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Postnatal foot length measurement as a proxy to identify low birth weight for frontline health workers in rural Sindh Province, Pakistan: a diagnostic accuracy study

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ABSTRACT

Objective To assess the diagnostic accuracy of postnatal foot length (FL) measurements as a proxy to identify low birth weight (LBW) for frontline healthcare workers in rural Sindh Province, Pakistan.

Design A community-based cross-sectional study.

Setting This study was conducted in the catchment area of Global Network's Maternal and Newborn Health Registry, Thatta, Sindh Province, Pakistan, from January to June 2023.

Participants Singleton live births irrespective of gestational age at birth.

Reference standard Birth weight was measured using calibrated digital weighing scales in grams based on the average of three readings with minimal clothing.

Index test FL was measured within 48 hours of birth using a rigid transparent plastic ruler in centimetres based on the average of three measurements.

Primary outcome Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), receiver operating characteristics curve and area under the curve with 95% CI were calculated. Euclidean distance was used to identify the cutoff of FL to identify LBW. A simple linear equation was created to predict the birth weight.

Results Out of 336 analysed newborns, 179 (53.3%) were male and 157 (46.7%) were female. The median birth weight was 2801 g (IQR: 2465–3057), of whom 88 (26.2%) were LBW. The median foot length was 7.9 cm (IQR: 7.6–8.1). For identifying LBW, the foot length cutoff was ≤7.6 cm with 90.3% sensitivity, 81.8% specificity, 63.8% PPV and 96.0% NPV. A FL of 7.6 cm predicted birth weight of 2459.4 g.

Conclusion Postnatal FL cutoff of ≤7.6 cm has adequate predictive value served as a simple, low-cost and reliable method to identify LBW for frontline healthcare providers in the rural settings of Thatta without calibrated weighing scales to triage LBW newborns in need of higher-level care.

Trial registration number NCT05515211.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study was conducted in a predominantly rural area, reflecting a potentially high low birth weight (LBW) rate in the target population.
⇒ The study showed excellent intrarater reliability and inter-rater agreement, enhancing internal validity.
⇒ Most foot lengths were measured at home by research assistants, suggesting that foot length can be a reliable proxy for LBW for frontline health workers.
⇒ Birth weight was typically measured within 48 hours potentially affecting reliability due to newborns' temporary weight drop.
⇒ The results may apply only to the specific period of data collection, posing a risk to external validity.

INTRODUCTION

According to WHO, low birth weight (LBW) is defined as babies born with birth weight of <2500 g. LBW is an important and consistent risk factor for morbidity and mortality in newborns globally.[1 2] The short-term complications associated with LBW include neonatal hypoglycaemia, hypothermia, lower Apgar score and 20 times increased risk of dying compared with newborns with normal birth weight.[3] Potential long-term complications are neurologic disability, cardiovascular problems, stunting and diabetes mellitus.[4]

A significant proportion of Pakistan's population (61.3%) reside in rural areas, where access to healthcare facilities and skilled birth attendants can be limited. In Pakistan, healthcare delivery provided by the public sector is structured in a tiered system: primary, secondary, and tertiary. Overall, 30% of deliveries occur at home. The prevalence of LBW in Pakistan varies from 5% to 23%.[3 5–7] In a study from the Global Network's Maternal and Newborn Health Registry, the overall LBW rate was reported to be 13.6%. Within the African sites, the LBW rate ranged from 2.7% in Kenya to 9.5% in the Democratic Republic of Congo. In comparison, the Asian sites showed higher LBW rates, with Nagpur,

India, at 17.3% and Pakistan having the highest rate among all countries at 21.4%.[6] This highlights Pakistan's significant burden of LBW infants compared with both African and Asian settings, emphasising the need for targeted interventions.

