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Original Research Article

Foot length as a surrogate maker to identify birth weight

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ABSTRACT

Background: Gestational age and birth weight is an important predicator for morbidity and mortality in neonates. Aim was to determine the correlation of foot length with birth weight and gestational age in neonates.
Methods: This was a prospective observational study done in the neonatal unit department of pediatrics in Chirayu medical college and hospital, Bhopal. There were 1739 deliveries included during the study period from January 2016 to December 2020. Study group comprised of all live born babies delivered in within 24 hours of birth who fulfilled the inclusion criteria.
Results: The study comprised of 1739 newborn babies, out of which 896 (51.51%) were males and 843 (48.49%) were females. Male:female ratio 1.06:1. In our study group, 337 (15.6%) babies were preterm and 1385 (84.39%) were of term gestation. We found a positive linear correlation of foot length with all birth weight groups in a newborn with a correlation coefficient ($r=0.78$) and $p<0.001$ was found. Similarly, a positive correlation of foot length and gestational age of newborn in both term and preterm babies with ($r=0.83$) with $p<0.01$. Foot length has 87.4% sensitivity and 91.7% specificity among low-birth-weight babies with respect to cut off foot length of 75.5 mm. Foot length has 78.7% sensitivity and 63.7% specificity among preterm babies.
Conclusions: Foot length can be used as a screening tool to identify low birth weight (LBW) and preterm babies as it had a higher sensitivity and specificity.

Keywords: Foot length, Pre-term, LBW, Newborn

INTRODUCTION

Birth weight is affected by socio-demographic, clinical, racial, hereditary, personal and even seasonal and geographical factors. It is not only a critical determinant of survival, future growth and development of the child but also, a valuable indicator of maternal health, nutrition and quality of antenatal services.[1]

Birth weight has been accepted as the most important reliable index of the health status of the community and is an indicator of neonatal morbidity and mortality.[2]

About 15% or 20.3 million of all live birth worldwide are estimated to be LBW i.e. <2500 gm and account for 60-80% of all neonatal deaths.[3-5] Additionally, some 96.1% or 19.5 million LBW infants live in developing countries, with sub Saharan Africa accounting for about one fifth.[4,5] It is estimated that about 30% of babies born in India are LBW and prematurity contributes to over 80% of all neonatal deaths in developing countries and according to national family health survey phase III, prevalence of LBW babies is 22.5%.[6] Accurate weight record is a sensitive index of their well-being and availability of a sturdy and reliable weighing machine fulfils fundamental need. In the recent years, there has been a considerable interest in using simple anthropometric measures as a proxy for birth weight and gestational age. In response to the demand for a rapid, explicit, simple, and reliable screening approach for LBW, other anthropometric measurement at birth have been studied as surrogates for

birth weight.[1,7-12] Combinations of various anthropometric parameters have been used including foot length measurement to identify a newborn at risk.

So, for identification of low-birth-weight babies, there must be some alternate, simple, inexpensive, reliable and sensitive anthropometric indicator to delineate cases of LBW that such babies can be identified in the community and referred to nearby health care system where facilities are available for better care of preterm and LBW babies and thereby reducing their mortality and morbidity.[13]

An attempt is made through our study to find out relationship between gestational age, birth weight with foot length of the newborn baby so that it can be utilized as an alternative to birth weight and prematurity so as to identify LBW and high-risk babies at grass root level, for close supervision and care, as well as to prevent mortality and postnatal developmental retardation. This method has a great future potential for impact on newborn survival. In situation where it is not possible to measure the weight of the baby due to any reason, foot length can be used a proxy of birth weight to calculate initial fluid requirement and drug dosages to be administered. But more studies need to come up in this area so that a valid equation can be formulated to calculate birth weight from foot length.

