

Impact of Maternal Body Weight on the Growth of Offspring

Kristina Duh¹, Primož Budic², Aneta Soltirovska Šalamon^{3,4}

¹University Medical Centre Maribor, 2000 Maribor, Slovenia, ²University Medical Centre Ljubljana, 1000 Ljubljana, Slovenia,

³Department of Neonatology, University Children's Hospital, University Medical Centre Ljubljana, 1000 Ljubljana, Slovenia,

⁴Faculty of Medicine, University of Ljubljana, Slovenia

Correspondence: aneta.soltirovska@yahoo.com; Tel.: + 386 1 522 9274; Fax.: + 386 1 522 4035

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Abstract

Objective – Maternal general health and diet prior to and during pregnancy create conditions for intrauterine foetal development. This may influence long-term growth, development and health of the child. The aim of this study was to define the influence of maternal body weight (BW) on offspring growth in early childhood. **Materials and Methods** – 162 Slovenian mothers and their children were included in the study and subsequent analysis. We collected information on anthropometric measurements of mothers prior to and during pregnancy, and of their children (BW, length, head circumference (HC)) up to the age of three. To perform statistical analysis, the Pearson correlation test, linear regression and F-test were utilized. **Results** – A statistically significant association between the mother's BW and newborn BW ($P < 0.01$) and offspring BW up to three years of age ($P < 0.05$) was found. Linear regression showed a positive association between the mother's BW and the newborn's BW ($P < 0.01$) and child's BW at one year of age ($P < 0.05$). Additionally, a significant association between the mother's BW and children's HC at the age of 9 months ($P < 0.05$) was determined and further confirmed by regression analysis. **Conclusion** – The study findings bring to light an important link between maternal BW and offspring growth in early childhood. Furthermore, the findings confirm the relevance of preventive strategies for improving the awareness of the importance of maternal health during pregnancy and the impact it can have on offspring growth.

Key Words: Pregnancy Body Weight ■ Birth Weight ■ Head Circumference ■ Newborns ■ Children.

Introduction

Overweight and obesity are on the rise in developed as well as in developing countries. They represent a significant public health burden as they are associated with an increased risk of type 2 diabetes, various types of cancer, hypertension and cardiovascular diseases which are the most prevalent causes of mortality in Western civilization (1). Although genetic factors undoubtedly contribute to obesity, its development is mainly attributed to lifestyle changes due to urbanization. Such lifestyle is characterized by chronic imbalance of calories (1, 2) due to an abundance of food, high caloric intake and lack of physical activity.

Nutrition in the early stages of life establishes permanent physiological and metabolic determinants that are decisive for the risks of diseases that occur later in life (3). Hence, pregnant women represent an important social group as they are the ones providing early environment to the developing foetus. Mechanisms by which early environment in the period of pregnancy and breastfeeding has a long-lasting effect on child development have not been clarified yet. So far it has been established that a suboptimal amount of an important nutritional factor at a critical stage of development may cause permanent structural changes in a particular organ. Other mechanisms of metabolic programming include changes in cellular aging and epi-

genetic modifications. Through epigenetic mechanisms, a non-optimal intrauterine environment can cause phenotypic changes in metabolic and endocrine pathways of the foetus; which may lead to increased rates of diabetes, dyslipidaemia and cardiovascular diseases in adulthood. Such metabolic programming can be seen as a transgenerational phenomenon that is transmitted from generation to generation; also called the "metabolic cycle" (4).

Guidelines that determine how much weight a woman should gain during pregnancy are designed according to the body mass index (BMI) of women prior to their pregnancies, and also differ between countries, races and in cases of multiple pregnancies (5). More than half of pregnant women gain more weight than recommended during their pregnancy. Nutrient intake and weight gain in the course of pregnancy are the two main modifiable factors that influence maternal and infant outcomes. Both the excess and inadequate weight gain during pregnancy are well-recognized risk factors for an unfavourable pregnancy, labour and postnatal outcome, which may be associated with increased morbidity of the offspring. Appropriate antenatal management of maternal nutrition, as dictated by scientific evidence, is therefore critical for establishing a safer intrauterine environment and birth outcomes.

