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Research report

Low maternal sensitivity at 6 months of age predicts higher BMI in 48 month old girls but not boys ☆

Barbara E. Wendland [a,*], Leslie Atkinson [b], Meir Steiner [a,c], Alison S. Fleming [d], Paul Pencharz [e], Ellen Moss [f], Hélène Gaudreau [g], Patricia P. Silveira [g,h], Tamara Arenovich [i], Stephen G. Matthews [j], Michael J. Meaney [g], Robert D. Levitan [a,i], on behalf of the MAVAN [1] Study Team

[a] *Institute of Medical Science, University of Toronto, Toronto, ON M5S 1A8, Canada*
[b] *Ryerson University, Toronto, ON M5B 2K3, Canada*
[c] *McMaster University, Hamilton, ON L8N 4A6, Canada*
[d] *Department of Psychology, University of Toronto, Toronto, ON, Canada*
[e] *Nutritional Sciences, University of Toronto, Hospital for Sick Children, Toronto, ON, Canada*
[f] *Department of Psychology, Université du Québec à Montréal, Montréal, QC H3C 3P8, Canada*
[g] *Department of Psychiatry and Neurology, McGill University, Douglas Mental Health University Institute, Montreal, QC H4H 1R3, Canada*
[h] *Universidade Federal do Rio Grande do Sul, Brazil*
[i] *Centre for Addiction and Mental Health (CAMH), Toronto, ON M6J 1H4, Canada*
[j] *Departments of Physiology, Obstetrics and Gynecology, and Medicine, University of Toronto, Toronto, ON, Canada*

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ABSTRACT

Background: Large population-based studies suggest that systematic measures of maternal sensitivity predict later risk for overweight and obesity. More work is needed to establish the developmental timing and potential moderators of this association. The current study examined the association between maternal sensitivity at 6 months of age and BMI z score measures at 48 months of age, and whether sex moderated this association. *Design:* Longitudinal Canadian cohort of children from birth (the MAVAN project). *Methods:* This analysis was based on a dataset of 223 children (115 boys, 108 girls) who had structured assessments of maternal sensitivity at 6 months of age and 48-month BMI data available. Mother–child interactions were videotaped and systematically scored using the Maternal Behaviour Q-Sort (MBQS)-25 items, a standardized measure of maternal sensitivity. Linear mixed-effects models and logistic regression examined whether MBQS scores at 6 months predicted BMI at 48 months, controlling for other covariates. *Results:* After controlling for weight-relevant covariates, there was a significant sex by MBQS interaction ($P = 0.015$) in predicting 48 month BMI z. Further analysis revealed a strong negative association between MBQS scores and BMI in girls ($P = 0.01$) but not boys ($P = 0.72$). Logistic regression confirmed that in girls only, low maternal sensitivity was associated with the higher BMI categories as defined by the WHO (i.e. "at risk for overweight" or above). *Conclusions:* A significant association between low maternal sensitivity at 6 months of age and high body mass indices was found in girls but not boys at 48 months of age. These data suggest for the first time that the link between low maternal sensitivity and early BMI z may differ between boys and girls.

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* Corresponding author.
E-mail address: bwendlan@ryerson.ca; barbara.wendland@mail.utoronto.ca (B.E. Wendland).

[1] Maternal Adversity Vulnerability and Neurodevelopment.

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Introduction

It has been argued that the very rapid increase in obesity rates over recent decades cannot be accounted for based on purely metabolic factors, and must relate in large part to one or more environmental factors (Gundersen, Mahatmya, Garasky, & Lohman, 2011; Lajunen, Kaprio, Rose, Pulkkinen, & Silventoinen, 2012; Puder & Munsch, 2010; Suglia, Duarte, Chambers, & Boynton-Jarrett, 2012; Vámosi, Heitmann, & Kyvik, 2010). As summarized in recent reviews (Anzman, Rollins, & Birch, 2010; Mitchell, Farrow, Haycraft, & Meyer, 2013; Sleddens, Gerards, Thijs, de Vries, & Kremers, 2011; Ventura & Birch, 2008), the quality of parent–child interactions has been a focus of obesity work over several decades. However, much of this work has been either cross-sectional in design, done in relatively small samples and/or focused on school-age children and adolescents, which may limit the interpretation and generalizability of results. A greater focus on large, longitudinal, population-based studies, including data from the first few years of life, may point the way to more effective interventions going forward (Anzman et al., 2010).

