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Pre-pregnancy body mass index and parent and teacher-reported behavioral outcomes among offspring in childhood

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Abstract

Objective.—Pre-pregnancy obesity has been linked to childhood neurodevelopmental outcomes, including autism and attention-deficit hyperactivity disorder. The aim of our study was to examine the association between pre-pregnancy body mass index (BMI) and scores on behavioral scales according to both mother and teacher report.

Methods.—We conducted a longitudinal study of 469 mother-child pairs. Information on pre-pregnancy body mass index (BMI) was collected from standardized maternal interviews conducted after delivery and assessment of childhood behavioral problems was measured at 5–12 years of age according to maternal-report using the Child Behavior Checklist (CBCL) and teacher-report using the Teacher Report Form (TRF). Using normal pre-pregnancy BMI (18.5–24.9 kg/m^2) as the reference (n=305), we calculated adjusted mean differences (MD) for t-scores on broadband and syndrome scales of behavior for children of mothers with pre-pregnancy overweight (n=101) or obese (n=63) BMI. We also examined associations with scores in the clinical range using risk ratios (RR) and compared results across informants. To account for loss to follow-up between the initial interview and the childhood behavioral assessment, we weighted models using stabilized inverse probability weights.

Results.—Pre-pregnancy obesity was associated with a mean increase in child's total behavior problem t-scores according to both mother and teacher report, after adjustment for confounders and weighted for loss to follow-up (MD: 0.7, 95% CI: −2.2, 3.6 on CBCL; MD: 3.1, 95% CI: 0.5, 5.7 on TRF), indicating poorer behavioral outcomes. Comparing the magnitude of associations between mother and teacher-report, mean differences for pre-pregnancy obesity and most behavioral problem scales were larger for teacher-reported outcomes than mother-reported outcomes. Pre-pregnancy obesity was associated with increased risks of externalizing behaviors

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

in the clinical range regardless of informant (CBCL RR: 1.6, 95% CI: 0.8, 3.2 and TRF RR: 1.7, 95% CI: 0.8, 3.5). Pre-pregnancy obesity was also associated with increased risks of internalizing behaviors according to teacher-report (TRF RR: 2.6, 95% CI:1.5, 4.6).

Conclusions.—Pre-pregnancy obesity, compared to pre-pregnancy normal weight, is associated with generally higher scores on both mother and teacher reported childhood behavioral assessments, indicating an increased likelihood of behavioral problems.

Keywords

Neurodevelopment; Behavior; Pre-pregnancy BMI; Child Behavior Checklist (CBCL)

Introduction

In the United States between 2012 and 2014, more than 50% of reproductive-age women were overweight or obese[1]. Pre-pregnancy overweight and obesity are associated with adverse pregnancy and delivery outcomes, including gestational diabetes[2], pregnancy-induced hypertension[2,3], preeclampsia[4,5], cesarean delivery[5,6], and preterm delivery[7]. A growing body of literature suggests pre-pregnancy overweight and obesity also adversely affect childhood neurodevelopment[8–16]. Studies have reported increased risks of autism spectrum disorder and attention-deficit hyperactivity disorder among children of mothers in pre-pregnancy overweight and obese body mass index (BMI) categories, compared to mothers with pre-pregnancy BMI in the normal range[9,10,17–20]. In general, risks of these neurodevelopmental outcomes increases with increasing BMI values[21–23].

Pre-pregnancy BMI has also been linked with poorer scores on behavioral assessments in general population samples. Compared to children of mothers with normal pre-pregnancy BMI, children born to mothers with overweight or obese BMI are more likely to score high on scales of hyperactive and aggressive behavior, inattention, and internalizing and externalizing behavior problems[20,23,25–31]. However, most of these studies rely on maternal assessments of behavior, which can be discrepant with teacher reported behavior assessment scores. Furthermore, many studies rely on maternal report of both their own pre-pregnancy BMI and their assessment of child behavior and are thereby prone to differential error[32]. Two studies examining maternal pre-pregnancy BMI and child neurodevelopment using multiple informants demonstrate informant variability; stronger associations were observed for parent-reported behavior in a U.S. birth cohort[20] and for teacher-reported behavior in a Swedish cohort[25].

Accordingly, this study investigates the association between maternal pre-pregnancy BMI and child behavioral problems utilizing both mother- and teacher-reported assessments, namely the Child Behavioral Checklist (CBCL) and the Teacher Report Form (TRF), and to compare results across informants.