As many as 70% of obese adolescents remain obese in adulthood and, what is more, it is much more difficult for adults to lose the excess weight once it has already been gained. Scientific literature reports on poorer physical and mental health of overweight children (6), higher rates of cardiovascular and gastrointestinal disorders and higher mortality in adulthood (7). Accordingly, children should be the primary target in preventing the obesity epidemic, since establishing healthy eating and exercise patterns early on can influence the ability to maintain a healthy body and weight in the population for several generations (1).

The aim of this study was to define the influence of maternal body weight (BW) on offspring growth in early childhood.

Patients and Methods

All participants' data was coded, and all information was kept confidential. Exclusion criteria were pregnant women with chronic or syndromic disease; preterm newborns, twins and children with chronic and syndromic diseases. The target population (N=175) of the study comprised volunteer pregnant Slovenian women during their third trimester of gestation who were recruited in three Slovenian regions (Ljubljana, Maribor and Nova Gorica/Izola) in the period from December 2010 to October 2012. Twelve of them dropped out before the first appointment due to health complications during pregnancy (N=162). During their first appointment in the third trimester of pregnancy, anthropometrical measurements were taken in 162 volunteers. Body weight (BW) was measured with a certified medical scale to the nearest 0.1 kg, and body height to the nearest 0.5 cm (Seca digital scale 769, Germany). Data on BW prior to pregnancy were obtained on the basis of data provided by the volunteer. The infants' anthropometric measurements were taken between the 4th and the 5th week post-partum and at the 3rd month of age. Additionally, detailed information about the anthropometric measurements at birth (BW, length and head circumference) was gathered.

In the second phase of the research, at the children's age of approximately 5 years, we visited the children's personal paediatricians to obtain data collected within the framework of routine systematic examinations at the ages of 6 and 9 months as well as 1 and 3 years respectively. Data on BW, height and head circumference (HC) measurements were collected and expressed in percentiles (P). In terms of growth curves and deviation from the mean for a certain age, we determined the values as average if they were between 5 and 95 P; below average if they were less than 5 P; and above average if they were greater than 95 P. During the retrospective collection of data from the medical documentation, some volunteers dropped out of the final sample, either due to relocation to another country or region, unwillingness to participate, or due to the children's paediatricians being unavailable.

While performing statistical analysis we adopted the exclusion criterion for twins and thus eliminated four pairs of twins. The sample for which we obtained the data from the medical documentation thus included 141 mother-children pairs (N=141), of which 68 were girls (48%) and 73 boys (52%).

Ethics Statement

This study is a part of the project “The role of human milk in development of breast-fed child’s intestinal microbiota” (My-MILK). The present study was conducted in accordance with the Declaration of Helsinki from 1975 and its amendments adopted in 1983. The study protocol was approved by The National Medical Ethics Committee of the Republic of Slovenia (32/07/10, 38/02/12), and all participants have signed a written informed consent. The study was registered at ClinicalTrials.gov (NCT01548313).

Statistical Analyses

Statistical analysis was performed using R 3.2.2. and packages Performance Analytics (8) and Ggplot2 (9). For observed parameters, we calculated

mean values and standard deviation values. Associations between certain parameters were evaluated with the Pearson correlation test, used to make correlation matrix. Regression coefficients were calculated to determine association. To perform linear regression, F-test was used. P value of less than 0.05 was considered as statistically significant.

Results

The relationships between the mothers' BW prior to and during pregnancy, and the BW and the HC of children in these periods were analysed using the Pearson correlation coefficient. A high association of maternal BW before pregnancy with maternal BW during pregnancy was noted, therefore we used only BW during pregnancy in this and all subsequent analyses. We found statistically significant association between the BW of the mother and the birth weight of the child and the weight at 1 and 9 months as well as at 1 and 3 years of age. The correlation matrix also showed statistically significant association between the BW of the mother during pregnancy and the head size of the child at 1, 6 and 9 months as well as at 1 and 3 years of age (Table 1).