In a study in 2018 conducted in rural areas of Pakistan, the high burden of LBW in term pregnancies has been associated with illiteracy, nulliparity, previous miscarriage, antenatal care (ANC) of <2 visits, seeking ANC in the third trimester, non-use of iron and folic acid during last pregnancy, having hypertension in the last pregnancy, being anaemic and postpartum weight of <45 kg.[8] In 2020, a hospital-based study from Lahore, Pakistan, 20.6% of mortality in newborns, was attributed to LBW.[9]

Early detection of LBW newborns is crucial for potential lifesaving interventions, such as skin-to-skin care and early feeding.[10] In low- and middle-income countries, accurate birth weight measurement can be challenging. Approximately half of newborns are not weighed[11] or weighed inaccurately due to non-calibration of weighing scales.[12] This highlights the need for alternative methods for LBW identification.

Postnatal foot length (FL) was used for the identification of LBW. However, the FL cutoff for identification of LBW varies from 7.4 to 7.9 cm across different regions. Recognising the need for context-specific evaluations, to our knowledge, postnatal FL has not been previously assessed as a proxy to identify LBW in Pakistan, especially in rural settings. The objectives of the present study were to evaluate the diagnostic accuracy of postnatal FL measurement as a proxy for the identification of LBW in newborns in rural Pakistan using a rigid transparent plastic ruler. Birth weight was taken through calibrated digital weighing scales and was used as a reference standard.

METHODS AND ANALYSIS

Study design

This community-based cross-sectional study used the Standard for Reporting Diagnostic Accuracy Studies (STARD - https://www.equator-network.org/reporting-guidelines/stard/) for reporting.

Study setting

The study was conducted in Thatta district, Sindh Province, part of the catchment area of the Global Network's Maternal Newborn Health Registry (MNHR). The MNHR provides population-based fetal, maternal and neonatal outcomes.[13] The MNHR enrols pregnant women in early pregnancy. The enrolled women are followed at the time of delivery and 42 days postpartum. In rural Sindh, about 70% of newborns are delivered to health facilities and then cared for at home after a normal vaginal delivery, as these cases are typically discharged following 24 hours of observation due to the high patient load.

Study population

Singleton live births between January and June 2023, irrespective of gestational age at birth, were consecutively included in this study. Stillbirth, gross congenital malformations (such as spinal cord defects, omphalocele) or newborns with clinical signs suggestive of chromosomal anomalies (such as Down syndrome), or foot deformity (talipes equinovarus) were excluded.

Operational definitions

Low birth weight: According to WHO, a live birth weighing<2500 g.[12]

Maternal body mass index: Body mass index (BMI - kg/m^2) was categorised into four categories: (A) underweight (<18.5), (B) normal (≥18.5 to ≤24.9), (C) overweight (≥25 to ≤29.9) and (D) obese (≥ 30).[14]

Maternal anaemia: Haemoglobin level<11.5 g/L.[15]

Maternal hypertension: A pregnant mother with a blood pressure of>140/90 mm Hg on two consecutive readings.[16]

Data collection procedure

Two midwives served as research assistants (RA) in this study and took postnatal FL measurements and weighed the newborns. The MNHR data management unit compiled a list of pregnant women with an anticipated delivery date within the study period. MNHR staff collaborate closely with healthcare providers, informers and key informants in the villages. MNHR staff informed the study RAs by telephone within 24 hours of birth in their respective areas or place of delivery. Based on the availability of newborns, the study RAs visited the homes or health facility within 48 hours of birth to record weight and foot length. The data were collected on tablets using REDCap, an Android-based application.[17] Variables such as maternal age, maternal education, antenatal care, gestational age, maternal morbidities, place of delivery and delivery attendants were obtained from the MNHR.

Birth weight

Birth weight was measured using calibrated digital weighing scales (Paediatric Weight Scale; Tanita BD 590) with a 10 g accuracy. The RA measured the weight of the newborn three times with minimal clothing and an average of three readings was taken. During weighing, the baby wore a simple cloth napkin. All other types of commercially available absorbent napkins were removed before taking weight. RA calibrated the weighing scales daily, using a standard weight of 3 kg.

Post-natal foot length

The length of the right foot was measured using a rigid transparent plastic ruler. The measurement was taken three times from the midpoint of the heel to the tip of the longest toe. The average of three measurements was used as the final FL. The posterior landmark of the heel was defined as the most prominent point of the calcaneus when the foot is held at a 90-degree angle to the leg. To reduce the effect of the plantar grasp reflex on FL, RA was instructed to stabilise the ankle gently, touching the top of the foot to maintain its straight position.