Materials and Methods

Study Population

We conducted a follow-up study of children aged 5–12 years whose mothers previously participated in a case-control study of risk factors for hemifacial macrosomia (HFM), a type of structural birth defect. The case-control study included children born in 1996–2002, and details of that study are described elsewhere[33]. Briefly, cases of HFM were ascertained from 26 craniofacial centers across the United States and Canada. Controls were matched to cases on birth year and pediatric practice or practices within the same zip code. Mothers of the children that participated in the case-control study were subsequently contacted when their child was at least five years old and invited to participate in the follow-up study. Of the 839 eligible control subjects, 570 (68%) participated. The follow-up study consisted of a battery of neurodevelopmental assessments completed by the child and psychosocial questionnaires completed by both mothers and teachers, including measures of behavioral problems. The present analysis is restricted to singleton control children with completed behavioral assessments by both mother and teacher (n=484). We further excluded children of women in the pre-pregnancy underweight category due to the small sample size (n=15). This study was approved by the Institutional Review Board at Boston University and was completed in compliance with HIPAA standards.

Pre-pregnancy BMI

Data on maternal height and pre-pregnancy weight were self-reported and collected through standardized interviews conducted on average within 12 months of delivery (IQR: 3–20 months). Pre-pregnancy BMI (kg/m^2) was calculated from reported height and weight measurements and subsequently categorized based on the Centers for Disease Control (CDC) guidance as: underweight (≤ 18.5 kg/m^2), normal (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥ 30 kg/m^2)[34].

Childhood behavioral adjustment

Psychosocial assessments of the child according to both mother and teacher report were obtained using the Child Behavior Checklist (CBCL) and the Teacher Report Form (TRF), respectively. These assessments are part of the Achenbach System of Empirically Based Assessment (ASEBA) and allow for systematic comparison of child behavior across informants.[35] Both tests provide measures of three broadband scales, which include total behavior problems, internalizing behavior problems (e.g., shy, withdrawn), and externalizing behavior problems (e.g., hyperactive, disruptive). Scores for eight syndrome scales are also tallied to reflect problem behavior in the following domains: anxious/depressed, withdrawn/depressed, somatic, social, thought, attention, rule-breaking, and aggressive. T-scores (mean=50, SD=10) standardized by child age and sex are calculated for broadband and syndrome scales. Information regarding the administration and internal consistency of these tests has been detailed elsewhere[36,37]. T-scores were also dichotomized based on a deviant cut point (broadband scales: T >=60; syndrome scales T >=65), to include scores in both the borderline and clinical range. This cut point is determined by comparing scores to a standard derived from a normative sample and aligns with the 93rd percentile or above[35]. We chose to include the borderline scores in the dichotomous outcome, in addition to the clinical

scores, because a prior publication of these data showed only 4–7% of this non-clinic population met criteria for the clinical range[38].

Demographic and health characteristics were collected through the standardized interviews conducted after delivery that were administered as part of the original case-control study. These characteristics included maternal race (white non-Hispanic, Hispanic, black non-Hispanic, other), maternal age at conception (≤25, 26–34, ≥35), maternal education (<12, 12, 13–15, ≥16), marital status (married/cohabitating, single/divorced/separated), family income (≤25,000, 25,001–35,000, 35,001–65,000, ≥65,000 USD). Pregnancy characteristics included parity (0, 1, ≥2), infant sex, and binge drinking (≥ 3 drinks per sitting), and smoking (smoker, non-smoker) in the periconceptional period. The periconceptional period was defined using the first lunar month, or four weeks from the last menstrual period.

Statistical analyses

Demographic and health characteristics by pre-pregnancy BMI category were summarized using frequencies. Simple linear regression models were used to examine associations between pre-pregnancy BMI categories and behavioral problem T-scores for each broadband and syndrome scale on the CBCL and TRF. Using normal BMI as the referent, mean differences in t-scores and 95% confidence intervals (CI) were calculated. Multivariable linear regression models, adjusted for maternal age at conception, education, marital status, periconceptional binge drinking and smoking, were used to calculate adjusted mean differences (MD). Mothers with missing covariate information (n=1) were excluded. Covariates included in the adjusted models were selected based on a 10% change in mean differences when included in the model for total behavior problems. Models were additionally weighted using stabilized inverse probability weights (SIPW) to account for attrition of the cohort between the delivery interview and the childhood behavioral assessments. Mothers of children who participated in the behavioral assessments were more likely to be white, non-Hispanic, have more years of education, and have higher family incomes, than mothers of non-participants. Inverse probability weights were calculated by fitting a logistic regression model predicting participation using the following covariates: maternal age at delivery, maternal race, marital status, maternal education, alcohol drinking, binge drinking, smoking, parity, pre-pregnancy BMI, and infant sex. The c-statistic of the model was 0.704. To avoid the influence of extreme weights, stabilized weights were created, which divide the predicted probability of participation by the proportion of mothers that participated instead of one.