METHODS

This was prospective observational study undertaken in the neonatal unit of department of pediatrics in Chirayu medical college and hospital, Bhopal. There were1739 deliveries included from January 2016 to December 2020 period. Study group comprised of all live born babies delivered in within 24 hours of birth who fulfilled the inclusion criteria. Purpose of study explained to parents and informed consent were obtained at time of enrolment.

Inclusion criteria

All live born babies delivered in Chirayu medical college and hospital of different gestational ages during the study period within 24 hours of life were included in the study.

Exclusion criteria

Sick newborns (seriously ill, severe respiratory distress, birth asphyxia, etc.,) deformities of foot and vertebral deformities, twins/ triplets and babies with congenital anomalies/ syndromic were excluded from the study.

The study was approved by institutional ethic committee and was meant for finding out the correlation of gestational age, birth weight with foot length in newborn infant. In all cases, gestational age, birth weight and foot length were measured. All the measurements were taken by single observer and no other person was involved.

Gestational age of each new born was estimated by using new Ballard score.[14] Birth weight recorded within 24 hrs after the delivery. Nude weight of the baby was taken in an electronic weighing machine, with an accuracy of ±1 gm (Salter model no: 914, calibrated monthly). Foot length measured by a plastic stiff transparent ruler. The foot was dorsi-flexed, and hip and knee kept in neutral position. The ruler was placed under the baby's right foot heel in such a way that heel and toe are aligned in parallel. Foot length measured along the sole of the right foot, from the farthermost point on the heel to the tip of the great toe or 2nd toe (whichever be longer), ensuring the toes are fully extended. Measurement recorded three times (in mm) and its mean calculated.

Statistical analysis

Data was recorded and analyzed using SPSS for windows statistical software (SPSS; version 17). Categorical variables presented as percentages and proportions; and continuous variables presented as mean (±SD). Correlation between foot length and gestational age as well as between foot length and birth weight calculated using Pearson's correlation coefficient.

RESULTS

During the study period (January 2016 to November 2020), Out of total 1802 newborns recruited for the study and only 1739 babies fulfilled the inclusion criteria and 63 newborns were excluded. Eight babies were sick (hemodynamically unstable), 15 babies born with various foot deformities (CTEV, Rocker bottom foot, syndactyly, polydactyly). There were 15 twin pairs, 1 baby born twin pair and 7 newborns had multiple congenital infections or syndromic facies. All parents gave consent and none refused. Out of the total 1739 babies, 896 (52%) were males and 843 were females (48%).

The mean weight of the babies in our study population was 2896.32 gm±536.02. In the study population, out of 1739 newborns, LBW babies were 337 (19.4%) including ELBW and VLBW, whereas 1385 (79.6%) babies were above 2500 grams and only 17 babies, (1%) had birth weight above 4000 gm. In the study group, the mean gestational age was 37.61 weeks±1.82. 271 (15.6%) babies were born preterm (less than 37 weeks), 1468 babies (84.4%) were term.

Foot length between 41-50 mm is 0.06% (1), 51-60 mm is 0.92% (16), 61-70 is 4.08% (71), 71-80 mm is 93.84% (1632) and between 81-90 mm is 1.10% (19) The mean foot length is 76.05±3.47 mm.

Most of the babies 1205 (69.29%) in study population had foot length between 76-80 mm whereas 1032 babies (29%) have foot length less than 76 mm.

In the study group, 70 (4%) babies were small for gestation age, and 88 (5%) were large for gestational age. While, majority of babies 1581 (91%) comprise appropriate for gestational age group.

The mean foot length is 76.05±standard deviation 3.47. With the help of regression equations cut off values for foot length determined as 75.5 mm. Each of the study parameters relation to birth weight (2.5 kg), which divides the newborns into LBW (<2.5 kg) and normal birth weight (≥2.5 kg).

