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Original Research Article

Study of Neonatal Anthropometry as Screening Tool for Identifying Low Birth Weight Babies in Western Rajasthan

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Abstract:

Background: Low birth weight (LBW) is linked to perinatal mortality and morbidity, growth, and cognitive developmental defects, along with a greater tendency to develop non – communicable diseases later in life. In rural settings, where health care facilities are not adequate, the birth weight of infant is not properly noted; weight is either not measured properly or tabulated accurately. This has necessitated the use of alternative indices in lieu of birth weight to reliably identify LBW babies, especially in settings where the availability of weighing scales is very limited.

Aims and Objective: To determine the reliability of anthropometric parameters as a surrogate marker of weight in low birth weight babies.

Materials and Methods: This hospital-based cross-sectional study was conducted in postnatal wards in Government Medical College Pali and attached Bangur hospital for 6 months duration from March 2024 to September 2024. All live birth healthy newborn babies, who were less than or equal to 48 hours of life and not admitted in NICU, were included in present study. All recruited babies were weighed and measured. Student's t test, Pearson correlation coefficient, Scatter plot and Receiver operating characteristic curve analysis were used to statistically analyse the data.

Results: Total 515 neonates were enrolled and evaluated. All neonatal anthropometric parameters had positive and statistically significant correlation with birth weight at $p < 0.001$. Amongst all parameters, highest correlation with birth weight was observed with mid upper arm circumference (MUAC) and least with foot length with $r = 0.917$ and $r = 0.831$ respectively. The best predictive regression model was formulated as birth weight (gm) = [531.58 * MUAC (cm)]- 1595.7. Cut off value of MUAC was found to be 7.4 cm to predict low birth weight newborns. As compared to individual neonatal anthropometric parameters, a combination of all four parameters (head circumference, mid-upper arm circumference, foot length and chest circumference) had highest significant correlation ($r = 0.933$) and multiple regression equation was formulated as birth weight = -4770.450 + {7.032 * HC (cm)} + {258.617 * MUAC (cm)} + {27.123 * FL(cm)} + {151.004 * CC(cm)}.

Conclusion: Using combination of all four anthropometric parameters (head circumference, mid-upper arm circumference, foot length and chest circumference) followed by individual parameter MUAC of neonate within first 48 hours of life, we can identify low birth weight babies in rural areas where conventional weighing scale are not easily available. It is because combination of all parameters had the best predictive performance in detecting low birth weight babies. This is crucial for early and timely institution of life saving interventions or referring to higher centres.

Keywords: Low birth weight, Surrogate marker, Anthropometric parameters.

Introduction:

Globally about 20.5 million infants are born with birth weight of <2500g every year, with Southern Asia having highest prevalence of low birth weight (LBW) infants (26.4%) in the world. [1] Though these LBW infants constitute only 15% of total live births, they account for 80% of neonatal deaths. [2] As per NFHS – 5 (2019 – 2021), neonatal mortality rate and infant mortality rate is 20 and 30 per 1000 live births of Rajasthan state. [3] Thus, Birth weight is an important indicator of survival, future growth, and overall development of child. It is associated with socio-economic, clinical, racial, hereditary, personal, and geographical factors. [4] This underlies the importance of early identification of LBW babies. But the situation is made worse in rural and distant setup with poor resources as lack of trained health care personnel and lack of basic facilities. [2,5] To determine gestational age in newborns, clinicians use various prenatal and postnatal indicators such as first trimester ultrasound, last menstrual period (LMP), neonatal scoring system such as Ballard scoring system, etc. But there are certain limitations, many mothers have irregular cycles and some do not know exact LMP. Moreover, ultrasound facilities are difficult in rural areas due to lack of resources and trained health care personnels.

This emphasizes for need of an alternative measurement that can reliably predict LBW. These alternative measurements should be easy, reliable, having good correlation with both birth weight and gestational age, and should have minimum inter and intra observer variability. Assessment of gestational age by New Ballard scoring system is time consuming and requires expertise, which can result in delayed referrals to higher centres. Henceforth, alternative measurement must be simple and easy so that even an untrained health care personnel can do measurement reliably. This study is undertaken to study simple method like head circumference (HC), mid upper arm circumference (MUAC), foot length (FL) and chest circumference (CC) for identification of LBW babies in western Rajasthan.

Aims and Objectives: To determine the reliability of anthropometric parameters as a surrogate marker of weight in low birth weight babies.

