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The effect of maternal glucose metabolism, iron, vitamin B_{12} and folate status on pregnancy outcomes

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Objective. To evaluate the effect and consequences of certain maternal factors (nutritional, sociodemographic and glucose metabolism) on pregnancy outcome of women recruited during the third trimester.

Design. A longitudinal analytical study.

Setting. Villages in the central region of the Limpopo province.

Subjects. Third-trimester pregnant women attending prenatal clinics at nine local clinics in the villages (N = 219) and their newborn infants.

Results. The study showed that predictors of birth weight were found to be maternal body mass index (BMI), beta-cell function, haemoglobin and ferritin levels, while birth length was predicted by maternal height, fasting glucose and ferritin. The models accounted for 12.4% and 8.6% of the variation in both birth weight and length respectively. The 30-minute glucose (5.56 ± 1.31; 6.23 ± 1.59 mmol/l; p = 0.027) and haemoglobin levels (12.22 ± 1.76, 11.46 ± 1.87 g/dl; p = 0.041) differed significantly between the first and third birth weight tertiles. With respect to birth length tertiles, fasting (4.18 ± 0.55, 3.84 ± 0.92 mmol/l; p = 0.045), 30-minute (5.72 ± 1.24, 6.31 ± 1.50 mmol/l; p = 0.047) and 2-hour glucose levels (5.04 ± 1.32, 6.13 ± 2.50 mmol/l; p = 0.004) differed significantly between the first and third tertiles.

Conclusion. The study showed that normal glucose metabolism is essential for the optimal growth of the fetus with respect to attained weight and length at birth. Furthermore, maternal stature and iron status (as measured by haemoglobin and ferritin levels) appear to be playing vital roles in predicting both birth weight and length.

Fetal growth is controlled by several factors during pregnancy. Altered fetal growth (AFG) has been shown to increase the risks of perinatal mortality and morbidity.[1] Causes of AFG are heterogeneous and result in either fetal growth restriction or increased fetal growth. Included among the causes of altered fetal growth are the mother's iron stores, vitamin status, pre-eclampsia, impaired glucose metabolism, anaemia, fetal infections, uteroplacental insufficiency and both environmental and genetic factors.[2-5]

Research in both animals and humans has found that low maternal preconception weight and low maternal weight gain in either the second or third trimester increase the risk of premature delivery and intrauterine growth restriction,[6,7] especially in overweight mothers (body mass index (BMI) 27 - 30 kg/m^2) and those who are either younger (< 20 years) or older (≥ 35 years).[6, 8-10]

Chronic maternal undernutrition influences birth weight through its effects on maternal stature independent of body weight.[11] It may also be associated with deficiencies in specific micronutrients that influence fetal growth, including vitamins A, C and D, folate, iron and zinc.[12,13] Rao *et al*.[12] found that micronutrient intake during pregnancy was associated with birth outcomes, suggesting important roles of different micronutrients in improving fetal growth.

Several studies have found that preterm delivery and low birth weight (LBW) are associated with ferritin levels that fail to decrease during pregnancy. Additionally there is an increase in ferritin levels during pregnancy.[14,15] Hou *et al*.[16] found that increased ferritin levels in the second and third trimesters were associated with asymmetrical fetal growth restriction (FGR). Scholl[14] suggested that the observed increase in ferritin may be a result of an acute phase response suggesting maternal infection and an increased risk of poor pregnancy outcomes.

Maternal folate deficiency early in pregnancy leads to an increased risk of neural tube defects in the fetus that is reduced by folate supplementation early in pregnancy. During pregnancy folate metabolism has to adapt to multiple fetal and maternal physiological influences that change throughout gestation. Adequate folate intake is essential throughout gestation to ensure normal growth and development.[17] Impaired maternal folate status has been associated with reduced birth weight and preterm delivery.[18]

Even though rare, vitamin B_{12} deficiency has been implicated as one of the factors causing neural tube defects (NTDs). In fact, studies have reported increased levels of methyl-malonic acid status in women carrying NTD-affected fetuses and their fetal amniotic fluid. Steen *et al*.[19] suggested that deranged vitamin B_{12} and/or transport may be the pathophysiological mechanism involved in development of NTDs.

