Correlation of neonatal birth weight with other anthropometric measurements - A cross-sectional study

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ABSTRACT

Background: About 60–80% of neonatal deaths are due to low birth weight (LBW <2500 g) in developing countries. **Objectives:** The objectives of this study was to identify a suitable anthropometric surrogate and to identify LBW babies in the resource limited settings like rural areas where 80–90% deliveries take place to screen the LBW babies. **Materials and Methods:** A total of 1000 newborns were studied by random sampling method. BW and other anthropometric measurements were taken within 24 h of birth. **Results:** All key anthropometric parameters were significantly correlated to each other. The maximum correlation was with midthigh circumference (MTC) (R^2=0.683), followed by foot length (FL), midarm circumference (MAC), and head circumference (HC), followed by length and least with the chest circumference (CC). **Conclusion:** Although MTC is the most sensitive parameter in this study, additional use of other parameters such as FL, HC, MAC, and length and CC significantly improves the predictive value of identifying LBW babies.

Key words: *Anthropometry, Low birth weight, Neonate*

Low birth weight (LBW) (<2.5 kg) babies who survive the critical neonatal period may suffer from impaired physical and mental growth. Therefore, the early identification and prompt referral is important in prevention of neonatal deaths. Using a cheap and easily available measuring tape for measuring various anthropometric parameters in those places where properly calibrated weighing machine is not available, we shall be able to diagnose the high-risk babies who need early referral to higher center [1,2]. This will prevent neonatal mortality and morbidity [3]. Most of the neonatal death occurs in developing countries, where most newborns die at home while they are being cared by mothers, relatives, and traditional birth attendants. Various studies supported significant correlation of birth weight with midarm circumference [4,5], with chest circumference [6,7], with foot length [8,4], and also with mid thigh circumference [9,10]. The presentstudy was undertaken to find out the best surrogate parameter to identify the LBW babies.

MATERIALS AND METHODS

This cross-sectional study was conducted in postnatal wards and SNCU of a tertiary care teaching hospital in the year May 2015–May 2016, after getting ethical approval from the Institutional Ethical Committee. A random sampling technique was used for recruitment.

BW and other anthropometric measurements were taken within 24 h of birth. Newborns with visible gross congenital anomalies, clinically seriously ill, twin, and babies delivered from mothers suffering from diabetes and hypertension and other documented medical illnesses such as chronic kidney diseases and collagen vascular diseases, were excluded from this study. BW was measured by electronic weighing machine, other anthropometric measurements were taken by non-stretchable measuring tape, and length was measured by infant meter.

Relevant history and informed consents were taken from the mothers for measuring the anthropometric parameters of the newborns and height of the mother. The following anthropometric measurements were recorded. BW: Babies were weighed naked using the electronic weighing scale to the nearest of 10 g. Crown-rump length was measured using infantometer by the nearest of 0.1 cm in supine position with knees fully extended and soles of the feet firmly held against the footboard and head touching the fixed board.

The following measurements were recorded using measuring tape to the nearest of 0.1 cm. Head circumference (HC) was measured at the level of occipital protuberance, above supraorbital ridges, and ears. CC was measured at the level of nipple in a plane right angle to the spine. MAC was measured at the midpoint between the tip of acromion and olecranon process. MTC was recorded in supine position using the left thigh at the level of the lowest fold in gluteal region. Tape was placed perpendicular to long axis of the lower limb with its top edge just under gluteal fold. FL was measured from heel to tip of the great toe using a stiff plastic transparent ruler. Maternal height was measured by

stadiometer, measured as the vertical distance from the vertex to the floor when the head is held in Frankfort horizontal plane.

The babies were classified into different groups according to their BW as laid down by the WHO. A total of three consecutive measurements were taken for each variable and the mean values were recorded.

Continuous variables were reported as mean and standard deviation and comparison of continuous variables was performed using independent sample t-test. Pearson's product-moment correlation coefficient was used to assess the association between anthropometric measurements. Receiver operating characteristic (ROC) curves were used to evaluate the accuracy of different anthropometric measurements to predict LBW. Non-parametric ROC analysis was done to compare the overall utility of anthropometric measurements for identifying LBW infant. Sensitivity and specificity were calculated at all cut points for any anthropometric measurement. We choose as "optimum" the cut point with the highest [(sensitivity+specificity)/2] ratio. This criterion was chosen to allow comparison with previous studies available in the literature. Data were entered into excel data sheet and analyzed using statistical software SPSS version 19.0 (SPSS Inc., Chicago, Illinois, USA) and $p < 0.001$ was considered statistically significant.

