RESEARCH PAPER

Prediction of Birth Weight by Using Other Neonatal Anthropometric Parameters at Birth: A Cross-Sectional Study

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ABSTRACT

Background

Low birth weight (LBW), defined as birth weight less than 2.5 kg, remains a major public health concern and an important determinant of neonatal morbidity and mortality worldwide. In many resource-limited settings, newborns are not routinely weighed at birth due to lack of functional weighing scales or inadequate documentation. Simple anthropometric measurements may therefore serve as practical surrogate indicators for identifying LBW infants.

Objective

To evaluate the relationship between neonatal anthropometric parameters and birth weight and to determine the most reliable anthropometric predictor of low birth weight.

Methods

A hospital-based cross-sectional study was conducted among 100 term neonates delivered at a tertiary care teaching hospital in Karad, Maharashtra, India. Birth weight was measured using a calibrated digital weighing scale. Anthropometric parameters including mid-upper arm circumference (MUAC), chest circumference, and foot length were recorded within 24 hours of birth. Statistical analysis included descriptive statistics, Pearson correlation analysis, regression analysis, and receiver operating characteristic (ROC) curve analysis.

Results

Among the 100 neonates, 21% were classified as low birth weight. All anthropometric parameters showed significant positive correlation with birth weight ($p < 0.001$). MUAC demonstrated the strongest correlation ($r = 0.436$) and emerged as the most reliable predictor in regression analysis. ROC analysis showed acceptable discriminatory ability for MUAC (AUC = 0.707), chest circumference (AUC = 0.707), and foot length (AUC = 0.704). The optimal cut-off values for identifying LBW were MUAC < 8.8 cm, chest circumference < 30.1 cm, and foot length < 6 cm.

Conclusion

Neonatal anthropometric measurements are simple, reliable, and cost-effective surrogate indicators for identifying low birth weight infants. Among the parameters studied, MUAC showed the strongest predictive value and may be useful for early screening of LBW infants in resource-limited settings.

Keywords: Low birth weight; neonatal anthropometry; mid-upper arm circumference; chest circumference; foot length; neonatal screening.

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Introduction

Low birth weight (LBW), defined by the World Health Organization (WHO) as a birth weight of less than 2.5 kg, remains one of the most important indicators of neonatal health and survival worldwide [1]. Infants born with LBW have a significantly higher risk of neonatal morbidity and mortality compared with those with normal birth weight. In addition to immediate complications such as hypothermia, hypoglycaemia, respiratory distress, and infections, LBW infants are also at increased risk for long-term consequences including impaired physical growth, neurodevelopmental delays, and chronic diseases such as hypertension, diabetes, and cardiovascular disorders later in life [2,3].

Globally, an estimated 20 million infants are born with low birth weight every year, accounting for approximately 15-20% of all live births [4]. The burden of LBW is disproportionately higher in low- and middle-income countries, where nearly 96% of affected infants are born [5]. South Asia contributes a substantial share of the global LBW burden, with India alone accounting for nearly one-fifth of all LBW births worldwide [6]. According to national survey data, a considerable proportion of newborns in India either are not weighed at birth or lack accurate documentation of birth weight, particularly in rural and resource-limited settings [7].

Birth weight measurement using a calibrated weighing scale is considered the gold standard method for identifying LBW infants. However, in many developing countries, access to reliable weighing scales and trained healthcare personnel remains limited [8]. A significant proportion of deliveries continue to occur at home or in peripheral healthcare facilities where weighing equipment may not be available [9]. In such circumstances, newborns are often not weighed immediately after birth, resulting in delayed identification of high-risk infants who require specialized care and monitoring [10].

Early identification of LBW neonates is critical for improving neonatal survival and reducing preventable deaths. Timely recognition allows healthcare providers to implement essential interventions such as maintaining thermal stability, ensuring adequate feeding, preventing infections, and initiating early referral when necessary [11]. Therefore, simple, rapid, and reliable alternative methods for identifying LBW infants are particularly important in low-resource settings where conventional weighing equipment is unavailable or impractical [12].

