Adiposity, psychomotor and behaviour outcomes of children born after maternal bariatric surgery

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Short title: Adiposity and behavior of children after maternal bariatric surgery.

Keywords: Maternal obesity, Pediatric obesity, Maternal bariatric surgery

Abstract

Background: Bariatric surgery before pregnancy can result in improved maternal fertility. However, long-term data on the consequences at childhood age are currently lacking.

Methods: EFFECTOR is a prospective cohort study of children (aged 4 to 11 years) born to mothers who underwent bariatric surgery (BS) before pregnancy (n= 36), controls with overweight/obesity (OW/OB) matched on pre-pregnancy BMI (n=36) and normal weight controls (NL) (n=35). We performed prospective collection of anthropometric data, data on psychomotor development, school functioning and behavior (Strengths and Difficulties Questionnaire (SDQ), Child Behavior Checklist (CBCL))

Results: The children born after bariatric surgery (BS) presented with the highest body weight SDS (0.70 vs. 0.14 in OW/OB and -0.09 in NL; p=0.006).and BMI SDS (0.47 vs. -0.02 in OW/OB and -0.42 in NL; p=0.01). A higher excess in body fat percentage and waist circumference SDS were found in the BS group (5.7 vs. 1.4 in OW/OB and -0.1 in NL; p<0.001 and 0.61 vs. 0.16 in OW/OB and -0.15 in NL; p=0.04). The SDQ questionnaires revealed a higher amount of overall problems in the BS offspring (11.1 vs. 7.5 in OW/OB and 8.1 in NL; p = 0.03), with a higher Externalizing score at the CBCL (52.0 vs. 44.2 in OW/OB and 47.0 in NL; p=0.03).

Conclusion: Maternal bariatric surgery does not appear to protect the offspring for childhood overweight and obesity. Parents reported more behavior problems in these children, especially externally of nature.

Main manuscript

Introduction

Current health care approaches fail to put a stop to the rising prevalence of overweight and obesity, causing a pandemic in all age groups of society. [1] Since the WHO reports a worldwide prevalence of 18% of overweight or obesity in children aged 5 to 19 years and this problem is likely to persist into adulthood, the prevention of childhood obesity is crucial for future generations. [2-4]

Maternal obesity during pregnancy is a known risk factor for childhood obesity and behavioral problems. [5-12] It also increases the risk for fetal macrosomia, large-for-gestational-age infants and pregnancy complications. [6,13] Lifestyle-interventions during pregnancy do not always result in sustainable weight loss nor improved neonatal outcomes. [14] Therefore, bariatric surgery before pregnancy has gained some more popularity since this can offer advantages for both mother and child. [15] However, certain birth and neonatal risks have been reported; such as a higher prevalence of growth retardation in utero, congenital abnormalities, and premature delivery. [15]

A substantial hiatus in the current literature is the lack of long-term outcomes in the offspring of mothers who underwent bariatric surgery before pregnancy. The scarce available data is heterogeneous and the focus has mainly been on short-term neonatal outcomes. [16,17]

In order to counsel our patients in a correct way, we urgently need data on the long-term effects of the surgery techniques that are currently used.[18] In this study, we prospectively studied growth and development of the offspring of mothers who underwent bariatric surgery before pregnancy and compared them to the offspring of controls with a comparable pre-pregnancy BMI and normal weight controls.

Methods

Study design

The EFFECTOR-study is a prospective cohort study of the offspring of different maternal cohort studies.(16) (Figure 1) The study obtained approval from the Ethics Committee UZ Brussels and the Ethics Committee UZ Leuven/KU Leuven and was registered at ClinicalTrials.gov (NCT02992106). A written informed consent was obtained from the parents and each child received age-adjusted information through an assent. A total of 143 children were included between June 2017 and March 2019. Overall participation rate of 48.6% (143/294) was reached due to a large amount of lost-to-follow-up (107/294; because of missing or changed contact details). The participation rate of parents who were actually reached was 76.5% (143/187). (Figure 2) The maternal and neonatal characteristics across the included subjects and the ones that were lost-to-follow-up or refused to participate were comparable.