In view of the problems in newborns caused by maternal factors, this study was undertaken to investigate the consequences of certain maternal factors (glucose metabolism, nutritional and anthropometric) on the newborn infants in a group of women with a high prevalence of abnormal glucose metabolism (gestational diabetes mellitus/impaired glucose tolerance) (unpublished data), low folate deficiency, and high prevalences of serum iron and vitamin B_{12} deficiencies during pregnancy.[20]

Subjects and methods

Study area and subjects

The survey took place in nine randomly selected local clinics in the central region of Limpopo province, the northernmost province of South Africa. Each clinic renders services to at least 10 surrounding villages. These are predominantly semi-rural with poor infrastructure, poor roads, and lack of electricity and proper sanitation. The housing is a mixture of traditional mud houses, shacks and modernised brick houses.[21]

Third-trimester (28 - 36 weeks) pregnant women receiving antenatal care at these clinics were approached to participate in the study by the nursing staff. The two periods of recruitment (May - August 1999 and February - April 2000) yielded 262 participants (14 refused). This represents a 95% response rate. The mothers were asked to give birth at Mankweng Hospital, where after birth a paediatrician examined the newborns for any congenital abnormalities. Birth anthropometric measurements were done for 219 newborns, all of which were included in the study. None of the infants were pre-term or had any congenital abnormalities. The missing subjects were due to the mother migrating out of the study area, home deliveries or spontaneous miscarriages.

Anthropometric measurements and blood collection

Maternal weight was measured to the nearest 0.1 kg with a beam balance weighing scale. Height was measured to the nearest 0.5 cm using a horizontal measuring tape mounted on a board with a flat sliding headpiece. For the measurements the women were wearing light clothes and no shoes. The BMI was calculated as (weight)/(height^2). Blood pressure was determined with a mercury manometer, with the participants in a sitting position after resting quietly for 5 minutes. Blood pressure measurements were repeated twice (≈3 minutes apart) and the average calculated and used in the analysis. The infants' birth anthropometric measurements were taken from hospital records.

Fasting serum and plasma samples were collected from the women, who then consumed a 75 g glucose solution in 250 ml water. The full blood count (FBC) and red cell folate were assessed on the day of the study. Thereafter blood was centrifuged and stored at –70°C for further analyses including glucose and insulin ferritin, vitamin B_{12} and folate.

Further blood samples were taken at 30 minutes and after 2 hours for the determination of glucose and insulin concentrations. All samples were collected in fluoride tubes, after which they were separated and stored at –70°C until analysed. Glucose was measured using the RAXT-100 autoanalyser using a glucose oxidase kit (Bayer Diagnostics, New York, USA) and insulin was assayed on the Access Immunoassay System (Beckman Coulter, California, USA). The method used for the determination of insulin has a cross-reactivity of –0.26% with proinsulin and C-peptide is not detected by the test. Serum ferritin, vitamin B_{12}, folate, and red cell folate were determined with the Access Immunoassay System. Haemoglobin and red cell indices (FBC) were determined with a Coulter STKS analyser (Beckman Coulter Inc., California, USA). Red cell folate was then calculated as (haemolysed folate × 21)/(haematocrit/100).

World Health Organization (WHO) criteria for the diagnosis of gestational impaired glucose tolerance

(GIGT) and gestational diabetes mellitus (GDM) were used,[22] as follows: GIGT – fasting glucose < 7 mmol/l and 2-hour glucose between 7.8 and 11.1 mmol/l; GDM – fasting plasma glucose ≥ 7 mmol/l or 2-hour glucose ≥ 11.1 mmol/l. Insulin resistance and beta-cell function were calculated using the homeostasis model assessment (HOMA) as derived by Matthews *et al.*,[23] later corrected and computerised, then updated to HOMA 2.2 calculator.[24]

Statistical analysis

Statistical analysis was done using SPSS 11.0 for Windows.[25] Variables that were not normally distributed were log-transformed to approximate normality. Statistical analyses performed included descriptive statistics, Pearson's correlations, and linear regressions on birth weight and length. Since some of the variables were highly correlated, factor analysis was used to identify factors that affect birth outcome. Maternal glucose metabolism parameters, biochemical and anthropometric variables were entered, and using principal components extraction and verimax rotation yielded eight variables: maternal height, BMI, fasting glucose, HOMA IR, HOMA beta-cell function, 30-minute insulin increment, vitamin B_{12}, ferritin and haemoglobin. These were entered into a stepwise linear regression with either birth weight or birth length as the dependent variable. Analysis of variance (ANOVA) was computed and differences between the various groups tested by the Bonferroni method.