Neonatal anthropometric measurements have been proposed as practical surrogate indicators for estimating birth weight. Measurements such as mid-upper arm circumference (MUAC), chest circumference (CC), foot length (FL), head circumference, and thigh circumference have demonstrated significant correlations with birth weight in several studies [13-15]. These measurements are inexpensive, easy to perform, and require minimal equipment and training, making them suitable for use by community health workers and traditional birth attendants in remote areas [16].

Among the various anthropometric parameters, mid-upper arm circumference and chest circumference have been reported to show particularly strong correlations with birth weight [17]. Bhargava et al. demonstrated that mid-arm circumference measurements were comparable to birth weight in predicting neonatal outcomes and could serve as an effective screening tool for identifying LBW infants in community settings [18]. Similarly, studies conducted in Nigeria, Bangladesh, and Nepal have reported that anthropometric parameters such as chest circumference and foot length can reliably identify newborns at risk of low birth weight [19-21].

The use of simple anthropometric measurements can therefore provide a feasible strategy for early identification of LBW infants, especially in settings where birth weight measurement is not routinely available. By enabling prompt identification and referral of high-risk newborns, these surrogate indicators may contribute to improved neonatal care and reduced mortality.

Hence, the present study was conducted to evaluate the relationship between birth weight and selected neonatal anthropometric parameters and to identify the most reliable anthropometric measurement for predicting birth weight among term neonates.

Materials and Methods

Study Design and Setting

This hospital-based observational cross-sectional study was conducted in the Department of Paediatrics at Krishna Hospital, Karad over a period of 24 months.

Study Population

The study included term neonates delivered in the hospital during the study period who fulfilled the eligibility criteria. Newborns were assessed within the first 24 hours of life to ensure consistency of measurements and minimize postnatal physiological variations.

Sample Size

The sample size was calculated using the formula:

[N = Z^2PQ/L^2]

Assuming a prevalence of 50%, allowable error of 10%, and confidence level of 95%, the calculated sample size was 97. A total of 100 neonates were included in the study.

Inclusion Criteria

- Term neonates delivered in the hospital
- Clinically stable newborns
- Parental consent obtained

Exclusion Criteria

- Neonates with birth trauma
- Congenital anomalies or chromosomal abnormalities
- Neonates older than 24 hours
- Unknown gestational age
- Maternal history of smoking or alcohol consumption

Data Collection

After delivery, detailed demographic and clinical information was collected using a structured proforma. Data recorded included:

- Sex of the newborn
- Gestational age
- Mode of delivery
- Maternal risk factors
- Birth weight

Anthropometric Measurements

All measurements were obtained within 24 hours of birth.

Birth Weight

Birth weight was measured using a calibrated digital neonatal weighing scale with the newborn unclothed.

Mid-Upper Arm Circumference (MUAC)

MUAC was measured at the midpoint between the acromion and olecranon process using a non-stretchable measuring tape.

Chest Circumference (CC)

Chest circumference was measured at the level of the nipples during expiration.

Foot Length (FL)

Foot length was measured from the heel to the tip of the longest toe using a measuring tape.

All measurements were recorded to the nearest 0.1 cm.

Statistical Analysis

Data were analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation.

Statistical tests included:

- Pearson correlation coefficient to determine association between anthropometric parameters and birth weight
- Linear regression analysis to identify independent predictors of birth weight
- Receiver Operating Characteristic (ROC) curve analysis to determine optimal cut-off values for identifying LBW infants

A p-value < 0.05 was considered statistically significant.