In total, 36 children born after maternal bariatric surgery (n= 36) could be studied (BS group). Outcome data in these children were compared with two control groups: offspring of mothers who had overweight or obesity (BMI ≥ 25 kg/m²) at the start of pregnancy (n=71) (OW/OB group) and offspring of mothers who had a normal BMI (BMI ≥ 18.5 and ≤ 25 kg/m²) at the start of pregnancy (n=36) (NL group). In the latter group, we excluded one child from the analysis because the parents did not complete the questionnaires. In order to have the best matching control group regarding degree of obesity of the mother before and during pregnancy, we selected the best 36 matching subjects in the OW/OB control group based on pre-pregnancy maternal BMI and gender of the children (paired matching).

Studied outcomes

Maternal and neonatal data were used as secondary analysis from the originating, prospective studies in the past. [19] Standardized definitions were used for the outcomes and comorbidities.

The follow-up data were prospectively collected during a single home visit, which was performed by the same trained pediatric physician. All anthropometric measurements were performed according to the “International society for the advancement of kinanthropometry”. [20] BMI was calculated and expressed as SD score according to the national reference data. [21]

Additional data were collected through parental questionnaires. A questionnaire on socio-demographic characteristics and developmental milestones was specifically designed for the study. The Strengths and Difficulties Questionnaire (SDQ) and the Child Behavior Checklist (CBCL) were used to screen for psychopathology. [22,23] The parental version of the Pediatric Quality of Life Inventory (PEDS QL) was used to assess the quality of life. [24] Age-specific and standardized scores were used where applicable.

Statistical analyses

All statistical analysis were performed using SPSS version 25. Descriptive statistics were used to describe the population characteristics according to the different subgroups. For continuous variables, after testing for normality, one-way ANOVA tests with post-hoc testing were used to investigate differences across the groups. Data are presented as mean ± standard deviation. Chi-Square tests were used for the comparison of categorical variables. Data are presented as proportions. Additional Pearson Correlation as well as ANCOVA tests were performed. Factorial ANOVA analyses were conducted on the main adiposity outcomes including a set of confounders. The set of confounders consisted of the age of the children, maternal pre-pregnancy BMI, the birth weight SDS, the original maternal cohort, the gender of the child, maternal smoking behavior and maternal education level. These variables were chosen because all of them have a known influence on the adiposity in children. The F-ratio was reported as indication for the goodness of fit of the model. P values below 0.05 were considered statistically significant.

Results

1. Maternal characteristics during pregnancy (Table1)

Despite having a comparable age, there were more nulliparous women in the normal weight control group (NL) (p=0.05). There was no difference in the pre-pregnancy BMI of the women after bariatric surgery (BS) compared to the women of the control group with overweight/obesity (OW/OB) (p=0.10). The mean interval between surgery and pregnancy was almost 4 years (mean 47.4 months; ranging from 2 to 113 months); 8/36 (22.2%) got pregnant within the first year after the weight-loss procedure. The majority of the women underwent a Gastric Bypass Surgery (n=24; 66.7%), the others underwent a LABG (n=10; 27.8%) or a Scopinaro Procedure (n=2; 5.6%). The difference in maternal BMI (pre-surgery to pre-pregnancy) was comparable in all studied BS women.

In the BS group, 21/36 (58.3%) women had GWG above the recommended 9 kg and a significant higher percentage of BS women smoked during pregnancy (27.8% vs. 8.3% in OW/OB and 8.6% in NL; p=0.03). On the other hand, more women in the OW/OB group had arterial hypertension during pregnancy (38.9% vs. 19.4% in BS and 2.9% in NL; p=0.001).

2. Neonatal characteristics at birth (Table 1)

Mean gestational age at the moment of delivery and gender distribution was not different between the groups. The BS neonates had the lowest birth weight SD score (-0.26 vs. 0.34 in OW/OB and -0.09 in NL; p=0.04) and smallest birth height SD score (-0.18 vs. 0.36 in OW/OB and 0.04 in NL; p=0.04). The prevalence of SGA after bariatric surgery and LGA in the OW/OB control group were higher, however both not significant (p = 0.13 and p = 0.08). The prevalence of macrosomia was highest in the OW/OB group (22.2% vs. 8.3% in BS and 2.9% in NL; p=0.03). In the OW/OB group, there was one infant who presented with a congenital abnormality (toxoplasmosis seroconversion during pregnancy with asymptomatic ventriculomegaly). The percentage of women who initiated breastfeeding after childbirth was the lowest in the BS group (41.7% vs. 66.7% in OW/OB and 91.4% in NL: p<0.001).