We also used modified Poisson regression models to calculate risk ratios (RR) and 95% confidence intervals (CI) between pre-pregnancy BMI category and the dichotomous outcome of behavioral problems in the borderline/clinical range for the broadband scales. These models were adjusted using the same covariates as the linear models and weighted using SIPW. We also examined effect measure modification by infant sex at birth to detect potential differences in associations between male and female offspring.

All analyses were performed using SAS Software Version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Our final study population consisted of 469 mother-child pairs. The majority of mothers had a normal pre-pregnancy BMI (n=305, 65%). Approximately 21.5% (n=101) and 13.4% (n=63) of mothers were in the overweight and obese pre-pregnancy BMI categories, respectively. Among the mothers with pre-pregnancy obesity, 52% were in obesity class 1 (30–34.9 kg/m^2), 29% were in obesity class 2 (35–39.9 kg/m^2) and 19% were in obesity class 3 (≥40 kg/m^2). Mothers with pre-pregnancy obesity were more likely to be Hispanic, have fewer years of education, a lower family income, and be multiparous, compared to mothers in the normal BMI category. Comparatively, women in the pre-pregnancy overweight category were more likely than mothers with normal pre-pregnancy BMI to be Black, non-Hispanic, and be smokers and non-drinkers during the periconceptional period (Table 1).

Children of mothers with pre-pregnancy obesity had higher average scores on all CBCL outcome measures than children of mothers with normal pre-pregnancy BMI, indicating poorer behavioral outcomes based on maternal report. After adjustment for covariates and weighting for loss to follow up, mean differences were the largest for the syndrome scales of somatic complaints (MD: 1.3; 95% CI: −0.3, 2.9), thought problems (MD: 1.4; 95% CI: −0.2, 3.0), and attention problems (MD: 1.1; 95% CI: −0.4, 2.7), although these estimates were imprecise given the wide confidence intervals. Mean differences in child behavioral scores comparing overweight and normal pre-pregnancy BMI categories varied. For example, children of mothers in the pre-pregnancy overweight category scored 0.9 (95% CI: −1.3, 3.2) points higher on average for externalizing behaviors and 1.3 points lower on anxious/depressed behavior (95% CI: −2.6, 0.0). Of note, weighting models to account for loss to follow-up attenuated nearly all associations in the obese category, while estimates in the overweight category remained relatively unchanged (Table 2).

For teacher-reported outcomes measured using the TRF, children of mothers with pre-pregnancy obesity scored higher on all outcome measures than children of mothers with normal pre-pregnancy BMI. For example, outcomes with at least a two-point mean difference in t-scores included, total problems (MD: 3.1; 95% CI: 0.5, 5.7), internalizing problems (MD: 3.3; 95% CI: 0.8, 5.7), somatic problems (MD: 2.6; 95% CI: 1.2, 3.9) and social problems (MD: 2.0; 0.5, 3.4). Corresponding mean differences for overweight compared to normal pre-pregnancy BMI groups were null for the majority of teacher-reported outcomes. Furthermore, the adjusted but unweighted MDs were not materially different than those estimated from models weighted by SIPW (Table 2).

Comparing mother and teacher reported outcomes within BMI categories, we observed stronger associations between pre-pregnancy obesity and outcomes on the TRF than with outcomes on the CBCL. For example the adjusted and weighted MDs for total behavior problems were 0.7 (95% CI: −2.2, 3.6) and 3.1 (95% CI: 0.5, 5.7) on the CBCL and TRF, respectively. Associations between pre-pregnancy overweight and behavioral outcomes were similar regardless of reporter (Table 2).

Children of mothers in both the pre-pregnancy overweight and obese categories had modestly higher risks of scoring in the borderline/clinical range for externalizing behaviors on the CBCL (RR: 1.4; 95% CI: 0.8, 2.6; and 1.6; 0.8, 3.2), compared to children of mothers with normal pre-pregnancy BMI. These estimates were based on a small sample of 13 and 11 children in the borderline/clinical range in the overweight and obese BMI categories, respectively. According to teacher-report, children of mothers in the overweight and obese pre-pregnancy BMI category also had a greater risk than those with normal pre-pregnancy BMI mothers of scoring above the borderline/clinical cutoffs for externalizing problems (RR: 1.5, 95% CI: 0.8, 2.8; and 1.7; 0.8, 3.5). Increased risks of total problems and internalizing problems on the TRF were also observed for children of mothers with pre-pregnancy obesity (Table 3).