Results

A total of 100 term neonates were included in the present study. The demographic characteristics of the study population are summarized in Table 1. Among the neonates, 41% were male and 59% were female. Most of the newborns had normal birth weight (≥2.5 kg), accounting for 79% of the study population, whereas 21% were classified as low birth weight (<2.5 kg). The mean birth weight among female neonates was 2.77 kg and among male neonates was 2.90 kg; however, this difference was not statistically significant (p = 0.112). The distribution of maternal risk factors is presented in Table 2. The majority of mothers (76%) had no associated antenatal risk factors. Among the identified conditions, hypothyroidism was the most common maternal risk factor (11%), followed by gestational hypertension (3%) and severe pre-eclampsia (3%). Other risk factors including gestational thrombocytopenia, prolonged rupture of membranes, rheumatoid arthritis, HBsAg positivity, and imminent eclampsia were observed in small proportions. The mode of delivery of the neonates is shown in Table 3, where a majority of the births occurred through lower segment caesarean section (70%), while 30% of the neonates were delivered through normal vaginal delivery.

The mean values of the anthropometric parameters are summarized In Table 4. The mean birth weight of the neonates was 2.71 ± 0.42 kg. The mean mid-upper arm circumference (MUAC) was 9.45 ± 0.92 cm, mean chest circumference was 32.40 ± 3.10 cm, and mean foot length was 6.83 ± 0.71 cm. Estimated birth weights derived from anthropometric formulae showed close agreement with the measured birth weight, with mean estimated values of 2.66 ± 0.39 kg using MUAC, 2.72 ± 0.41 kg using chest circumference, and 2.69 ± 0.40 kg using foot length.

A comparison between low birth weight (<2.5 kg) and normal birth weight (≥2.5 kg) neonates is presented in Table 5. Neonates with low birth weight had significantly lower anthropometric measurements compared with normal birth weight neonates. The mean MUAC among LBW neonates was 8.42 ± 0.51 cm compared to 9.75 ± 0.71 cm among NBW neonates. Similarly, the mean chest circumference was 28.7 ± 1.9 cm among LBW neonates compared with 33.4 ± 2.4 cm among NBW neonates. Foot length was also significantly lower among LBW neonates (5.96 ± 0.41 cm) compared with NBW neonates (7.05 ± 0.53 cm). Gestational age was lower in the LBW group (37.6 ± 1.2 weeks) compared with the NBW group (38.9 ± 1.4 weeks). All these differences were statistically significant with p-values <0.001.

Regression analysis of the anthropometric parameters is presented in Table 6. Among the parameters studied, MUAC demonstrated the strongest predictive ability for estimating birth weight with a regression coefficient (B value) of 0.604. Chest circumference and foot length showed comparatively weaker predictive values with coefficients of −0.022 and −0.330 respectively.

Receiver operating characteristic (ROC) curve analysis was performed to assess the predictive performance of anthropometric parameters in identifying low birth weight neonates (Table 7). The area under the curve (AUC) was 0.707 for both MUAC and chest circumference and 0.704 for foot length, indicating acceptable discriminatory performance of these parameters. Comparative ROC performance with confidence intervals is shown in Table 8, where all parameters demonstrated statistically significant predictive ability with 95% confidence intervals above 0.5. Statistical significance testing of the ROC predictors is summarized in Table 9, which showed that MUAC, chest circumference, and foot length were all highly significant predictors of low birth weight (p < 0.05).

Optimal cut-off values for identifying low birth weight neonates were determined using Youden's index as shown in Table 10. The optimal cut-off values were <8.8 cm for MUAC, <30.1 cm for chest circumference, and <6 cm for foot length. These cut-offs showed a sensitivity of 57.1% and specificity of 82.3%, with a Youden's index of 0.394. The odds ratio for predicting low birth weight using these parameters was 6.19 (p < 0.001).

Pearson correlation analysis between birth weight and anthropometric parameters is presented in Table 11. All anthropometric parameters demonstrated positive correlations with birth weight. Among them, MUAC showed the strongest correlation (r = 0.436), followed by foot length (r = 0.432) and chest circumference (r = 0.426). Gestational age showed a weaker correlation with birth weight (r = 0.240).