3. Anthropometric measurements at follow-up (Table 2)

Because of the difference in recruitment period of the original maternal participants (Figure 1), the BS children were significantly younger than the children of the other two groups (resp. mean age 6.5 years vs. 10.8 years and 10.5 years) (p<0.001).

The children in the BS group presented with the highest body weight and BMI SD scores (0.70 vs. 0.14 in OB and -0.09 in NL; p=0.006 and 0.47 vs. -0.02 in OW/OB and -0.42 in NL; p=0.01). Weight SD did not correlate with birth weight SD (R=0.053, p= 0.59). BS children showed the highest relative weight gain, expressed as current body weight SD - birth weight SD. (0.97 vs. -0.19 in OW/OB and 0.01 in NL; p=0.001) (data not shown). The offspring of the BS group also presented with the highest excess fat percentage and waist SD scores (5.7 vs. 1.4 in OW/OB and -0.1 in NL; p<0.001 and 0.61 vs. 0.16 in OB and -0.15 in NL; p=0.04).

In order to explore the influence of maternal education level and smoking behavior on these differences, regression analysis with variance analysis were performed. Maternal smoking could be present or absent and the maternal education consisted of two levels (high school level or higher). These only showed a significant effect on the excess of fat percentage measured by BIA at childhood age. All effects were statistically significant at the 0.05 level. The main effect for maternal smoking yielded an F ratio of F(1,84)=6.48; p=0.01 and the main effect for maternal education level yielded an F ratio of F(1,84)=4.56; p=0.04. The interaction effect was not significant F(1;84)=1.53; p=0.22.

4. Development and behavior (Table 3)

The lowest levels of education in both parents were observed in the BS group. There was a trend towards a more frequently delayed milestones attainment in the offspring after BS (18.7%

vs. 8.8% in OW/OB and 6.1% in NL; p =0.23) while no difference in attending special education or repeating of a class were observed between the groups. The parents in all groups reported a comparable amount of behavior or mental health problems in their children.

Analysis of the Strengths and Difficulties questionnaires revealed a higher amount of overall problems in the BS group (11.1 vs. 7.5 in OW/OB and 8.1 in NL; p = 0.03). The overall problem score (p=0.1) and the internalizing problems scale (p=0.42) at the CBCL did not differ across the groups. However, the Externalizing score of the CBCL was the highest in the BS group (52.0 vs. 44.2 in OW/OB and 47.0 in NL; p=0.03). The quality of life, questioned through the PEDS-QL questionnaire, was comparable in all children (p=0.50).

Discussion

This study represents the first controlled long-term follow-up of children born after maternal bariatric surgery. While these children have the lowest weight and BMI SD scores at birth, they have the highest adiposity parameters at school age. Despite a comparable school career, their parents reported more behavior problems, especially externally of nature. Maternal bariatric surgery therefore does not appear to improve long-term outcome in the children.

Maternal and neonatal differences

Most differences found in the maternal characteristics during pregnancy are easily explained by the nature of the recruited cohorts. The pre-pregnancy BMI is indeed a discriminatory variable. As expected, GWG was inversely related to the maternal BMI at the start of pregnancy. [25]

Despite a similar age at inclusion, there were more nulliparous women in the normal weight controls. Parity is a known risk factor for obesity and could therefore have contributed to the overrepresentation in both the OW/OB and BS group. The women included in the normal weight group were not matched for parity to the women with obesity. The exclusion criteria of the original study also account for the absence of women with GDM in the group of women with overweight/obesity. [26] Parity and GDM differences between the groups might have influenced the adiposity outcomes at neonatal and childhood age.