Table 1. Body Weight and Head Circumference and Their Association With Mother's Body Weight During Pregnancy

Anthropometrical measurements	N	Mean value	Minimum	Maximum	Standard deviation	Association to mother's body weight during pregnancy (r)
Mother's BW prior to pregnancy (kg)	151	62.9	46.0	115.0	10.3	0.942*
Mother's BW during pregnancy (kg)	151	73.7	53.0	127.1	11.1	-
Birth weight (g)	149	3374	2040	5030	491	0.327†
BW at 1 month (g)	150	4617	3190	6450	666	0.241†
BW at 6 months (g)	136	7757	5700	10040	928	0.151
BW at 9 months (g)	136	8856	6340	11500	1009	0.191*
BW at 1 year (g)	146	9817	7310	12610	1058	0.203*
BW at 3 years (g)	134	15278	11700	18600	1627	0.192*
Mother's BW during pregnancy (kg)	162	74.4	53.0	128.8	12.4	-
HC at birth (cm)	161	33.8	31.0	39.0	5.6	0.097
HC at 3 months (cm)	161	38.3	34.5	41.0	1.3	0.19*
HC at 6 months (cm)	146	43.5	40.0	46.5	1.4	0.17*
HC at 9 months (cm)	141	45.3	41.8	48.5	1.4	0.34‡
HC at 1 year (cm)	155	46.7	43.3	50.0	1.3	0.29‡
HC at 3 years (cm)	95	50.1	45.0	54.0	1.5	0.19*

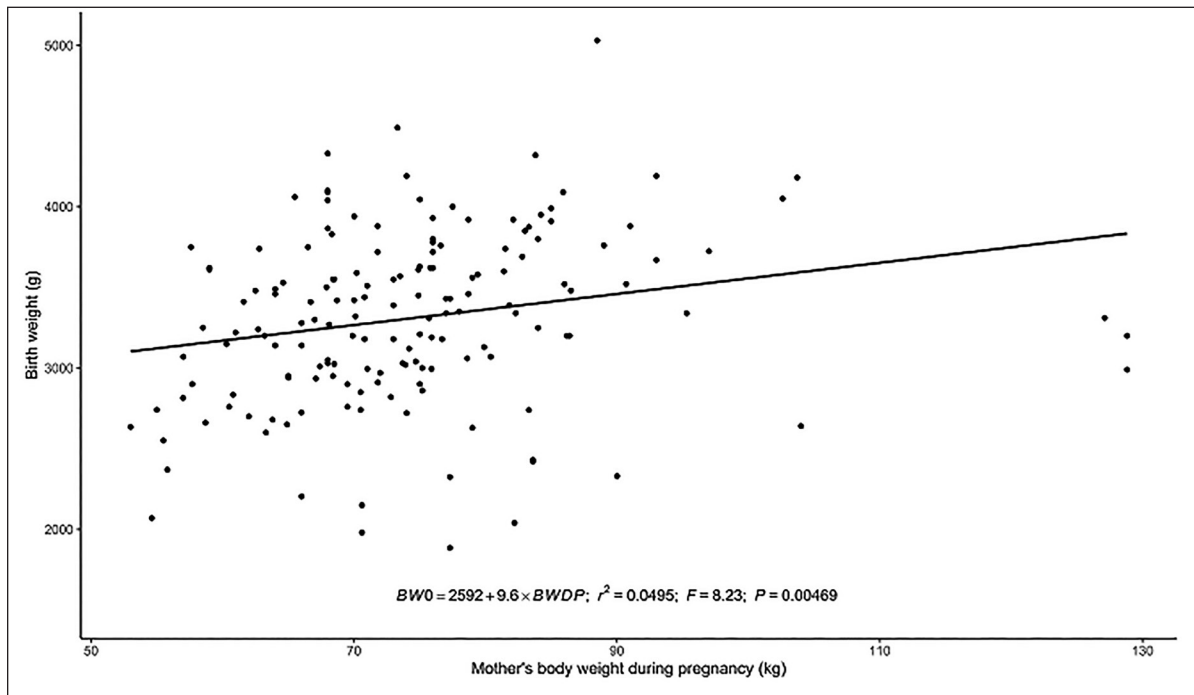
*P<0.05; †P<0.01; ‡P<0.001; N=Number of participants; r=Correlation coefficient.

Additionally, we analysed several linear models in which the weight of the mother during pregnancy was an independent variable, while the values of the BW of children at birth, at 1 and 9 months, and at 1 and 3 years of age, as well as the HC at birth, at 1, 6 and 9 months, and at 1 and 3 years of age, were used as dependent variables (Table 1).

