. *Child Body Mass Index (BMI)*

At age 13 years, the body mass index was measured when the children visited the Generation R research center. On this occasion, child height was measured in a standing position using a Harpenden stadiometer, and weight was measured using a personal mechanical scale (SECA) without shoes and heavy clothing. The BMI was calculated in kg/m^2 and sex and age-specific based on Dutch national reference data (www.growthanalyzer.org) (Fredriks et al., 2000).

2.3.3. *Child eating behaviour*

Child eating behaviour was assessed when children were 10 years old using the mother reported Child Eating Behaviour Questionnaire (CEBQ). The CEBQ is a 35-item instrument developed by Wardle, Guthrie, Sanderson, and Rapoport (2001) that assesses variation in eating behaviours among children using seven subscales. For this study, we selected two subscales focused on general overeating and overeating related to emotions. The subscale Emotional Overeating assesses the regulation of emotions through food consumption and consists of 4 items (i.e., "My child eats more when he/she is upset"). The Food Responsiveness subscale is a 5 item-subscale assessing children's sensitivity to external cues (i.e., "Given the choice, my child would eat most of the time"). Both subscales showed good internal consistency in the Generation R sample, as reflected in Cronbach's alpha of .92 and .87, respectively (Derks et al., 2019).

Additionally, we assessed children's dietary restraint using the Restrained Eating scale of Dutch Eating Behaviour Questionnaire (DEBQ) – parent version (Braet & Van Strien, 1997). This scale assesses the tendency to eat less than desired to lose or maintain body weight. Mothers indicated on nine items whether the described behaviors occurred in their children, on a five-point Likert scale from 1 = never to 5 = always (i.e., "Does your child deliberately eat foods that are slimming?"). One item of the original scale (regarding eating in the evening after dinner) was not assessed as we deemed it less relevant for 9-year old children. In our sample, Cronbach's alpha was .87, indicating a good internal consistency.

2.3.4. *Observed self-regulation*

In this study, children's self-regulation was assessed by several direct observations obtained during a laboratory visit when children were 3 years old. These tasks are described below.

The ability to delay gratification was evaluated using an adapted version of the *Gift Delay Task* (Kochanska, Murray, & Harlan, 2000; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996). This recorded procedure was done by a trained experimenter who brought a paper bag containing a wrapped gift and placed the bag on the table in front of the child. Then the experimenter asked the child to wait in their chair and not to touch the bag until a sticker was brought in, which was a part of the gift. Finally, the experimenter left the room and returned after 180 s. Afterwards, the recordings were coded, with scores given for: the gift behaviour dimension, from 1 (opens the gift) to 3 (touches the gift), to 6 (does neither touch the bag nor the gift), and for the time the child stayed seated: scores for the time in seat ranged from 1 (less than 15 s) to 3 (30–59 s), to 6 (remains seated all the time) (Henrichs et al., 2011). In the study sample, the gift behaviour and seating time scores correlated moderately ($r = .45$, $p < .001$) and were therefore averaged into a total gift delay score. The internal consistency of the gift delay scores was .51.

Committed Compliance was assessed in a 2-min disciplinary context (*Don't task*). During the task, the parent allowed the child to play with an unattractive teddy bear and prohibited the child from touching or playing with a set of attractive toys displayed in front of the child. Child behaviour was coded every 20 s using a coding system (Kochanska & Aksan, 1995; Kuczynski, Kochanska, Radke-Yarrow, & Girnius-Brown, 1987). Compliance was coded into different categories: committed compliance (i.e., the child did not attempt to touch/play with toys, did not need prompting), situational compliance (i.e., the child needed regular prompting/showed difficulties complying), passive non-compliance (i.e., the child ignored requests) and resistant non-compliance (i.e., active resistance, protesting, whining). The average intercoder reliability (ICC) was .87 ($n = 53$). An overall compliance score was obtained through a categorical principal components analysis in which the factor scores were extracted by a regression method. A one-dimensional structure explained 50% of the variance. The factor score was log-transformed to approach normality (Kok, Bakermans-Kranenburg et al., 2013).