The prevalence of arterial hypertension, a risk factor for decreased birth weight, was as expected higher in the subgroup of women with overweight and obesity [13,27], explaining in part the lower prevalence of LGA infants than expected in this OW/OB group.

Children born after bariatric surgery, presented with the smallest weight and length SDS at birth. Although not significant, a tendency towards a higher prevalence of SGA after bariatric surgery and LGA in the control group with overweight/obesity was observed, in line with previous studies. [13,15]

The higher prevalence of smoking in the group after bariatric surgery fits with the increase in substance use seen after bariatric surgery and lower education level. [28] It has been suggested that this group of patients are vulnerable to the transfer of "food addiction" to other addictive behavior after the surgical procedure. [29,30]

The rates of breastfeeding initiation were the lowest in women who underwent bariatric surgery. We know that a higher pre-pregnancy BMI is associated with a decreased breastfeeding intention and initiation due to a combination of anatomical, sociocultural and psychological factors. [31-33]

Childhood anthropometry and adiposity

The age difference at evaluation between the groups is an inevitable consequence of the timing of recruitment in the original cohorts. We included the children in chronologic order, starting with the oldest. Age related SD-scores for the anthropometric and behavior measurements were therefore used.

In our study, children born after bariatric surgery had the highest body weight and BMI SD scores at evaluation. In contrast, a Canadian study previously reported a decreased prevalence of childhood obesity after maternal bariatric surgery [16,34], however using a different design, by using siblings as controls. The mean maternal pre-pregnancy BMI in these studied children decreased respectively from 46.5 to 30.6 kg/m² and from 48.0 to 31.0 kg/m². [16,34]Therefore, the reported decrease in prevalence of childhood obesity after maternal BS might be explained by a dose-response association between the maternal pre-pregnancy BMI and the risk on childhood obesity. [7] In our BS group, the mean BMI before surgery was 43.0 kg/m² and declined to 29.5 kg/m² before pregnancy. The research group from Karolinska University in Stockholm, Sweden, used register data on childhood BMI before and after bariatric surgery with partly sibling controls. [35] They could not find a decrease in the prevalence of childhood obesity, moreover reported an increased risk for obesity in 10-year old girls of which a larger proportion was born SGA. [35] Subsequently, we also found the highest gain in SD score for weight in the SGA subgroup (data not shown). Therefore, a probable predisposition for an early adiposity rebound following their smaller birth weight and length might also play a role. [36,37]

Childhood behavior

Overall, milestones achievement, the children's educational level and reported repeats of a class are comparable across the groups. In all the groups, parents reported pathologies associated with an impact on neurologic or psychosocial functioning of the children. These figures are comparable with the prevalence of mental disorders at childhood age. [38]

Despite the comparable education attendance, some differences appeared in the behavior questionnaires. After bariatric surgery, the overall problem score in the children was higher compared to their peers in the two control groups. The results of the CBCL revealed more externalizing problems in this group of children, meaning parents observed more aggressive and rule-breaking behavior. The behavior in this group of children remains understudied until now, so caution is needed when interpreting these results. An association between maternal obesity during pregnancy and behavioral difficulties in their offspring has been reported by recent studies respectively at the age of 4, 5, 7 and 9-11 years old. [8-11,39] A longitudinal American study showed higher externalizing behavior in boys at the age of 9-11 years when the mother had a higher pre-pregnancy weight.[39] Similar increase in externalizing problems has been reported by other authors as well. [10,40] However, based on our own cross-sectional results, we have no proof for causality. We did find that the mothers of the BS group had a lower education level compared to the others. This might also contribute since a lower maternal education level correlates with behavior problems in her children. [41]

All of the above findings regarding the anthropometrics and behavior outcomes in the group of children after bariatric surgery makes us think about the role of bariatric surgery before pregnancy. The offspring of the normal weight control group still have the most favorable growth and development profile. It seems as if the bariatric surgery cannot undo all 'evil' since it does not tackle the multifactorial causes of obesity. Therefore, clinicians should always outweigh the benefits for the pregnancy to the possible adverse effects for the children on the longer run before performing bariatric surgery. Emphasis should be made on performing pre-conceptual counselling before surgery, improving the lifestyle of women after bariatric surgery and giving advice to postpone a pregnancy until two years after surgery. In addition, future research and clinical practice should aim to provide a regular, prospective follow-up for body composition and psychomotor development of children born after maternal pre-pregnancy bariatric surgery.