Ethics approval

Ethics approval and permission to undertake the study were obtained from the Ethics Committee of the University of Limpopo (Turfloop campus) and the Limpopo Province Department of Health and Welfare's Research Committee. Written informed consent was obtained from the women before commencement of the test procedures.

Results

According to the WHO criteria,[22] gestational diabetes was present in 1.5% of the pregnant women and glucose intolerance in 7.3%. Iron deficiency was present in 50.9% (26.4% were severely iron depleted and 24.5% moderately iron depleted) and vitamin B_{12} deficiency in 16.4%. Serum folate and red cell folate were deficient in 10.3% and 4.6% respectively. In addition, 16.4% of the women were anaemic.[20] Pregnancy-related hypertension was found in 6.5% (unpublished data).

Table I shows the mean (± SD) of the maternal and newborn measurements and Table II the mean (± SD) of the biochemical parameters measured during the third trimester of pregnancy.

Birth weight correlated positively with maternal height (r = 0.155, p= 0.031) and 30-minute glucose levels (r = 0.157, p = 0.026) and negatively with maternal haemoglobin levels (r = –0.183, p = 0.008). Birth length correlated positively with 30-minute glucose levels (r = 0.194, p = 0.006), 2-hour glucose levels (r = 0.325, p < 0.0001) and 2-hour insulin levels (r = 0.185, p = 0.008) and correlated negatively with the 30-minute insulin increment (r = –0.189, p = 0.010). The newborns' ponderal indices correlated positively with maternal fasting glucose (r = 0.153, p = 0.030) and negatively with both 2-hour glucose (r = –0.187, p = 0.008) and haemoglobin levels (r = –0.151, p = 0.031).

Selected measures of glucose metabolism, serum nutrient analyses and maternal anthropometric measurements were fitted into a stepwise linear regression model to see which of them predicted the birth weight and length in the newborns. The models of these regressions are shown in Tables III and IV. The predictors of birth weight were found to be maternal BMI, beta-cell function, haemoglobin and ferritin levels.

Table I. Maternal and neonatal anthropometric measurements

Variables	Mean ± SD (*N* = 219)
Maternal	
Age (years)	25.45 ± 7.02
Parity	1.53 ± 1.86
Maternal weight (kg)	68.27 ± 11.83
Maternal height (m)	1.59 ± 0.06
Maternal BMI (kg/m^2)	27.09 ± 4.38
Maternal SBP (mmHg)	112.76 ± 12.26
Maternal DBP (mmHg)	70.25 ± 10.02
Neonatal	
Birth weight (kg)	3.12 ± 0.55
Birth length (cm)	49.01 ± 2.74
Birth head circumference (cm)	35.16 ± 1.96
Ponderal index (kg/m^3)	26.64 ± 4.69

SBP = systolic blood pressure; DBP = diastolic blood pressure.

Table II. Third-trimester maternal metabolic values

Variables	Mean ± SD (*N* = 219)
Fasting glucose (mmol/l)	3.96 ± 0.81
30-min glucose (mmol/l)	5.94 ± 1.44
2-h glucose (mmol/l)	5.64 ± 1.97
Fasting insulin (µIU/ml)	6.30 ± 7.59
30-min insulin (µIU/ml)	46.63 ± 47.22
2-h insulin (µIU/ml)	32.51 ± 27.55
30-min insulin increment	155.28 ± 734.30
Haemoglobin (g/dl)	11.77 ± 1.75
Ferritin (µg/ml)	25.07 ± 28.84
Vitamin B_{12} (pg/ml)	236.91 ± 103.77
Serum folate (ng/ml)	8.30 ± 4.87
Red cell folate (ng/ml)*	490.94 ± 281.67

*N = 134.

Birth length was predicted by maternal height, fasting glucose and ferritin levels.

Both birth weight and length were then divided into tertiles to look at maternal differences based on their magnitude (Tables V and VI). There was a significant difference in both the 30-minute glucose (5.56 ± 1.31; 6.23 ± 1.59 mmol/l; $p = 0.027$) and haemoglobin levels (12.22 ± 1.76, 11.46 ± 1.87 g/dl; $p = 0.041$) between the first and third tertiles. Between the second and third tertiles differences were seen in the red cell folate levels (9.45 ± 5.23, 7.04 ± 4.77 ng/ml; $p = 0.049$).

