ARTICLE

The influence of pre-pregnancy BMI and weight gain during pregnancy on pregnancy outcomes

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School of Physiology, Nutrition and Consumer Science, North-West University, Potchefstroom
Elbie Ward, MScDiet
H Salome Kruger, PhD
Averalda van Graan, MScDiet

Objective. The purpose of this study was to evaluate the association between pre-pregnancy body mass index (BMI) and maternal pregnancy weight gain and pregnancy outcomes.

Methods. Ninety-eight pregnant black women were followed up during pregnancy. Pre-pregnancy weight was recorded or calculated by regression analysis, and weekly weight gain was calculated. The correlation between pre-pregnancy BMI, weekly weight gain, blood pressure, and the infants' birth weight, length and head circumference was assessed, adjusting for gestational age and smoking. Adjustment for HIV status was also done in subjects with known status. Participants were categorised into three groups: pre-pregnancy BMI <19.8, BMI 19.8 - 26, and BMI >26.

Results. According to the Institute of Medicine (IOM)'s weight gain recommendations, women in all BMI categories tended to gain excessive weight. Pregnancy weight gain was significantly associated with infant birth weight (χ^2=6.25; p=0.04), although no significant correlations were found between weekly weight gain or mothers' pre-pregnancy BMI, respectively, and birth outcomes. Pre-pregnancy BMI correlated significantly with blood pressure at the second clinic visit. Age and parity correlated significantly with pre-pregnancy BMI; and household income correlated with mothers' weekly weight gain.

Conclusion. Inadequate weight gain was associated with a significantly lower infant birth weight. No correlation was found between infant birth weight and mother's pre-pregnancy BMI.

Pregnancy (a physiologically demanding process) and its outcome are strongly influenced by the nutritional status of the mother, both before pregnancy and during gestation.[1] Weight gains within the Institute of Medicine (IOM)'s recommendations are associated with healthy fetal and maternal outcomes; weight gains below these goals are associated with low infant birth weight; higher gains are associated with macrosomia in the infant.[2,3] The guidelines recommended are 0.45 - 0.7 kg/week for underweight mothers, 0.4 - 0.6 kg/week for normal weight mothers, and 0.25 - 0.4 kg/week for overweight/obese mothers. The guidelines have been validated by several studies demonstrating that weight gain in accordance with the guidelines is associated with optimal birth weight and obstetric outcomes. Women gaining either above or below IOM guidelines are at higher risk of adverse outcomes.[3-7] Other reports, of mothers with low maternal weight with an increased risk of low pregravid BMI, highlight the influence of maternal weight alone on the risk of perinatal complications.[4,8-11] Low maternal weight at delivery was also associated with preterm labour and low birth weight (LBW), as well as prematurity.[11] Women with low incomes are often of lower educational status, which is associated with many adverse behavioural and psychosocial factors, such as smoking, drugs, sexual promiscuity and stress, that can cause adverse pregnancy outcomes.[12]

Data on pregnancy weight gain patterns in developing countries are scarce, owing to difficulties in collecting data throughout pregnancy.[13] Limited data are available on the effects of pregnancy weight gain on birth outcomes of pregnant South African women.[14,15] There are no clear recommendations for the monitoring of pregnancy weight gain in South African outpatient clinics, and the view prevails that routine recording of maternal weight at each antenatal visit is unnecessary.[15,16] However, it is accepted that obesity is a public health problem among South African women,[17] and that an estimated 29% of pregnant women (albeit of unknown HIV status) are HIV-positive and therefore at risk of poor pregnancy weight gain.[18] For these reasons, the aim of this study was to evaluate the association between pre-pregnancy BMI and maternal pregnancy weight gain and pregnancy outcomes in a group of women attending a primary health care clinic. The results may be of value in revising recommendations for monitoring of weight gain in South African pregnant women attending primary health care clinics.

Methods

Permission was granted by the Department of Health's Potchefstroom District Manager to conduct the study at the Potchefstroom Primary Health Care Clinic. The Ethics Committee of North-West University approved this project, and the subjects gave informed consent. Black pregnant volunteers (*N*=98) visiting the Potchefstroom Clinic were followed up during pregnancy. The inclusion criteria were that they should be on their first visit to the clinic, still within the first 28 weeks of pregnancy, and have a singleton pregnancy. The study was conducted over 1 year.