Agreement between actual birth weight and estimated birth weight derived from anthropometric formulae is summarized in Table 12. The MUAC-based formula slightly overestimated birth weight by an average of 0.1512 kg, while the chest circumference method slightly underestimated birth weight by 0.046 kg. The foot length-based estimation demonstrated the least mean difference from the actual birth weight (+0.0328 kg), indicating better agreement and predictive accuracy compared with MUAC- and chest circumference-based estimations.

Overall, anthropometric parameters including MUAC, chest circumference, and foot length were significantly lower among low birth weight neonates compared with normal birth weight neonates. Among these parameters, MUAC demonstrated the strongest correlation with birth weight and the best predictive performance in regression and ROC analyses, indicating that it is the most reliable anthropometric indicator for predicting birth weight in the present study population.

Table 1. Demographic Characteristics of Study Population (n = 100)

Variable	Frequency (N)	Percentage (%)
Gender		
Male	41	41.0
Female	59	59.0
Birth Weight (kg)		
< 2.5 kg (LBW)	21	21.0
≥ 2.5 kg (NBW)	79	79.0

Table 2. Maternal Risk Factors

Risk Factor	Frequency (N)	Percentage (%)
Gestational hypertension	3	3.0
Gestational thrombocytopenia	2	2.0
HbsAg positive	1	1.0
Imminent eclampsia	1	1.0
PROM since 22 hours	2	2.0
Rheumatoid arthritis	1	1.0
Severe pre-eclampsia	3	3.0
Hypothyroidism	11	11.0
Nil	76	76.0
Total	**100**	**100.0**

Table 3. Mode of Delivery

Type of Delivery	Frequency	Percentage (%)
Lower Segment Caesarean Section (LSCS)	70	70.0
Normal Vaginal Delivery (NVD)	30	30.0
Total	**100**	**100.0**

Table 4. Mean Anthropometric Parameters of Neonates

Parameter	Mean	Standard Deviation	N
Birth Weight (kg)	2.71	0.42	100
Mid Upper Arm Circumference (MUAC) (cm)	9.45	0.92	100
Chest Circumference (cm)	32.40	3.10	100
Foot Length (cm)	6.83	0.71	100
Estimated Birth Weight (MUAC formula)	2.66	0.39	100
Estimated Birth Weight (Chest Circumference)	2.72	0.41	100
Estimated Birth Weight (Foot Length)	2.69	0.40	100

Table 5. Comparison of Anthropometric Parameters Between LBW and NBW Neonates

Parameter	Birth Weight Category	N	Mean	SD	p-value
Gestational Age (weeks)	<2.5 kg	21	37.6	1.2	<0.001
	≥2.5 kg	79	38.9	1.4	
MUAC (cm)	<2.5 kg	21	8.42	0.51	<0.001
	≥2.5 kg	79	9.75	0.71	
Chest Circumference (cm)	<2.5 kg	21	28.7	1.9	<0.001
	≥2.5 kg	79	33.4	2.4	
Birth Weight (kg)	<2.5 kg	21	2.18	0.19	<0.001
	≥2.5 kg	79	2.86	0.29	
Foot Length (cm)	<2.5 kg	21	5.96	0.41	<0.001
	≥2.5 kg	79	7.05	0.53	

Table 6. Regression Analysis for Prediction of Birth Weight

Parameter	Regression Coefficient (B value)
MUAC (cm)	0.604
Chest Circumference (cm)	−0.022
Foot Length (cm)	−0.330

Table 7. ROC Analysis for Prediction of Low Birth Weight

Parameter	Area Under Curve (AUC)
Chest Circumference (cm)	0.707
MUAC (cm)	0.707
Foot Length (cm)	0.704

Table 8. Comparative ROC Performance for LBW Prediction

Predictor Measurement	AUC	95% Confidence Interval

Chest Circumference (cm)	0.707	0.560 - 0.848
MUAC (cm)	0.707	0.555 - 0.846
Foot Length (cm)	0.704	0.554 - 0.843