Differences were also observed between the first and third birth length tertiles in fasting (4.18 ± 0.55, 3.84 ± 0.92 mmol/l; $p = 0.045$), 30-minute (5.72 ± 1.24, 6.31 ± 1.50 mmol/l; $p = 0.047$) and 2-hour glucose levels (5.04 ± 1.32, 6.13 ± 2.50 mmol/l; $p = 0.004$). Between the second and third tertiles differences were seen between the 30-minute glucose levels (5.62 ± 1.40, 6.31 ± 1.50 mmol/l; $p = 0.011$). Trend analysis revealed that with an increase in birth weight according to their tertiles there was an increase in maternal 30-minute glucose ($P_{\text{linear trend}} = 0.009$) and a decrease in haemoglobin levels ($P_{\text{linear trend}} = 0.015$). With respect to birth length an increasing trend was seen with maternal height ($P_{\text{linear trend}} = 0.016$) and 2-hour glucose ($P_{\text{linear trend}} = 0.001$), while fasting glucose ($P_{\text{linear trend}} = 0.019$) showed a gradual decrease.

Discussion

The mother's carbohydrate metabolism (as assessed by glucose and insulin levels in response to the oral glucose tolerance test (OGTT)) in pregnancy is an important determinant of fetal growth.[26-28] Insulin resistance has been shown to have a positive correlation with birth weight,[28-30] while plasma glucose and insulin levels after an OGTT are lower in women with growth-retarded fetuses than in women with normal fetuses.[3,31]

This study's findings that maternal glucose metabolism predicts both birth weight and length support observations by several researchers who found that increased postprandial glucose in pregnancy was associated with heavier babies.[2,29,31] The relationship between maternal hyperglycaemia and birth weight has been attributed to increased nutrient transfer to the fetus due to diminished insulin sensitivity leading to maternal utilisation of free fatty acids for energy. The fetus is thought to respond by increasing insulin secretion, with increased fat storage to prevent fetal hyperglycaemia and ultimately increased fetal weight. This suggestion was supported by Villar *et al.*,[32] who found that 90% of fat in Guatemalan women was deposited as maternal stores in the first two trimesters of pregnancy, and could later be used as an energy source.

Table III. Linear regression model for assessing the association between maternal parameters and birth weight

Variables	Equation of regression of weight	*p*-value
Maternal BMI (x)	3.240 + 0.227 (x)	0.002
Beta-cell function (x)	3.240 – 0.168 (x)	0.020
Ferritin (x)	3.240 – 0.164 (x)	0.024
Haemoglobin (x)	3.240 – 0.178 (x)	0.015

$R = 0.352$, $R^2 = 0.124$, $SE_E = 0.487$, $p < 0.0001$.
SE_E = standard error of the estimate.

Table IV. Linear regression model for assessing the association between maternal parameters and birth length

Variables	Equation of regression of weight	*p*-value
Maternal height (x)	33.534 + 0.148 (x)	0.043
Maternal BMI (x)	33.534 + 0.138 (x)	0.064
Fasting glucose (x)	33.534 + 0.218 (x)	0.045
HOMA IR (x)	33.534 – 0.268 (x)	0.060
Beta-cell function (x)	33.534 + 0.265 (x)	0.065
Ferritin (x)	33.534 – 0.169 (x)	0.020

$R = 0.293$, $R^2 = 0.086$, $SE_E = 2.628$, $p = 0.013$
IR = insulin resistance; SE_E = standard error of the estimate.

Table V. Comparison between maternal anthropometric and metabolic variables based on the infants' birth weight tertiles