One systematic way of assessing the quality of early parental–child relationships is to measure maternal–infant attachment and maternal sensitivity based on direct observation using standardized coding to score these interactions. Attachment can be defined as a bio-behavioural system to facilitate protection and survival through proximity and a secure base between mammalian caregivers and their infants (Bowlby, 1973; Goldberg, 2000). Maternal sensitivity refers to one specific aspect of the attachment system i.e. timely and appropriate responsivity on the part of the mother towards the cues of her infant (Ainsworth & Marvin, 1995). In addition to providing a framework for the objective and standardized assessment of parent–child interactions, attachment and maternal sensitivity have the further advantage of contributing to individual differences in emotion regulation (Sherman, Stupica, Dykas, Ramos-Marcuse, & Cassidy, 2013; Waters et al., 2010) and stress responsivity (Champagne & Meaney, 2001; Fernald & Gunnar, 2009; Loman & Gunnar, 2010; Walker, 2010). Increased consumption of highly palatable foods in the face of strong emotions, often triggered by daily stressors, is thought to be a major factor contributing to obesity over time (Dallman et al., 2003). Given these practical and theoretical advantages, standardized assessments of attachment and maternal sensitivity have recently been included in large, systematic population studies of obesity risk. For example, Anderson and Whitaker in 2011, using a version of the Attachment Q-sort (van Ijzendoorn, Vereijken, Bakermans-Kranenburg, & Riksen-Walraven, 2004; Waters & Deane, 1985) in a large U.S. population sample, found that attachment insecurity measured at 24 months increased the risk of obesity at 54 months of age. This same team later showed that low maternal sensitivity in the pre-school years was an even stronger risk factor for the development of obesity in adolescence than insecure attachment (Anderson, Gooze, Lemeshow, & Whitaker, 2012). Wu, Dixon, Dalton, Tudiver, and Liu (2011) showed that the combination of low maternal sensitivity and a difficult child temperament predicted an increased risk of overweight-or-obesity during school age, but not in earlier childhood.

While these initial studies suggest that insecure attachment and low maternal sensitivity in pre-schoolers is a risk factor for later obesity, much more work is needed to replicate these findings in independent samples and to establish at what age these effects first come into play. For example, while Anderson et al. (2012) report a link between 24 month attachment behaviours and later obesity risk, extending this finding to interactions measured at 6 months of age might inform a different interventional approach implemented at a very different time in the emerging dyadic relationship. Another important question for this area of work is whether sex moderates the link between attachment and/or maternal sensitivity behaviours and later obesity risk. Anderson and Whitaker (2011) reported that sex did not moderate the association between insecure attachment and childhood obesity; however, they did not report on similar moderation effects related to maternal sensitivity and later weight gain (Anderson et al., 2012). Several authors have identified important sex differences associated with the early mother–child relationship and the development of social interactions (Biringen, Robinson, & Emde, 1994; Goldberg & Lewis, 1969; Gunnar & Donahue, 1980; Hinde & Stevenson-Hinde, 1987). Furthermore, several aspects of eating behaviour and weight gain may develop differently in girls and boys (Govindan et al., 2013; Suzuki et al., 2012). Thus, it is reasonable to hypothesize that the link between maternal sensitivity and later obesity risk might differ in the two sexes.

