Maternal MUAC and fetal outcome in an Indian tertiary care hospital: A prospective observational study

Donugama Vasundhara¹ | Hemalatha Rajkumar¹ | Saurabh Sharma² |
Baru Anantha Ramalaxmi¹ | Varanasi Bhaskar¹ | JagJeevan Babu¹ |
Radha Krishna Kankipati Vijaya¹ | RajaSriswan Mamidi¹

¹National Institute of Nutrition (ICMR), Jamai Osmania, Hyderabad, India
²National Institute of Medical statistics (ICMR), New Delhi, India

Correspondence
Hemalatha Rajkumar, National Institute of Nutrition (ICMR), Jamai Osmania, Tarnaka, Hyderabad - 500007 India.
Email: rhemalathanin@gmail.com

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Abstract
Studies to date demonstrated the relatedness of mid-upper arm circumference (MUAC) measurement of pregnant women to their anthropometry/weight. Hence, the objective was to determine whether maternal MUAC at different gestational age predicted birthweight, and if so, to identify which cut-offs provided the best prediction of low birthweight (LBW) in pregnant women cohort. A total of 928 pregnant women, free of any obstetrical and medical complications known to affect fetal growth, were followed from 20 to 24 weeks' gestation till delivery. Weight, height, and MUAC were determined for the pregnant women, and gestational age along with newborns anthropometry was collected. The mean birthweight was 2.6 ± 0.460 kg. Maternal age, height, weight, MUAC (three time points), gestational age at delivery, and post-natal weight showed positive correlation with birthweight, crown heel length, and head circumference of the neonates. The cut-off limit with the best sensitivity–specificity (54.0 and 59.8, respectively) for MUAC was 23 cm, whereas maternal weight of 55 kg had sensitivity and specificity of 62.5 and 59.9 for predicting LBW. Maternal weight of 55 kg and MUAC value of 23 cm had almost similar sensitivity and specificity for predicting LBW. MUAC (≤23 cm) can be considered as a potential indicator of LBW where weighing of pregnant women is not feasible or when presentation for antenatal care is late, especially where pre-pregnancy weights are not available.

KEYWORDS
Birth Weight, Fetal outcome, Gestational weight gain, Low birthweight, MUAC, Pregnancy

1 | INTRODUCTION

Low birthweight (LBW) is recognized as an important determinant of neonatal mortality and morbidity, and it is one of the World Health Assembly targets by 2025. The annual average rate of reduction in LBW prevalence globally was only 1.2% between the year 2000 and 2015 (UNICEF-WHO LBW estimates, 2019). To affect the future survival of the newborn and to improve quality of adult life, neonatal...
birthweight (BW) should be improved, which in turn is directly dependent on maternal anthropometry (Sen, Roy, & Mondal, 2009). Considerable attention has been focused on the maternal anthropometric measurements as indicators of LBW for identifying women at risk of LBW. Impaired nutritional status of women before conception, short stature, and poor nutrition during pregnancy are important contributing factors of LBW (Sen et al., 2009; Muthayya, 2009; WHO-Provisional agenda item 6.3, 2011).

Maternal anthropometry such as maternal weight (Wt), height (Ht), mid-upper arm circumference (MUAC), and maternal body mass index (BMI) in the first trimester are suggested as good predictors of LBW. Nevertheless, pre-pregnancy body mass index and gestational weight gain are the preferred anthropometric indicators to identify women at risk of producing LBW babies. However, in India, pregnant women begin to visit antenatal clinics after 10 to 12 weeks of pregnancy, and therefore, pre-pregnancy weight may not be available to calculate BMI. Considering various influencing factors, studies have demonstrated that MUAC is closely related to maternal weight, and therefore, it has been suggested as an effective tool for maternal nutrition status screening (Elshibly & Schmalisch, 2008; Tang et al., 2016; Lechtig, 1988). However, knowledge about its changes during the course of pregnancy and the cut-off that could predict LBW is limited (Frison, Kerac, Checchi, & Prudhon, 2016). There is lacuna of established cut-off points of maternal MUAC by taking demographic differences into account. MUAC of <22 cm has been suggested as an indicator of wasting, but MUAC cut-off points to predict LBW are suggested to be different for different regions (Villamor et al., 2002). Yet most studies have measured MUAC just before or after delivery; data on changes in MUAC values during pregnancy are limited (Tang et al., 2016; Ojha & Malla, 2007; Dhar & Bhadra, 2008; Sebayang et al., 2012; Assefa et al., 2012; Shrivastava, Agrawal, & Giri, 2016; Mohanty et al., 2005; Ricalde, Velásquez-Meléndez, Tanaka, & de Siqueira, 1998; López, Calvo, Poy, del Valle Balmaceda, & Cámara, 2011). Ricalde et al. collected three serial measurements on 92 pregnant women in Brazil, and Lopez et al. determined pattern of changes in MUAC, triceps, biceps, and subscapular skinfold thicknesses during the course of pregnancy. In 2016, WHO has recommended that MUAC may be useful to identify undernourished pregnant women and suggested that the optimal cut-off points must be determined for individual countries based on context-specific cost-benefit analyses (World Health Organization-Recommendations on antenatal care, 2016). Keeping in view the above, the current prospective cohort study determined maternal MUAC at different gestational age and also assessed the sensitivity of predicting women at risk of LBW.