Table 9. Statistical Significance of ROC Predictors

Predictor Measurement	**AUC**	**p-value**	**Significance**
Chest Circumference (cm)	0.707	<0.05	Highly Significant
MUAC (cm)	0.707	<0.05	Highly Significant
Foot Length (cm)	0.704	<0.05	Highly Significant

Table 10. Optimal Cut-off Values for Predicting Low Birth Weight

Parameter	**Cut-off**	**Sensitivity**	**Specificity**	**Youden's Index**
MUAC (cm)	<8.8 cm	57.1%	82.3%	0.394
Chest Circumference (cm)	<30.1 cm	57.1%	82.3%	0.394
Foot Length (cm)	<6 cm	57.1%	82.3%	0.394

Table 11. Pearson Correlation Matrix Between Birth Weight and Anthropometric Parameters

Variable	**Birth Weight**	**MUAC**	**Chest Circumference**	**Foot Length**	**Gestational Age**
Birth Weight	1.000	0.436	0.426	0.432	0.240
MUAC	0.436	1.000	0.994	0.995	0.021
Chest Circumference	0.426	0.994	1.000	0.998	0.022
Foot Length	0.432	0.995	0.998	1.000	0.024
Gestational Age	0.240	0.021	0.022	0.024	1.000

Table 12. Agreement Between Actual and Estimated Birth Weight

Estimation Method	**Mean Difference (kg)**	**Standard Deviation**
MUAC-based formula	+0.1512	0.374
Chest circumference method	−0.0460	0.402
Foot length method	+0.0328	0.397

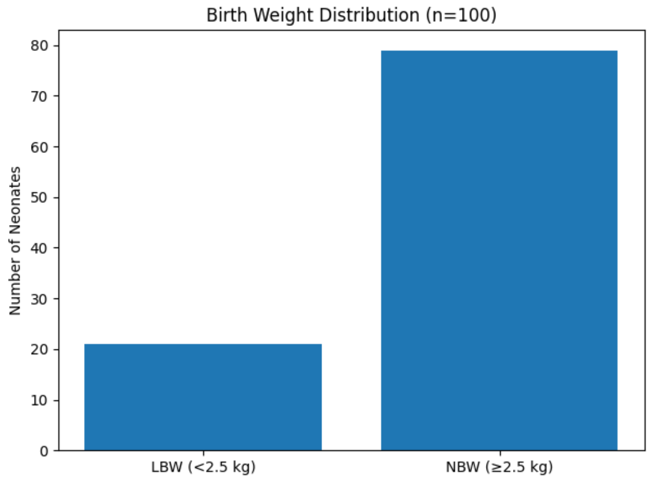

Figure 1. Distribution of birth weight among the study population (n = 100).

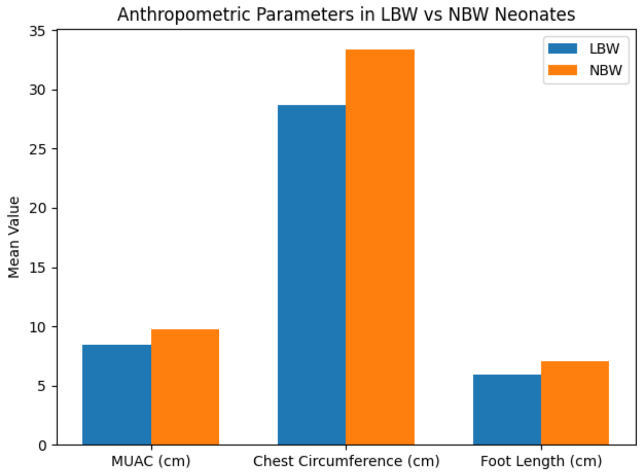

Figure 2. Comparison of neonatal anthropometric parameters between low birth weight (LBW) and normal birth weight (NBW) neonates.