Persistence on a task was measured through an *Impossible Puzzle Task*, following Harris's (1986) example. In this task, children were instructed to assemble a wooden puzzle in which one piece was intentionally made too big so that it would never fit. The experimenter and the caregiver were required not to help the child during the procedure. The task was recorded and coded from a DVD in which the child's persistence on the task was scored on a 7-point scale, ranging from 1 (quits playing with the major piece immediately) to 7 (plays with the major piece continuously). The average intercoder reliability (ICC) of the persistence score was 0.75 ($n = 76$ sessions).

2.3.5. Covariates

The variables selected as covariates in this study were child sex, family income, and BMI of the mother. The selection of these potential confounders was based on past research on the association between maternal sensitivity and child BMI (Song & Trommsdorff, 2016; Wendland et al., 2014). The information on family income was obtained by parental questionnaire at child age 6 years and defined by the total net monthly income of the household; it was classified as low family income (<2,000 euros) and modal to high income (more than 2,000 euros). BMI of the mother was measured at intake at the research center.

2.4. Data analysis

First, the data were explored using the Statistical Package for the Social Sciences (SPSS) version 22.0 (IBM Corporation, 2013). Descriptive statistics were calculated for all variables, using independent sample *t*-test for continuous variables and χ^2-tests for categorical variables to compare the descriptive variables between boys and girls. Second, bivariate correlations were conducted to explore the relations among the study variables, using Pearson correlation coefficients. Third, Confirmatory Factor Analysis (CFA) was conducted to evaluate the measurement model of maternal sensitivity, including sensitivity at 1 and 3 years, as well as to evaluate the measurement model of observed self-regulation (including committed compliance, gift delay, and persistence). For each latent variable (i.e. maternal sensitivity and child self-regulation), the variance was set to 1. The maternal sensitivity factor has only 2 indicators (overall scores at 1 and 3 years); consequently, the number of parameters is equal to the number of observed variances/covariances, meaning that the model fit cannot be assessed. However, when this factor was included as part of the larger model, the latent variable seemed acceptable as it correlated with at least one other factor without error terms being correlated with each other (Wang & Wang, 2019). Fourth, for our first aim, structural equation modelling (SEM) was employed to test the extent to which maternal sensitivity in early childhood (1 and 3 years) was associated with BMI at the age of 13 years and whether these associations were mediated by children's self-regulation at 3 years and eating behaviour at 10 years. To examine the mediated effect of maternal sensitivity on BMI through self-regulation, we evaluated the specific indirect effects, total indirect effects, and total effects using the model indirect option in Mplus. The significance of the parameter estimates was tested with a bootstrap approach (Bollen & Stine, 1992; Shrout & Bolger, 2002).

Furthermore, to ensure that the latent variable self-regulation evaluated the same construct across groups (boys and girls); we tested measurement invariance with the multiple group CFA approach. The different levels of measurement invariance were tested in several steps. First, we tested configural measurement invariance, which defined the same number of factors and the same patterns of free and fixed factor loadings across groups. Second, we tested metric invariance of factor loadings across group. Third, we tested scalar invariance of both factor loadings and intercepts across the groups. After measurement invariance was examined, we analysed structural invariance of the entire model by testing the invariance of structural parameters, such as factor variance, covariance, and factor means across groups by using the Satorra-Bentler Scaled Chi-Square Difference Test (Wang & Wang, 2019).

The CFA and SEM analyses were estimated using full information maximum likelihood (FIML) estimation with robust standard errors to account for non-normality in our data (Enders & Bandalos, 2001). Model fit was evaluated with the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Root-Mean-Square Error of approximation (RMSEA). Good model fit was achieved if the TLI and CFI were $\geq .90$ and RMSEA ≤ 0.08 (Hu & Bentler, 1999; Marsh, Hau, & Wen, 2004). We also adjusted the analyses for the covariates listed above, as modification indices suggested meaningful improvements. Both CFA and SEM were conducted using MPlus version 7.4 (Muthén & Muthén, 1998).

Finally, for our second aim, using the parenting observations at age 4 years, we applied multivariable linear regression analyses to examine whether parental sensitivity was associated with child BMI at 13 years. This analysis was done twice, for maternal and paternal sensitivity separately. Analyses were adjusted for covariates. We also examined interactions by child sex. In case of a significant interaction, analyses were presented separately for boys and girls.