2 | METHODS

2.1 | Study setting

In a prospective cohort study, pregnant women who received antenatal care at a tertiary care government maternity hospital located at Hyderabad, Telangana, and were delivered at the same hospital from the period May 2012 to May 2015 were screened.

2.2 | Sample size calculation

Assuming a sensitivity of 60% with a similar specificity of 60%, taking a precision of 10% and 95% confidence interval (CI) with 80% power the sample size required was 556. However, expecting attrition of 35% due to long follow-up, the sample size was calculated to 751. But 928 were found to be eligible and were recruited for screening (Nahar, Mascie-Taylor, & Begum, 2007; Roy & Sen, 2018).

2.3 | Participants

Pregnant women in their first and second trimester, willing to participate in the study, were included for the recruitment. Women with gestational age nearing 30 weeks, gestational diabetes, severe anaemia, pre-eclampsia, chronic hypertension, fetal anomaly, rheumatoid arthritis, thyroid and parathyroid disorders, and hepatic or renal or cardiovascular diseases were excluded from the study. Nine hundred and twenty eight (928) pregnant women who fulfilled inclusion criteria were registered after obtaining written informed consent and were followed through during pregnancy till child birth. Of the 928, 615 and 563 turned up for follow-up during 30–34 weeks' and >36 weeks' gestation, respectively; but delivery data such as BW and gestational age were collected from 804 of 928 recruited women. Only singleton deliveries were included in the final analysis of the data (Figure 1). In India, various programmes like “Janani Suraksha Yojana” under the National Rural Health Mission are functional under which women are paid a substantial fund for each ANC (antenatal check) visit to encourage ANCs and institutional deliveries. This enabled us to get good follow-up of the study cohort. In the state where the study was
conducted, 74.9% of pregnant women had four antenatal care visits to the health centers (Fact sheets-2015-16, NHFS-4, India). All procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments.

2.4 | Procedures

Anthropometric indicators include maternal weight in kg, height in cm, and MUAC in cm. BMI was calculated by taking pregnant women’s weight in kg divided by her height in metres squared. BMI of less than 18.5 was classified as chronic energy deficiency or undernourished. Wt, MUAC, and skinfolds at four sites were collected at three time points during pregnancy (20–26 weeks’, 30–34 weeks’, and >36 weeks’ gestation). MUAC was measured in the right arm at the level, midway between acromion and olecranon processes in centimetre, to the nearest decimal place. Triceps, biceps, and subscapular skinfold thickness were measured by trained nutritionists using a Lange skinfold caliper (nearest to 1 mm) according to standardized methods. The average of three measurements was recorded at each site. Maternal body composition was evaluated for all the three times during gestation. Postnatal weight was collected after 24 hr but within 5 days after delivery. Two dedicated project staff, nutritionists were doing the anthropometry after due training and inter/intra rater reliability was done every 3 months to keep the CV below 10%. All the demographic and pregnancy details along with 24-hr diet recall were collected from the participants.