Method

Study Design: This is a cross-sectional study conducted in 6 months duration from March 2024 to September 2024 in postnatal wards in Government Medical College Pali and attached Bangur hospital.

Inclusion Criteria:

1. All live birth healthy newborn
2. Age less than or equal to 48 hours
3. Not admitted in NICU

Exclusion Criteria:

1. All sick newborns requiring NICU care
2. Newborn with congenital malformation
3. Twins or multiple births
4. Age more than 48 hours

Study procedure: For every newborn enrolled for study, procedure was explained to mother. After obtaining mother's consent, research proforma was used to record relevant data. Gestational age of newborns was assessed by New Ballard Scoring system. Hand washing was done before and after taking measurements of each newborn. Following measurements were taken within 48 hours of birth.

1. Weight: All enrolled newborn babies were weighed naked in supine position on weighing scale. Weight was then approximated to nearest 10gm for this study.

2. Head Circumference (HC): Non-elastic measuring tape was used to measure HC, with glabella anteriorly and occipital prominence posteriorly taken as landmarks. Measurement was then taken to nearest 0.1cm.

3. Mid upper arm Circumference (MUAC): Acromion process and olecranon of left arm were palpated, and their midpoint was then identified to get MUAC. Measurement was then taken to nearest 0.1cm.

4. Foot length (FL): FL was measured from heel to big toe (medial aspect of foot) using hard transparent plastic ruler. Ruler was pressed against sole of foot with zero end at heel and measurement was then taken at top border of big toe of left foot.

5. Chest Circumference (CC): Tape was passed around chest using the two nipples as reference points anteriorly and just below the inferior angle of scapulae posteriorly. Care was taken not to pull the tape too tight, and to take measurement at expiration.

All measurements were taken thrice to ensure accuracy and then average reading was recorded. Weighing scale was calibrated after every 30 subjects.

Results

Among 515 newborns recruited in study, 317 (61.5%) were males and 198 (38.5%) were females.

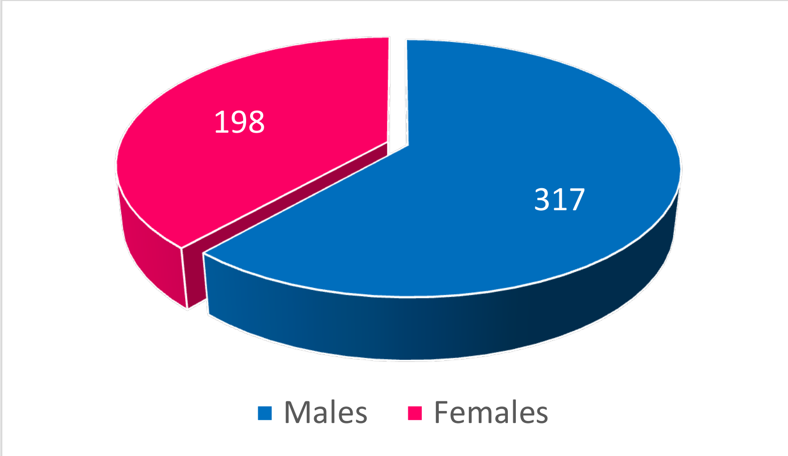

Figure 1: Newborns recruited in study (Gender wise distribution)

Also, 170 (33%) babies were preterm and remaining 345 (67%) babies were term.

Using cut-off value of <2.5kg for LBW, 185 (36%) babies were LBW, 316 (61.3%) babies were weighing 2.5kg to 3.9kg and 14 (2.7%) babies were weighing ≥4kg.

Among 185 LBW, 88 (47.5%) babies were males, and 97(52.5%) babies were females.

