

Maternal Anthropometry as a Predictor of Birth Weight

R. Jananathan, D.G.N.G. Wijesinghe¹ and T. Sivananthawerl²

Postgraduate Institute of Agriculture
University of Peradeniya
Peradeniya, Sri Lanka

ABSTRACT. Maternal nutritional status is closely associated with birth weight of the newborn and perinatal morbidity and mortality. The usefulness of maternal anthropometric parameters i.e. maternal weight (WT), maternal height (HT) and maternal body mass index (BMI) as predictors of low birth weight (LBW) was studied in 563 full term babies selected from 2056 singleton live births. The sample included normotensive adult pregnant women who had their first visit to the clinics ≤ 13 weeks of gestation. Most of the pregnant mothers (80%) were between 20 and 34 years of age. Over one third of the mothers were nulliparous, while 12% were multiparous (parity ≥ 4). The incidence of LBW was 8.7% among the studied sample. The mean WT, HT and BMI of the sample were 53 kg, 155 cm and 22 kgm⁻² respectively. Significant positive correlations were observed with birth weight (BW) and WT ($r=0.27$), BW and BMI ($r=0.24$) and BW and HT ($r=0.11$). Polynomial regression analysis predicted LBW significantly with the critical limits of WT, HT and BMI at 50.3 kg, 154 cm and 21.1 kgm⁻², with the sensitivity of 54%, 45% and 60% respectively. Logistic regression analysis showed the risk ratio (RR) for critical limits. Mothers with low WT (<50.3 kg), HT (<154 cm) and BMI (<21.1 kgm⁻²) showed 1.5, 1.4 and 1.8 fold LBW respectively than mothers having values above the cut-off. At the highest sensitivity of 80% WT, HT and BMI have a RR of 1.8, 0.9 and 2.1 respectively but only the BMI reached a significant level. The best predictor of birth weight with 80% sensitivity was BMI of 23.7 kgm⁻² at or below 13 weeks of gestation.

INTRODUCTION

Birth weight is closely associated with the health and survival of the newborn. The relationship between maternal malnutrition and consequent low birth weight babies and the perinatal morbidity and mortality is now an accepted fact. WHO defines low birth weight (LBW) as birth weight less than 2500 g. The definition of LBW does not take into account the gestational period (Ojha and Malla, 2007).

In developing countries, LBW with accompanying high mortality and morbidity continues to be a major public health problem. There are two main causes of LBW: being born small for gestational age (SGA) or being born prematurely. In developing countries, the majority of LBW infants are SGA but are not born prematurely (Nahar *et al.*, 2007). Nevertheless, 6.7% of LBW infants are born preterm in developing countries.

¹Department of Food Science & Technology, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

²Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

For timely and optimum care, LBW babies should be delivered at places where such care is possible. For this purpose, reasonable antenatal prediction is essential. Many risk factors contributing to LBW have been recognized, which include low maternal weight and height, low body mass index, adolescent mother, short birth interval, primiparity, and rural residences (Ojha and Malla, 2007).

Child malnutrition is largely determined during the period of fetal and infant growth, when maternal nutrition has its strongest influence. Thus a LBW newborn comes to this world insufficiently equipped and has a higher risk of morbidity and mortality relative to the risk in an infant of normal birth weight. These babies are at an increased risk of developing perinatal asphyxia, hypoglycaemia, polycythemia-hyperviscosity, hypothermia, etc., and are more prone to impaired neurodevelopment, diabetes mellitus and hypertension in adult life (Ojha and Malla, 2007).

Assessment of maternal nutritional status relies on measures of stature, pre-pregnancy weight (PPW), height, body mass index (BMI), weight gain at different trimesters, weight gain during pregnancy, skinfold thickness and limb circumferences. Maternal weight (WT), height (HT) and pregnancy weight gain have all been shown to be significant predictors of birth weight (Nahar *et al.*, 2007). Numerous research projects have studied maternal anthropometric indicators as predictors of birth weight. Maternal anthropometry does not predict an increased risk for the birth of a preterm infant (Neumann *et al.*, 1995).