3. Results

3.1. Population characteristics and bivariate correlations

The sample characteristics are presented by child sex in Table 1. In this sample, half of the children were boys, and about 7% of the families had a relatively low family income (<= 2,000 euros net per month). Boys experienced less maternal sensitivity at 1 year ($t(457) = -2.87$, $p = .01$, $d = .27$), had lower scores on each self-regulation task (e.g. Gift Delay: $t(515) = -2.74$, $p = .01$, $d = .24$), had a lower BMI at 13 years ($t(514) = -4.07$, $p < .01$, $d = .35$) and also had lower scores on emotional eating at 10 years ($t(483) = -2.47$, $p = .01$, $d = .22$) than girls.

Correlations among the variables in the study are presented in Table 2. The maternal sensitivity variables were correlated with each other over time. Higher levels of maternal sensitivity at 3 years were correlated with all child self-regulation variables. Of all sensitivity measures, only maternal sensitivity at 4 years was (negatively) related to BMI at 13 years. Finally, higher levels of the different child self-regulation variables were correlated with a lower BMI at 13 years.

Table 1
Sample characteristics.

		Total		Boys		Girls	
	n	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)
Child characteristics							
Sex (% boys)	540	51.3 (%)					
Age at assessment:							
Sensitivity at 1y	540	14.6	(0.9)	14.6	(0.8)	14.6	(0.9)
Sensitivity and self-regulation at 3y	540	37.5	(1.5)	37.4	(1.3)	37.6	(1.6)
Sensitivity at 4y	520	51.4	(1.3)	51.4	(1.3)	51.4	(1.3)
Eating behaviour at 10y	485	9.8	(0.3)	9.8	(0.3)	9.8	(0.3)
BMI at 13y	540	13.6	(0.3)	13.6	(0.3)	13.6	(0.3)
BMI at 13y, kg/m^2	540	19.2	(2.9)	18.7	(2.6)	19.7	(3.0)***
Gift delay score	517	5.4	(0.8)	5.3	(1.0)	5.5	(0.7)**
Committed Compliance score	539	0.7	(0.2)	0.7	(0.2)	0.8	(0.2)**
Persistence score	505	4.7	(1.3)	4.5	(1.3)	4.8	(1.3)*
Emotional overeating score	485	6.0	(2.7)	5.7	(2.5)	6.3	(2.8)*
Food responsiveness score	485	9.2	(3.9)	8.9	(3.4)	9.5	(4.3)
Restrained eating score	492	11.6	(3.9)	11.5	(4.1)	11.7	(3.7)
Parental characteristics							
Maternal sensitivity z-score at 1y	459	−0.02	(0.8)	−0.13	(0.8)	0.10	(0.8)**
Maternal sensitivity z-score at 3y	538	−0.01	(0.7)	−0.07	(0.7)	0.06	(0.7)
Maternal sensitivity z-score at 4y	402	−0.01	(0.7)	−0.01	(0.6)	−0.01	(0.7)
Paternal sensitivity z-score at 4y	440	−0.01	(0.7)	−0.03	(0.6)	0.03	(0.7)
Maternal BMI, kg/m^2	533	24.3	(4.3)	24.2	(4.4)	24.5	(4.2)
Household Income (%<=2000)	540	6.9 (%)		8.1 (%)		5.7 (%)	

Note. All values represent raw values except maternal sensitivity variables (standardised).
*p ≤ .05, **≤0.01, ***≤0.001 for difference between boys and girls, derived from independent sample t-tests for continuous variables and chi-square tests for categorical variables.

3.2. Predictive models

First, we tested the measurement models for the child self-regulation latent variable: the scores of 3 indicators were used, namely Gift Delay, Don't Task and Persistence of the Task. We found a good fit of this model (CFI = 1; TLI = 1; RMSEA = 0). Moreover, we tested measurement invariance in the self-regulation latent variable across child sex. The metric invariance model fitted just as well as the configural invariance model and the scalar invariance model (see Supplementary Table 1). Thus, measurement invariance holds for the self-regulation factor. However, when we compared the scalar invariance model (most parsimonious model with more degrees of freedom) with the residual invariance model, we found significant differences (TRd = 16,74, Δdf = 1, $p < .001$). The residuals were not equal and the latent means for the self-regulation factor were different between boys and girls, indicating that girls scored higher on self-regulation than boys (ΔM = 0.78, *SE* = 0.31, $p < .001$).