The main goals of the current study were thus: 1) to examine the association between 6 month maternal sensitivity scores and body mass indices measured at 48 months of age in a new longitudinal study of developing children, thus extending the work of Anderson et al. to an earlier developmental stage, and 2) to assess whether sex might moderate this association. We hypothesized that exposure to low maternal sensitivity at age 6 months would be associated with higher child BMIs at age 48 months, and that sex would moderate this association i.e. that girls would show this association more so than boys. The latter was based on recent work demonstrating a link between social adversity and obesity risk in girls but not in boys at 5 years of age (Suglia et al., 2012). Differences in parental expectations, perceived roles and maternal behaviours towards boys and girls might also be contributory in this regard (Biringen et al., 1994; Carper, Fisher, & Birch, 2000; Elfhag & Linné, 2005; Goldberg & Lewis, 1969; Hinde & Stevenson-Hinde, 1987).

Participants and methods

The current study sample included 223 children recruited in either Montréal, Québec (N = 105) or Hamilton, Ontario (N = 118), Canada as part of an established prospective birth cohort, the Maternal Adversity, Vulnerability and Neurodevelopment (MAVAN) project. For the current analysis, all available participants who had been enrolled in the MAVAN study at birth, been scored for maternal sensitivity at 6 months of age and who had participated in a laboratory visit to measure growth at 48 months of age were included. Eligibility criteria for mothers at study entry included age ≥18 years, singleton gestation, and fluency in French or English. Women with severe chronic illness, placenta previa, with history of incompetent cervix, impending delivery, or a foetus/infant affected by a major anomaly or born at a gestational age less than 37 weeks were excluded. Birth records were obtained directly from the birthing unit.

The current study sample was found to be comparable to the overall birth cohort in terms of maternal age at childbirth, gestational age, birth size, income categories, and maternal education. MAVAN is a multidisciplinary, collaborative study, recruiting pregnant women from obstetric clinics in hospitals located in Montréal, Québec and Hamilton, Ontario. All participants experienced identical home and laboratory based assessments. We excluded very low birth weight infants and included those born at 37–41 weeks gestation. The maternal age at childbirth was also comparable to the general population within Canada (study sample = 30.5 years; Québec = 29.5 years, Ontario = 30.2 years) (Statistics Canada, 2012). The MAVAN project over-samples from low SES settings, thus the prevalence of families receiving income below the low income cut off (LICO; Statistics Canada, 2005) was near 30% compared to 15% in the general population (Statistics Canada, 2009). However, while education below 10 years was found in only 4% of the mothers of our sample, this number reaches 12% of adults in the provinces of

Table 1
Sample characteristics and bivariate association of independent variables with 48 month BMI z-scores.

Independent variable	*n*		Mean	Std Dev	Bivariate association with 48 month BMI (WHO z-scores)			
	Boys	Girls			Beta estimate (SE)	df	t-statistic	*P* value
Sex	115 (51.6%)	108 (48.4%)			0.18 (0.14)	223	1.31	0.19
SES/Maternal education blended (high vs. other)[a]	High 156 (77.6%)	Other 45 (22.4%)			–0.55 (0.17)	201	–3.14	0.002
Birth weight z-score	223		–0.12	0.91	0.20 (0.08)	223	2.56	0.011
Maternal BMI	185		27.4	6.5	0.06 (0.01)	185	5.43	<0.001
MBQS-25 score at 6 months	223		0.41	0.43	–0.26 (0.16)	223	–1.59	0.11

Notes: Discrepancies in sample size are due to missing/incomplete data.
MBQS-25 = Maternal Behaviour Q-Sort 25-item (maternal sensitivity).
[a] High = high SES and high maternal education; Other = low SES and/or low maternal education.

Québec and Ontario (Statistics Canada, 2011). In sum, SES status was relatively low but education relatively high, relative to Canadian population norms.

Approval for the MAVAN project was obtained from obstetricians performing deliveries at the study hospitals and by the ethics committees and university affiliates (McGill University and l'Université de Montréal: the Royal Victoria Hospital, Jewish General Hospital, Centre hospitelier de l'Université de Montréal, and Hôpital Maisonneuve-Rosemount), and St. Joseph's Hospital and McMaster University, Hamilton, Ontario, Canada. Details of the procedures are available (Silveira et al., 2012). Informed consents were obtained from all participants.