RESULTS

This study was a hospital-based cross-sectional study which consisted of 1000 newborns and their mothers. Of 1000 babies,

507 babies (50.7%) were male and 493 babies (49.3%) were female. Among 1000 newborns, 795 (79.5%) were normal BW (NBW) and 205 (20.5%) babies were LBW.

In the present study, the minimum BW was 1200 g, maximum BW was 4000 g, and the mean BW was 2738±436 g. The mean length was 48.49±2.19 cm (range 42.5 cm–55 cm). Summary of the anthropometric measurements is presented in Table 1.

Table 2 shows the anthropometric measurements of male and female newborns. Among the male newborns, the mean BW was 2755±456 g, whereas mean BW of female newborn was 2721±414 g. The mean length of male and female newborn was 48.58±2.19 cm and 48.41±2.19 cm, respectively.

Table 3 shows simple linear regression equation for estimating BW. The anthropometric measurements were correlated with BW with statistically significant p value. Maximum correlation was with MTC (R^2=0.683), followed by FL, then MAC, and then HC, followed by length and least with CC.

Multiple linear equation showed correlation with BW increases adding the number of multiple anthropometric measurements; although, the single best anthropometric parameter, which correlates with BW, was MTC (R^2=0.683). When it was combined with length, R^2 becomes 0.761; when MAC was added, R^2 becomes 0.796; and when FL was combined, R^2 becomes 0.811. Therefore, the correlation is maximum when all the five parameters are combined together.

Matrix of zero-order correlation coefficients between BW and other anthropometric measurements of newborns at birth showed that

Table 1: Descriptive statistics neonatal anthropometric measurements

Variables	Birth weight (g)	Length (cm)	Head circumference (cm)	Chest circumference (cm)	Midarm circumference (cm)	Midthigh circumference (cm)	Foot length (cm)
Mean	2738.68	48.49	33.36	31.25	9.72	13.56	7.80
SD	436.31	2.19	1.45	1.55	1.06	1.32	0.36
Median	2700.00	48.20	33.00	31.00	9.50	13.80	7.90
Minimum	1200.0	42.50	27.00	25.50	7.00	8.20	6.70
Maximum	4000.0	55.00	37.50	35.50	16.00	16.50	8.70
Percentiles							
25th	2500.0	47.00	32.50	30.00	9.00	13.00	7.50
50th	2700.0	48.20	33.00	31.00	9.50	13.80	7.90
75th	3000.0	50.00	34.50	32.00	10.50	14.50	8.00

SD: Standard deviation

Table 2: Anthropometric measurements of male (n=507) and female (n=493) newborns

Variables	Birth weight (g)		Length (cm)		Head circumference (cm)		Chest circumference (cm)		Midarm circumference (cm)		Midthigh circumference (cm)		Foot length (cm)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mean	2755.34	2721.55	48.58	48.41	33.44	33.27	31.33	31.18	9.76	9.68	13.58	13.53	7.82	7.78
SD	456.41	414.39	2.19	2.19	1.47	1.41	1.58	1.51	1.13	0.98	1.43	1.21	0.37	0.35
Median	2730.0	2700.00	48.50	48.00	33.00	33.00	31.00	31.00	10.00	9.50	14.00	13.50	8.00	7.80
Minimum	1200.0	1600.00	42.50	43.00	27.00	28.00	25.50	25.50	7.00	7.50	8.20	9.50	6.70	6.80
Maximum	4000.0	4000.00	55.00	55.00	36.00	37.50	35.50	35.50	16.00	16.00	16.50	16.00	8.70	8.70
Percentiles														
25th	2500.0	2500.00	47.00	47.00	32.50	32.50	30.00	30.00	9.00	9.00	13.00	13.00	7.50	7.50
50th	2730.0	2700.00	48.00	48.00	33.00	33.00	31.00	31.00	10.00	9.50	14.00	13.50	8.00	7.80
75th	3000.0	2960.00	50.00	50.00	35.00	34.00	32.50	32.00	10.50	10.50	14.50	14.20	8.00	8.00

all measurements significantly correlated with each other. Hence, we can predict BW using any one of these measurements. Correlation was highest with MTC (0.827) and lowest with CC (0.759) (Table 4).

Table 5 shows the comparison of different anthropometric measures such as length, HC, CC, MAC, MTC and FL for NBW and LBW babies. The correlation coefficient between weight and study parameters of male and female babies where weight significantly correlated (p=0.001) with all study parameters.