The measurement below the cut off value of the respective parameter indicates LBW while those above the cut off value indicates normal birth weight

The mean foot length is 76.05±3.47 mm. There were 338 (19.4%) low birth babies and 1401 (80.5%) normal birth weight babies out of total 1739. Small infants with birth weight <2500 gm, 315 out of 338 (93.1%) babies have foot length below 75.5 mm (cut-off). Those who have birth weight above 2500 gm, out of 1402 only 201 babies had foot length below 75.5 mm (14.3%).

There were 271 (15.6%) preterm newborns (born less than 37 weeks of gestation). Among preterm babies it was found that 178 (63.9%) have foot length below the cut-off value 75.5 mm foot length. In comparison, among term babies 343 babies (23.3%) out of 1468 term babies born>37 weeks have foot length below cut-off value.

The mean weight of study population was 2896.32 gm with a standard deviation of 536.02 gm. Mean gestational age at delivery was 37 weeks 4 days with a standard deviation of 1.82 weeks. We found a correlation of foot length with gestational age of 0.83. We also observed a linear correlation of foot length and LBW and a correlation coefficient of 0.78.

Area under the curve is 0.948, which indicates that the test is a good predictor of normal/ LBW of the child.

At cut-off value of 75.5 mm, the sensitivity is 87.4% and specificity is 91.7%.

Area under the curve is 0.774, which indicates that the test is a good predictor of prematurity of the newborn. At cut-off value of 75.5 mm, the sensitivity is 78.7% and specificity is 63.7%

Table 1: Baseline characteristics of enrolled newborn, (n=1739).

Parameters		Frequency, (N)	Percentage (%)
Parity	Primigravida	759	(43.63)
	Multigravida	980	(56.37)
Gender	Male	896	(51.51)
	Female	843	(48.49)
Mode of delivery	Cesarean	875	(50.33)
	Vaginal	843	(48.46)
	Forceps	16	(0.92)
	Vacuum	5	(0.29)
Weight (gm), mean ± SD=2896.32±536.02	ELBW* (<1000)	08	(0.46)
	VLBW** (<1500)	26	(1.52)
	LBW (<2500)	303	(17.42)
	NBW$^{\#}$ (2500 to 4000)	1385	(79.62)
	ANW (>4000)	17	(0.98)
Weight, (gm) according to gestational age, (weeks)	SGA$^{\#\#}$ (< 10th percentile)	70	(4.00)
	AGA^ (10-90th percentile)	1581	(90.92)
	LGA^^ (>90th percentile)	88	(5.09)
Gestational age (weeks), mean ± SD=37.61±1.82	Preterm	26	(1.52)
	Late preterm	246	(14.08)
	Term	1467	(84.39)
	Post term	00	(00)

*ELBW-Extremely low birth weight, **VLBW-Very low birth weight, $^{\#}$ NBW-Normal birth weight, $^{\#\#}$SGA-Small for gestational age, ^AGA-Appropriate for gestational age, ^^LGA-Large for gestational age.

Table 2: Distribution of foot length with birth weight in the among study population.

Foot length, (mm)	Birth weight, (gm)					Total
	ELBW, (<1000)	VLBW, (1000-1499)	LBW, (1500-2499)	NBW*, (2500-4000)	ANBW, (>4000)	
41-50	1	0	0	0	0	1
51-60	5	7	4	0	0	16
61-70	0	18	50	3	0	71
71-80	3	2	248	1360	04	1632
81-90	0	0	0	06	13	19
Total	09	27	302	1384	17	1739

*NBW-Normal birth weight

Table 3: Distribution of foot length with gestational age in the study group.

Foot length, (mm)	Gestational age, (Weeks)				Total
	Early pre-term, (<32)	Late pre-term, (32-36)	Term, (37-42)	Post term, (>42)	
41-50	1	0	0	0	1
51-60	08	04	05	0	17
61-70	08	43	19	0	70
71-80	09	197	1425	0	1631
81-90	0	1	19	0	20
3478	26	245	1468	0	1739

Table 4: Weight and gestational age.