The babies were examined within 24 hr of delivery, and BWs, crown heel length, and head circumference were recorded using the Seca weighing scales (to the nearest 1 g), infanto-metre, and measuring tape (to the nearest 1 cm), respectively. As per the WHO (1995) definition, newborns weighing less than 2.5 kg were considered as LBW neonates. Gestational age was determined by dating the last menstrual period and at the time of recruitment and was corrected by first trimester ultrasonographic findings if the difference exceeded 5 days. SGA neonates were determined by comparing the BW with fetal growth standard by gestation week. Neonates with BW less than 10th percentile of the standard population for gestation week were considered as small for gestational age (Papageorghiou et al., 2014). SGA is a surrogate marker for identification of newborns with fetal growth restriction.

2.5 | Statistical analysis

Data were analysed using SPSS 17.0 for windows IBM, Chicago. Mean and SD were calculated; mothers’ weight, height, MUAC, and BMI were ascertained for a BW of 2.5 kg. Odds ratios were computed to assess the risk of LBW between various cut-off points of MUAC and 95% CIs were calculated. Adjusted odds ratios from multivariable regression models were also performed. In addition, sensitivity, specificity, positive predictive value, negative predictive value, and area under the receiver operating characteristic curve (AUC) were calculated for predicting BW outcome for various MUAC cut-offs. Pearson’s correlation coefficients between longitudinal measurements of mothers’
2.6 | Ethical considerations

Institutional ethical committee approval was taken bearing the number 04/1/2014.

Note. Values are mean ± SD. Values in parenthesis indicate number of pregnant women.
Abbreviations: HB, haemoglobin; HC, head circumference; MUAC, mid-upper arm circumference.
A total of 928 pregnant women were followed from 20 to 24 weeks' gestation till delivery. Mean age of the pregnant women was 21.9 ± 2.642, and 1.4% were less than 18 years age. A total of 17.8% of them were illiterate, 14.6% were moderate workers, and the rest were being sedentary. However, all the study participants belonged to low socio-economic status based on Kuppuswamy’s guidelines (Bairwa, Rajput & Sachdeva, 2013). Mean energy (1,980 ± 829 kcal) and fat (33.8 ± 7.2 g) intakes were within recommended levels, whereas protein intake (54.66 ± 29.8 g) was lower than the recommended values of RDA for pregnant women. All the study participants were non-smokers, non-alcoholic, and free of any obstetrical and medical complications known to affect fetal growth. The mean ± SD gestational age at the time of recruitment was 23.6 ± 6.55. Of the 928 pregnant women followed, birth outcome data were collected from 804 pregnant women and their newborn children. Over the same period, mean ± SD maternal MUAC increased from 23.7 ± 2.863 cm to 24.5 ± 2.866 cm. Predictably, mean age, height, weight, MUAC, and gestational age at delivery (GAD) were significantly low in LBW (Table 1). Post-natal maternal weight was also low in LBW (Table 1). Likewise, Weight and MUAC during three time points were significantly low in SGA neonates (Table 2). Mean values of MUAC of pregnant women at 23 weeks gestation was 23.7 ± 2.86 cm to 24.5 ± 2.86 cm. Predictably, mean age, height, weight, MUAC, and gestational age at delivery (GAD) were significantly low in LBW (Table 1). Post-natal maternal weight was also low in LBW (Table 1). Likewise, Weight and MUAC during three time points were significantly low in SGA neonates (Table 2). Mean values of MUAC of pregnant women at 23 weeks gestation was 23.7 ± 2.86 cm to 24.5 ± 2.86 cm. Predictably, mean age, height, weight, MUAC, and gestational age at delivery (GAD) were significantly low in LBW (Table 1). 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with the highest sensitivity–specificity product for weight was 55 kg and height was 152 cm. Similarly, MUAC value of 23 cm had sensitivity and specificity of 54.0 and 59.8, respectively, whereas at 24 cm, the sensitivity rose to 71.3, but specificity decreased with an AUC value of 0.57. The mothers' weight, height, and MUAC values corresponding to BW of 2,500 g was calculated using the regression equation. The regression equation, 35.562 + 5.027 BW considering the mothers’ weight corresponding to a BW of 2,500 g, was calculated to be 48.1 kg. Height was calculated to be 152.1 cm using the regression equation, 145.229 + 2.732 BW. Similarly, the maternal MUAC corresponding to a BW of 2,500 g was calculated to be 23.66 cm using the regression equation, 20.236 + 1.372 BW. 