The regression model suggested a statistically significant association between maternal body weight during pregnancy and child's body weight

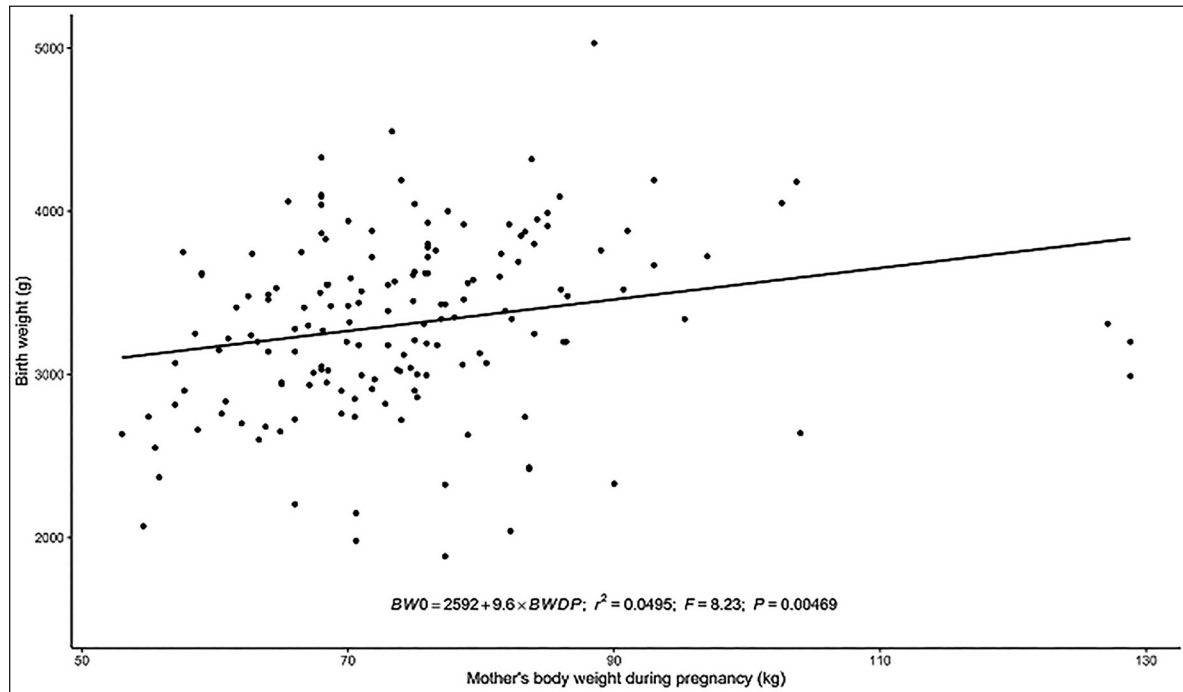
at birth and at 1 year of age. However, the explanation of the variance in the dependent variable is weak (Fig. 1, Fig. 2).

We also established a linear association between the children's HC at birth, 1, 6 and 9 months, and at 1 and 3 years of age, depending on the body weight of the mother during pregnancy. Again, the explanation of variation in the dependent variable is weak. It is the highest for the head size at 9 months ($r^2=12\%$) (Fig. 3).