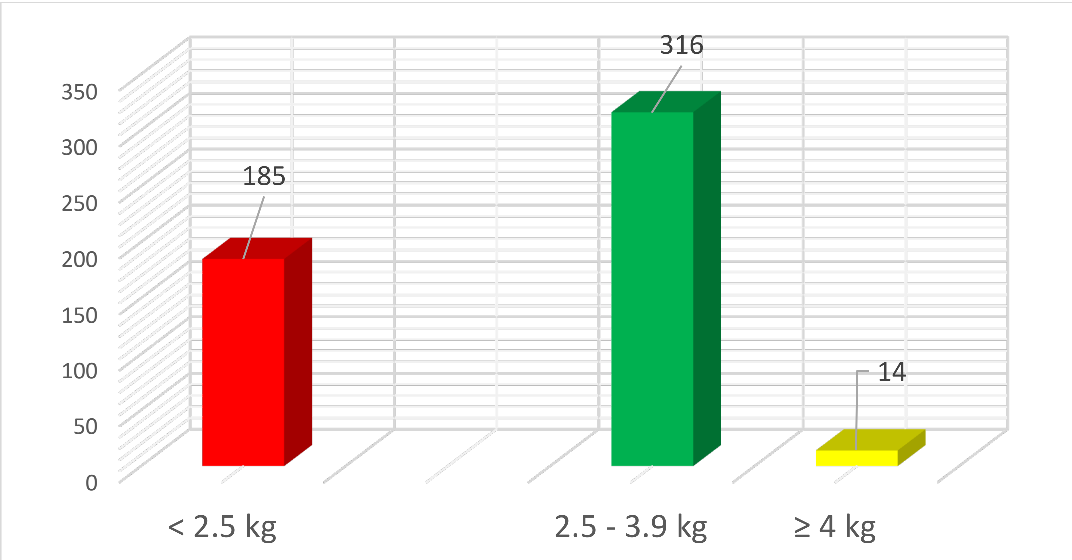

Figure 2: Birth Weight wise distribution of recruited Newborns

Table 1: Socio-demographic characteristics of respondents in postnatal wards in Bangur Hospital, Pali

Variables		**Frequency**	**Percent**
Maternal age	<20 years	45	8.7%
	20 – 24 years	123	23.8%
	25 – 29 years	222	43.1%
	30 – 35 years	109	21.2%
	>35 years	16	3.2%
Gender of neonate	Male	317	61.5%
	Female	198	38.5%
Gestational Age	Preterm (<37 weeks)	170	33%
	Term (37 – 42 weeks)	345	67%
Residence	Urban	303	58.9%
	Rural	212	41.1%
Religion	Hindu	256	49.7%
	Muslim	189	36.7%

	Jain	43	8.3%
	Christian	8	1.5%
	Other	19	3.8%
Educational status of mother	Illiterate (cannot read & write)	37	7.2%
	Can read & write	20	3.9%
	Primary School completed	51	10%
	Secondary School completed	67	13%
	Senior Secondary School completed	111	21.5%
	Graduation completed	201	39%
	Post-Graduation completed	28	5.4%
Occupation of mother	Housewife	238	46.2%
	Government employee	195	37.8%
	Employed in private sector	69	13.4%
	Self-employed (Business)	13	2.6%

Table 2 shows mean and standard deviation of anthropometric parameters of whole study participants as well as both preterm and term study subjects. Then parameters are compared using T test statistics which is statistically significant for all parameters.

Table 2: Mean anthropometric data of study participants with Preterm and Term subgroups

Parameters	All babies	Preterm (Mean ± SD)	Term (Mean ± SD)	T test	P value
Weight (gm)	2469.11 ± 525.23	1964.19 ± 356.01	2717.92 ± 402.31	- 21.62	< 0.001
HC (cm)	34.19 ± 1.88	32.17 ± 1.41	35.18 ± 1.15	- 24.14	< 0.001
MUAC (cm)	7.64 ± 0.89	6.65 ± 0.59	8.13 ± 0.54	- 27.33	< 0.001
FL (cm)	7.03 ± 0.96	5.97 ± 0.81	7.55 ± 0.48	- 23.36	< 0.001
CC (cm)	31.99 ± 1.59	30.21 ± 0.93	32.87 ± 1.01	- 29.62	< 0.001

Table 3 & 4 shows Gender and Gestational age distribution as per weight categories. From table 3, we can infer that more females are born low birth weight as compared to males which could be because of Gender Insulin Hypothesis. [6]

Table 3: Gender distribution as per weight categories

Weight (gm)	Male frequency	Female frequency	Total
<2500	88 (47.5%)	97 (52.5%)	185 (100%)
≥2500	229 (69.3%)	101 (30.7%)	330 (100%)
Total	317 (61.5%)	198 (38.5%)	515 (100%)

Table 4: Gestational age distribution as per weight categories

Weight (gm)	Gestational Age (weeks)		Total
	< 37 (Preterm)	37 – 42 (Term)	
< 2500	152 (82.2%)	33 (17.8%)	185 (100%)
≥ 2500	18 (5.4%)	312 (94.6%)	330 (100%)
Total	170 (33%)	345 (67%)	515 (100%)

Table 5 outlines mean values of anthropometric variables for different weight categories. Overall, mean for each of measurements for LBW neonates were; 31.15 ± 1.61 cm for HC, 6.41 ± 0.91 cm for MUAC, 5.57 ± 1.00 cm for FL, and 29.93 ± 1.11 cm for CC.