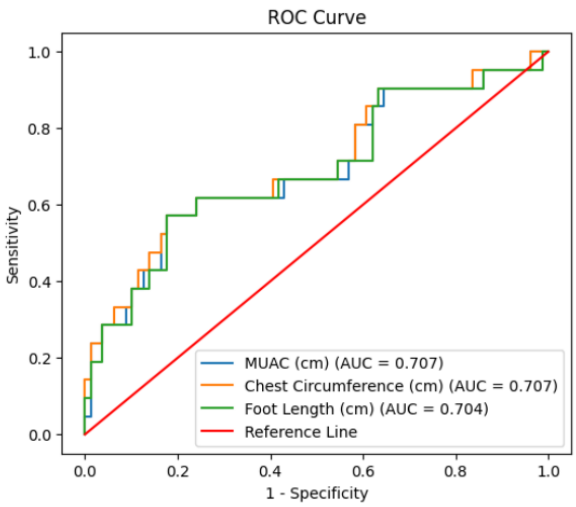

Figure 3. Receiver operating characteristic (ROC) curve showing the diagnostic performance of neonatal anthropometric parameters for predicting low birth weight.

Discussion

Low birth weight (LBW) remains a major global public health challenge and is a significant contributor to neonatal morbidity and mortality, particularly in low- and middle-income countries. According to global estimates, approximately 14-20% of all live births worldwide are classified as LBW, with the highest burden reported in South Asia and sub-Saharan Africa [1]. The World Health Organization (WHO) Country Cooperation Strategy highlighted that several developing regions continue to experience high LBW prevalence due to maternal undernutrition, inadequate antenatal care, and socioeconomic disparities [2]. Historical epidemiological data from several African countries have also demonstrated declining mean birth weights over time accompanied by increasing LBW prevalence, further emphasizing the magnitude of the problem [3].

Despite improvements in maternal and neonatal healthcare services, accurate measurement and documentation of birth weight remain challenging in many resource-limited settings. In many developing regions, a considerable proportion of deliveries occur at home or in peripheral healthcare facilities where functional weighing scales may be unavailable or poorly calibrated. Even when weighing devices are present, systematic documentation of birth weight is often inadequate [4]. Studies conducted by the WHO collaborative groups have reported that weighing equipment used in rural health facilities frequently becomes unreliable due to poor maintenance and continuous use [5]. These limitations highlight the importance of identifying simple and reliable surrogate indicators for estimating birth weight.

India presents a unique public health context because of its wide regional variations in socioeconomic development and healthcare infrastructure. Considerable disparities exist in child health indicators across different states. For instance, states such as Kerala and Puducherry report under-five mortality rates comparable to high-income countries, whereas states such as Uttar Pradesh and Bihar continue to report significantly higher mortality rates [6]. These disparities have led to the adoption of decentralized public health strategies in India, allowing states to tailor maternal and child health programs according to local needs.

In recent years, India has achieved significant improvements in maternal and child health indicators. Data from the Sample Registration System (SRS) indicate that the Infant Mortality Rate (IMR) declined from 39 per 1,000 live births in 2014 to 27 per 1,000 live births in 2021 [7]. Similarly, the Maternal Mortality Ratio (MMR) declined from 130 deaths per 100,000 live births during 2014-2016 to 93 per 100,000 live births during 2019-2021, reflecting improvements in antenatal care coverage and institutional delivery rates [7]. The Neonatal Mortality Rate (NMR) has also shown a steady decline, decreasing from 26 per 1,000 live births in 2014 to 19 per 1,000 live births in 2021, while the Under-Five Mortality Rate (U5MR) declined from 45 to 31 per 1,000 live births during the same period [7].

Anthropometry refers to the systematic measurement of the external dimensions of the human body and represents one of the simplest and most cost-effective methods for assessing nutritional and health status [8]. In neonatal care, anthropometric measurements such as mid-upper arm circumference (MUAC), chest circumference, and foot length have been widely explored as surrogate indicators for birth weight estimation. These measurements are easy to perform, require minimal equipment, and can be reliably obtained by healthcare workers even in community-based settings [9].