Variables		N	Mean	SD	SE	F statistic	P value
Foot length (mm)	SGA	70	67.82	6.297	0.534	603.459	0.001
	AGA	1581	76.27	2.790	0.050		
	LGA	88	78.68	2.382	0.179		
	Total	1739	76.05	3.469	0.059		

Table 5: Correlation coefficient between foot length and birth weight among SGA, AGA, LGA babies.

Variables	SGA		AGA		LGA	
	Wt vs FL*	GA vs FL**	Wt vs FL	GA vs FL	Wt vs FL	GA vs FL
Pearson correlation (R)	0.833	0.627	0.735	0.563	0.691	-
Sig (2 tailed)	0.001	0.001	0.001	0.001	0.001	-

*Wt vs FL-Weight vs foot length, **GA vs FL-Gestational age vs foot length.

Table 6: Correlation coefficient (R) between foot length and birth weight among preterm and term babies.

Variables	Weight, (gm)	Foot length, (mm)
	Pre-term	Term
Pearson correlation (R)	0.833	0.696
Sig (2-tailed)	0.001	0.001

DISCUSSION

Early identification of high-risk babies, LBW and preterm babies is an important prerequisite to reduce neonatal mortality and morbidity in developing countries like India. Several studies have been done to find out a surrogate parameter which can be used in rural areas with ease for detection of high-risk babies which should be simple, inexpensive, reliable and sensitive enough to be used by community health workers that babies requiring further care can be timely referred to higher centre.

Such an indicator should have a good correlation with birth weight and gestational age and should be highly sensitive so that a good proportion of 'at risk' neonates can be identified and referred to a higher centre. At the same time good specificity is also required so that unnecessary referrals do not burden the referral centre.

Studies favoring foot length to be used as an alternative to birth weight for identification of birth weight

Daga et al showed that foot length of 6.5 cm corresponded to the gestational age 34 weeks. Among the 660 babies they referred 20 newborns to higher center. The 18 (90%) of them had a foot length less than cut off 6.5 cm which clearly helped to identify LBW babies needing extra care.[15] Foot length sensitivity was 85%, specificity was 41.5%, positive predictive value was 54.9% and negative predictive value was 76.9%. In our study we also found high sensitivity of 87.4% and specificity 91.7% of foot length with birth weight and support that foot length measurement can be used as a reliable tool for screening small babies. Hirve and Gantara showed a correlation of 0.82 between foot length and birth weight and found a cut off value of 7.63 cm thus devised a tri-color foot tape intended for use at home by birth attendant and neonatal caretaker having a red zone (0-6.3 cm) suggesting immediate referral, yellow zone (>6.3-7.5 cm) advising domiciliary management and green zone (>7.5 cm) as an indication for routine care. The reliability of foot tape was observed to be high in their study.[16] Similarly we used stiff plastic ruler for taking foot length measurement as there is a felt need for a low cost, handy, easy to use device which can be used in resource constraints areas. We observed a mean foot length is 76.05±3.47 mm and found a cut-off value of 7.5 cm in babies <2500 gm and less than 37 weeks of gestation with sensitivity of 78.7% and specificity of 63.7%. Our study was similar in methodology to that of Mukherjee et al where 351 babies enrolled and plastic