Table 5: Mean values of anthropometric variables for different weight categories

Birth Weight wise categories (gm)	HC		MUAC		FL		CC	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
< 2500	31.15	1.61	6.41	0.91	5.57	1.00	29.93	1.11
>2500	35.21	1.29	8.23	0.81	7.59	0.79	32.98	1.29

Table 6: Pearson correlation coefficient with Birth weight

Anthropometric variables	Pearson Correlation Coefficient (r) with Birth weight	R^2	P - value
HC	0.886	0.785	< 0.001
MUAC	0.917	0.841	< 0.001
FL	0.831	0.691	< 0.001
CC	0.905	0.819	< 0.001

Table 6 shows results of analysis of variance with respect to all; there was a statistically significant difference among two different weight categories for all measurements, hence indicating all anthropometric variables had significant, linear and positive correlation with birth weight (P = <0.001). Among all parameters, MUAC had highest correlation with birth weight (r = 0.917) while FL attained lowest correlation (r = 0.831).

Table 7 shows Predictive performance of selected median cut-off points of HC, MUAC, FL, CC indices for birth weight <2500g

Parameters	Youndens Index (J)	Cut off values (cm)	Sensitivity (%)	Specificity (%)	Predictive Value (%)		AUC	95% CL (%)
					Positive	Negative		
HC	0.8310	32.2	99.46	83.64	76.60	99.65	0.975	97.60 – 99.95
MUAC	0.9734	7.4	99.46	97.88	96.19	99.70	0.996	97.94 – 99.95
FL	0.8460	6.8	87.03	97.58	95.08	93.32	0.948	90.58 – 95.30
CC	0.8118	30.5	90.27	90.91	84.24	94.55	0.972	91.78 – 96.42

ROC Curves of different anthropometric parameters: The ROC curves for individual anthropometric measurements are depicted in figure 3 to 6. While combination of all ROC curves can be seen in figure 7. As seen in figure 4, MUAC out-performs other anthropometric measurements due close proximity of plotted points to Y-axis and it has highest AUC of 0.996.

Henceforth, MUAC is chosen as gold standard.