Gestational age assessment

Gestational age based on antenatal ultrasonography before 20 weeks was used. Trained sonographers measured crown-rump length (6–13 weeks) or biparietal diameter and femur length (14–20 weeks) to determine GA, following the Hadlock criteria for GA estimation and calculation of the delivery date.[18]

Sample size

The reported rate of LBW in the Thatta birth registry was 21.4% (*Pre*).[6] An 80% sensitivity (*SE*) rate and a 10% margin of error (*d*) were considered adequate predictive performance. This analysis indicated that a sample size of around 292 participants would be necessary. Assuming a 10% rate of refusal or withdrawal from the study, the final estimated sample size was adjusted to 330.

$$n_{se} = \frac{(Z_{\alpha/2})^2(\widehat{Se})(1-\widehat{Se})}{Pre \times d^2}$$

Data analysis

Data analysis was undertaken with Stata V.18 (StataCorp, Texas, USA). Continuous variables were assessed for normality. Continuous variables such as the age of the baby at the time of examination, birth weight, foot length, maternal age and gestational age were presented as median (IQR). Categorical variables such as sex of the baby, place of delivery, place of examination and birth weight categories were presented as frequencies and percentages. Non-parametric receiver operating characteristic (ROC) curves were generated, and the area under the curve (AUC) with a 95% CI was reported. MedCalc was used to identify various FL cutoffs that were calculated against standard digital weighing scales, considering sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and likelihood ratios (LR). The Euclidean distance method was used to determine the cutoff of FL for identifying LBW. This method involves using the distance from the coordinate (0, 1), also known as the upper left (UL) index.[19] The approach follows the principle that the AUC should be maximised. Therefore, the optimal cutoff value is found by minimising the distance between the coordinate (0, 1) and the ROC curve.[20 21] We also assessed the intraobserver reliability of three measurements of foot length and birth weight using the intraclass correlation coefficient.

$$\text{Euclidean distance} = \sqrt{(1-Se)^2 + (1-Sp)^2}$$

A scatter plot was created to assess the linearity between gestational age (GA) and FL, with the coefficient of determination (r^2) and correlation coefficient (r) calculated. A simple linear equation was created to predict birth weight. The dependent variable was mean birth weight, and the independent variables were mean .

Training and quality control

The RAs got their study-specific training at the Civil Hospital, Makli, from a Paediatrician, and the Principal Investigator-PI (SST). Two refresher trainings were conducted. During the study, PI measured the foot length of 10% of cases within 2 hours of enrolment. Mean differences and levels of agreement were measured between study RA and PI (SST).

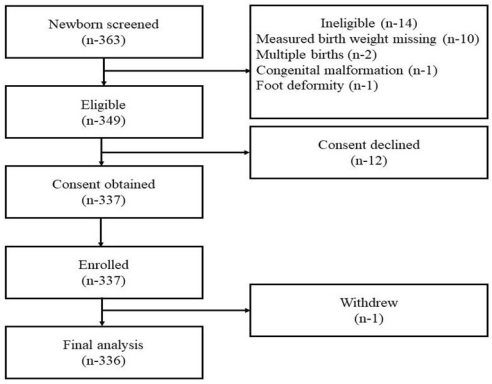

Figure 1 Study flow diagram.

Ethical consideration

Written informed consent was obtained from the mother before enrolling the newborns, wherein we secured permission from the parents for the publication of data from the study participants. Study registration: NCT05515211.

RESULTS

A total of 363 newborns were screened for eligibility, and 349 (96.1%) were found to be eligible. Informed consent was obtained from 337 (96.6%), all of whom were enrolled, except for one who was withdrawn due to a mother being concerned about her child during the examination of the baby. The analysis was, therefore, based on 336 newborns (figure 1).