Demographic information (including age, educational status, occupational status, average household income, and marital status) on the participants was collected during face-to-face interviews. A maternal health questionnaire was used to record blood pressure, symphyseal fundal (SF) measurement, smoking status, allergies, parity and haemoglobin levels. Blood pressure was measured by experienced registered nurses using a sphygmomanometer after a rest period of at least 5 minutes with the patient sedentary. The clinic nurses also did blood tests for HIV only on subjects who gave their consent (*N*=32), and haemoglobin tests by comparing undiluted blood with pre-calibrated colour standards (Haemoglobinmeter, Medsurge, Johannesburg).

To determine the anthropometric status and weight gain during pregnancy, each participant's weight, height, subscapular and triceps skinfold thickness, and mid-upper arm circumference (MUAC) were measured and recorded using standard methods at each clinic visit.[19] Weight was measured using a Precision electronic scale (A & D Company, Saitama, Japan), after removal of heavy clothing such as jackets and shoes, for each weighing session. Height was measured using a wall-mounted stadiometer, and MUAC using a Lufkin steel tape (Cooper Tools, Apex, NC, USA). Subscapular and triceps skinfolds were measured using a John Bull skinfold caliper (British Indicators, London, UK).[19] Measurements were done in triplicate, and the mean value was recorded. The anthropometric measurements were done by dietitians or trained final-year students. Pregnancy weight gain was categorised as optimal weight gain, insufficient weight gain, and excessive weight gain, according to the IOM guidelines.[20] For statistical analysis, a regression analysis to estimate the mother's pre-pregnancy weight in order to calculate the pre-pregnancy weight and BMI, as described by Olson and Strawderman,[21] was applied. The regression was done back to week 14 (gestational age) because weight gain is linear during the second and third trimesters, and little weight is gained during the first 14 weeks.

Trained fieldworkers collected information regarding the women's dietary intakes, using a previously validated food frequency questionnaire (FFQ) and food portion photo book.[22]

Each participant was followed up for a minimum of 3 visits. Where possible, the first visit was done within 16 - 28 weeks of gestation, the second at 30 - 32 weeks, and the third at 36 - 38 weeks. Most participants were followed up for more than 3 visits, with a mean total of 3.6 visits per subject. Taxi fees were reimbursed at each visit (ZAR R10/visit).

At birth, a hospital visit was done to record the infant's birth weight, which was measured by the hospital staff (Salter scale, model 40A, Tokyo, Japan); length and head circumference were measured with a non-stretch tape (Butterfly, China); and gestational age and Apgar score were recorded. The gestational age of the infant was determined according to ultrasonography at a previous hospital clinic visit. Participants were referred to the hospital for ultrasonography at approximately 12 weeks' pregnancy, or at their first visit to the antenatal clinic if it was still earlier than approximately 24 weeks' pregnancy.

Underweight, HIV-positive women and those not gaining enough weight during pregnancy received specialised care, such as individualised advice from dietitians; and all women received standard clinic nutritional supplements (folic acid, iron and vitamin C tablets).

Statistical analyses

Regression analysis was used to estimate mothers' pre-pregnancy weight for those whose first visit was during the second trimester of pregnancy. This was done by plotting all measured weights against gestational age (in weeks) and applying a regression line through all points.[21] Pre-pregnancy weight was taken as the intercept at 14 weeks' pregnancy, because there is little weight gain beforehand, and a constant weight gain from 14 weeks.[20] Weight gain between visits was used to calculate weekly weight gain by dividing the difference in weight by the number of weeks between visits. Partial correlation coefficients were calculated for the association between pre-pregnancy BMI, as well as weekly weight gain and infants' birth weight, length and head circumference, with adjustment made for gestational age (in weeks), smoking and HIV status as dichotomous variables. The correlation between infants' birth weight, length and head circumference, and mothers' educational status as well as household income, was calculated. The age-adjusted correlation between blood pressure of mothers during pregnancy and pre-pregnancy BMI, triceps and subscapular skinfold thicknesses, was also calculated. Infants' birth weight, length and head circumference in cases of mothers gaining weight below, within and above the IOM recommendations were compared using the medians test. For this test, infants with gestational age $\leq$36 weeks were excluded.