Then, we examined the association of maternal sensitivity with child BMI at 13 years, and whether this was mediated by self-regulation and eating behaviours (see Fig. 2 and Supplementary Table 2). This path model had a good fit (CFI = .97; TLI = .95; RMSEA = .02). Moreover, 18.4% of the self-regulation variable was explained by its predictors (maternal sensitivity and covariates), while a 37.9% of the variance in BMI at 13 years was explained by the predictor variables in the model (mediators and covariates). There was a significant positive association between maternal sensitivity and self-regulation at age 3 years (β = .33, *SE* = .16; *p* = .02. Furthermore, lower levels of self-regulation (β = -.33, *SE* = .13; *p* = .00) and higher levels of food responsiveness (β = .31, *SE* = .06; $p < .01$) and restrained eating (β = .20, *SE* = .05; $p < .01$) predicted a higher child BMI. We did not find a significant direct association between maternal sensitivity and later BMI, thus no significant variance in BMI was explained by the main predictor, and also no statistically significant indirect association via self-regulation (β = -.11 (95% CI = -.28, .06)), emotional overeating (β = -.01 (95% CI = - .03, .02)), food responsiveness (β = -.02 (95% CI = -.08, .04)) and restrained eating (β = -.03 (95% CI = -.07, .01)). We found no significant sex differences (TRd = 33.06, Δdf = 35, *p* = .56).

3.3. Maternal sensitivity and paternal sensitivity at 4 years and child BMI

We examined the association of maternal and paternal sensitivity at child age 4 years with child BMI at 13 years, and whether this association was different between boys and girls. Neither maternal nor paternal sensitivity was significantly associated with child BMI. However, because child sex was a significant predictor in both models, the analyses were performed stratified by sex. After adjusting the model for covariates, analyses showed that only paternal sensitivity, but not maternal sensitivity, was a significant predictor of child BMI at 13 years but only in girls (β = -.13, *SE* = .31; *p* = .04). In boys, the association was not significant (see Table 3).

Table 2
Correlations among the study variables.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Maternal sensitivity at 1y	1											
2. Maternal sensitivity at 3y	.23**	1										
3. Maternal sensitivity at 4y	.15**	.38**	1									
4. Paternal sensitivity at 4y	.13*	.20**	.23**	1								
5. Gift delay	.05	.08*	.12*	.10*	1							
6. Committed compliance	.07	.08*	.06	.04	.15**	1						
7. Persistence	.05	.11**	.07	.03	.14**	.06	1					
8. Food responsiveness at 10y	.02	−.03	.08	−.02	.04	.01	.01	1				
9. Emotional overeating at 10y	−.04	−.04	−.09	.06	.04	−.03	.01	.38**	1			
10. Restrained eating at 10 y	−.01	−.06	−.01	.03	.01	−.02	−.01	.25**	.19**	1		
11. BMI at 13y	.02	−.05	−.11*	−.06	−.10*	−.09*	−.09*	.41**	.24**	.27**	1	
12. Maternal BMI at intake	−.10*	−.05	−.10*	−.14**	−.05	.03	−.08	.15**	.06	.07	.31**	1

***p* < .01, **p* < .05 Note. Variables are child characteristics unless otherwise indicated.

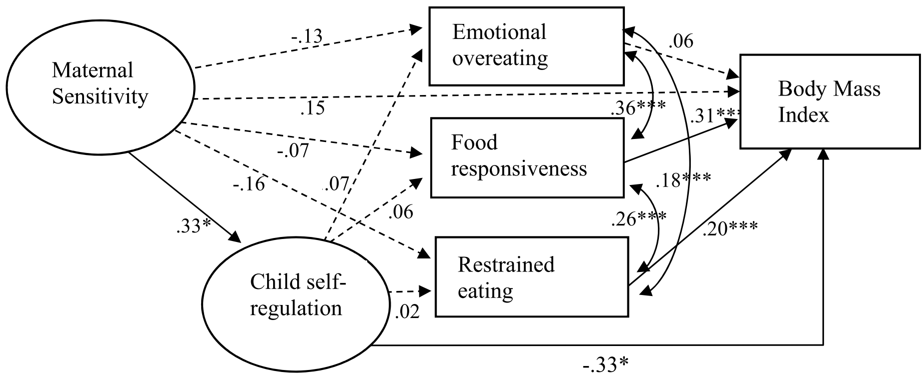

Fig. 2. Structural equation model of maternal sensitivity with observed child self-regulation and BMI.
Notes. Numeric values are standardised path regression coefficients. Covariates (child sex, household income and maternal BMI) are included, but paths are not shown to improve readability. The bold lines denote significant associations. The dotted lines denote non-significant associations. Model fit was good (CFI = .97; TLI = .95; RMSEA = .02).