The association between maternal pre-pregnancy BMI category and child behavioral outcomes varied slightly by offspring sex at birth. On both the CBCL and TRF, associations between pre-pregnancy obesity and most outcomes examined were stronger among male offspring and closer to the null for female offspring, although many estimates were imprecise with wide confidence intervals. The mean difference among males in the obese group and mother-reported externalizing problems was 1.1 (95% CI: −3.2, 5.3) versus 0.0 (95% CI: −3.4, 3.5) among females. Following the same pattern, the mean difference for teacher-reported total problems among males was 1.6 (95% CI: −1.8, 5.0) versus 1.0 (95% CI: −2.1, 4.1) among females. Findings regarding the pre-pregnancy overweight group did not demonstrate a clear pattern with many mean differences close to the null (Table 4).

Discussion

In the present study, maternal pre-pregnancy BMI was associated with both mother and teacher-reported measures of child behavior at 5–12 years of age. Children of mothers with pre-pregnancy obesity scored higher across all domains than children of mothers with normal pre-pregnancy BMI, and had a higher risk of scoring in the borderline/clinical range for externalizing behaviors according to both informants, and internalizing behaviors according to teachers only. This finding is consistent with prior studies that report high sores on measures of externalizing behaviors, including aggression, negative emotion regulation, and negative affect, among children with mothers in higher pre-pregnancy BMI categories in comparison to children of normal weight mothers[25,26,31,39].

While our study shows increased associations indicating worse behavior for pre-pregnancy obesity, these associations were consistently larger when the outcome was based on teacher-report, except for attention problems. This finding is inconsistent with past research which suggests stronger associations between maternal BMI and child externalizing and internalizing behavior problems when maternally reported compared to teacher reported[20], but is consistent with a study reporting stronger associations based on teacher-report[24]. In studies that have examined CBCL and TRF score distributions in non-clinical populations, CBCL scores are generally higher. In our sample, this depended on the outcome being examined, with children more likely to score in the borderline/clinical range of total problems based on the TRF and externalizing and internalizing behavior based on the CBCL. In a clinical setting, neither the CBCL nor TRF is considered more accurate, instead

these tools are used in conjunction to identify consistencies and inconsistencies in behavior in various settings.

Maternal obesity correlates with other factors that can contribute to child neurodevelopment, making disentangling any biological effect of maternal pre-pregnancy BMI challenging. The exact mechanism linking maternal pre-pregnancy BMI to neurodevelopment in children remains unknown. Researchers, however, hypothesize that adiposity may alter neurodevelopment through increases in placental inflammation via adiposity-associated releases of inflammatory cytokines, alterations in neuroendocrine signaling, changes in insulin resistance, and micronutrient deficiencies. In addition to functional changes, maternal pre-pregnancy BMI has also been associated with structural deficits. Previous research using functional magnetic resonance imaging and diffusion tensor imagining finds an association between maternal pre-pregnancy obesity and decreased connectivity in the dorsal anterior cingulate cortex, an area of the brain associated with attention, emotion, and decision making and well decreases in global white matter myelination and neuron density[40,41].

Selected associations between pre-pregnancy maternal obesity and neurobehavioral outcomes differed by sex of the child at birth. Our data suggest that the mean differences in several behavioral outcomes when comparing pre-pregnancy obesity to normal pre-pregnancy BMI, were larger among male offspring, although our sample size was small and no clear patterns emerged. We were also lacked information on gender identity and expression during childhood. The different effect of BMI on behavior by sex may be contributed to known sex differentials in the intrauterine environment.

Alves et al., (2019) found significant associations between maternal pre-pregnancy BMI and child hippocampal volume in males but not females[42]. Research indicates that maternal inflammatory markers vary by fetal sex, such that mothers with male fetuses had higher pro-inflammatory cytokines and nitric oxide than mothers with female fetuses[43].

Our study is not without some limitations. The possibility of confounding by unmeasured factors is possible. This study lacked information on maternal IQ and parental mental health conditions that may influence childhood neurodevelopment. While not confounders, we also lacked information on parenting style, stress during pregnancy, child BMI, and the nature and quality of the home environment beginning at birth, each of which may play an important role in mediating associations between pre-pregnancy BMI and neurobehavior [44–49]. Mechanistically, previous literature also suggests weight gain during gestation may be a better predictor, and a potentially modifiable factor, of maternal inflammatory status and consequently, of behavioral outcomes in offspring[20]. While we did have data on weight gain, our sample size prohibited examination of weight gain patterns within pre-pregnancy BMI categories. It is worth noting that data on pre-pregnancy BMI were self-reported and collected retrospectively, which may result in the misclassification of exposure. However, previous literature suggests that women accurately recall pre-pregnancy height and weight values many years after delivery[50]. Data on covariates such as drinking and smoking during pregnancy were also collected after delivery, but prior to the childhood outcomes assessed in this study, therefore reducing the likelihood of differential recall errors. Although nearly

500 children were included in this analysis, numbers were small for some comparisons, particularly for borderline/clinical outcomes and sex subgroups.