Table 3: Simple linear regression equation for estimating birth weight among neonates

Anthropometry	Regression equation	p value	Adjusted R^2
Length	WT=−4724.67+1531*length	0.001	0.596
HC	WT=−5101.11+235.01*HC	0.001	0.606
CC	WT=−3952.31+214.09*CC	0.001	0.575
MAC	WT=−422.30+325.22*MAC	0.001	0.623
MTC	WT=−953.40+272.36*MTC	0.001	0.683
FL	WT=−4841.71+971.37*FL	0.001	0.633

HC: Head circumference, CC: Chest circumference, MAC: Midarm circumference, MTC: Midthigh circumference, FL: Foot length

The best discrimination of LBW, as detected by ROC-area under curve (AUC), was obtained by MTC (AUC=0.897, 95% confidence interval (CI) - 0.874–0.921) followed by MAC (AUC=0.884, 95% CI - 0.858–0.910), HC (AUC=0.882, 95% CI 0.885–0.909), FL (AUC=0.882, 95% CI - 0.859–0.904), length (AUC=0.879, 95% CI - 0.856–0.902), and CC (AUC=0.826, 95% CI - 0.795–0.857) (Table 6 and Fig. 1).

The optimum cutoff points identifying LBW were 47.9 cm for length, 32.9 cm for HC, 30.7 cm for CC, 9.4 cm for MAC, 13.3 cm for MTC, and 7.7 cm for FL. MTC had sensitivity of 91% (most sensitive) and specificity of 70% and it had negative predictive value of 96.9 (maximum of all parameters); so, MTC was the most important parameter related to BW (Table 7).

DISCUSSION

In this study, a total of 1000 babies were enrolled with a mean BW of 2738±436 g (range - 1200–4000 g). In the present study, among the 1000 newborns, 795 (79.5%) babies were of

Table 4: Correlation coefficient matrix between birth weight and other anthropometric measurements of newborns (n=1000), Pearson correlation coefficient

Anthropometric parameters	Birth weight (g)	Length (cm)	Head circumference (cm)	Chest circumference (cm)	Midarm circumference (cm)	Midthigh circumference (cm)	Foot length (cm)
Birth weight (g)	1	0.772**	0.779**	0.759**	0.790**	0.827**	0.796**
Length (cm)		1	0.721**	0.672**	0.639**	0.689**	0.765**
Head circumference (cm)			1	0.820**	0.720**	0.745**	0.761**
Chest circumference (cm)				1	0.725**	0.727**	0.748**
Midarm circumference (cm)					1	0.760**	0.702**
Midthigh circumference (cm)						1	0.740**
Foot length (cm)						0.740**	1

**Correlation is significant at the 0.01 level (two-tailed)

Table 5: Comparison of different anthropometric measurement between LBW and NBW groups

Anthropometric parameters	Birth weight		t value	p value
	LBW (<2500 g) (n=205)	NBW (≥2500 g) (n=795)		
	Mean±SD	Mean±SD		
Length (cm)	46.30±1.32	49.06±2.01	18.67	0.001
Head circumference (cm)	31.72±1.33	33.78±1.14	22.19	0.001
Chest circumference (cm)	29.76±1.49	31.64±1.31	17.72	0.001
Midarm circumference (cm)	8.598±0.76	10.01±0.92	20.16	0.001
Midthigh circumference (cm)	12.00±1.25	13.96±1.01	23.59	0.001
Foot length (cm)	7.395±0.29	7.901±0.29	22.58	0.001

LBW: Low birth weight, NBW: Normal birth weight

Table 6: AUC of anthropometric variables

Test result variable (s)	Area	Standard error[a]	Asymptotic significant[b]	Asymptotic 95% CI	
				Lower bound	Upper bound
Length (cm)	0.879	0.012	0.000	0.856	0.902
Head circumference (cm)	0.882	0.014	0000	0.855	0.909
Chest circumference (cm)	0.826	0.016	0.000	0.795	0.857
Midarm circumference (cm)	0.884	0.013	0. 000	0.858	0.910
Midthigh circumference (cm)	0.897	0.012	0.000	0.874	0.921
Foot length (cm)	0.882	0.012	0.000	0.0859	0.904

AUC: Area under curve, CI: Confidence interval

NBW and 205 (20.5%) babies were of LBW. LBW babies were 48.7%, 41%, 55.27%, and 17.56% in studies conducted by Kaur *et al*. [6], Dhar *et al*. [7], Kumar *et al*. [11], and Ezeaka *et al*. [12], respectively. Sharma *et al*. [9] showed that MTC is the best alternative parameters in identifying LBW babies which is in accordance with our study. Ahmed *et al*. [13] also showed that the best surrogate parameter to identify LBW baby was thigh circumference.