ruler was used to record right foot length. Foot length showed a sensitivity of 92.3% (our study 78.7%)and specificity of 86.3% (our study 63.7%) for identification of preterm neonates and 100% sensitivity (our study 87.4%) and 95.3% (our study 91.7%) specificity for LBW (<2500 gm).[17] James et al in their study of 123 neonates of gestational age 26 to 42 weeks, measured foot length and found a positive linear correlation among foot length and other indices of body size in SGA newborns.[18] Similar results were obtained in our study with a positive linear correlation between foot length and SGA babies. The correlation coefficient of FL and gestational age was r=0.83. Madhulika et al studied 1000 live newborns of various gestational age for various limb anthropometric measurements using non stretchable measuring tape and found foot length correlated best with gestational age amongst all the measurement (r=0.94).[19] We studied 1739 babies, largest sample size so far. We found a correlation of foot length with gestational age 0.83. We observed a linear correlation of foot length and LBW (<2500 gm) and a correlation c (r=0.78). Shah et al conducted a study with 1000 newborns between 26-44 weeks and found that foot length measurement showed highest correlation (r=0.92) among various anthropometric measurements with birth weight.[20] They also devised a formula "Length=(Foot length×6.5)±20'' with positive correlation. Mathur et al had cut off foot length <7.2 cm in newborns weighing <2.5 kg group.[21] Hirve et al had <7.6 cm (weight 1.5-2.5 kg) and Mukherjee et al had 7.9 cm whereas in our study foot length cut off for LBW newborns weighing less than 2.5 kg was found to be <7.5 cm.[16-17] Mullany et al described that a foot length cut off <6.9 cm were 88% sensitive and 86% specificity found a correlation of 0.85 between and foot length with a cut off value of 6.9 cm in VLBW infants.[22] They found chest circumference superior to foot length in classification of infant into LBW categories. However, according to them foot length may be preferable to chest circumference, as the former does not require removal of infant clothes. In our study we also found high sensitivity of 87.4% and specificity 91.7% of foot length with cut off less than 7.5 cm in low-birth-weight babies less than 2500 gm. However, we only studied foot length as a sole-criteria for classification of LBW and preterm babies and did not compare the values of other anthropometric parameters. Marchant et al found a correlation of 0.47 with a mean foot length of 7.8 cm and mean difference between first- and fifth-day foot length was 0.1 cm with a correlation of 0.3.[22] Our study was similar to that of Elizabeth et al which found that there was a positive correlation of foot length with birth weight.[23] In study foot length had the highest predictive value (Area under the curve 0.97).

Thus, the analysis of the result of this study shows that foot length may be used as a surrogate parameter to identify LBW babies which can be used at community level by health workers for identification of high risk and LBW babies so that their timely referral can thereby help in reducing infant mortality in rural areas.

Limitations

Despite a large sample size, proportion of low-birth-weight babies and premature babies was much less. A large study population is needed prior to validation in community. The study was conducted at only one institution; the generalize ability of our findings to other institutions remains unknown. It was a hospital-based study with no community follow-up and hence it may not be representative of general population. There is chance of false positive rates that leads to over estimation of LBW and unnecessary referral rates but this is acceptable as benefits of early referral of a high-risk baby clearly outweighs the costs of treating a normal baby. Foot ruler method has practical applicability in specific areas where deliveries either occur at home or conducted by trained dais. In institutional deliveries weight measurements and meticulous observation serves as a better tool for detection of at-risk small babies

CONCLUSION

In the recent years there has been a considerable interest in using simple anthropometric measures as a proxy for birth weight and gestational age. Foot ruler method is simple, inexpensive, reliable method and can be carried out by even an unskilled person including social workers, ASHA, ANMs and even mothers. But more studies need to come up in this area so that a valid equation can be formulated to calculate birth weight from foot length.

Recommendations

Our study highlights that Foot length has high sensitivity and specificity with birth weight and prematurity and thus can serve as a reliable screening tool for identification and early referral of small babies and thereby reducing neonatal morbidity and mortality. Foot length can be used as an anthropometric surrogate for identification of LBW and preterm babies. It has great practical utility especially in remote areas where logistic constraints make timely identification of low-birth-weight babies difficult. Foot ruler method can be used as a low-cost alternative and easy to carry and operate by ASHA and ANMs and trained dais at grass root level. We found a positive correlation of foot length and birth weight of a newborn. Hence, it has a great potential to enhance yield of identifying small babies at home and community settings. We recommend that foot length should be recorded along with other anthropometric measurements in newborn birth records. Further research needs to be done to explore and ensure that foot length is reliable in community settings especially in resource constraint countries like ours.

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