4. Discussion

The present study aimed to determine whether parental sensitivity in early childhood was associated with adolescents' body mass index and whether self-regulation and eating behaviour explained this relationship. We found evidence that early maternal sensitivity was positively associated with child self-regulation, while in turn, higher levels of self-regulation in early childhood predicted a lower BMI ten years later. Yet, maternal sensitivity was not directly associated with BMI in adolescence and no mediation through self-regulation and eating behaviour was found. In contrast, higher levels of paternal sensitivity were associated with a lower BMI, but only in girls.

Our findings are not in line with our expectations regarding a direct association between early maternal sensitivity and later child BMI. This expectation was based on past prospective research in population-based samples in early in life with a follow-up period of at most three years, reporting that children of less sensitive mothers had a higher risk of later overweight (Wendland et al., 2014; Worobey et al., 2009). On the other hand, our findings are in line with the study of Anderson, Lemeshow, and Whitaker (2014), which had a follow-up of 5.5 years and showed that early maternal-infant interaction was not associated with later obesity risk.

Table 3
Linear regression coefficients of maternal and paternal sensitivity with BMI at 13 years.

Independent variable	Sample	Model	β for BMI at 13y	Standard Error	P-value
Maternal sensitivity[#]	All (n = 582)	Model 1	−.13	.22	.01*
		Model 2	−.06	.20	.14
Paternal sensitivity[#]	All (n = 582)	Model 1	−.07	.22	.14
		Model 2	−.03	.20	.54
Regression with parental sensitivity by child sex					
Maternal Sensitivity	Boys (n = 290)	Model 1	−.05	.26	.47
		Model 2	−.03	.24	.63
	Girls (n = 292)	Model 1	−.19	.30	.01*
		Model 2	−.08	.30	.23
Paternal Sensitivity	Boys (n = 290)	Model 1	.04	.25	.55
		Model 2	.08	.24	.21
	Girls (n = 292)	Model 1	−.18	.32	.01*
		Model 2	−.13	.31	.04*

Notes. Model 1: unadjusted model. Model 2: adjusted model for child sex, SES, child age, and maternal BMI. [#]For mothers and fathers, the child sex was significant in the model 2. Therefore, analyses were performed in boys and girls separately.
*Represents p value < .05, ** < .001.

Besides these studies, research on maternal sensitivity with a longer follow-up or beyond the preschool period is scarce. Only one study reported evidence of a direct relationship between maternal sensitivity (measured in adolescence) and obesogenic risk at age 15 years (Davis et al., 2011). Two other studies found a significant relationship between early maternal sensitivity and BMI in adolescence, but only in interaction with child temperament (Wu et al., 2011) or insecure attachment (Anderson et al., 2012). This suggests that sensitivity may have a long-lasting impact, but only under certain conditions.

An explanation for the lack of finding associations for maternal sensitivity may be that in our study maternal sensitivity in the first few years of life was too distal to directly impact child BMI nine years later. Indeed, the small association of the latest paternal sensitivity assessment (at 4 years) with later BMI, support the idea that the follow-up was perhaps too long to detect associations. Alternatively, a small effect of parental sensitivity on child BMI may only become visible when children grow older. Considering the strong sensitivity–child self-regulation and self-regulation–BMI associations, an effect of parental sensitivity on offspring BMI (via self-regulation) seems conceivable and is already reported by Davis et al. (2011), but may only become apparent later in a child's life. Unfortunately, there are hardly any studies on parental sensitivity beyond the preschool period to test this hypothesis. Even studies on sensitivity around age 4 years, like our study, are scarce. Yet, around this age, children become more active agents in the interaction with their parents through vocalisation and approach towards the caregiver (Kok, Linting, et al., 2013). Therefore, being sensitive to the child's wishes and behaviours becomes more manifest in the interaction. In this way, the mother-child interaction might have a different impact on child weight development depending on the stage of children's lives, i.e., early childhood vs. adolescence (Blewitt, Bergmeier, Macdonald, Olsson, & Skouteris, 2016).