Birth weight itself is influenced by multiple factors including maternal nutrition, socioeconomic status, genetic predisposition, environmental exposures, and quality of antenatal care. It is widely considered one of the most reliable indicators of neonatal survival and long-term health outcomes [10]. However, in many rural areas of developing countries, birth weight is frequently not recorded due to lack of appropriate equipment. Studies have reported that a substantial proportion of deliveries in India still occur in rural or peripheral settings where weighing scales may be unavailable or inadequately maintained [11]. In such circumstances, neonatal anthropometric measurements provide an alternative method for identifying infants at risk of LBW.

Biological factors also play an important role in determining neonatal outcomes. Infants born small for gestational age (SGA) or preterm have a substantially higher risk of neonatal mortality and long-term developmental complications. Globally, it is estimated that more than 80% of neonatal deaths are associated with prematurity, intrauterine growth restriction, or low birth weight [12]. South Asia reports the highest prevalence of infants born small for gestational age, while sub-Saharan Africa has the highest incidence of preterm births [13]. Each year, approximately 15 million infants are born prematurely worldwide, and those born before 32 weeks of gestation face particularly high risks of severe complications and long-term disabilities [13].

Despite improvements in maternal and neonatal healthcare services, India continues to experience a substantial burden of childhood malnutrition and adverse birth outcomes. Preterm birth and low birth weight remain major contributors to early childhood growth failure and under-five mortality [14]. Addressing these challenges requires early identification of high-risk neonates and timely referral for appropriate medical care.

The present study evaluated the relationship between birth weight and selected neonatal anthropometric parameters among 100 term neonates. The findings demonstrated significant associations between birth weight and anthropometric measurements including MUAC, chest circumference, and foot length. All these parameters showed statistically significant correlations with birth weight, indicating their potential usefulness as surrogate indicators for identifying LBW infants.

Among the anthropometric parameters evaluated in this study, MUAC demonstrated the strongest correlation with birth weight and emerged as the most reliable predictor in regression analysis. ROC analysis also demonstrated acceptable discriminatory performance for MUAC, chest circumference, and foot length, with MUAC showing slightly superior predictive ability. These findings are consistent with previous studies that have reported MUAC as one of the most reliable anthropometric indicators for identifying LBW neonates in community settings.

Overall, the results of this study support the use of neonatal anthropometric measurements as simple and practical screening tools for identifying LBW infants, particularly in resource-limited settings where accurate birth weight measurement may not be feasible. These measurements can be easily incorporated into community-based neonatal care programs and may facilitate early identification and referral of high-risk newborns, thereby contributing to improved neonatal survival outcomes.

Strengths and Limitations

The present study has several strengths. It evaluated multiple neonatal anthropometric parameters, including mid-upper arm circumference (MUAC), chest circumference, and foot length, in relation to birth weight using standardized measurement techniques and appropriate statistical analyses such as correlation, regression, and ROC curve analysis. The study also provided practical cut-off values for identifying low birth weight (LBW) infants, which may be useful for screening in resource-limited settings where accurate weighing facilities may not always be available. However, the study also has certain limitations. It was conducted at a single tertiary care center with a relatively small sample size of 100 neonates, which may limit the generalizability of the findings to the wider population. Additionally, only term neonates were included, and therefore the applicability of these anthropometric indicators to preterm infants could not be assessed. Larger multicentric studies including both term and preterm neonates would be useful to validate and further refine these findings.

Conclusion

Neonatal anthropometric measurements provide a simple, reliable, and cost-effective method for estimating birth weight in settings where weighing scales are unavailable.

Among the parameters evaluated, mid-upper arm circumference emerged as the most reliable predictor of birth weight, followed by chest circumference and foot length.