Strengths of this analysis include our use of ASEBA's companion instruments- CBCL and TRF – which enabled direct comparisons of scales for reports by mothers and by teachers. Our analysis used the t-scores from these instruments, which account for child sex and age. We were also able to quantify subclinical effects with the ASEBA instruments. Further, having two reporters on child's behavior can help capture variations in behavioral problems in two different settings and situations. The stronger associations observed for teacher-reported behavior problems suggests setting and situation matter and that these associations would have been missed had we relied solely on maternal report. We also used existing data on demographic and other factors for families that were lost to follow-up to create SIPW to assess the potential bias arising from selected participation. Bias was evident for mother-reported outcomes; positive associations with pre-pregnancy obesity approached the null after adjustment with SIPW. In contrast, teacher reported outcomes associated with obesity were similar or stronger after SIPW adjustment. This pattern suggests that mothers with pre-pregnancy obesity who participated in the follow-up study were more likely to report behavior problems than their counterparts who were lost to follow-up and that mother's participation had little or no bearing on teacher's report.

In conclusion, we observed associations between maternal pre-pregnancy obesity and a variety of neurobehavioral outcomes. These relationships varied by sex with larger mean differences generally observed among male offspring. These findings support the impact of pre-pregnancy BMI as a contributor to adverse neurobehavioral outcomes during early childhood. Further investigation into the biological mechanism is warranted and should include measures of inflammatory biomarkers, measures of the postnatal environment, and multiple informants.

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Highlights.

- Pre-pregnancy obesity is associated with an increase in child's total behavioral problem score.
- Differences in pre-pregnancy obesity and behavior were larger for outcomes reported by teachers.
- There were increased risks of externalizing behavior measured by both mother and teacher-reports.

Table 1.

Demographic and reproductive characteristics by maternal pre-pregnancy BMI categories, 1996–2002, 469 mother-child pairs

Characteristic	Pre-pregnancy BMI Category		
	Normal (n=305) n (%)	Overweight (n=101) n (%)	Obese (n=63) n (%)
Maternal Race			
White, non-Hispanic	232 (76.1)	76 (75.3)	48 (76.2)
Hispanic	30 (9.8)	12 (11.9)	10 (15.9)
Black, non-Hispanic	25 (8.2)	12 (11.9)	3 (4.8)
Other	18 (5.9)	1 (1.0)	2 (3.2)
Maternal Age at Conception			
≤ 25	73 (23.9)	26 (25.7)	12 (19.1)
26– 34	179 (58.7)	59 (58.4)	40 (63.5)
≥ 35	53 (17.4)	16 (15.8)	11 (17.5)
Maternal Education (years)			
< 12	23 (7.5)	10 (9.9)	7 (11.1)
12	58 (19.0)	20 (19.8)	14 (22.2)
13–15	65 (21.3)	34 (33.7)	16 (25.4)
≥ 16	158 (51.8)	37 (36.6)	26 (41.3)
Missing	1 (0.3)	0 (0.0)	0 (0.0)
Marital Status			
Married/Cohabitating	268 (87.8)	91 (90.1)	58 (92.1)
Single/Divorced/Separated	37 (12.1)	10 (9.9)	5 (7.9)
Family Income (USD)			
≤ 25,000	45 (14.8)	16 (15.8)	17 (27.0)
25,001 – 35,000	31 (10.2)	15 (14.9)	9 (14.3)
35,001 – 65,000	88 (28.9)	42 (41.6)	24 (38.1)
≥ 65,000	127 (41.6)	24 (23.8)	11 (17.5)
Missing	14 (4.6)	4 (4.0)	2 (3.2)
Parity			
0	140 (45.9)	41 (40.6)	25 (39.7)
1	113 (37.1) 52	38 (37.6)	22 (34.9)
≥2	(17.1)	22 (21.8)	16 (25.4)
Periconceptional[a] Smoking			
Non-smoker	267 (87.5)	84 (83.2)	55 (87.3)
Smoker	38 (12.5)	17 (16.8)	8 (12.7)