Although there is considerable work done on this topic in other countries, the present work is done in a selected population in Jaffna MOH division in Jaffna district in Sri Lanka. The LBW prevalence in Jaffna MOH division and Jaffna district is around 9% and 15% respectively (Anon., 2007). This paper examines the relationship between the birth weights of a full-term baby with certain maternal anthropometric measurements and determines the sensitivity, specificity and risk ratio (RR) of these measures in predicting LBW.

MATERIALS AND METHODS

Study subjects

A 3-year, retrospective, community based study was conducted in Jaffna Medical Officer of Health (MOH) division, which is located in Jaffna district in Sri Lanka. Jaffna district has 7 MOH divisions, which covers 47 Grama Niladhari divisions with a population of 80,850. Maternal and child health activities were carried out from 10 clinic centres for this MOH division.

Subjects were pregnant mothers who had registered and delivered a singleton live birth and had clear records from the beginning of January 2006 to the end of December 2008. A total of 2056 records were selected from the antenatal pregnant mothers' register which included the date of registration and gestational age, age, parity, gestational age at first visit, maternal anthropometric measurements including weight and height at first visit, date of delivery and birth weight of the baby. The details of multiple pregnancies, hypertension, diabetes, malaria, heart disease, renal disease, anaemia and other diseases were taken from the B card of the pregnant mother's records.

Pre-pregnancy weight (PPW) should be taken before the woman is diagnosed as pregnant. An Indian study assumed no weight gain up to 13 weeks gestation, because they found that women do not gain much weight in this period (Tripathi *et al.*, 1987). In the present study PPW was taken as the weight at the first visit ≤ 13 weeks of gestation.

Selection criteria

A total of 563 normotensive, non-morbid and adult (>19 years old) pregnant mothers who had the first visit ≤ 13 weeks and had birth at term (37 completed weeks to 41 weeks) were selected to the study from the total of 2056 live birth from singleton pregnant mothers. Excluded pregnant mothers were those who had first visit after 13 weeks of gestation, not having clear data of gestational week at registration, pre-term (<37 weeks) and post-term (>41 weeks) deliveries and mothers with diseases such as hypertension, diabetes, malaria, heart disease, renal disease, fits, rheumatoid arthritis, thyroid, chikungunya, wheeze and severe anaemia. Adolescent mothers (≤ 19 years old) were also excluded.

Data collection

Secondary data were collected from the records available at the Jaffna MOH office. Weights and heights had been recorded by trained public health midwives and family health assistants from the MOH office using standard scales which were routinely checked for accuracy. Pregnant mothers' HT measurement was taken to the nearest 0.1 cm and the WT measurement was recorded to the nearest 0.1 kg. Weights of the newborn were recorded to the nearest 0.01 kg within 24 hours of delivery in the labour room by senior registered nursing officer using an electronic scale. Gestational age was assessed by the MOH from the last menstrual period (LMP). Maternal BMI was calculated using the formula: $\text{weight (kg)}/[\text{height (m)}]^2$.

Data analysis

Descriptive analysis was carried out on maternal anthropometric measurements and newborn babies' data. Pearson product moment correlation coefficients were calculated to estimate correlations among maternal anthropometric measurements with birth weight of the child. Polynomial regression analysis was performed to find the strength of the associations.

To predict LBW, specificity and sensitivity tests were performed with height, BMI and weight at first visit. In this context, sensitivity is the ability to detect an LBW baby while specificity is the ability to detect a normal birth weight baby (Nahar *et al.*, 2007). A good predictor is one which has a high sensitivity and high specificity.

Sensitivity and specificity are dependent on one another; high sensitivity is required for the identification of all LBW babies. Unfortunately, this leads to lowered specificity and a high false positive rate, resulting in incorrect identification of mothers as high risk. A high false positive rate is not as serious as a high false negative rate, i.e. failing to identify mothers at high risk, but it will burden any screening programme (Nahar *et al.*, 2007).

Logistic regression analysis was done to present the exposures of cut-off values in magnitude as RR.