Strengths

This is the first study to show that, although bariatric surgery seams to improve neonatal outcomes, long-term childhood outcomes might be worse. The strength of the study is its pioneering nature, since there is no other long-term data available compared to matched cases with overweight/obesity and cases with normal weight. The number of children in each group is satisfactory, taken into account that all data was collected in a standardized manner during a home visit and there is an average difference of 10 years between the original and follow-up study.

Limitations

The age difference across the groups is the most limiting factor of our current study. With the use of SD scores and the fact that the majority of the children were pre-pubertal, we are convinced that groups are comparable. However, since we do not have information on the growth trajectories, some caution is needed. Because of the single study visit and cross-sectional design, we also might have missed possible confounders. Another limiting factor are the differences in maternal education level and smoking behavior across the groups. The choice for the paired matching on pre-pregnancy BMI differs from a matching on pre-surgery BMI, the pre-pregnancy BMI of the mothers in the overweight/obesity group was insufficient to match on pre-surgery BMI.

Conclusion

We presented pioneering long-term growth and development data on the offspring born after maternal bariatric surgery. Although presenting with the smallest birth weight, these children had the highest weight and BMI at childhood age. Despite a comparable school career, their parents reported more behavior problems, especially externally of nature. These findings stress the importance of the prevention of obesity in women of childbearing age to prevent them from needing bariatric surgery before pregnancy.

List of abbreviations

BIA: Bioelectrical impedance analysis

BMI: Body Mass Index

BS: Bariatric Surgery group

CBCL: Child Behavior Checklist

GDM: Diabetes Mellitus Gravidarum

GWG: Gestational Weight Gain

LABG: Laparoscopic Adjustable Gastric Banding procedure

NICU: Neonatal Intensive Care Unit

NL: Normal Weight Control group

OW/OB: Control group with Overweight/Obesity

PEDSQL: Pediatric Quality of Life Inventory

SDS: Z-score according to Belgian growth data

SDQ: Strengths and Difficulties Questionnaire

Figures and tables legends:

- Figure 1: This figure provides an overview of the study design.
- Figure 2: This figure contains a flow chart of the inclusion process.
    - Footnote for figure 2: Flow of inclusion: All eligible study subjects did receive a letter by mail. One to two weeks later, they received a text-message. Afterwards we tried to contact them at least twice by phone call and left at least one message on their voicemail. When the phone number was no longer in use, a second letter was sent by mail.
- Table 1: Cohort characteristics during pregnancy and at birth
- Table 2: Body composition children
- Table 3: Psychomotor development and behavior outcomes

Contributors' Statement

Drs. Van De Maele conceptualized and designed the study, performed data collection, supervised the analyses and reviewed and revised the manuscript.

Prof. De Schepper, Prof. Bogaerts, Prof Provyn, Dr Ceulemans and Mrs Guelinckx critically reviewed and revised the manuscript.

Prof. Gies and Prof. Devlieger conceptualized and designed the study, drafted the initial manuscript and reviewed and revised the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Conflict of Interest

The authors have no potential conflicts of interest to disclose.

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Table 1: Cohort characteristics during pregnancy and at birth

	Bariatric surgery N= 36	Control group with Overweight/Obesity N= 36	Control group with normal weight N= 35	Overall p-value
Maternal characteristics pregnancy				
Age (years)	30.2 ± 4.2	29.5 ± 3.7	29.5 ± 3.6	0.67
Parity	1 ± 1	1 ± 1	0 ± 1	0.05
Pre-pregnancy BMI (kg/m²)	29.5 ± 5.0	31.2 ± 3.3	21.8 ± 1.8	**<0.001****
Gestational Weight Gain (kg)	10.9 ± 8.7	11.0 ± 6.2	14.8 ± 4.0	**0.02***
Interval surgery-pregnancy (months)	47.4 ± 37.1	N/A	N/A	N/A
Gestational Age at Delivery (weeks)	38.7 ± 2.2	38.8 ±2.6	39.1 ± 1.2	0.74
Complications				
- Gestational Diabetes	2/36 (5.6%)	0/36	0/35	0.13
- Arterial Hypertension	7/36 (19.4%)	**14/36 (38.9%)**	1/35 (2.9%)	**0.001****
- Pre-eclampsia	2/36 (5.6%)	2/36 (5.6%)	0/35	0.36
- Macrosomia (= > 4000g)	3/36 (8.3%)	8/36 (22.2%)	1/35 (2.9%)	**0.03***
	3/36 (8.3%)	2/36 (5.6%)	1/35 (2.9%)	0.60