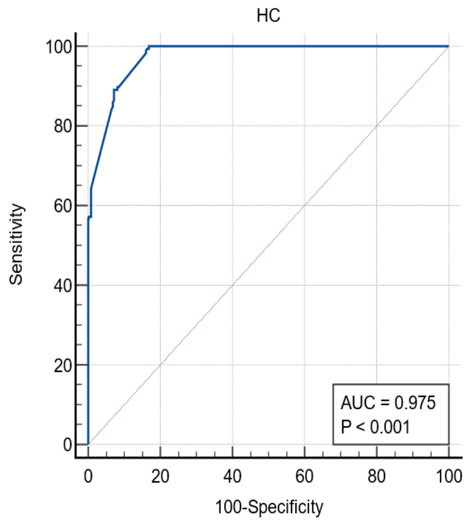

Figure 3: ROC of HC for diagnosis of LBW

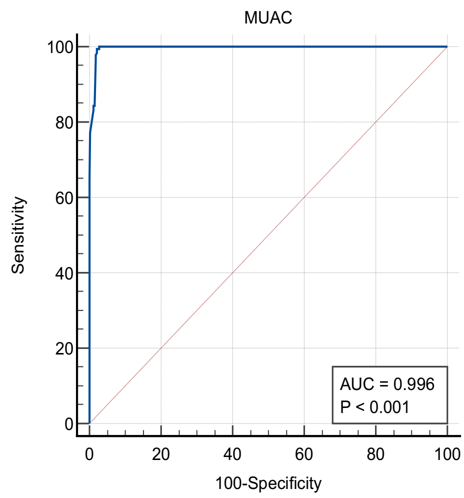

Figure 4: ROC of MUAC for diagnosis of LBW

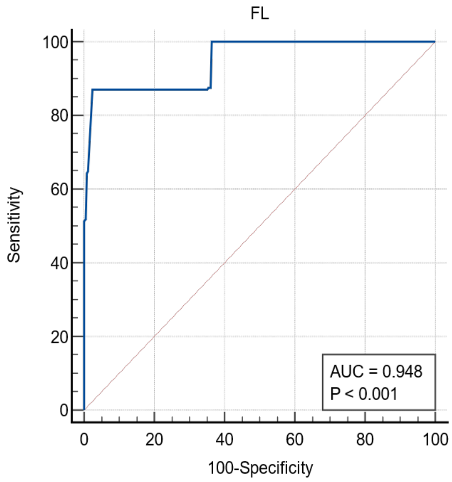

Figure 5: ROC of FL for diagnosis of LBW

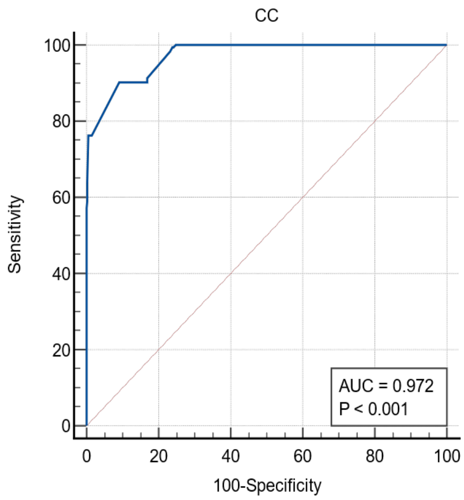

Figure 6: ROC of CC for diagnosis of LBW

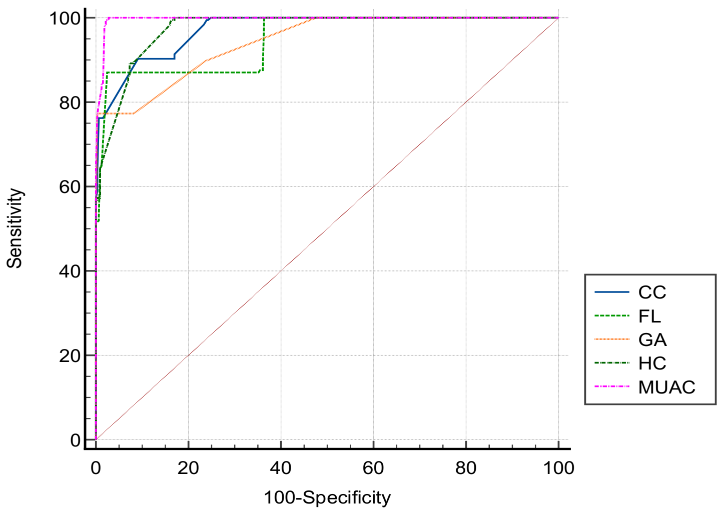

Figure 7: ROC curve for all anthropometric parameters

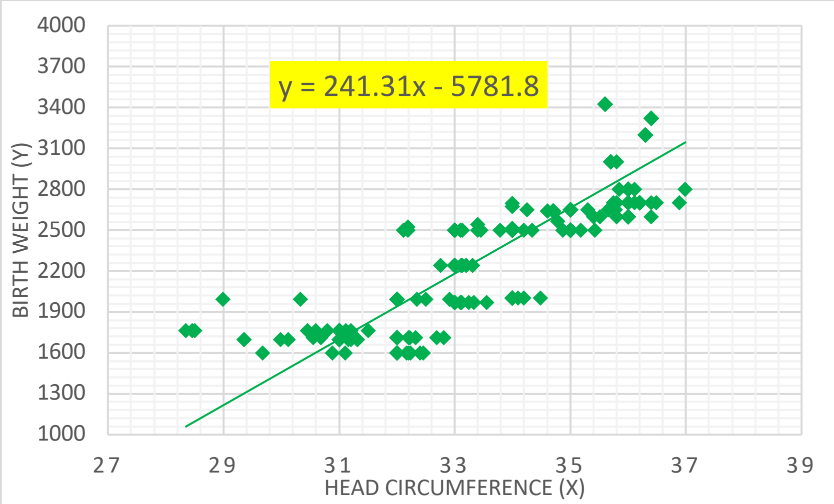

Figure 8: Scatter plot revealing the relationship between birth weight and head circumference