Newborn characteristics

Out of 336 newborns, 293 (87.2%) were born in a health facility and 255 (75.9%) were examined at home. The median age at the point for measurement of foot length was 29 (IQR 19–41) hours; 157 (46.7%) were female. The median GA at birth was 38 weeks and 2 days (IQR 37 weeks to 39 weeks and 3 days), and 75 (22.3%) were preterm newborns. The median birth weight was 2800 (IQR 2465–3057) g, and LBW was observed in 88 (26.2%). The median FL was 7.9 (IQR 7.6–8.1) cm (table 1).

Maternal characteristics

The median age of the mothers was 28 (IQR 24–30) years. The median height of the mothers was 153 (IQR 150–157) cm, and the median maternal weight was 48 (IQR 44–55) kg. The median BMI was 20.8 kg/m2 (IQR 18.63–23.3). 83 (24.9%) women were underweight, and 20 (6.0%) were obese. A total of 92 (28.0%) mothers were primiparous, 9 (2.7%) had hypertension and 265 (78.9%) mothers had anaemia (table 1).

Table 1 Baseline characteristics of enrolled newborns and their mothers

Characteristics of newborn	N (%)
Age at examination (hours)*	29 (19–41)
Sex	336
Female	157 (46.7)
Male	179 (53.3)
Gestational age (weeks)*	38.1 (37.0–39.3)
Birth weight (g)*	2801 (2465–3057)
Birth weight (g)	
<1000	0 (0)
1000–1499	3 (0.9)
1500–2499	85 (25.3)
≥2500	248 (73.8)
Low birth weight	88 (26.2)
Foot length (cm)*	7.9 (7.6–8.1)
Place of birth	
Home	43 (12.3)
Hospital/health facility	293 (87.7)
Place of assessment at screening	
Home	255 (75.9)
Hospital/health facility	81 (24.1)
Characteristics of mother	
Age of mothers (years)*	28 (24–30)
Mothers' height (cm)*	153 (150–157)
Mothers' weight (kg)*	48 (44–55)
Body mass index (kg/m^2)*†	20.8 (18.6–23.3)
Underweight	83 (24.9)
Normal	198 (58.7)
Overweight	35 (10.5)
Obese	20 (6.0)
Parity*	2 (0–8)
Primiparous	
<1	94 (27.9)
1–2	123 (36.6)
>2	119 (35.4)
Hypertensive disorder of pregnancy	9 (2.7)
Anaemia	265 (78.9)

*Median (IQR).
†Underweight (BMI: <18.5 kg/m^2), normal (BMI: ≥18.5 and ≤24.9 kg/m^2), overweight (BMI: ≥25 and ≤29.9 kg/m^2), obese (BMI: ≥30 kg/m^2).
BMI, body mass index.

Diagnostic accuracy

For identification of LBW, a potential cutoff of FL of ≤7.6 cm was identified with a sensitivity of 90.3% (95% CI: 85.9 to 93.7), specificity of 81.8% (95% CI: 72.2 to 89.2), PPV 63.8% (95% CI: 53.1 to 73.4) and NPV 96.0% (95% CI: 94.1 to 97.2) (table 2). Furthermore, the area under the curve for males was 93.2% (95% CI: 88.8 to 97.6), for females was 92.0% (95% CI: 87.2 to 96.8), and overall (combined male and female) was 92.7% (95% CI: 89.4 to 95.3) (figures 2 and 3). Setting the cutoff of FL to ≤7.5 cm for identifying LBW, the sensitivity was 96.4% (95% CI: 93.2 to 98.3), specificity was 75.0% (95% CI: 64.6 to 83.6), PPV was 57.8% (95% CI: 48.8 to 66.3) and NPV was 98.3% (95% CI: 96.8 to 99.1) (table 2).

The mean difference between raters' measurements was −0.026 (LoA: −0.084 to 0.033, p=0.378. Intrarater reliability was excellent, with ICCs of 0.90 for three FL readings and 0.87 for three birth weight readings.

Birth weight predicting equation

The correlation coefficient (r) was 82.1%, and the coefficient of determination (r^2) was 67.4% (online supplemental figure 1). A simple linear regression equation predicted a birth weight of 2459.4 g at a FL cutoff of 7.6 cm.