- Premature delivery (<37 weeks)				
Cesarean Section (%)	8/36 (22.2%)	8/36 (22.2%)	4/35 (11.4%)	0.75
Smoking (%)	10/36 (27.8%)	3/36 (8.3%)	3/35 (8.6%)	**0.03***
Neonatal characteristics				
Gender	17 Female 19 Male	17 Female 19 Male	18 Female 17 Male	0.92
Birth weight (kg)	3.2 ± 0.6	3.5 ± 0.7	3.3 ± 0.4	0.08
Birth weight SDS	-0.26 ± 1.02	0.34 ± 1.02	-0.09 ± 0.96	**0.04***
Birth length (cm)	49.4 ± 2.9	50.4- ± 4.0	50.3 ± 1.8	0.33
Birth length SDS	-0.18 ± 0.89	0.36 ± 0.86	0.04 ± 0.94	**0.04***
Small For Gestational Age (%)	6/36 (16.7%)	1/36 (2.8%)	3/35 (8.6%)	0.13
Large For Gestational Age (%)	2/36 (5.6%)	7/36 (19.4%)	2/35 (5.7%)	0.08
NICU admission (%)	4/36 (11.1%)	6/36 (16.7%)	1/35 (2.9%)	0.16
Congenital abnormalities (%)	0/36	1/36 (2.8%)	0/35	0.37
Breastfeeding initiation	15/36 (41.7%)	24/36 (66.7%)	32/35 (91.4%)	**<0.001****

Data are presented as mean ± standard deviation or number (proportions). * P-value below 0.05; ** P-value below 0.001. Abbreviations: **BMI** body mass index; **SDS** Z-score according to Belgian growth data; **NICU** Neonatal Intensive Care Unit

Table2: Body composition children

	Bariatric surgery N= 36	Control group with Overweight/Obesity N= 36	Control group with normal weight N= 35	Overall p-value
Anthropometric characteristics children				
Age (years)	6.5 ± 1.3	10.8 ± 0.3	10.6 ± 0.2	<0.001**
Gender	17 Female 19 Male	17 Female 19 Male	18 Female 17 Male	0.92
Weight SDS	0.70 ± 1.27	0.14 ± 0.99	-0.09 ± 0.84	0.006*
Height SDS	0.64 ± 0.92	0.33 ± 0.97	0.42 ± 0.81	0.35
BMI SDS	0.47 ± 1.50	-0.02 ± 1.01	-0.42 ± 1.06	0.01*
Fat Percentage BIA (%)	23.4 ± 5.2	21.9 ± 6.3	20.2 ± 4.4	0.61
Fat excess BIA † (%)	5.7 ± 5.1	1.4 ± 5.4	-0.1 ± 4.1	<0.001**
Fat Percentage Slaughter Formula (%)	19.7 ± 6.6	20.0 ± 8.2	18.3 ± 6.4	0.89
Waist SDS	0.61 ± 1.54	0.16 ± 1.09	-0.15 ± 1.12	0.04*
Waist – to – hip Ratio	0.86 ± 0.05	0.82 ± 0.04	0.83 ± 0.05	0.001**

Waist – to – height Ratio	0.47 ± 0.06	0.43 ± 0.05	0.41 ± 0.04	**<0.001****

Data are presented as mean ± standard deviation or number (proportions). * P-value below 0.05; ** P-value below 0.001. Abbreviations: **BMI** body mass index; **SDS** Z-score according to Belgian growth data; **BIA** Bioelectrical impedance analysis

†Calculated to the 50th percentile for age- and gender-specific reference values.