Furthermore, our results showed that early maternal sensitivity is associated with child self-regulation in the early stages of children's development. These findings are in line with previous studies showing that the quality of the caregiver-child relationship is associated with individual differences in the development of emotional control and regulatory skills in children (Carreras et al., 2019; Kohler-Dauner et al., 2019; Leerkes et al., 2009). In this way, maternal sensitivity influences children's capacity for self-regulation, which in turn may impact children's weight development by affecting the way in which a child regulates his/her own emotions (Anderson & Keim, 2016).

Moreover, our findings are consistent with a cross-sectional study that found that self-regulation was associated with lower odds of developing overweight at age 3 years (Anzman & Birch, 2009; Miller, Rosenblum, Retzloff, & Lumeng, 2016). Prospective studies also reported a longer-term effect of self-regulation on children's weight status.

These studies found that the ability to delay gratification at 4 years of age can impact the weight status seven years later (Seeyave et al., 2009) and later on in adulthood (Schlam, Wilson, Shoda, Mischel, & Ayduk, 2013). Moreover, poorer self-regulation skills of toddlers, such as emotion regulation and inhibitory control, predicted higher BMI at age 5.5 years (Graziano et al., 2010) and in early adolescence (Francis & Susman, 2009; Graziano et al., 2013). Similarly, difficulties in self-control in late childhood predicted weight gain in the transition to adolescence (Duckworth et al., 2010; Tsukayama et al., 2010). Consistent with this, we found that children who showed more ability to regulate themselves have a lower BMI in adolescence. However, in this study, we did not find a mediation effect of self-regulation. Given the absence of a mediation effect, other mechanisms contributing to the association between parental sensitivity and child BMI should also be considered. Such mechanisms may include a shared genetic vulnerability for later child BMI, considering that in our results, when we included maternal BMI, the contribution of maternal sensitivity at 4 years was diluted. Moreover, other mechanism could be the impact of parents' own self-regulation skills on both parenting and child self-regulation. Past research identified that parental self-regulation is key in the context of reading and effective caregiving that promotes child development (Bridgett, Burt, Edwards, & Deater-Deckard, 2015). More research is needed to further understand in the dynamics of parent-child relationships including the bi-directional contributions on that relationship.

Regarding our second hypothesis, about whether the association between sensitivity and child BMI depends on the parents' sex, we only found that after adjusting the model for covariates, paternal sensitivity at 4 years was associated directly with child BMI at 13 years, but this association was only observed in girls and not in boys. Maternal sensitivity was also directly associated with girls' BMI, but this association disappeared when the model was adjusted for covariates. This finding is in line with the study from Turner, Rose, and Cooper (2005) showing that female adolescents with overweight reported that their fathers, but not their mothers, were less caring and more overprotective as compared to normal weight peers. Moreover, Wake, Nicholson, Hardy, and Smith (2007) found that fathers parenting but not maternal control was associated with pre-schooler overweight and obesity. The authors suggested that warm and firm paternal parenting may partly protect against preschool overweight and obesity in the family environment, as such behaviour may be supportive of children's attempts to lose weight.

On the other hand, previous studies also suggested that for maternal sensitivity, this association with child BMI is conditional on child sex, with maternal sensitivity increasing the odds of overweight in girls (Schlensog-Schuster, Klein, Biringen, von Klitzing, & Bergmann, 2022; Wendland et al., 2014). Studies on fathers are scarce, but the findings from research focusing on maternal parenting suggest that girls seem more sensitive to the impact of parenting variables than boys. In accordance with the present results, previous studies have demonstrated that child sex contributes to the nature of maternal sensitivity as a function of the situational demands of the interaction (Ciciolla, Crnic, & West, 2013). For instance, mothers were more sensitive with their daughters than with their sons, and girls were more involved and responsive to their mothers than were boys (Bornstein et al., 2008). It is possible that this child sex variation may be explained by the theory of gender role socialisation between boys and girls. Girls tend to engage in more relational and less autonomous types of play than boys (Ruble, Martin, & Berenbaum, 2006). Moreover, girls tend to seek more close relationships, whereas boys may need more autonomy from their caregivers (Fukkink, 2022). However, as evidence regarding the association of paternal sensitivity and child BMI is limited, further research in this field is needed to better understand the role of gender-specific effects.