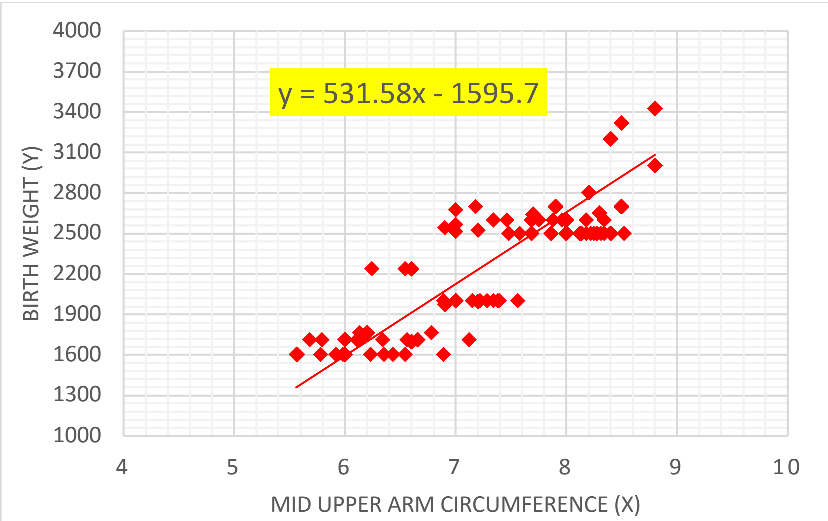

Figure 9: Scatter plot revealing the relationship between birth weight and mid upper arm circumference

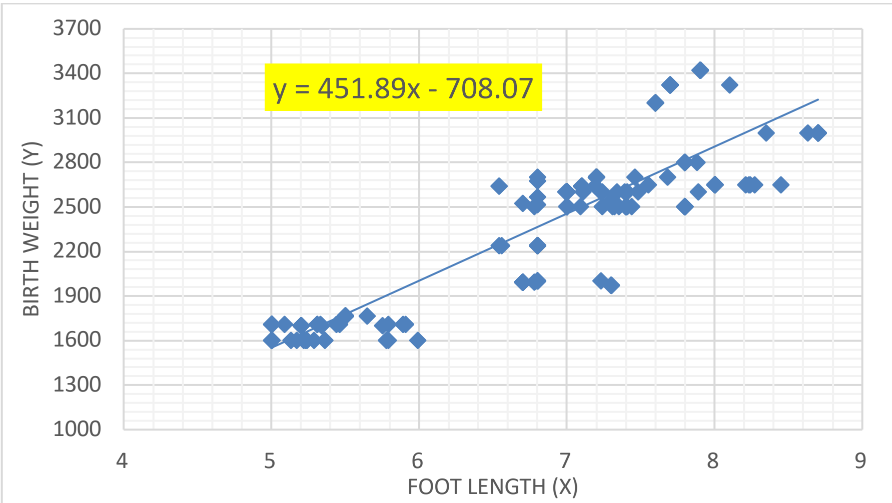

Figure 10: Scatter plot revealing the relationship between birth weight and foot length

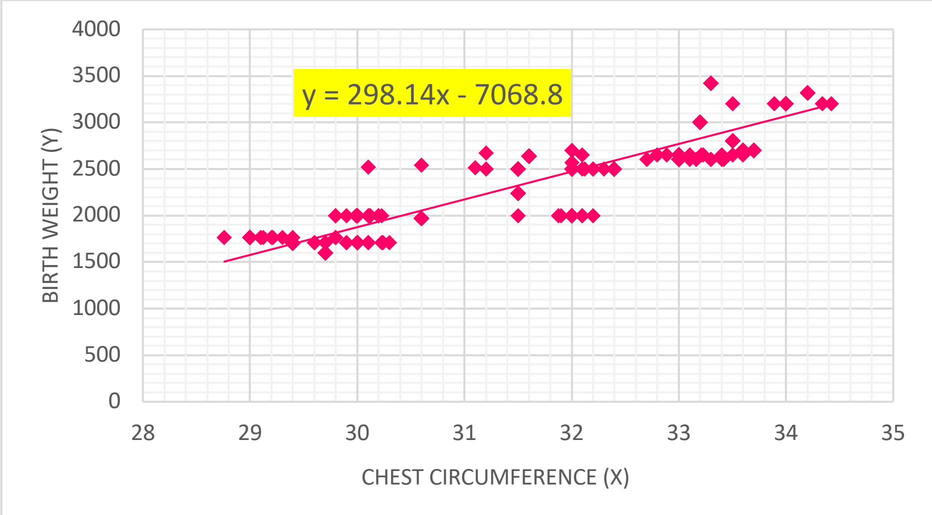

Figure 11: Scatter plot revealing the relationship between birth weight and chest circumference

To predict or estimate birth weight from neonatal anthropometric measurements, simple and multiple linear regression analyses were carried out.