Results

Of the 98 women included in the study, data on 92 could be analysed. Two pregnancies ended in miscarriage, and 4 were lost to follow-up. Numbers may vary due to incomplete data. Table I shows the demographic data of the group (N=95) collected through a demographic questionnaire on the first visit to the clinic. Tswana was the most common first language spoken by the participants. Most of the women were not married, and lived with relatives. More than half of the women were unemployed. Twenty per cent had studied beyond Grade 12. To determine if they had sound nutritional knowledge, they were asked if they had ever received education by a health professional regarding healthy eating during pregnancy, oral rehydration therapy, and breastfeeding practices. Only 28% had received education regarding healthy eating during pregnancy. Fig. 1 shows the women who gained adequate, inadequate or excessive weight according to the IOM's recommendation based on weekly weight gain.[20] Table II shows the data for age, weekly weight gain, dietary intake, and birth data for women according to their pre-pregnancy BMI categories. There were no significant differences between birth weight, length or head circumference of male and female infants (their data were analysed together).

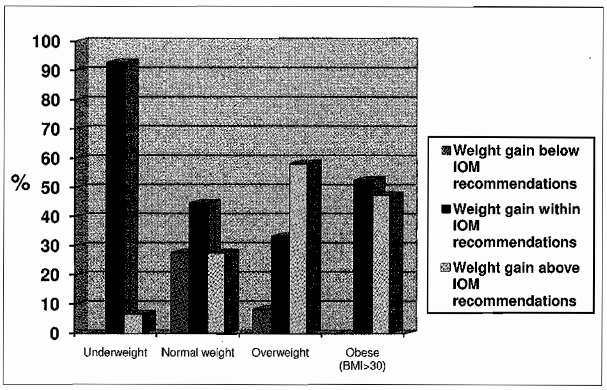

Fig. 1. Weight gain below, within and above the IOM's recommendations according to pre-pregnancy BMI classification (%).

Of 32 participants who gave consent for HIV/AIDS testing, 11 were HIV infected. Ages of all the women ranged from 14 to 47 years and correlated with pre-pregnancy BMI (r=0.460, p=<0.0001). As expected, gestational age correlated positively with infant birth weight (r=0.417, p<0.0001) and head circumference (r=0.233, p=0.04) and tended to correlate with infant birth length (r=0.195, p=0.08). In subsequent correlation analyses, adjustments were made for smoking as a dichotomous variable (smoking/non-smoking) and gestational age. Weekly weight gain correlated with total income in both the normal/underweight women (r=0.363, p=0.007) and the overweight/obese women (r=0.414, p=0.039), as well as in the total group (r=0.371, p=0.001).

Table I. Demographic data of the subjects (N=95)

Demographic data	N
First language	
Tswana	66
English, Afrikaans	2
Other	27
Marital status	
Live with husband/partner	47
Widow/not married, live alone with other relatives	46
Never married, live alone	1
Other children	
Yes	51
No (primiparous)	44
Highest qualification	
None	7
<Grade 8	17
Grade 8 - 12	80
Grade 12 +, technikon, university or college	8
Employment	
Employed	
Professional (teacher/ nurse/other with university degree)	4
Self-employed formal (business)	3
Office work/sales	14
Domestic worker/cleaner	22
Informal sector (hawker)	2
Unemployed	53
Education received from a qualified health professional	
Healthy eating during pregnancy	27
Oral rehydration therapy	35
Breastfeeding practices	33

Fig. 1 shows the weight gain of the mothers according to the IOM's weekly weight gain recommendations per BMI group.[20] There was a negative correlation (r=–0.32, p=0.034) in the underweight and normal weight group between pre-pregnancy BMI and weekly weight gain, which showed that women with a lower pre-pregnancy BMI gained more weight per week. All underweight women gained weight according to the IOM recommendations, or even more. Women in all BMI groups, however, tended to gain too much weight (Fig. 1).