DISCUSSION

In this study, 90.3% of LBW newborns with a postnatal FL cutoff value of ≤7.6 cm were correctly identified as LBW. This cutoff was determined using the Euclidean index and ROC curve analysis, balancing sensitivity and specificity to provide a practical screening tool. The study was conducted in a rural context where frontline healthcare workers face challenges such as limited access to calibrated weighing scales, ultrasound facilities or reliable recall of the last menstrual period (LMP) for estimating gestational age. The existing literature in this area suggests variation in regional FL cutoff predictive value. These studies have estimated cutoffs for various studies that propose distinct FL of northeastern Tanzania, ≤7.6 cm cutoff (70% sensitivity and 75% specificity)[22]; rural Nepal suggests ≤7.5 cm (97.4% sensitivity and 32.7% specificity)[23] and Papua New Guinea <7.7 cm cutoff (84.7% sensitivity and 69.6% specificity) for identifying LBW newborns.[24] Further studies from Ethiopia,[25] Uganda,[26] Vietnam,[27] India,[28] Papua New Guinea[24] and Tanzania[22] determined cutoffs of FL ranging from ≤7.4 cm to ≤7.9 cm for identification of LBW. A pooled analysis of the Asian studies showed that a FL of <7.7 cm had 88% sensitivity and 71% specificity for identifying LBW.[29]

Differences in the cutoff compared with non-Asian studies could be attributable to ethnic and genetic factors and may contribute to the observed variations, and these aspects warrant further investigation. Expanding research to include non-Asian populations is critical to understanding the broader applicability of FL as a proxy for LBW and to elucidate racial and regional differences. This perspective underscores the need for collaborative, multi-regional studies to establish globally relevant thresholds.

Together, these findings suggest that the operational thresholds for FL in identifying LBW are generally

Table 2 Sensitivity, specificity, predictive values and likelihood ratio at different foot length cutoffs for low birth weight

FL (cm)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	LR +ve (95% CI)	LR −ve (95% CI)	Euclidean distance
≤7	100 (98.5 to 100.0)	34.1 (24.3 to 45.0)	35 (31.7 to 38.5)	100	1.5 (1.3 to 1.8)	–	0.69
≤7.1	99.2 (97.1 to 99.9)	43.2 (32.7 to 54.2)	38.3 (34.1 to 42.7)	99.3 (97.4 to 99.8)	1.7 (1.5 to 2.1)	0.02 (0.005 to 0.08)	0.56
≤7.2	99.2 (97.1 to 99.9)	45.5 (34.8 to 56.4)	39.2 (34.8 to 43.9)	99.4 (97.5 to 99.8)	1.8 (1.5 to 2.2)	0.02 (0.004 to 0.07)	0.54
≤7.3	98 (95.4 to 99.3)	57.9 (47.0 to 68.4)	45.3 (39.3 to 51.4)	98.8 (97.1 to 99.5)	2.3 (1.8 to 3.0)	0.04 (0.014 to 0.084)	0.42
≤7.4	97.6 (94.8 to 99.1)	64.8 (53.9 to 74.7)	49.6 (42.5 to 56.6)	98.7 (97.1 to 99.4)	2.8 (2.1 to 3.7	0.04 (0.017 to 0.084)	0.35
≤7.5	96.4 (93.2 to 98.3)	75 (64.6 to 83.6)	57.8 (48.8 to 66.3)	98.3 (96.8 to 99.1)	3.9 (2.7 to 5.5)	0.05 (0.025 to 0.093)	0.25
≤7.6	90.3 (85.9 to 93.7)	81.8 (72.2 to 89.2)	63.8 (53.1 to 73.4)	96 (94.1 to 97.2)	4.9 (3.2 to 7.7)	0.1 (0.08 to 0.18)	0.20
≤7.7	83.1 (77.8 to 87.5)	86.4 (77.4 to 92.8)	68.4 (56.0 to 78.6)	93.5 (91.5 to 95.0)	6.1 (3.6 to 10.3)	0.2 (0.15 to 0.26)	0.21
≤7.8	71.8 (65.7 to 77.3)	88.6 (80.1 to 94.4)	69.2 (55.4 to 80.2)	89.8 (87.7 to 91.6)	6.3 (3.5 to 11.4)	0.3 (0.26 to 0.39)	0.30
≤7.9	57.7 (51.2 to 63.9)	93.2 (85.7 to 97.5)	75 (57.9 to 86.8)	86.1 (84.1 to 87.9)	8.5 (3.9 to 18.4)	0.5 (0.39 to 0.53)	0.42
≤8	47.2 (40.8 to 53.6)	98.9 (93.8 to 100.0)	93.6 (67.6 to 99.0)	84.1 (82.4 to 85.6)	41.5 (5.9 to 292.8)	0.5 (0.47 to 0.60)	0.52