RESULTS AND DISCUSSION

Characteristics of the pregnant mothers and their newborn babies

The anthropometric characteristics of the sample are shown in Table 1. Mean values and standard deviations of anthropometric measurements are presented both for the mothers and their newborn babies. Most of the pregnant mothers were between 20 and 34 years of age (80%). Over one third of the mothers were nulliparous (43%), while 12% were multiparous (parity ≥ 4). There were 8.8% pre-term deliveries in the total sample (n=2056) which were excluded in the analysis.

Table 1. Characteristics of pregnant mothers and the new born babies (n=563)

Characteristic	Mean	SD
Age	28.2	5.5
Parity	2.0	1.2
Weight at first visit (kg)	53.3	10.6
Height (cm)	155.1	6.2
Pre-pregnancy Body mass index (kgm ⁻²)	22.2	4.3
Birth weight (g)	3040.0	441.9

Correlations between maternal anthropometric variables and birth weight

Table 2 shows the correlation coefficients for birth weight and various maternal anthropometric measures. Of the anthropometric measures, WT and BMI showed the highest correlations with birth weight (BW) with $p < 0.0001$. However, the maternal HT showed a weak correlation with BW ($p < 0.05$).

Table 2. Correlations between birth weight and maternal anthropometry

Antecedent variable	r	p
Weight at first visit (kg)	0.27	< 0.0001
Height (cm)	0.11	0.0114
Body mass index (kgm ⁻²)	0.24	< 0.0001

A study published in the WHO bulletin (Backstrand, 1995) reported by the Mexico Nutrition CRSP research project in six villages in the rural Solis Valley of central Mexico during 1984-1986 also reported that weight and body mass index showed the highest association with birth weight while the effect of maternal height on BW was not significant.

Differences in anthropometry during pregnancy appear to be related to birth weight. It was found that the smallest infants were those whose mothers had a relatively lower PPW and early pregnancy weight, and who subsequently failed to gain much weight by the third trimester (Backstrand, 1995).

Relative importance of maternal anthropometric variables on birth weight

Distribution of the sample showed that polynomial regression model (second order) has good fit with these variables and it was used to determine the relative importance of maternal anthropometric variables on birth weight. Individual polynomial regression analyses were undertaken using pregnant mother's weight at first visit, height and body mass index.

The polynomial model is $y = b_0 + b_1x + b_2x^2$

where, y is the predicted outcome value for the polynomial model with regression coefficients b_1 to k for each degree and y intercept b_0 . A second order ($k=2$) polynomial forms a quadratic expression (parabolic curve).

The best predictors of BW (based on r) were WT and BMI than HT. The r values were 7.52%, 6.32% and 1.35% for maternal weight, BMI and height, respectively (Table 3). All these variables have statistically significant relationships with birth weight at 0.05 level of probability.

Table 3. Polynomial regression analyses showing effect of maternal anthropometry on birth weight

Antecedent variable	F	r	p
Weight at first visit (kg)	22.70	7.52	< 0.0001
Height (cm)	3.62	1.35	0.0275
Body mass index (kgm ⁻²)	17.95	6.32	< 0.0001

Using polynomial regression, the critical values of WT, HT and maternal BMI were ascertained for a birth weight of 2500 g.

Out of 563 newborns studied, 8.7% were LBW cases. The prevalence of LBW reported here was lower than the national average figure of 17% (Anon, 2006). Since all babies under study were full-term, intra-uterine growth retardation (IUGR) could be the main reason for their low birth weight.

The WT, HT and maternal BMI were plotted against the birth weight and the regression curves are shown in Figs 1, 2 and 3, respectively.

Maternal weight

The polynomial regression equation for WT and BW was derived as follows:

$$WT = 59.57 - 0.011 BW + 0.0000028 BW^2$$

Accordingly, the pregnant mother's WT at first visit corresponding to a BW of 2500 g was calculated to be 50.3 kg. Table 4 shows the validity indices of WT at the cut-off value as an indicator of LBW. It is clear that the best cut-off limit is the highest sensitivity WT and Nahar *et al.*, (2007) suggested 80% sensitivity cut-off value as the best predicting value for maternal anthropometry. However, at this point, the sensitivity is only 54% while at the limit of <58.1 kg, the sensitivity increased to over 80%.