Among all statistically significant parameters used in this study, MTC correlates maximum with BW. However, the specificity and positive predictive value of this parameter was less than HC. In this study, it was found that HC has the best specificity and best positive predictive value. Although HC is based on bony landmarks, molding, and/or caput succedaneum may alter it immediately after birth, so it is not considered as a reliable parameter.

In this study, the second best parameter, which has better correlation with BW, was FL. In a study by Taksande *et al*. [14], of 520 newborn babies, there were 267 male and 253 female babies. FL attained the highest correlation with BW (r=0.715) while MAC attained the lowest (r=0.355). In the present study, specificity (74%) and positive predictive value (46.8%) of FL was less. In the present study, another important parameter was MAC. Specificity (74%) and positive predictive value (45.9%) both are less in MAC in our study. A study [14] showed very less correlation coefficient with MAC as an alternative to BW.

The second parameter which has maximum specificity (84%) and maximum positive predictive value (56.7%) was length, but it has very less correlation coefficient, less adjusted R^2 value, less

AUC in ROC, less sensitivity, and also less negative predictive value. In a study by Taksande [14], length was detected as the secondbest parameter after FL.

Another important parameter in this study was CC. Although it has good specificity and positive predictive value after HC and MAC, it was the least sensitive parameter and had least correlation coefficient with BW. In a study by Kaur *et al*. [6], CC showed the highest correlation (r=0.948) as compared to other anthropometric parameters. Matrix of zero-order correlation coefficients between BW and other anthropometric measurements of newborns at birth showed that all measurements significantly correlated with each other. Hence, we can predict the BW using any one of these measurements. Correlation is highest with MTC (0.827) and lowest with CC (0.759).

In a study by Kaur *et al*. [6], multiple regression equation showed that CC alone explained the variation of BW by 90%, and the additional use of MAC and HC did not significantly improve the prediction of BW. However, in this study, addition of other anthropometric parameters along with MTC significantly improves prediction of BW in spite of the best being the MTC.

This showed that incidence of LBW is still high in developing countries. It is estimated that, in India, about a large number of deliveries take place either at home or in the community till today. Trained birth attendants and health workers residing at the community can easily be provided with a measuring tape. Since it is a simple tool to measure babies and also to detect LBW babies, grass-root level health and family planning workers trained birth attendants can play a significant role in identifying LBW babies and in giving proper advice to mothers and other caretakers.

The limitation of our study was that the percentile values we obtained reflect the results of only one hospital and a limited population, indicating that generalization to the Indian population cannot be made.

CONCLUSION

Although MTC is the most sensitive parameter in this study, additional use of other parameters such as FL, HC, MAC, and length and CC significantly improves the predictive value of identifying LBW baby. This is particularly important in resource-constrained countries where neonatal mortality is very high. Detection of LBW babies is of utmost importance for infant's survival and this can be detected by easily available measuring tape where properly calibrated weighing machine is not available.
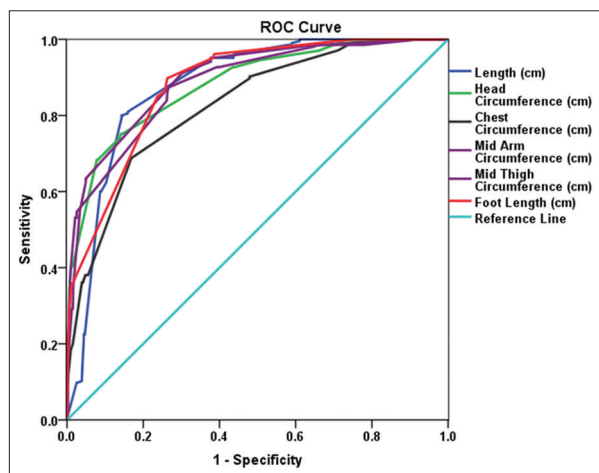

Figure 1: Area under curve of anthropometric variables

Table 7: Cutoff values of anthropometric indicators for detecting LBW babies

Anthropometry	Cutoff value	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Length (cm)	47.9	81	84	56.7	94.5
Head circumference (cm)	32.9	75	86	57.2	93.0
Chest circumference (cm)	30.7	69	83	51.3	91.2
Mid-arm circumference (cm)	9.4	87	74	45.9	95.7
Mid-thigh circumference (cm)	13.3	91	70	43.2	96.9
Foot length (cm)	7.7	90	74	46.8	96.5

LBW: Low birth weight

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