cm, centimetre; FL, foot length; LR, likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

shorter in Asia. This suggests a more prevalent intrauterine growth-restricted phenotype or genetic factors in this region. It is crucial to consider this geographical variation in thresholds when interpreting results from studies conducted in different regions.

Additionally, integrating FL measurements into daily clinical practice demands a keen awareness of geographical variations. The proximity of healthcare facilities, particularly the distance to the hospital, significantly influences decision-making. In cases where hospitals are distant, prioritising higher sensitivity may be clinically justified, even at the expense of specificity.[24]

It is crucial to recognise that the methodology employed to establish these thresholds of FL varies from one study to another.[23 26 30 31] The predominant approach involves selecting a threshold of foot length that maximises the average sensitivity and specificity, optimising the ability to detect a specific outcome. However, alternative methods have been employed in some studies.[23 26 27] These include selecting the FL cutoffs that maximise the ratio of (sensitivity+specificity)/2, choosing a threshold where both sensitivity and specificity are at least 0.8 or employing linear regression to derive the optimal threshold. These

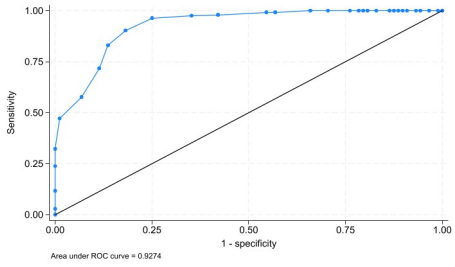

Figure 2 Receiver operating characteristic (ROC) curves and areas under each curve for foot length as diagnostic tools for predicting low birth weight.

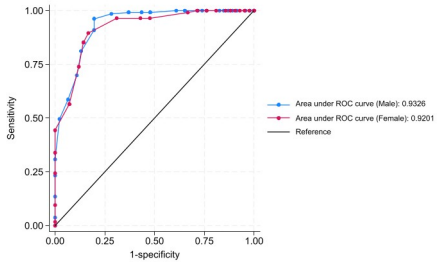

Figure 3 Receiver operating characteristic (ROC) curves and areas under each curve for foot length as diagnostic tools for predicting low birth weight by gender.

methodological variations contribute to the disparities in reported thresholds across studies.

Strengths

This study has several strengths. First, it was conducted in a predominantly rural setting, with a high LBW rate in the target population. Second, we evaluated separate FL cutoffs by gender, which has, to the best of our knowledge, never been studied previously. However, we did not find any difference between the area under the curves for male and female newborns. Third, excellent intra-rater reliability and inter-rater agreement significantly strengthen the internal validity of the study. Fourth, the Euclidean distance was identified threshold of FL, effectively balancing sensitivity and specificity. Additionally, the simple linear equation also predicted a birth weight of <2500 gm at FL of 7.6 cm. Lastly, the majority of FLs were taken at home by RA, suggesting that FL can be upscaled as a reliable proxy of LBW for frontline health workers.

Limitations

The present study has some limitations. Birth weight is typically measured within 48 hours of childbirth, but newborns often experience a temporary weight drop in the initial days. While the recorded weight after 48 hours is widely considered reasonable,[12 32] studies indicate that relying on birth weight taken after this timeframe may be unreliable.[12] In this study, 55.1% of birth weight was taken within 24 hours of birth. Moreover, the posterior landmark (heel midpoint) was not fixed with additional support, which could have further improved consistency and may reduce intraobserver and interobserver variability. Data on maternal anaemia, BMI and pre-eclampsia were not included in the model as the primary outcomes were based on vulnerable neonatal weight a composite of these exposures. Similarly, interpregnancy interval and intrauterine growth pattern were not part of the study. The focus was on creating a simple and practical screening tool for frontline healthcare workers in remote rural areas with limited resources, which is why maternal factors were not included in the model.