No correlation was found between infant birth weight and mother's pre-pregnancy BMI (r=0.123, p=0.27) or weekly weight gain (r=0.004, p=0.971). Birth length and head circumference of the two groups of infants, from underweight/normal weight mothers and overweight/obese mothers, respectively, did not differ significantly. Three overweight mothers (12%) had infants with macrosomia, defined as birth weight >4 kg, compared

Table II. Data regarding age, weight gain, dietary intake, haemoglobin and birth data for mothers with regard to their pre-pregnancy BMI category (numbers may vary owing to incomplete data)					
	N	**Mean**	**Minimum**	**Maximum**	**SD**
BMI <19					
Age (yrs)	14	24.71*	18.00	40.00	6.32
Weekly weight gain (kg)	14	0.64	0.340	0.94	0.17
Energy intake (kJ)	14	12 497.86	6 467.00	17 988.00	3 568.03
Protein intake (g)	14	92.89	35.30	183.10	38.70
Iron intake (mg)	14	11.61	4.30	15.50	3.72
Calcium intake (mg)	14	756.29	337.00	1 219.00	274.08
Zinc intake (mg)	14	12.0	5.0	22.0	5.2
Haemoglobin (g/dl)	14	11.71	8.3	14.0	1.68
Birth weight (kg)	13	3.18	2.60	3.70	0.33
Birth length (cm)	13	50.31	46.00	57.00	3.07
Head circumference (cm)	13	34.46	33.00	38.00	1.56
BMI 19.1 - 26					
Age (yrs)	47	26.38	14.00	37.00	5.69
Weekly weight gain (kg)	45	0.49	0.12	1.08	0.24
Energy intake (kJ)	45	11 678.13	5 014.00	20 149.00	3 809.04
Protein intake (g)	45	79.56	23.80	178.70	29.08
Iron intake (mg)	45	10.98	4.90	19.60	3.83
Calcium intake (mg)	45	802.93	177.00	2 182.00	406.51
Zinc intake (mg)	45	11.9	3.4	26.8	4.9
Haemoglobin (g/dl)	46	11.52	8.5	14.5	1.57
Birth weight (kg)	42	3.08	1.90	4.12	0.45
Birth length (cm)	39	49.67	44.00	57.00	2.81
Head circumference (cm)	39	34.82	31.00	40.00	1.89
BMI >26					
Age (yrs)	31	29.55*	19.00	47.00	7.10
Weekly weight gain (kg)	28	0.44	0.13	1.13	0.27
Energy intake (kJ)	29	12 248.28	4 069.00	21 799.00	4 085.69
Protein intake (g)	29	86.22	22.60	175.60	29.99
Iron intake (mg)	29	13.32	3.70	30.00	5.48
Calcium intake (mg)	29	838.31	240.00	2 088.00	429.09
Zinc intake (mg)	29	12.8	3.1	26.6	6.5
Haemoglobin (g/dl)	30	12.47	7.5	17.0	2.29
Birth weight (kg)	26	3.20	2.490	4.20	0.50
Birth length (cm)	26	50.92	45.00	58.00	3.33
Head circumference (cm)	26	34.54	32.00	37.00	1.53

*Significant difference between BMI categories ($p<0.05$).
SD= standard deviation.

with 1 normal weight mother (2%) who had an infant with birth weigh >4 kg. The age-adjusted systolic ($r=0.30$, $p=0.005$) and diastolic blood pressure ($r=0.29$, $p=0.007$) of mothers during pregnancy at visits during the second trimester, correlated significantly and positively with pre-pregnancy BMI, as well as subscapular skinfold thickness at second trimester follow-up visits ($r=0.30$, $p=0.005$; $r=0.29$, $p=0.007$, respectively).

The median birth weights of the infants according to the mothers' weekly weight gain category are shown in Table III, after excluding infants with gestational age ≤36 weeks. Mothers whose weekly weight gain was below the IOM recommendation for their BMI category had infants with a significantly lower birth weight than mothers who gained weight according to the recommendation or above, as assessed by the medians test ($\chi^2=6.25$, $p=0.04$). Birth length of these infants also tended to be shorter ($\chi^2=4.66$, $p=0.098$), but there was no difference between the head circumferences of the 3 groups of infants ($\chi^2=1.48$, $p=0.48$).