Footnote with supplementary Factorial ANOVA analyses:

The set of confounders consisted of the age of the children, maternal pre-pregnancy BMI, the birth weight SDS, the original maternal cohort, the gender of the child, maternal smoking behavior and maternal education level.

- Interaction of most influencing covariates on BMI SD score at childhood age

Only maternal pre-pregnancy BMI showed significant interaction to the dependent variable. This effect was statistically significant at the 0.05 level. The main effect for maternal pre-pregnancy BMI yielded an F ratio of $F(1,85)=6.55$; $p=0.01$.

- Interaction of most influencing covariates on waist SD score at childhood age

Only maternal pre-pregnancy BMI showed significant interaction to the dependent variable. This effect was statistically significant at the 0.05 level. The main effect for maternal pre-pregnancy BMI yielded an F ratio of $F(1,85)=4.67$; $p=0.03$.

- Interaction of most influencing covariates on waist to hip ratio at childhood age

No statistical significant interactions were found.

- Interaction of most influencing covariates on waist to height ratio at childhood age

Only maternal pre-pregnancy BMI showed significant interaction to the dependent variable. This effect was statistically significant at the 0.05 level. The main effect for maternal pre-pregnancy BMI yielded an F ratio of $F(1,85)=4.87$; $p=0.03$.

Table 3: Psychomotor development and behavior outcomes

	Bariatric surgery N= 36	Control group with Overweight/Obesity N= 36	Control group with normal weight N= 35	Overall p-value
Parental Education level				
Mother High school as highest degree	20/36 (55.6%)	7/36 (19.4%)	5/35 (14.3%)	**<0.001****
Father High school as highest degree	27/34 (79.4%)	16/32 (50.0%)	10/34 (29.4%)	**<0.001****
Aberrant psychomotor development or functioning				
Special education	2/36 (5.6%)	5/36 (13.9%)	1/35 (2.9%)	0.18
Reported repeat of a class	4/36 (11.1%)	2/36 (5.6%)	1/35 (2.9%)	0.36
Reported delayed milestones	6/32 (18.7%)	3/34 (8.8%)	2/33 (6.1%)	0.23
Reported mental health or neurological Problems	8/36 (22.2%)	10/36 (27.8%)	7/35 (20%)	0.73
Specific diagnosis	ADHD (n=2)	ADD (n=1)	ADHD (n=1)	

	Autism (n=1) Behavior problems (n=2) Chronic hydrocephalus (n=1) Dyslexia (n=1) High sensitivity (n=1)	ADHD (n=1) ADHD combined with autism (n=1) Autism (n=2) Behavior problems (n=1) Epilepsy (n=1) Gifted (n=1) Gilles de La Tourette (n=1) Selective mutism with dyscalculia (n=1)	ADHD combined with autism (n=1) Autism (n=2) Behavior problems (n=1) Dyslexia (n=1) Dyslexia with Dysorthography (n=1)	
Behavior Problems				
SDQ Total Difficulties (score)	11.1 ± 6.2	7.5 ± 5.9	8.1 ± 6.0	**0.03***
CBCL Total problems (T-score)	53.3 ± 13.0	46.5 ± 11.6	47.9 ± 12.4	0.10
CBCL Externalizing problems (T-score)	52.0 ± 12.2	44.2 ± 10.2	47.0 ± 10.9	**0.03***
CBCL Internalizing problems (T-score)	53.6 ± 11.2	49.5 ± 12.0	50.6 ± 12.1	0.42

Quality of life (Total PedsQL score)	80.2 ± 15.8	83.2 ± 11.9	84.0 ± 11.4	0.50

Data are presented as mean ± standard deviation or number (proportions). * P-value below 0.05; ** P-value below 0.001. Abbreviations: **ADHD** Attention Deficit Hyperactivity Disorder; **ADD** Attention Deficit Disorder; **SDQ** Strengths and Difficulties Questionnaire; **CBCL** Child Behavior Checklist; **PedsQL** Pediatric Quality of Life Inventory