Maternal variables	1st tertile (*N* = 66)	2nd tertile (*N* = 78)	3rd tertile (*N* = 75)	*p*-value
Birth weight (kg)	2.94 ± 0.04	3.09 ± 0.14	3.72 ± 0.27	† ‡
Birth length (cm)	47.09 ± 0.22	49.69 ± 0.25	49.99 ± 0.03	† ‡
Age (years)	25.20 ± 7.12	25.29 ± 7.04	25.84 ± 6.98	NS
Parity	1.33 ± 1.56	1.58 ± 1.88	1.64 ± 2.10	NS
Maternal weight (kg)	66.69 ± 10.85	68.43 ± 12.47	69.43 ± 11.95	NS
Maternal height (m)	1.58 ± 0.05	1.58 ± 0.06	1.60 ± 0.07	NS
Maternal BMI (kg/m^2)	26.77 ± 4.13	27.48 ± 4.83	26.98 ± 4.14	NS
Maternal SBP (mmHg)	113.28 ± 14.18	112.63 ± 12.11	112.46 ± 10.75	NS
Maternal DBP (mmHg)	71.40 ± 9.88	70.44 ± 10.59	69.07 ± 9.54	NS
Fasting glucose (mmol/l)	3.93 ± 0.57	3.99 ± 0.90	3.94 ± 0.87	NS
30-min glucose (mmol/l)	5.56 ± 1.31	5.96 ± 1.32	6.23 ± 1.59	†
2-h glucose (mmol/l)	5.30 ± 1.29	5.83 ± 2.37	5.73 ± 1.97	NS
Fasting insulin (µIU/ml)	7.54 ± 11.20	5.65 ± 4.79	5.96 ± 6.17	NS
30-min insulin (µIU/ml)	40.32 ± 31.68	47.54 ± 42.66	50.89 ± 60.74	NS
2-h insulin (µIU/ml)	28.99 ± 23.76	35.76 ± 35.04	32.01 ± 20.62	NS
30-min insulin increment	116.43 ± 214.21	110.38 ± 932.64	233.66 ± 782.64	NS
Haemoglobin (g/dl)	12.22 ± 1.76	11.71 ± 1.56	11.46 ± 1.87	†
Ferritin (µg/ml)	27.38 ± 45.01	23.79 ± 19.61	24.48 ± 18.13	NS
Vitamin B_{12} (pg/ml)	237.88 ± 100.09	235.92 ± 105.58	237.14 ± 106.30	NS
Serum folate (ng/ml)	8.92 ± 5.30	8.33 ± 5.03	7.76 ± 4.31	NS
Red cell folate (ng/ml)*	8.69 ± 4.78	9.45 ± 5.23	7.04 ± 4.77	‡

*N = 134.
†$p < 0.05$ between 1st and 3rd tertiles.
‡$p < 0.05$ between 2nd and 3rd tertiles.
SBP = systolic blood pressure; DBP = diastolic blood pressure; NS = not significant.

Table VI. Maternal anthropometric and metabolic variables based on the infants' birth length tertiles

Maternal variables	1st tertile (*N* = 66)	2nd tertile (*N* = 78)	3rd tertile (*N* = 75)	*p*-value
Birth weight (kg)	2.79 ± 0.58	3.02 ± 0.43	3.43 ± 0.44	† ‡
Birth length (cm)	45.90 ± 0.16	48.51 ± 0.01	51.47 ± 0.02	† ‡
Age (years)	25.30 ± 7.12	25.64 ± 7.17	25.41 ± 6.91	NS
Parity	1.42 ± 1.73	1.57 ± 1.86	1.57 ± 1.97	NS
Maternal weight (kg)	67.90 ± 10.90	67.68 ± 12.95	68.93 ± 11.64	NS
Maternal height (m)	1.58 ± 0.06	1.58 ± 0.06	1.60 ± 0.69	NS
Maternal BMI (kg/m^2)	27.35 ± 4.27	27.20 ± 4.80	26.86 ± 4.18	NS
Maternal SBP (mmHg)	113.62 ± 13.85	114.10 ± 13.09	111.25 ± 10.42	NS
Maternal DBP (mmHg)	70.81 ± 10.82	70.90 ± 10.01	69.42 ± 9.57	NS
Fasting glucose (mmol/l)	4.18 ± 0.55	3.91 ± 0.80	3.84 ± 0.92	†
30-min glucose (mmol/l)	5.72 ± 1.24	5.62 ± 1.40	6.31 ± 1.50	† ‡
2-h glucose (mmol/l)	5.04 ± 1.32	5.49 ± 1.40	6.13 ± 2.50	†
Fasting insulin (µIU/ml)	5.65 ± 7.17	7.29 ± 9.93	5.99 ± 5.69	NS
30-min insulin (µIU/ml)	45.06 ± 30.95	57.09 ± 70.05	40.07 ± 32.10	NS
2-h insulin (µIU/ml)	28.68 ± 25.14	35.50 ± 27.67	32.76 ± 28.92	NS
30-min insulin increment	146.08 ± 168.13	242.39 ± 128.78	97.49 ± 215.27	NS
Haemoglobin (g/dl)	11.86 ± 1.64	11.82 ± 1.48	11.68 ± 1.99	NS
Ferritin (µg/ml)	29.07 ± 47.61	24.11 ± 17.62	23.24 ± 17.59	NS
Vitamin B_{12} (pg/ml)	221.44 ± 99.91	237.58 ± 91.23	246.13 ± 114.15	NS
Serum folate (ng/ml)	8.37 ± 4.77	8.93 ± 5.19	7.81 ± 4.70	NS
Red cell folate (ng/ml)*	8.20 ± 5.07	9.22 ± 5.19	8.03 ± 4.96	NS