Characteristic	Pre-pregnancy BMI Category		
	Normal (n=305) n (%)	**Overweight (n=101) n (%)**	**Obese (n=63) n (%)**
Periconceptional[a] Alcohol Use			
Non-Drinkers	148 (48.5)	61 (60.4)	35 (55.6)
< 3 per sitting	72 (23.6)	17 (16.8)	11 (17.5)
≥ 3 per sitting	85 (27.9)	23 (22.8)	17 (27.0)
Infant Sex at Birth			
Female	150 (49.2)	57 (56.4)	32 (50.8)
Male	155 (50.8)	44 (43.6)	31 (49.2)
Child Age at Assessments (years)			
5–6	140 (45.9)	49 (48.5)	22 (34.9)
7	113 (37.0)	38 (37.6)	31 (49.2)
8–11	52 (17.0)	14 (13.9)	10 (15.9)

[a]Periconceptional defined as the lunar month before and after the last menstrual period.

Table 2.

Adjusted and Weighted Mean differences between maternal pre-pregnancy BMI category and change in t-score for CBCL and TRF.

	Normal n=304	Overweight n=101			Obese n=63		
	Mean ± SD	Mean ± SD	Adjusted MD (95% CI)[a]	SIPW-Adjusted MD (95% CI)[b]	Mean ± SD	Adjusted MD (95% CI)[a]	SIPW-Adjusted MD (95% CI)[b]
CBCL							
Total Problems	47.0 ±10.1	47.3 ± 9.6	0.0 (−2.4, 2.3)	−0.1 (−2.5, 2.3)	48.6 ± 12.1	1.7 (−1.2, 4.5)	0.7 (−2.2, 3.6)
Externalizing	47.2 ± 9.6	48.2 ± 9.2	0.9 (−1.3, 3.1)	0.9 (−1.3, 3.2)	48.7 ± 10.9	1.6 (−1.0, 4.3)	0.6 (−2.2, 3.3)
Internalizing	48.4 ± 9.7	48.1 ± 8.8	−0.4 (−2.6, 1.8)	−0.4 (−2.6, 1.8)	49.1 ± 10.9	0.7 (−1.9, 3.4)	0.3 (−2.4, 3.0)
Anxious/Depressed	53.8 ± 5.7	52.6 ± 4.1	−1.2 (−2.5, 0.1)	−1.3 (−2.6, 0.0)	53.9 ± 7.1	0.2 (−1.3, 1.8)	−0.2 (−1.8, 1.4)
Withdrawn/Depressed	52.6 ± 4.4	52.6 ± 3.9	0.1 (−0.9, 1.1)	0.1 (−1.0, 1.1)	53.2 ± 5.0	0.7 (−0.5, 1.9)	0.5 (−0.7, 1.8)
Somatic Complaints	54.0 ± 5.4	54.6 ± 5.5	0.5 (−0.8, 1.8)	0.5 (−0.8, 1.9)	55.3 ± 6.9	1.2 (−0.3, 2.8)	1.3 (−0.3, 2.9)
Social Problems	53.1 ± 4.5	52.5 ± 3.5	−0.7 (−1.7, 0.4)	−0.8 (−1.9, 0.3)	53.5 ± 6.3	0.3 (−0.9, 1.6)	−0.2 (−1.5, 1.2)
Thought Problems	53.6 ± 5.4	53.5 ± 5.2	0.0 (−1.3, 1.3)	−0.2 (−1.5, 1.1)	55.5 ± 7.2	2.0 (0.4, 3.5)	1.4 (−0.2, 3.0)
Attention Problems	53.3 ± 5.5	53.4 ± 5.0	0.1 (−1.2, 1.3)	0.2 (−1.1, 1.4)	54.7 ± 6.7	1.5 (−0.1, 3.0)	1.1 (−0.4, 2.7)
Rule−Breaking Behavior	52.9 ± 4.3	53.5 ± 4.8	0.6 (−0.5, 1.7)	0.6 (−0.4, 1.7)	53.9 ± 5.6	1.1 (−0.2, 2.3)	0.8 (−0.5, 2.1)
Aggressive Behavior	53.1 ± 5.1	52.9 ± 5.2	−0.1 (−1.3, 1.2)	−0.1 (−1.3, 1.2)	54.3 ± 7.5	1.3 (−0.1, 2.8)	0.9 (−0.6, 2.4)
TRF							
Total Problems	47.8 ± 9.3	48.8 ± 9.8	0.5 (−1.7, 2.6)	0.7 (−1.5, 2.8)	51.0 ± 10.4	3.2 (0.6, 5.7)	3.1 (0.5, 5.7)
Externalizing	48.4 ± 8.0	49.2 ± 8.8	0.4 (−1.4, 2.3)	0.3 (−1.6, 2.2)	49.4 ± 9.9	1.2 (−1.1, 3.4)	1.2 (−1.1, 3.5)
Internalizing	48.0 ± 8.6	47.1 ± 8.7	−1.3 (−3.3, 0.7)	−1.0 (−3.0, 1.0)	50.8 ± 10.1	2.7 (0.2, 5.1)	3.3 (0.8, 5.7)
Anxious/Depressed	53.4 ± 4.8	52.7 ± 4.4	−1.0 (−2.1, 0.2)	−0.8 (−1.9, 0.4)	54.7 ± 7.0	1.2 (−0.2, 2.6)	1.3 (−0.1, 2.7)
Withdrawn/Depressed	52.5 ± 4.2	52.9 ± 4.7	0.2 (−0.9, 1.2)	0.3 (−0.7, 1.4)	54.1 ± 5.9	1.5 (0.3, 2.8)	1.6 (0.3, 2.8)
Somatic Complaints	51.9 ± 4.5	52.1 ± 4.9	0.0 (−1.1, 1.1)	0.1 (−1.0, 1.2)	53.8 ± 6.0	1.9 (0.5, 3.2)	2.6 (1.2, 3.9)
Social Problems	53.3 ± 4.6	53.6 ± 5.1	0.1 (−1.1, 1.3)	0.0 (−1.2, 1.1)	55.3 ± 7.5	2.0 (0.6, 3.4)	2.0 (0.5, 3.4)
Thought Problems	52.5 ± 5.1	52.0 ± 4.7	−0.5 (−1.7, 0.7)	−0.1 (−1.3, 1.1)	54.2 ± 6.6	1.7 (0.2, 3.1)	1.6 (0.2, 3.1)
Attention Problems	53.3 ± 5.3	54.0 ± 5.5	0.5 (−0.8, 1.7)	0.8 (−0.5, 2.0)	54.3 ± 6.5	0.9 (−0.5, 2.4)	0.7 (−0.9, 2.2)
Rule−Breaking Behavior	52.4 ± 4.7	53.2 ± 5.2	0.6 (−0.5, 1.7)	0.5 (−0.6, 1.7)	53.7 ± 6.1	1.4 (0.1, 2.8)	1.3 (−0.1, 2.6)
Aggressive Behavior	52.8 ± 4.9	53.2 ± 5.6	0.3 (−0.9, 1.5)	0.2 (−1.0, 1.4)	53.7 ± 7.6	1.0 (−0.5, 2.5)	1.0 (−0.5, 2.4)