Regression analysis of the LBW and the SGA neonates on Maternal MUAC1 with different cut-offs showed 3.4 folds and 2.7 folds higher odds of having LBW or SGA neonates if the MUAC was less than 24 cm (Table 4).

Maternal weight and MUAC at all the three time points (20–26 weeks, 30–34 weeks, and >36 weeks' gestation) were related not only to BW but also to gestational age at delivery were related. This is the first study to demonstrate the relationship between MUAC and maternal weight gain on three serial measurements. Pearson's correlation showed association (r = .554; P = .000) between MUAC changes and gestational weight gain during the 15-week period of pregnancy in this cohort. Pregnant women with lower height, weight, MUAC, lower fat mass, and lean body mass had smaller babies. The best cut-off limit with the highest sensitivity–specificity product for weight was 55 kg and height was 152 cm for LBW.

The incidence of LBW and anaemia in the present study was well within the prevalence range reported from India (National Family Health Survey [NFHS-4], Report 2015-16: India, 2018). Moreover, the subjects in the current study belong to disadvantaged population and represents majority of women in India. Most studies have shown similar sensitivity and specificity values for MUAC. Predictably, weight also showed similar sensitivity and specificity values to identify women at risk of LBW. In a community-based longitudinal study conducted by Nahar et al., the sensitivity and specificity values (45 and 59) of maternal weight for predicting LBW were similar to the present study, and the authors stated that maternal weight best predicted the BW. However, obviating pre-pregnancy weight was their limitation. Though weight was the traditional marker, when presenting late for the antenatal checkups and in resource poor settings, MUAC acts as a simple tool to assess poor pregnancy outcomes (Katz, Khatry, LeClerq, West, & Christian, 2010; Lechtig, 1988; Mohanty et al., 2005; Ricalde et al., 1998; Roy & Sen, 2018).

WHO (Recommendations on antenatal care, 2016) has recommended that MUAC may be useful to identify under nutrition in pregnant women. However, the WHO suggests that the optimal cut-off points must be determined for individual countries based on context-specific cost-benefit analyses. This study helped us to identify a cut-off value of MUAC 23 cm as risk indicator for LBW and SGA. Its performance was similar to other established anthropometric indicators. In non-pregnant women, a study by Rodrigues et al. suggested a similar cut-off value of 24 cm as a sensitive marker for identification of women with BMI<18.5 with sensitivity and specificity of 71.1% percent and 69.6%, respectively. The MUAC value of ≤23 cm is recommended to include pregnant women at risk of LBW for infants in the Asian contexts (Ververs et al., 2013). The WHO Collaborative Study in1997 (Kelly, Kevany, De Onis, & Shah, 1996) also showed MUAC cut-off values of ≤23 cm as having significant risk for LBW (OR 1.9, 95% CI 95% [1.7, 2.1]). The observations made in the current study indicate an odds of nearly threefold higher risk of having LBW or SGA babies with a MUAC of <24 cm; however, MUAC value of ≤24 cm had very poor specificity though the sensitivity was higher.

Hence, the observations in the current study recommend a MUAC cut-off limit (≤22.5 cm) as the best predictor for LBW, but MUAC data were taken from antenatal visit records in the first trimester. Similarly, Sen et al. and Shrivastava et al. suggested a lower MUAC cut-off of <22 cm and <23 cm, respectively, to be the best surrogate measure of LBW, but these studies collected MUAC measurements at postpartum period and therefore are not comparable with our study. As LBW has detrimental effects...
on a child's health and survival, a more inclusive approach with a MUAC cut-off of ≤23 cm should be used to indicate risk of LBW or SGA and to use as entry criterion for nutritional programmes.