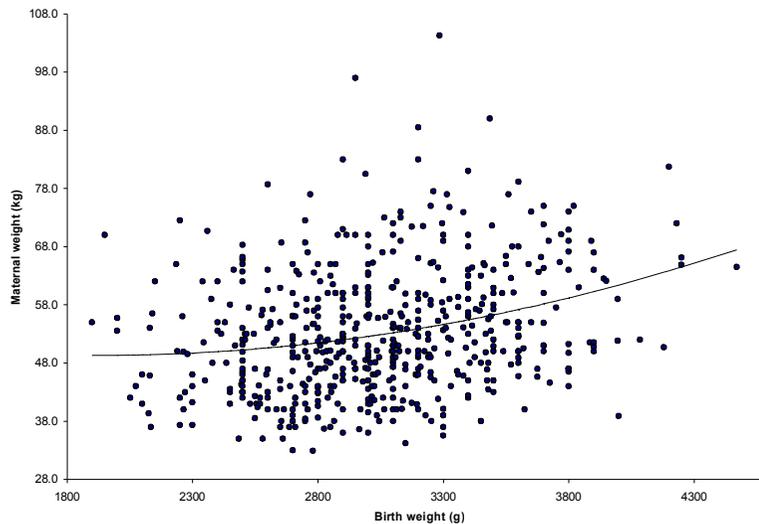


Fig. 1. Polynomial regression showing relation between maternal WT and BW

Several studies have reported that mothers who have a PPW of <40 kg have a three-fold greater risk of having a LBW baby than mothers with PPW >40 kg, and a PPW cut-off of 40 kg is the most commonly cited figure in developing countries used to assess risk of various pregnancy outcomes (Nahar *et al.*, 2007).

Tripathi *et al.*, (1987) suggested a cut-off of 45 kg at 13 weeks of gestation, based on work in India, to the prediction of LBW. Nahar *et al.*, (2007) suggested that ≤ 43 kg WT at registration (3-5 months of pregnancy) provided high sensitivity (80%) for predicting LBW. Mohanty *et al.*, (2005) suggested <45 kg with 62% sensitivity and <47 kg with 72% sensitivity.

Whole sample (n=1104) of the study by Nahar *et al.*, (2007) had mean values for WT, HT and BMI as 42.8 kg, 150.5 cm and 18.9 kg m^{-2} , respectively. In the present study, sample mean values for WT, HT and BMI were 53.3 kg, 155.1 cm and 22.2 kg m^{-2} respectively.

Maternal height

The polynomial regression equation for HT and BW is given below:

$$\text{HT} = 162.65 - 0.0066 \text{ BW} + 0.0000013 \text{ BW}^2$$

Accordingly, the HT corresponding to a BW of 2500 g was calculated to be 154 cm. Table 4 shows the validity indices of HT at this cut-off value. However, at this point, the sensitivity is only 45% while at the limit of <162 cm, the sensitivity increases to over 80%.

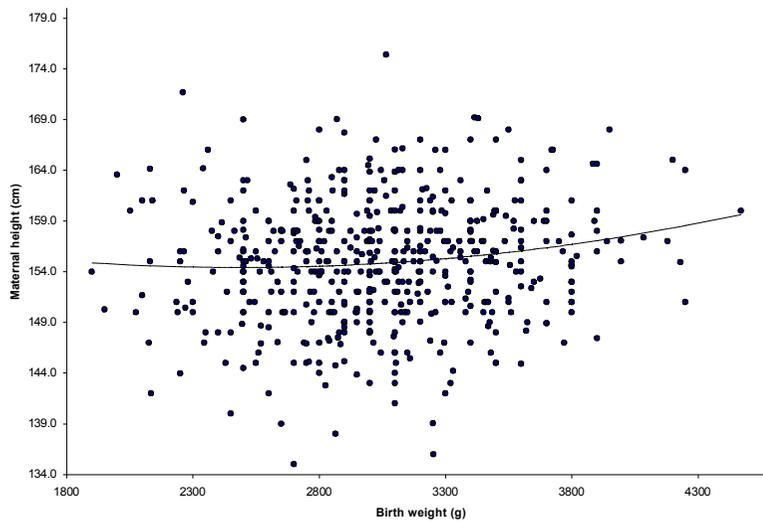


Fig. 2. Polynomial regression showing relation between maternal HT and BW.