Measures

Mother–child interaction using video-taping

For the purposes of assessing maternal sensitivity (appropriately, and timely response to infant signals) at 6 months, 30 minutes of non-feeding mother–infant interactions were videotaped in the home. The 6 month videos were entirely free-play. The recordings were later coded by staff that were independent from the MAVAN study and had no awareness of the primary study hypotheses. The instrument used was the 25 item Maternal Behaviour Q-sort (MBQS revised-25) which has been shown to correlate with constructs central to infant development and attachment, including other measures of maternal sensitivity as well as infant attachment security and cognitive development (Pederson et al., 1990; Tarabulsy et al., 2009). Three MBQS revised-25 observers independently coded 28 6 month tapes to obtain intra-class correlations between 0.82 and 0.94.

Growth measures

At the 48 month visit children had length and weight measures taken. Standing height, without shoes, was measured (to the nearest 0.1 cm) with the use of a stadiometer (Perspective Enterprises, PE-AIM-101, Portage, MI). Body weight, in light clothing, was measured (to the nearest 0.1 kg) with the use of a digital floor scale (TANITA BF625, Arlington Heights, IL). BMI was calculated as weight in kilograms divided by height in metres squared (kg/m^2). BMI z-scores were calculated based on well established World Health Organization (WHO) growth curves for girls and boys (The WHO Multicentre Growth Reference Study (MGRS) 2006).

Covariates related to BMI

Based on their established relationship with early growth and overweight-obesity risk, we included birth-weight (based on WHO z scores; Oken, Kleinman, Rich-Edwards, & Gillman, 2003), maternal BMI and a blended variable for socio-economic status and maternal education in our analyses. Regarding the latter, bivariate low/high sub-groupings for both maternal SES and maternal education were first established based on Canadian norms (Statistics Canada, 2005). Maternal SES groupings were: "low" = total family income after tax <\$21,359; "high" = total income after tax >\$21,358 (Statistics Canada, 2005). Maternal education was defined as "low" if high school graduation was not achieved (Statistics Canada, 2011). A single composite variable for socio-economic status and maternal education was next generated based on the following three groupings: "low/low" identifies low income and low maternal education; "low/high" identifies low income and high maternal education or high income and low maternal education; "high/high" identifies high income and high maternal education. As relatively few mothers in this sample met criteria for both low education and low income, a bivariate factor for SES and maternal education was ultimately used for the statistical analyses i.e. high education–high SES (n = 156; 77.6%) versus all other subgroups combined (n = 45; 22.4%). No data for maternal SES and education was available for 22 other subjects (see Table 1).

Statistical methods

Analyses were conducted with IBM SPSS statistical software, version 21 (IBM SPSS Statistics for Windows, Armonk, NY) and SAS version 9.2 software (SAS Institute, Cary, NC). The main goal was to investigate the relationship between maternal sensitivity measured at 6 months of age and BMI of the child measured at 48 months of age, and whether sex moderated this association. Data modelling using regression analysis and analysis of variance was used to evaluate the effects of covariates on the study results. To account for the relatedness of observations taken from the same study site (Montréal or Hamilton), linear mixed-effects models controlling for site, implementing the method of maximum likelihood were used to predict 48 month BMI z scores based on maternal sensitivity as reflected by the MBQS-25 score at age 6 months, sex, the MBQS by sex interaction and the BMI-relevant covariates listed above.

Variables that were focal components of the hypothesis, i.e., maternal sensitivity score (MBQS-25), sex and the MBQS by sex interaction, were entered into the multivariate regression model at each step. The random variable for site was kept in the model at each step because it is central to our methodology and our mixed model analyses. The decision to include other covariates was based on the following procedure: Firstly, we examined the simple bivariate associations between each of these covariates and BMI z-scores at 48 months, using a series of linear mixed-effects models (each including a random intercept to control for site – Montréal versus Hamilton). Covariates that were not associated with BMI at $P < 0.05$ were eliminated at this step. Next, a preliminary multivariate linear mixed model to predict 48 month BMI z scores was completed including all of the variables identified as central to our hypothesis, a random variable for site, and additional covariates that were significantly associated with 48 month BMI z scores in the bivariate analyses described above. For the covariates that were not central to our hypothesis, the basis to retain a given covariate in the final model was done using a "purposeful selection of covariates" procedure i.e. covariates that did not prove significant in the final multivariate regression model were eliminated until all remaining covariates were significant at $P < 0.05$.