Table 8: Prediction of Birth Weight from Neonatal Anthropometric parameters in Bangur Hospital, Pali

Parameters	r	R^2	Regression Equation	p value
HC	0.886	0.785	-5781.8 + {241.31 * HC}	< 0.001
MUAC	0.917	0.841	-1595.7 + {531.58 * MUAC}	< 0.001
FL	0.831	0.691	-708.07 + {451.89 * FL}	< 0.001
CC	0.905	0.819	-7068.8 + {298.14 * CC}	< 0.001
HC, MUAC, FL, CC	0.933	0.870	-4770.450 + {7.032 * HC] + {258.617 * MUAC} + {27.123 * FL} + {151.004 * CC}	< 0.001
MUAC, CC	0.933	0.870	-4850.050 + {280.034 * MUAC} + {161.849 * CC}	< 0.001

It was observed from table 8 that maximum significant correlation was obtained when all neonatal anthropometric parameters were entered in multiple regression analysis.

Thus, in present study there are 2 best regression models to predict birth weight (gm).

1. Birth weight (gm) = -4770.450 + {7.032 * HC (cm)] + {258.617 * MUAC (cm)} + {27.123 * FL(cm)} + {151.004 * CC(cm)}
2. Birth weight (gm) = -4850.050 + {280.034 * MUAC (cm)} + {161.849 * CC(cm)}

As from table 8, it can be depicted that by using MUAC as a single anthropometric parameter, next best regression model can be derived.

Birth weight (gm) = -1595.7 + {531.58 * MUAC}

Discussion:

This Observational study had certain similarities and differences from other studies. The mean of some anthropometric parameters from present study were slightly lower or slightly higher or similar to mean from other studies. The mean FL from present study was 7.03 ± 0.96 cm, which was lower than 7.45 ± 0.658 cm and 8.12 ± 0.58 cm found by Doddamani R et al in Karnataka and Modibbo et al in Kano, Nigeria respectively. [7,8] Mean HC and CC from present study were 34.19 ± 1.88 cm and 31.99 ± 1.59 cm respectively, which were higher than 32.74 ± 1.724 cm and 30.56 ± 1.839 cm for HC and CC found by Doddamani R et al. [7] Also these were higher than 30.8 ± 2.51 cm and 27.07 ± 2.90 cm for HC and CC found by Abhijit Dutta et al in Assam. [9] But mean HC found in present study were similar to mean HC (34.12 ± 2.25) found by Achebe et al in Anambra state in Southeast Nigeria. [10] Mean MUAC of 7.64 ± 0.89 cm from present study was similar to mean MUAC of 7.47 ± 0.9 cm found by Ankit Agarwal et al in Gwalior. [11] But mean MUAC of present study was lower than mean MUAC of 9.53 ± 1.108 cm found by Doddamani R et al in Karnataka. [7]

All anthropometric parameters in this study correlated positively to birth weight as seen in other studies. [7-14] There was a high positive correlation for all the anthropometric measurements and all correlation coefficients (r) were between 0.75 – 0.95. [12 – 16]

In the present study, MUAC demonstrated a high correlation with birth weight probably because it can assess foetal nutrition; reduction in muscle mass or subcutaneous fat in this region would lead to decrease in weight. CC had a good correlation with birth weight probably because of use of fixed landmark for measuring chest circumference (nipple line), thus decreasing chances of significant errors in measurement. In spite of using hard plastic ruler for measurement of foot length in present study, FL ranked 4th in our study (in order of correlations). However, though foot length ranked low in present study, it showed a higher correlation with birth weight in study done by Srinivasa S et al and Ashvini A et al [17,18]. The use of plastic ruler for measurement of foot length is more accurate method with less inter-observer variation than use of measuring tape. [19]

In present study, the cut off value for HC was 32.2cm which was similar to cut off of 32.35cm and 32.9 cm as reported in other studies such as done by Saba Annigeri et al and Srinivasa et al respectively. [16,17] Among all anthropometric parameters, HC had lowest specificity, this implies that it had high false positive rates than other parameters. Thus, diagnostic performance of HC was lower than other anthropometric parameters in this study. This finding is similar to other study done by Osagie J Ugowe et al. [20]