Discussion

No correlation between pre-pregnancy BMI, as well as maternal weight gain during pregnancy and infant birth weight, length or head circumference, was found. This could be explained by the observation that all

Table III. Birth data of infants (median, inter-quartile range) according to mothers' weekly weight gain category based on pre-pregnancy BMI (N=89, infants of gestational age ≤36 weeks excluded)

	Median	25th percentile	75th percentile
Insufficient weight gain (*N*=14)*			
Birth weight (kg)	2.87†	2.78	3.0
Birth length (cm)	49.0	48.0	50.0
Head circumference (cm)	34.0	34.0	35.0
Adequate weight gain (*N*=46)‡			
Birth weight (kg)	3.06†	2.9	3.4
Birth length (cm)	50.0	48.0	52.0
Head circumference (cm)	34.0	33.0	35.0
Excessive weight gain (*N*=29)§			
Birth weight (kg)	3.20†	2.85	3.5
Birth length (cm)	50.0	48.0	52.0
Head circumference (cm)	35.0	34.0	36.0

*Underweight mother <0.45 kg/week, normal weight mother <0.4 kg/week, overweight/obese mother <0.25 kg/week.
†Significant differences between weight gain categories, medians test.
‡Underweight mother 0.45 - 0.7 kg/week, normal weight mother 0.4 - 0.6 kg/week, overweight/obese mother 0.25 - 0.4 kg/week.
§Underweight mother >0.7 kg/week, normal weight mother >0.6 kg/week, overweight/obese mother >0.4 kg/week.

underweight women gained sufficient weight during pregnancy, which could possibly be attributed to the regular visits of the mothers to the clinic, with dietary counselling and nutrient supplements. Weekly weight gain correlated negatively with pre-pregnancy BMI in the underweight and normal weight women. This observation confirms that women with a lower pre-pregnancy BMI gained more weight during pregnancy, which could have helped to prevent LBW of their infants. Adequate weight gain of underweight women apparently prevented LBW in their infants.

The chances of pregnant women having positive pregnancy outcomes through good, timely care are also confirmed and described by other studies.[23,24] A study on participants who do not visit clinics regularly could produce different results, but such a study is almost impossible because subjects would be very difficult to trace, and the ethics of such a study could be questionable.

Women with the lowest income gained the least weight. Of all the participants, 67% (*N*=60) had a household income of less than R1 000 per month. This is in line with the findings by Kramer *et al.*[12]

The median birth weight of infants of women who gained insufficient weight was significantly lower than that of women who gained sufficient or excessive weight. Pregnancy weight gain according to the IOM recommendations was apparently a more important determinant of pregnancy outcomes than pre-pregnancy BMI in these women. Other data[11] suggest that the contribution of maternal weight gain in pregnancy is a predominant influence among the body habitus parameters studied in complications such as prematurity, preterm labor, and LBW. Furthermore, analysis using the rate of weight gain during the entire gestation avoids the influence of length of gestation. In this way, weight gained in pregnancy can be considered a more potent predictor of adverse outcome than weight or BMI before pregnancy or at delivery. Poor maternal weight gain in pregnancy may herald nutritional deficiencies that predispose to preterm delivery.[11]

In the present study, pre-pregnancy BMI correlated positively with the number of previous pregnancies, indicating that each new pregnancy could have contributed to weight gain and the development of obesity.

According to the 'hypothesis of fetal origin',[25] an unfavourable intrauterine environment can predispose to the development of a number of chronic diseases in adult life. In line with this view, a recent study has shown that high birth weight was associated with insulin resistance and higher fat mass in adolescents.[26] Pre-pregnancy BMI was significantly associated with systolic and diastolic blood pressure at the first as well as the second follow-up visits, indicating that overweight and obese women were more at risk of hypertension during pregnancy. In a study by Jensen *et al.*,[27] both obesity and overweight were significantly associated with hypertensive complications, caesarean section, induction of labour, and macrosomia. Although overweight and obese women did not require more caesarean sections in the present study, 12% of women in this group had infants with a birth weight >4 kg.

A limitation of this study was the relatively small sample size, which might have limited the possibility to determine adverse outcomes associated with pre-pregnancy BMI and rate of pregnancy weight gain. However, the study contributes important information about weight gain during pregnancy in women attending South African antenatal clinics, which may be of value to nutritionists.

Although the monitoring of weight gain in all pregnant women in antenatal clinics may not be warranted,[14-16] pregnancy weight gain of women from the lowest income groups should be monitored during pregnancy to ensure adequate weight gain according to the IOM recommendations.

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