Implications

The study's findings have significant clinical as well as public health implications, particularly in rural areas of Thatta. The identified optimal FL cutoff value (≤7.6 cm) serves as a practical tool for frontline healthcare providers in resource-limited settings, where access to quality weighing scales may be limited. The simplicity and affordability of foot length measurement make it a potential reliable option for the early detection of LBW newborns, presenting crucial public health implications. This approach can enhance timely interventions and improve outcomes in neonatal care. To promote widespread adoption in clinical practice in Thatta district Pakistan, targeted training programmes can educate healthcare workers on accurate measurement techniques and interpretation. Integrating FL measurement into routine delivery protocols seamlessly incorporates this low-cost, non-invasive screening method, further contributing to improved identification of LBW and overall child health.

CONCLUSION

In conclusion, postnatal FL cutoff of ≤7.6 cm has adequate predictive value serve as a simple, low-cost and reliable method to identify LBW for frontline healthcare providers in the rural settings of Thatta without calibrated weighing scales to triage LBW newborns in need of higher level care. For future research, it is recommended to incorporate maternal factors such as anaemia, preeclampsia, gestational diabetes, BMI, interpregnancy interval and intrauterine growth to create a more comprehensive model. Additionally, there are few comparisons with studies from non-Asian countries, which is important since racial differences may affect the findings. Pointing out this gap could offer useful insights for future research. Moreover, FL should be measured using a fixed vertical ruler which could further standardise the measurement.

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Contributors SST, NB, AM, SS and TM conceptualised this study and developed the methodology, data synthesis and interpretation. AIA performed data analysis and interpretation. SST wrote the first draft of this manuscript. SST is the overall guarantor. SST accepts full responsibility for the work and the conduct of the study, has access to the data and controls the decision to publish. We used artificial intelligence to check the grammar, spelling and consistency.

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Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval This study involves human participants and was approved by Ethical Review Committee of Aga Khan University. Reference ID: 2023-7421-24941. Participants gave informed consent to participate in the study before taking part.