By using hard transparent ruler, FL measurement was easy and yielded higher diagnostic accuracy as compared to studies where flexible tapes were used for measurement. [19] Though AUC of FL was 0.948 which was the lowest among all, it was similar to AUC values of 0.97 found by Nabiwemba et al. (21) A cut off value of 6.8cm from this study was similar to study done by Kumar V et al and in the range of 6.4cm to 7.3cm given by P. Sudhapriya et al. [12,15] FL measurement had an advantage of being relatively easy to carry out and does not require much exposure as needed for CC and HC measurements.

The cut off value of 30.5 cm for chest circumference was similar to cut off range of 29.8 to 31 cm as reported in other similar studies. [17,22,23] Also, this study confirms that chest circumference had both high sensitivity and specificity rates in detecting low birth weight babies. Furthermore, with an AUC of 0.972, chest circumference demonstrated high diagnostic accuracy, after MUAC, in detecting low birth weight babies similar to AUC values of 0.96 and 0.94 as reported by Osagie J. Ugowe et al and Netsanet Workneh Gidi et al [20,24]

In present study, MUAC was accurate in predicting LBW as it had highest AUC. Also, this study confirms that MUAC had both high sensitivity and specificity in detecting low birth weight. Furthermore, with an AUC of 0.996, MUAC had highest diagnostic accuracy in diagnosing LBW babies similar to AUC values of 0.98 as reported by Hai Nguyen Thi et al. [25] Cut off for MUAC was 7.4 cm which was similar to study done by Kumar V et al [15] and lower as compared to other studies. [7,9,11,16] In order to assess how the most accurate measure compares with others, present study had compared area under curves of MUAC alongside other parameters. A logical inference that can be drawn is that mid-upper arm circumference can be used as best surrogate for identification of LBW babies. MUAC had advantage of easy measurement with less exposure of baby, hence decreased the risk of hypothermia in smaller babies. Also, the process of measurement of MUAC was also familiar to community health workers because they are employed in growth monitoring and assessment of nutritional status.

This study only evaluated predictive capacity of neonatal anthropometric parameters for identification of low birth weight babies only within 48 hours of birth, which was similar to other studies such as done by Saba Annigeri et al and done by Abhijit Dutta et al. [9,16] However, a study conducted by Marchant et al revealed predictive capacity of anthropometric parameter up to 5 days after birth. [26] Another study conducted by Wabwire-Mangen et al did measurement in first 2 weeks of birth. [27] Therefore, our finding could be crucial as identification of low birth weight babies could be done before discharge.

This study formulated different regression equations from different neonatal anthropometric parameters to predict or estimate birth weight in grams. It was found in our study that best correlation was obtained in either combination of all anthropometric parameters or combination of MUAC and CC, followed by simple linear regression equation on MUAC as individual parameter. Amongst the individual parameters, the best correlation was obtained from MUAC followed by CC. The best regression models were birth weight (gm) = -4770.450 + {7.032 * HC (cm)] + {258.617 * MUAC (cm)} + {27.123 * FL (cm)} + {151.004 * CC(cm)} and birth weight (gm) = -4850.050 + {280.034 * MUAC(cm)} + {161.849 * CC(cm)}. The simple linear regression equation using only MUAC parameter was birth weight (gm) = -1595.7 + {531.58 * MUAC (cm)}. These formulated equations could be used by community health care workers for identification of low-birth-weight babies as they are simple, quick and cost-effective, which would help in timely interventions and referrals.

Conclusion:

All the anthropometric parameters studied were found to have positive correlation with birth weight. The best correlation was found by either combination of all four anthropometric parameters or combination of only MUAC and CC, followed by MUAC individual parameter. Among all parameters, MUAC and CC had highest coefficient of correlation (r). Also, MUAC demonstrated highest diagnostic accuracy in predicting low birth weight babies with cut off of 7.4 cm and AUC of 0.996. As individual parameter, MUAC is considered as best surrogate measure to birth weight as it showed statistically significant difference in AUC when compared to other parameters. Though it is mandatory and expected that all babies are weighed at birth, but in rural areas where adequate health care facilities are lacking, there surrogate markers to birth weight can be used to identify low birth weight babies. Thus, this helps in early and timely referral to higher centers, ultimately beneficial in reducing neonatal mortality.

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