These measurements can be easily performed by community health workers and may help in early identification and referral of low-birth-weight infants, particularly in resource-limited settings.

References

1. World Health Organization. Global nutrition targets 2025: low birth weight policy brief. Geneva: World Health Organization; 2014.
2. Blencowe Hannah, Krasevec Julia, de Onis Mercedes, Black Robert E, An Xinyi, Stevens Gretchen A, et al. National, regional, and worldwide estimates of low birth weight in 2015, with trends from 2000: a systematic analysis. Lancet Global Health. 2019;7(7):e849-e860.
3. United Nations Children's Fund (UNICEF), World Health Organization. Low Birthweight: Country, Regional and Global Estimates. New York: UNICEF; 2019.
4. Kramer Michael S. Determinants of low birth weight: methodological assessment and meta-analysis. Bulletin of the World Health Organization. 1987;65(5):663-737.
5. Lawn Joy E, Cousens Simon, Zupan Jelka. 4 million neonatal deaths: when? where? why? Lancet. 2005;365(9462):891-900.
6. Lee Anne C, Katz Joanne, Blencowe Hannah, Cousens Simon, Kozuki Naoko, Vogel Joshua P, et al. National and regional estimates of low birth weight in 2015. Lancet Global Health. 2013;1(1):e26-e36.
7. World Health Organization. Every Newborn: an action plan to end preventable deaths. Geneva: World Health Organization; 2014.
8. Bhargava Suresh K, Ramji S, Kumar Arun, Mohan Mahendra, Marwah Jagdish, Sachdev HPS. Mid-arm and chest circumferences at birth as predictors of low

birth weight and neonatal mortality. Indian Pediatrics. 1985;22(11):851-856.

9. Huque F, Hussain Z. Detection of low birth weight newborn babies by anthropometric measurements in Bangladesh. Indian Journal of Pediatrics. 1991;58(2):223-231.
10. Sreeramareddy Chandrashekhar T, Chuni Neelam, Patil Rajesh, Sreekumaran Nair N. Anthropometric surrogates to identify low birth weight newborns in Nepal. BMC Pediatrics. 2008;8:16.
11. James David K, Dryburgh Edward H, Chiswick Malcolm L. Foot length measurement in neonates. Archives of Disease in Childhood. 1979;54(3):226-230.
12. Villar José, Belizán José M. The relative contribution of prematurity and fetal growth retardation to low birth weight in developing societies. American Journal of Obstetrics and Gynecology. 1982;143(7):793-798.
13. Ulijaszek Stanley J, Kerr David A. Anthropometric measurement error and the assessment of nutritional status. British Journal of Nutrition. 1999;82(3):165-177.
14. International Institute for Population Sciences (IIPS), ICF. National Family Health Survey (NFHS-5), India 2019-21. Mumbai: IIPS; 2021.
15. Registrar General of India. Sample Registration System Statistical Report 2021. New Delhi: Office of the Registrar General; 2025.
16. World Health Organization. WHO Country Cooperation Strategy: Ethiopia 2008-2011. Geneva: WHO; 2008.
17. NITI Aayog. Healthy States, Progressive India: Report on the Ranks of States and Union Territories. New Delhi: Government of India; 2021.
18. Black Robert E, Victora Cesar G, Walker Susan P, Bhutta Zulfiqar A, Christian Parul, de Onis Mercedes, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382(9890):427-451.
19. Blencowe Hannah, Cousens Simon, Oestergaard Mikkel Z, Chou Doris, Moller Ann-Beth, Narwal Rajesh, et al. National, regional, and worldwide estimates of preterm birth rates in 2010 with time trends since 1990. Lancet. 2012;379(9832):2162-2172.
20. Darmstadt Gary L, Bhutta Zulfiqar A, Cousens Simon, Adam Taghreed, Walker Neff, de Bernis Luc. Evidence-based, cost-effective interventions: how many newborn babies can we save? Lancet. 2005;365(9463):977-988.