Prediction of higher BMI categories

In theory, the link between maternal sensitivity and body mass may operate at the lower and/or higher extremes of BMI, and this would not be discernable in the analysis described above. To more specifically determine whether maternal sensitivity at age 6 months was predictive of the higher BMI categories outlined by the WHO (i.e. at risk of overweight, overweight or obese), a logistic regression predicting membership in any of the higher weight categories considered together (yes/no) was performed using maternal sensitivity scores, sex, the sensitivity by sex interaction and maternal BMI as independent variables. The goal was to determine if maternal sensitivity was relevant to childhood overweight/obesity risk per se.

Results

Table 1 summarizes the sample characteristics including potential covariates and provides the simple bivariate associations between each independent variable and 48 month BMI z scores.

As shown, there was a significant bivariate association between the SES/maternal education variable and 48 month BMI z scores, with high SES/high maternal education status being associated with lower 48 month BMI. Higher birth weight z scores and higher maternal BMI were both positively associated with 48 month child BMI. Neither infant sex nor maternal sensitivity scores were significantly related to BMI z score at this step.

Final model predicting BMI z scores at age 48 months

After implementing the purposeful selection of covariates methodology as outlined above, maternal BMI was retained as a significant covariate in the final multivariate model (at $P < 0.001$), while birth weight and SES/maternal education were not. Notably, the sex by MBQS interaction was also significant in this model ($P = 0.015$). To explore this interaction in more detail, two separate mixed effects models were completed in boys and girls. Table 2 indicates that after controlling for maternal BMI, there was a negative association between maternal sensitivity at age 6 months and BMI z scores at age 48 months in girls (at $P = 0.01$), while in boys there was no significant association between maternal sensitivity at 6 months and 48 month BMI z scores ($P = 0.72$).

Prediction of higher BMI categories

Of the 223 children included in the current sample, a total of 60 (26.9%) would be considered as "at risk of overweight", "overweight" or "obese" based on WHO criteria. The logistic regression predicting membership in any one of these categories at age 48 months (yes/no), controlling for maternal BMI, was highly significant (chi-square = 21.9, df = 4, $P < 0.001$). Consistent with the mixed model analysis described earlier, the maternal sensitivity by sex interaction was significant (Wald = 6.75, df = 1, $P = 0.009$, odds ratio = 10.73 (95% confidence interval = 1.79–64.26). Separate logistic regressions done in girls and boys revealed that after controlling for maternal BMI, lower maternal sensitivity was associated with membership in a higher BMI category in girls (Wald = 6.66; df = 1, $P = 0.01$; odds ratio = 7.18, 95% CI = 1.61–32.12) but not in boys (Wald = 0.66; df = 1, $P = 0.42$; odds ratio = 0.67, 95% CI = 0.25–1.78).

Table 2
Final models, split by sex, predicting 48 month BMI z-scores.

Variable	Beta Estimate (SE)	
	Boys	Girls
MBQS-25 score at 6 months	0.07 (0.20) $P = 0.72$	–0.85 (0.32) $P = 0.01$
Maternal BMI	0.06 (0.01) $P < 0.001$	0.05 (0.02) $P = 0.002$

Notes: MBQS-25 = Maternal Behaviour Q-Sort 25 item (maternal sensitivity).

Discussion

The main goals of the current study were : 1) to examine the association between 6 month maternal sensitivity scores and body mass indices measured at 48 months of age in a new longitudinal study of developing children, thus extending the work of Anderson et al. to an earlier developmental stage, and 2) to assess whether sex might moderate this association. After controlling for covariates known to have a strong relationship with child BMI, we found a significant negative association between maternal sensitivity at 6 months of age and body mass indices in 48 month old girls, but not in their male peers. Further analysis revealed that in girls only, low maternal sensitivity was associated with an increased likelihood of being at risk for overweight, overweight or obese based on established WHO cut-offs. This suggests for the first time that the link between maternal sensitivity and early markers of obesity risk may in fact differ between the two sexes.