There are eight cross-sectional studies (measured MUAC at the time of labour or postpartum) that analysed maternal MUAC and LBW outcome, of which six studies showed positive association between MUAC and LBW, whereas two studies did not show any correlation (Elshibly & Schmalisch, 2008; Villamor et al., 2002; Ojha & Malla, 2007; Dhar & Bhadra, 2008; Shrivastava et al., 2016; Ricalde et al., 1998; López et al., 2011). Six longitudinal studies that measured MUAC during antenatal visits also reported MUAC as predictor of LBW in pregnant women, similar to the current study. All the six found significantly increased risk of LBW among mothers with low MUAC during pregnancy (Frison et al., 2016; Sebayang et al., 2012; Assefa, Berhane, & Worku, 2012; Mohanty et al., 2005; Kelly et al., 1996; Karim & Mascie-Taylor, 1997). However, of the six longitudinal studies that identified MUAC as predictor of LBW, two were on HIV population and therefore not comparable with our study. Sebayang et al. studied 14,040 births in Indonesia to examine the determinants of LBW and concluded that MUAC < 23.5 cm or short stature (height < 145 cm), or both increased the likelihood of having a LBW baby.

In addition to LBW, we also compared BW with fetal growth standards by week of gestation and identified 33% neonates to be SGA for both preterm and full-term births. SGA is a surrogate marker of fetal growth restriction. There are myriad causes of fetal growth restriction, but as observed in the current study, maternal weight, BMI, and weight gain during pregnancy are strong indicators predicting LBW and SGA. One study by Sebayang et al. reported MUAC as a predictor of SGA similar to our findings.

Limitations of the study include usage of right arm and lack of data on MUAC and maternal weight during the first trimester, which would have added more insight on the outcome. Major strengths of the study include serial measurements of maternal MUAC at three time points during antenatal period by well-trained field staff; and this is the first prospective study that measured MUAC during the course of pregnancy in the same cohort. Unlike many other researches, data on BW were collected within 24 hr after delivery.

Although recognized earlier, the importance of MUAC in predicting BW was first published by Lechtig (1988) in a study comparing MUAC and other conventional high-risk anthropometric indicators during pregnancy for LBW assessment in Guatemala. Being simple and cost-effective, MUAC was rapidly promoted as an indicator for risk of LBW baby by many longitudinal and cross-sectional studies (Dhar & Bhadra, 2008; Elshibly & Schmalisch, 2008; Sebayang et al., 2012). LBW or SGA babies are not only at greater risk of dying than infants of average weight but also at risk of more frequent infections and impaired cognitive development and are more likely to become undernourished children and adolescents (Saugstad, 1981). Evidence is now pointing that LBW/SGA predisposes children to a high risk of diabetes, heart diseases, and other chronic conditions later in life (Barker, 1990). Hence, it is an urgent need to identify pregnant women at risk, to decrease the burden of LBW or SGA babies. MUAC is a simple, easy to conduct marker of maternal nutrition status and therefore has been suggested to identify women at risk of delivering LBW.

LBW less than 2.5 kg, defined as LBW, is a poor outcome as a consequence of being born prematurely, having fetal growth restriction or both. Globally, an estimated 20 million births a year are LBW, which is about 20% of all live births, but most of the LBW babies are born in developing countries, and India contributes to 30% of global LBWs (WHO-GNT 2025:2015). There are ongoing nutrition supplementation programmes for adolescent girls and pregnant and lactating women in India. Identifying additional women as high risk based on MUAC might lead to additional allowance of food supplements especially protein-rich foods such as milk and eggs, apart from care and increased follow-up visits for counselling.

Knowledge about MUAC changes during the course of pregnancy and the cut-off that could predict LBW is limited (Frison et al., 2016). MUAC of <22 cm has been suggested as an indicator of wasting, but MUAC cut-off points to predict LBW are suggested to be different for different regions (Villamor et al., 2002). Moreover, MUAC collected during any point of time during pregnancy has been proposed to be able to predict LBW.

5 | CONCLUSION

The current study demonstrated predictive ability of MUAC ≤23 cm at all three time points during pregnancy (20–24 weeks', 30–34 weeks', and >36 weeks' gestation). Maternal MUAC cut-off of ≤23 cm from 20 weeks' gestation up till delivery can be considered for prediction of LBW. However, further studies need to be taken up with a nationally representative sample to validate this method.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

RH designed the study concept and substantially contributed in executing and writing the manuscript. VD and RB handled the data collection. BV and RS substantially contributed in data analysis. RK, SS, and JJ involved in interpreting the results. RH and VD wrote the manuscript and all the authors reviewed and approved the final manuscript.
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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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