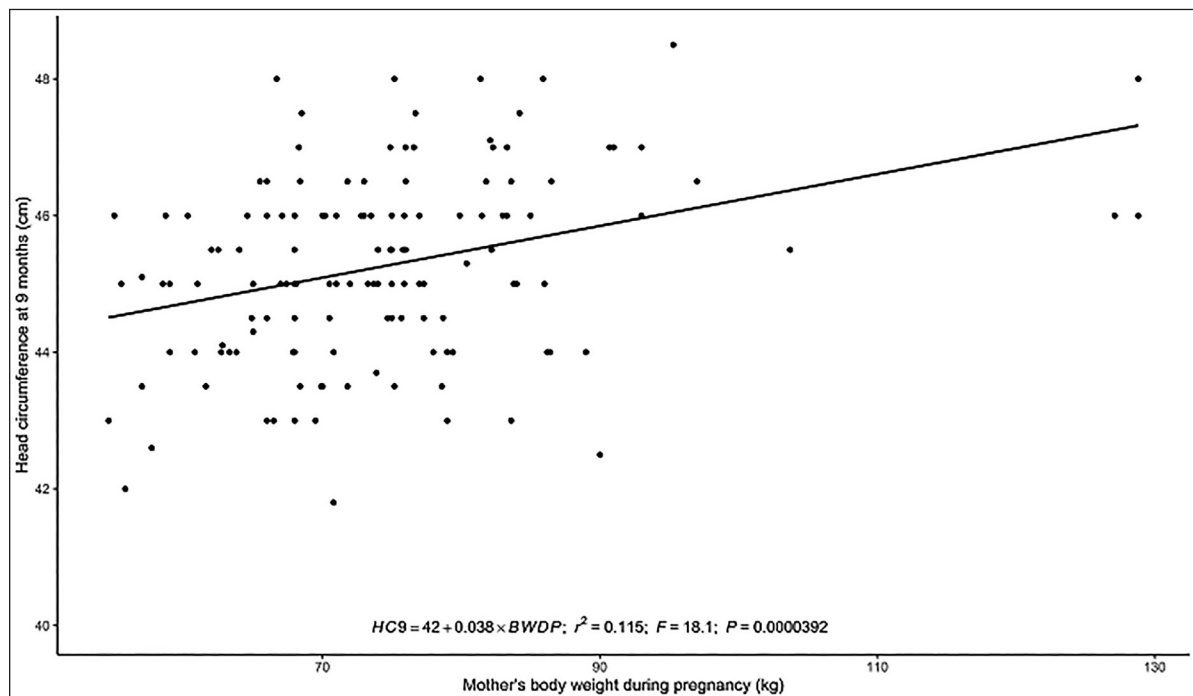
BW0=Body weight at birth; BWDP=Body weight during pregnancy; r^2 =Variation; F=F-test value; P=Statistical significance.

Fig. 1. Impact of Mothers' Body Weight during Pregnancy on Newborn's Body Weight.



BW1=Body weight at 1 year; BWDP=Body weight during pregnancy; r^2 =Variation; F=F-test value; P=Statistical significance

Fig. 2. Impact of Mothers' Body Weight during Pregnancy on Child's Body Weight at 1 Year of Age.



HC9=Head circumference at 9 months; BWDP=Body weight during pregnancy; r^2 =Variation; F=F-test value; P=Statistical significance.

Fig. 3. Impact of Mother's Body Weight during Pregnancy on Child's Head Circumference at 9 Months of Age.

Discussion

The study confirmed the association between BW of mothers during pregnancy and BW of children at birth and at the age of up to three years. Our findings were in line with the findings of several earlier studies where they examined either the impact of the mother's BMI prior to or during pregnancy, or an increase in BW during pregnancy on the child's birth weight and BW in post-natal period (10, 11). Despite the fact that the association in our study was statistically significant, the model explained only 4% of the child's body weight variation, similar to the findings of Madi et al. in 2017 (12). A similar association was also observed in the studies that followed children in late childhood and adolescence (13, 14).

The mechanisms through which maternal BW affects the BW of a child have not been understood fully. The hypothesis of over-nutrition during development states that high levels of glucose, free fatty acids and amino acids in the mother cause permanent changes in appetite control, neuroendocrine functions, and energy metabolism in the foetus, causing the foetus to develop insulin resistance and become more prone to accumulating fat through life. In other studies, however, the influence of maternal factors on the BW of a child was also explained through the influence of genetics and a similar lifestyle in terms of diet and exercise (11, 14). Recent research has also revealed deviant epigenetic mechanisms associated with DNA methylation that lead to a disruption of cell cycle and gene expression in adulthood.