4.1. Strengths and limitations

Several potential strengths and limitations of the study need to be considered. First, one of the significant strengths of this study was the longitudinal evaluation of early parenting variables and their impact on the child's emotional and physical development. In addition, the use of observational assessment related to parental sensitivity and child self-regulation allows us to evaluate these constructs more accurately instead of using self-reports. Last, we included observations in fathers, which is not frequently done in population-based studies related to parental sensitivity and BMI. However, several limitations should be considered as well. First, we assessed only paternal sensitivity at 4 years and not before, limiting our conclusions on any potential timing effects. Second, our population consisted of relatively highly educated families of Dutch origin only; therefore, this limits the generalisation of our results towards the general population. Finally, although none of the variance was explained by maternal sensitivity, the hypothesized mediators and covariates in the model were able to explain a substantial part of the variance in BMI. However, despite the available information on potential confounding variables, residual confounding due to unmeasured lifestyle variables (e.g. physical activity) and factors related to the parental context might still be an issue explaining some of the differences in self-regulation and its relationship with BMI.

5. Conclusions

Results from this population-based study suggest that maternal sensitivity is related to self-regulation, while self-regulation was associated with BMI at the age of 13 years. Although we did not find a mediation, our findings highlight the importance of self-regulation in the early years for subsequent weight and the importance of parenting in the development of self-regulation. These findings could be an important aspect to consider in terms of interventions focused on healthy diets and eating behaviours. In this context, it seems relevant to expand the nutritional or medical interventions for obesity prevention that have a broader focus than diet and physical activity, as emotional components also play a role in children's weight development.

Finally, further research is needed to better understand the father's role in child development and should incorporate other contextual variables that may contribute to this relation. Besides, while the current study focused on parental behaviour and self-regulation variables at early stages, future studies on weight development could benefit from repeated measures of parenting, child self-regulation and BMI within a shorter timeframe (e.g., every two years) to closely monitor development and mutual influences from early childhood until late adolescence in order to unravel any potential age-specific processes.

Potential conflict of interest and source of funding

The general design of Generation R Study is made possible by financial support from the Erasmus Medical Center and the Erasmus University Rotterdam, the Netherlands Organization for Health Research and Development (ZonMW), the Netherlands Organisation for Scientific Research (NWO), the Ministry of Health, Welfare and Sport and the Ministry of Youth and Families. The current study was made possible by a grant awarded to Patricia Bravo by the National Agency for Research and Development (ANID)/Scholarship Program/DOCTORADO BECAS CHILE/2019–72200575 and by a grant from the Netherlands Organization for Health Research and Development (Mental Health Care Research Program, Fellowship 636320005 to Pauline W. Jansen). The funders had no role in the design and conduct of the study or the writing of the report. All authors declare that they have no conflicts of interest.

Ethical statement

The general design, all research aims and the specific measurements in the Generation R Study have been approved by the Medical Ethical Committee of the Erasmus Medical Center, Rotterdam. New measurements will only be embedded in the study after approval of the Medical

Ethical Committee. Participants are asked for their written informed consent for the four consecutive phases of the study (prenatally, birth to 4 years, 4–16 years, and from 16 years onwards). At the start of each phase, mothers and their partners received written and oral information about the study. Even with consent of the parents, when the child is not willing to participate actively, no measurements are performed.

Data availability

Data will be made available on request.

Acknowledgments

The general design of Generation R Study is made possible by financial support from the Erasmus Medical Center and the Erasmus University Rotterdam, the Netherlands Organization for Health Research and Development (ZonMW), the Netherlands Organisation for Scientific Research (NWO), the Ministry of Health, Welfare and Sport and the Ministry of Youth and Families. The current study was made possible by a grant awarded to Patricia Bravo by the National Agency for Research and Development (ANID)/Scholarship Program/DOCTORADO BECAS CHILE/2019–72200575 and by a grant from the Netherlands Organization for Health Research and Development (Mental Health Care Research Program, Fellowship 636320005 to Pauline W. Jansen). The funders had no role in the design and conduct of the study or the writing of the report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2022.106418.

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