[a]Adjusted for maternal age, maternal education, marital status, periconceptional alcohol use, and periconceptional smoking.

[b] Adjusted for maternal age, maternal education, marital status, periconceptional alcohol use, periconceptional smoking, and weighted by stabilized inverse probabilities of participation (SIPW).

Table 3.

Risk ratios and 95% confidence intervals for pre-pregnancy BMI category and borderline/clinical scores of CBCL and TRF broadband scales, adjusted, and SIPW models.

	Normal weight n=304	Overweight n=101		Obese n=63	
	n (%) Borderline/Clinical	n (%) Borderline/Clinical	SIPW-Adjusted RR (95% CI) [a]	n (%) Borderline/Clinical	SIPW-Adjusted RR (95% CI) [a]
CBCL					
Total Problems	34 (11.2)	10 (9.9)	0.9 (0.4, 1.7)	8 (12.7)	0.9 (0.4, 2.2)
Externalizing	32 (10.5)	13 (12.9)	1.4 (0.8, 2.6)	11 (17.5)	1.6 (0.8, 3.2)
Internalizing	40 (13.1)	12 (12.9)	0.8 (0.4, 1.5)	9 (14.3)	1.0 (0.5, 2.1)
TRF					
Total Problems	40 (13.1)	18 (17.8)	1.4 (0.8, 2.3)	13 (20.6)	1.5 (0.8, 2.7)
Externalizing	27 (8.9)	16 (15.8)	1.5 (0.8, 2.8)	9 (14.3)	1.7 (0.8, 3.5)
Internalizing	30 (9.8)	11 (10.9)	1.1 (0.6, 2.2)	15 (23.8)	2.6 (1.5, 4.6)

n/c: not calculated, model did not converge

[a] Adjusted for maternal age, maternal education, marital status, periconceptional alcohol use, periconceptional smoking, and weighted by stabilized inverse probabilities of participation (SIPW).