*N = 134.
†$p < 0.05$ between 1st and 3rd tertiles.
‡$p < 0.05$ between 2nd and 3rd tertiles.
NS = not significant.

Several other studies have reported that low serum levels of nutritional indicators such as iron, vitamin B_{12} and folate are associated with low birth weight.[12,33] In the present study ferritin showed a negative prediction of both birth weight and length, a finding in agreement with observations by some authors[34,35] but contrary to findings of others.[2,36] Scholl,[14] having found the same association, has speculated that the situation is a result of an acute-phase response indicating maternal infections, which in themselves are predictors of poor pregnancy outcome. This suggests that some of the women in the present study might have had infections (something the study did not look at), which could have resulted in the observed associations. Another serious shortcoming of this study was that maternal HIV status was not investigated, as this would have also shed some light on the observed association.

Our findings are further supported by the observation of lower haemoglobin levels in mothers who gave birth to heavier babies than in those who gave birth to lighter ones. The association between maternal haemoglobin levels and birth weight is a difficult one to understand. It has been suggested that anaemia in pregnancy is a result of plasma volume expansion and that this is associated with no negative effects on birth outcome.[35,37] This view was supported by Singla *et al*.,[36] who stated that anaemia has to be severe for its effects on birth weight to be expressed. Other studies,[34,37,38] however, have found that levels usually regarded as representing anaemia (9.5 - 11.5 g/dl) were optimal for infant growth and observed low birth weights in infants born to mothers whose lowest recorded haemoglobin level during their entire pregnancy was around 14.5 g/dl. Similarly, in the present study maximal fetal weight gain was observed at mean haemoglobin concentrations of 11.5 g/dl and minimum weight gain at higher levels (12.2 g/dl).

Surprisingly, and in contrast to earlier studies,[18,33] serum folate levels showed no association with either birth weight or length of the newborns. On the other hand it is well established that serum folate levels respond readily to changes in dietary folate intake,[39] which may have occurred in the women in our study. This suggestion is based on observations that folate supplementation in pregnancy is effective in this area even though the majority of women attend their first prenatal clinics in the last two trimesters.[13] Furthermore, it has been previously reported that the diet in this area is rich in folate as it consists mainly of green leafy vegetables.[40,41]

Maternal factors such as age, parity, pre-pregnancy weight, BMI, maternal weight gain during pregnancy and height have been described as factors affecting pregnancy outcome.[6,8-10] In this study, however, information on the maternal pre-pregnancy weight and BMI, as well as weight gain during pregnancy, was not available. Nevertheless, from the models obtained age and parity did not feature as predictors of fetal growth, possibly due to the fact that most women were in their early reproductive stages (18 - 30 years) and only a few had more than 3 children. The finding that maternal BMI predicted birth weight seems to support the effects of both pre-pregnancy weight and weight gain during pregnancy on fetal growth.

The positive prediction of maternal height on birth length has been reported previously[7] and has been linked to genetic factors. Some studies have also shown that early maternal undernutrition resulting in stunting can lead to future poor fetal growth for the shorter mothers.[11] This could not be ascertained in this study, becuase data on maternal nutrition and growth during early life are unavailable in South Africa.

In conclusion, findings in this study support what has been previously reported, i.e. that insulin sensitivity is necessary for the good postprandial control of glucose levels that will enable the newborn to have normal birth weight and length. However, more studies need to be done to explain the effect of haemoglobin levels on birth weight and to find levels at which growth is optimal.

The importance of other factors in the prediction of birth weight and birth length is evident in the low variance (12.4% and 8.6% respectively) explained by the factors examined. Prospective studies on women of differing sociodemographic status followed from the preconception period until birth, and also taking age distribution and parity into account, are warranted to fully elucidate the interrelationships of these various factors in determining both birth weight and length. The effect of nutritional intake and hormones, as well as their interactions, in determining fetal growth should also be looked at.

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