While the prior literature linking parent–child interactions with obesity risk is substantial, recent reviews have highlighted several potential limitations of this work (Anzman et al., 2010; Mitchell et al., 2013; Sleddens et al., 2011; Ventura & Birch, 2008), including a heavy reliance on cross-sectional designs, relatively small samples and with a primary focus on school-aged children and adolescents. Only recently has objective, systematic scoring of early mother–child interactions been used in the context of large population-based studies (Anderson et al., 2012; Anderson & Whitaker, 2011). In these latter studies, children at 24 and 36 months with both insecure attachment and exposure to low maternal sensitivity had a particularly high risk of obesity in adolescence (Anderson et al., 2012). In their 2011 paper, Anderson and Whitaker tested sex as a moderator of the association between attachment categories and the risk of obesity, reporting no significant effect. However their subsequent paper looking at maternal sensitivity and obesity risk did not include sex as a potential moderator. A smaller study by Wu et al. (2011) found that maternal sensitivity influenced the relationship between temperament and the risk of overweight–obesity in children who were at school age, with the combination of insensitive mothering and a difficult temperament being associated with the greatest risk (Wu et al., 2011); again, sex was not considered as a potential moderator of this association. Thus, in linking low maternal sensitivity with higher BMIs in girls but not boys, the current findings both replicate and extend the work of Wu et al. (2011) and Anderson et al. (2012).

The current findings suggest that 6 months of age may encompass a significant period of development when human infants are highly sensitive to maternal signals, with implications for early prevention and management of childhood obesity risk. However, low maternal sensitivity has also been associated with feeding problems and failure to thrive in some children (Block & Krebs, 2005; Drotar, Eckerle, Satola, Pallotta, & Wyatt, 1990; Feldman, Keren, Gross-Rozval, & Tyano, 2004; Hagekull, Bohlin, & Rydell, 1997; Ward, Kessleer, & Altman, 1993), suggesting that the link between early maternal sensitivity and weight regulation may be bidirectional. Understanding the moderators of these two different growth trajectories in response to low maternal sensitivity is an important question for future research.

Important meta-analyses reported from Europe suggest that maternal sensitivity and attachment behaviours can be modified through learning; early preventive interactions focussing on maternal sensitivity have been effective in enhancing maternal sensitivity as well as promoting child attachment security (Bakermans-Kranenburg et al., 2003; Bakermans-Kranenburg et al., 2005. If low maternal sensitivity is in fact causal of early weight gain, such interventions should make an impact on limiting childhood obesity over time. The current findings suggest that girls might benefit disproportionately in this regard.

Several potential strengths and limitations of the current study merit consideration. Strengths include our use of a population-based sample with highly structured and standardized assessments of maternal sensitivity done in the first year of post-natal life when plasticity effects are likely to be significant. The longitudinal aspect of our findings is also a potential strength. On the other hand, our current sample size is much smaller than that reported by Anderson et al. (2012), which limits statistical power. While the current data suggest that boys will not show an association between maternal sensitivity and BMI even with a much larger sample size, similar studies in other cohorts will be needed to assess this more fully. The generalizability of the current findings is another potential limitation, given the large number of mothers with low SES but high educational status. The latter could in theory limit the impact of social adversity on the outcome under consideration.

While the detailed phenotyping of the MAVAN sample is a major long term strength, we do not have sufficient data at this time to explain the mechanistic basis of our main finding, though this will be a goal of future work. Several potential variables have been linked to maternal–infant interactions on the one hand and obesity on the other, including HPA axis activity (Hillman, Dorn, Loucks, & Berga, 2012; Lumeng et al., 2014), emotion regulation (Harrist, Hubbs-Tait, Topham, Shriver, & Page, 2013; Vandewalle, Moens, & Braet, 2014) and brain reward processes (Berthoud, Lenard, & Shin, 2011; Sinha & Jastreboff, 2013).

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