In overweight or even obese mothers, there is a higher incidence of complications both during pregnancy and childbirth. These include excessive foetal growth, causing macrosomia (birth weight and/or length > 90P for its gestational age and gender) which is associated with a greater need for caesarean section, as well as with shoulder stasis, birth asphyxia, and birth trauma (15, 16). These complications can have a negative impact on morbidity and mortality of both the mother and the newborn. In addition, newborn babies with a higher birth weight gain, typically, BW more rapidly and have

a higher BMI in early childhood, which is also associated with obesity in childhood and adulthood (11). Additionally, a link has been found between a low BW of mothers and premature birth and newborns, born small for their gestational age (10) – which is primarily detrimental for the child. In addition to being born large for gestational age, there is evidence that being born small for gestational age is also a risk factor for the development of obesity and cardiovascular diseases in adulthood, possibly through mechanisms of foetal metabolic programming and epigenetic modifications of DNA structures (10). Maternal obesity and gestational weight gain, resulting in over-nutrition of the foetus, are major contributors to obesity and metabolic disturbances in the offspring. Once present, obesity is difficult to treat and early intervention strategies are urgently needed. Lifestyle intervention in obese pregnant women has the potential to modify the intrauterine environment and confer long-term benefits to the child.

Given the fact that our statistical model explained only 4% of the child's BW variation, it would be appropriate to investigate other causes that affect the child's BW. The BW and height of the father, the family history (including birth weight and obesity in childhood and later), the child's sex, the smoking of the mother in pregnancy, and the number of siblings should also be explored and considered (17). In order to assess more objectively the effect of the mother's BW, and indirectly her metabolic and medical condition on the child's BW, it would make sense to use the mother's BMI instead of BW to eliminate the effect of height. By using BMI, the influence of individual nutrition categories (malnutrition, normal body weight, overweight, obesity) on the outcome of childbirth could be further elaborated. It is assumed that if only neonates born with the same gestational age were analysed, stronger associations would have been found, since both preterm and post-term births have an influence on the child's birth weight and later body weight.

Head circumference reflects the growth of brain hemispheres and is significantly associated with

subsequent mental and physical development of children. Head circumference below 5P for gestational age is an important starting point for further diagnostic investigations and more intense monitoring of a child's development. Studies have shown that smaller HC correlates with lower intelligence and poorer linguistic and neurocognitive abilities later in life (18, 19). On the other hand, there is evidence that HC over 95P for gestational age has statistically significant association with delay in the progression of labour and consequently its instrumental or operative completion (20).

The analysis showed an association between the BW of the mother during pregnancy and the HC until the third year of age. In some previous studies, a significant association was found between excessive weight gain during pregnancy and increased HC at birth (21, 22). Swedish researchers investigated the effect of mothers' eating disorders on the anthropometric measurements of their babies. Their results show that women who had had anorexia or bulimia nervosa in the past had a statistically lower BW in pregnancy and gave birth to newborns with lower HC than in the control group (23).

The circumference of the child's head also depends on the size of their body (both body weight and length). We assume that by adjusting the value of HC to the values BW, more significant connections would be observed.

Limitations of the Study

Our study has some limitations that are worth considering. Given the fact that the research was carried out retrospectively, we were often faced with missing information, thereby dropping the size of the sample and consequently the statistical power of the analysis. Although the sample we used was rather small, it is generally representative of the population of healthy pregnant women in Slovenia. However, we found that almost 80% of women achieved at least a higher level of education, which is a deviation from the Slovenian average for the education of pregnant women (38%). The level of education may also be higher due to the fact that most of the data was collected in the region of Cen-

tral Slovenia which is considered to be the most developed region with the highest share of educated people in Slovenia. This fact must be taken into account if the results were to be generalized to the entire Slovenian population of women, since poorer education and lower financial and social status are associated with a lower level of awareness and, consequently, worse care for their own health and the health of their children.

Conclusion

The results of the research provide an insight into the connection between maternal health and the growth of offspring, and thus an important overview of the situation in Slovenia. In our research, we have demonstrated the influence of anthropometric measures pertaining to mothers on the growth of offspring up to the age of three, thus further confirming the necessity of preventive measures that could improve the awareness of the health effects of mothers during pregnancy on the growth of children. An important contribution of our study is that apart from the analysis of short-term effects on newborns, the effects of maternal factors on the health of the children in early childhood were also examined. Our study has confirmed that the relationship between maternal factors and foetal growth is complex, therefore requiring further interrogation. Our findings may further encourage gynaecologists and other health professionals to improve the awareness of the importance of appropriate weight before pregnancy in women of childbearing age and of sufficient but not excessive maternal weight gain during pregnancy. Additionally, this study can contribute to the development of more precise guidelines in the field of health care during pregnancy in the Slovenian population.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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