Table 4.

Mean Differences for CBCL and TRF t-scores by pre-pregnancy BMI category, adjusted and SIPW-adjusted, stratified by child's sex.

	Mean Difference and 95 % CI[a]			
	Overweight		Obese	
	Females n=57	Males n=44	Females n=32	Males n=31
CBCL				
Total Problems	1.1 (−1.8, 4.1)	−1.2 (−5.0, 2.6)	−0.4 (−4.1, 3.3)	1.6 (−2.9, 6.1)
Externalizing	2.4 (−0.4, 5.1)	−0.3 (−3.9, 3.2)	0.0 (−3.4, 3.5)	1.1 (−3.2, 5.3)
Internalizing	0.1 (−2.8, 3.0)	−1.0 (−4.5, 2.4)	−1.6 (−5.3, 2.0)	2.2 (−1.8, 6.3)
Anxious/Depressed	−0.7 (−2.3, 0.9)	−2.0 (−4.1, 0.0)	−0.9 (−3.0, 1.1)	0.2 (−2.2, 2.7)
Withdrawn/Depressed	0.5 (−0.7, 1.7)	−0.4 (−2.1, 1.3)	−0.4 (−1.9, 1.1)	1.4 (−0.6, 3.4)
Somatic Complaints	1.0 (−0.7, 2.7)	0.0 (−2.1, 2.1)	1.1 (−1.0, 3.2)	1.5 (−1.0, 3.9)
Social Problems	−0.7 (−2.0, 0.6)	−0.7 (−2.5, 1.1)	−0.3 (−1.9, 1.3)	−0.4 (−2.5, 1.7)
Thought Problems	1.1 (−0.4, 2.5)	−1.4 (−3.6, 0.8)	1.3 (−0.5, 3.1)	1.3 (−1.3, 3.9)
Attention Problems	0.8 (−0.7, 2.2)	−0.1 (−2.2, 1.9)	0.2 (−1.6, 2.1)	1.5 (−0.9, 4.0)
Rule-Breaking Behavior	0.8 (−0.6, 2.1)	0.5 (−1.1, 2.2)	0.4 (−1.3, 2.0)	1.3 (−0.6, 3.3)
Aggressive Behavior	0.4 (−1.0, 1.8)	−0.4 (−2.5, 1.7)	0.3 (−1.4, 2.0)	1.1 (−1.3, 3.6)
TRF				
Total Problems	−0.3 (−3.2, 2.5)	1.5 (−1.7, 4.7)	2.3 (−1.3, 6.0)	3.9 (0.1, 7.7)
Externalizing	−0.4 (−2.9, 2.1)	0.9 (−2.0, 3.8)	1.0 (−2.1, 4.1)	1.6 (−1.8, 5.0)
Internalizing	−2.2 (−4.8, 0.4)	0.1 (−2.9, 3.2)	2.5 (−0.8, 5.8)	3.5 (−0.1, 7.2)
Anxious/Depressed	−1.4 (−2.8, 0.1)	−0.2 (−2.0, 1.6)	1.4 (−0.4, 3.2)	1.0 (−1.1, 3.2)
Withdrawn/Depressed	0.0 (−1.4, 1.3)	0.6 (−1.1, 2.2)	0.2 (−1.5, 1.8)	2.7 (0.8, 4.7)
Somatic Complaints	−1.2 (−2.7, 0.4)	1.2 (−0.4, 2.7)	2.7 (0.7, 4.7)	2.5 (0.7, 4.3)
Social Problems	−0.5 (−2.1, 1.2)	0.3 (−1.3, 2.0)	2.1 (0.1, 4.2)	1.8 (−0.2, 3.8)
Thought Problems	−0.8 (−2.0, 0.4)	0.6 (−1.5, 2.7)	0.5 (−1.0, 2.0)	2.6 (0.2, 5.1)
Attention Problems	0.5 (−1.2, 2.2)	1.0 (−0.9, 2.9)	1.1 (−1.1, 3.2)	0.5 (−1.7, 2.8)
Rule-Breaking Behavior	0.7 (−0.8, 2.1)	0.4 (−1.4, 2.2)	1.0 (−0.9, 2.8)	1.8 (−0.4, 3.9)
Aggressive Behavior	−0.2 (−1.8, 1.5)	0.5 (−1.3, 2.3)	1.2 (−0.9, 3.2)	1.1 (−1.1, 3.2)

[a]Adjusted for maternal age, maternal education, marital status, periconceptional alcohol use, periconceptional smoking, and weighted by stabilized inverse probabilities of participation (SIPW).