Nahar *et al.*, (2007) suggested that a HT of about ≤ 154 cm is required for the 80% sensitivity for the prediction of LBW babies. Mohanty *et al.*, (2005) suggested a < 152 cm with 63% sensitivity and < 154 cm with the 75% sensitivity.

Maternal pre-pregnancy body mass index

The polynomial regression equation was derived as follows:

$$\text{BMI} = 24.44 - 0.0039 \text{ BW} + 0.0000010 \text{ BW}^2$$

Accordingly, the BMI corresponding to a BW of 2500 g was calculated to be 21.1 kgm^{-2} . Table 4 shows the validity indices of BMI at the cut-off value. However, at this point, the sensitivity is only 60% while at the limit of $< 23.7 \text{ kgm}^{-2}$, the sensitivity increases to 80%.

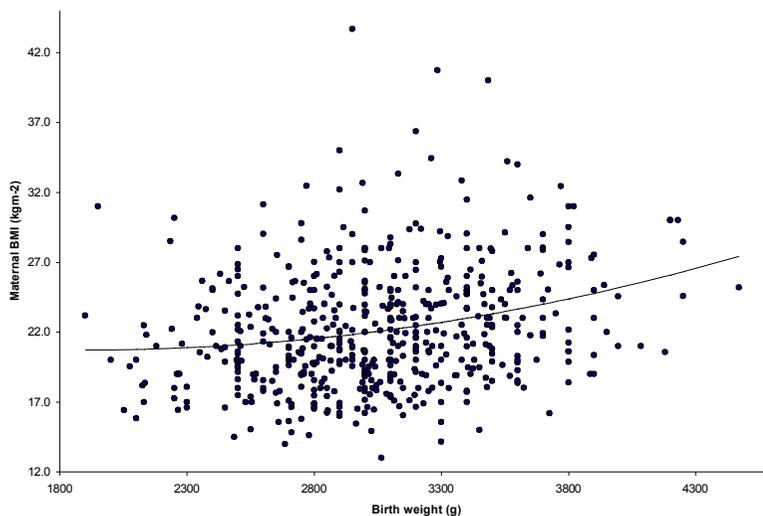


Fig. 3. Polynomial regression showing relation between maternal BMI and BW.

In a study involving Bangladeshi pregnant mothers, Nahar *et al.*, (2007) suggested a BMI of $\leq 19 \text{ kg m}^{-2}$ to predict 80% sensitivity at 3-5 months gestation, while a BMI of $\leq 22 \text{ kg m}^{-2}$ is required at 6 months. Mohanty *et al.*, (2005) suggested for Indian pregnant mothers a $< 20 \text{ kg m}^{-2}$ at the first trimester, with a sensitivity of 71% and $< 21 \text{ kg m}^{-2}$ with a sensitivity of over 81%.

Table 4. Validity indices of maternal WT, HT and BMI at their cut-off values as an indicator of LBW

Cut-off of variable	Sensitivity	Specificity
$< 50.3 \text{ kg}$	54.17	56.72
$< 154 \text{ cm}$	45.45	62.99
$< 21.1 \text{ kgm}^{-2}$	60.00	54.69

Risk ratio for low birth weight based on cut-off values of maternal variables

Logistic regression analysis were undertaken to present the exposures in magnitude as risk ratio (RR) using WT $< 50.3 \text{ kg}$, HT $< 154 \text{ cm}$ and BMI $< 21.1 \text{ kg m}^{-2}$ with LBW and the results are presented in Table 5.

The findings suggest that mothers with low WT ($< 50.3 \text{ kg}$) are 1.5 times more likely to have LBW babies. Similarly, mothers with low HT ($< 154 \text{ cm}$) are 1.4 times as likely to give birth to LBW babies and mothers with low BMI ($< 21.1 \text{ kg m}^{-2}$) has 1.8 times higher risk of delivering LBW babies. However, there were no significant differences between these values.

Table 5. Risk ratio for exposures with respect to LBW as the outcome variable

Exposure	RR	95% CI	p
Weight at first visit $< 50.3 \text{ kg}$	1.549	0.855 – 2.806	0.1486
Height $< 154 \text{ cm}$	1.418	0.762 – 2.639	0.2703
Body mass index $< 21.1 \text{ kgm}^{-2}$	1.811	0.972 – 3.374	0.0615

A study done by Ojha and Malla (2007) has used a cut-off point for low WT at $< 45.0 \text{ kg}$. At this cut-off, the undernourished women were three times more likely to have LBW babies as compared to those who had WT 45.0 kg (OR 3.5, 95% CI 1.82-6.77). It has also been reported that with the same cut-off point (45 kg) pregnant mothers were twice as likely to have LBW (RR 2.2, 95% CI 1.91-2.57) (MIRA, 2000). Ehrenberg *et al.*, (2003) showed that subjects with PPW of < 100 pounds (45.4 kg) were at an increased risk of having LBW babies (RR 1.8, 95% CI 1.1-2.9). All these studies showed that undernourished mothers have a significant risk of having LBW babies.

A study done by Mohamed *et al.*, (1995) reported that low HT (150 cm) had no association with LBW (OR 0.6, 95% CI 0.1-2.5). Wessel *et al.*, (1996) also reported that low HT (154 cm) was not significantly associated with LBW (RR 2.2, 95% CI 0.7-6.9).

Ehrenberg *et al.*, (2003) found the association with LBW at a cut-off point of pre-pregnancy BMI <19.8 kg m⁻² (RR 1.13, 95% CI 1.0-1.27). Abenhaim *et al.*, (2004) concluded that mothers with pre-pregnancy BMI of <20 kg m⁻² were more likely to have IUGR infants (OR 1.54, 95% CI 1.37-1.73).

Risk ratio for low birth weight based on cut-off values of maternal anthropometry at 80% sensitivity level

The logistic regression analysis showed that mothers with low WT (<58.1 kg), HT (<162 cm) and BMI (<23.7 kg m⁻²) are 1.8, 0.9 and 2.1 times, respectively, more likely to deliver LBW babies (Table 6). But the variables of WT and HT are not statistically significant at 5% level.

Table 6. Risk ratio for exposures with respect to LBW as the outcome variable with 80% sensitivity

Exposure	RR	95% CI	p
Weight at first visit < 58.1 kg	1.808	0.854 – 3.824	0.1215
Height < 162 cm	0.937	0.381 – 2.305	0.8867
Body mass index < 23.7 kgm ⁻²	2.125	1.000 – 4.515	0.0500

The above cut-off values are higher than the mean Sri Lankan WT, HT and BMI values and the values reported by Nahar *et al.*, (2007) for Bangladesh women. The reasons could be that the maternal WT and HT values reported in this study were higher and the prevalence of LBW was lower than the national values or the subjects studied by Nahar *et al.*, (2007). Among the three exposure variables shown in Table 6, BMI was statistically significant and gave the more accurate value for prediction of LBW.

CONCLUSIONS

In the present study intra uterine growth retardation (IUGR) appeared to be the major contributor to low birth weight deliveries.

Polynomial regression analysis showed that to achieve a normal birth weight (≥2500 g) maternal weight at first visit should be 50.3 kg (sensitivity 54%). The maternal height and BMI to achieve 2500 g birth weight are 154 cm (sensitivity 45%) and 21.1 kg m⁻² (sensitivity 60%) respectively.

To provide a high sensitivity (80%) in predicting LBW deliveries the best predictor is maternal BMI of 23.7 kg m⁻² at or below 13 weeks of gestation.

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