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REFERENCES

1 Lawn JE, Blencowe H, Oza S, *et al*. Every Newborn: progress, priorities, and potential beyond survival. *The Lancet* 2014;384:189–205.
2 Hughes MM, Black RE, Katz J. 2500-g Low Birth Weight Cutoff: History and Implications for Future Research and Policy. *Matern Child Health J* 2017;21:283–9.
3 Badshah S, Mason L, McKelvie K, *et al*. Risk factors for low birthweight in the public-hospitals at Peshawar, NWFP-Pakistan. *BMC Public Health* 2008;8:1–10.
4 Zerbeto AB, Cortelo FM, Filho ÉBC. Association between gestational age and birth weight on the language development of Brazilian children: a systematic review. *J Pediatr (Rio J)* 2015;91:326–32.
5 Northrop-Clewes CA, Ahmad N, Paracha PI, *et al*. Impact of health service provision on mothers and infants in a rural village in North West Frontier Province, Pakistan. *Public Health Nutr* 1998;1:51–9.
6 Pusdekar YV, Patel AB, Kurhe KG, *et al*. Rates and risk factors for preterm birth and low birthweight in the global network sites in six low- and low middle-income countries. *Reprod Health* 2020;17:187.
7 Saeed A, Saeed AM. Maternal predictors of Low Birth Weight among women attending private hospitals of Lahore, Pakistan. *Prog Nutr* 2017;19:257–63.
8 Habib MA, Greenow CR, Ariff S, *et al*. Factors associated with low birthweight in term pregnancies: a matched case-control study from rural Pakistan. *East Mediterr Health J* 2018;23:754–63.
9 Mehdi A, Ali M, Sultan A. Association of neonatal mortality with low birth weight. *Pak J Med Health Sci* 2020;14:282–5.
10 Dhage VD, Rannaware A, Choudhari SG. Kangaroo Mother Care for Low-Birth-Weight Babies in Low and Middle-Income Countries: A Narrative Review. *Cureus* 2023;15:e38355.
11 Wardlaw TM. Low birthweight: country, regional and global estimates: unicef. 2004.
12 Cutland CL, Lackritz EM, Mallett-Moore T, *et al*. Low birth weight: Case definition & guidelines for data collection, analysis, and presentation of maternal immunization safety data. *Vaccine (Auckl)* 2017;35:6492–500.
13 McClure EM, Garces AL, Hibberd PL, *et al*. The Global Network Maternal Newborn Health Registry: a multi-country, community-based registry of pregnancy outcomes. *Reprod Health* 2020;17:184.
14 Cedergren MI. Optimal Gestational Weight Gain for Body Mass Index Categories. *Obstet Gynecol* 2007;110:759–64.
15 Stevens GA, Paciorek CJ, Flores-Urrutia MC, *et al*. National, regional, and global estimates of anaemia by severity in women and children for 2000-19: a pooled analysis of population-representative data. *Lancet Glob Health* 2022;10:e627–39.
16 Ramakrishnan A, Lee LJ, Mitchell LE, *et al*. Maternal Hypertension During Pregnancy and the Risk of Congenital Heart Defects in Offspring: A Systematic Review and Meta-analysis. *Pediatr Cardiol* 2015;36:1442–51.
17 Harvey LA. REDCap: web-based software for all types of data storage and collection. *Spinal Cord* 2018;56:625.
18 Nwabuobi C, Odibo L, Camisasca-Lopina H, *et al*. Comparing INTERGROWTH-21st Century and Hadlock growth standards to predict small for gestational age and short-term neonatal outcomes. *The Journal of Maternal-Fetal & Neonatal Medicine* 2020;33:1906–12.
19 Koyama T, Hamada H, Nishida M, *et al*. Defining the optimal cut-off values for liver enzymes in diagnosing blunt liver injury. *BMC Res Notes* 2016;9:41.
20 Nahm FS. Receiver operating characteristic curve: overview and practical use for clinicians. *Korean J Anesthesiol* 2022;75:25–36.
21 Hajian-Tilaki K. Receiver Operating Characteristic (ROC) Curve Analysis for Medical Diagnostic Test Evaluation. *Caspian J Intern Med* 2013;4:627–35.
22 Paulsen CB, Nielsen BB, Msemo OA, *et al*. Anthropometric measurements can identify small for gestational age newborns: a cohort study in rural Tanzania. *BMC Pediatr* 2019;19:120.
23 Kc A, Nelin V, Vitrakoti R, *et al*. Validation of the foot length measure as an alternative tool to identify low birth weight and preterm babies in a low-resource setting like Nepal: a cross-sectional study. *BMC Pediatr* 2015;15.
24 Mengi A, Vallely LM, Laman M, *et al*. The use of newborn foot length to identify low birth weight and preterm babies in Papua New Guinea: A diagnostic accuracy study. *PLOS Glob Public Health* 2023;3:e0001924.
25 Gidi NW, Berhane M, Girma T, *et al*. Anthropometric measures that identify premature and low birth weight newborns in Ethiopia: a cross-sectional study with community follow-up. *Arch Dis Child* 2020;105:326–31.
26 Nabiwemba E, Marchant T, Namazzi G, *et al*. Identifying high-risk babies born in the community using foot length measurement at birth in Uganda. *Child Care Health Dev* 2013;39:20–6.
27 Thi HN, Khanh DKT, Thu HLT, *et al*. Foot Length, Chest Circumference, and Mid Upper Arm Circumference Are Good Predictors of Low Birth Weight and Prematurity in Ethnic Minority Newborns in Vietnam: A Hospital-Based Observational Study. *PLoS One* 2015;10:e0142420.
28 Srinivasa S, Manasa G, Madhu GN. Foot length of newborn: Its correlation with gestational age and various anthropometric parameters. *Curr Pediatr Res* 2017;21:248–53.
29 Folger LV, Panchal P, Eglovitch M, *et al*. Diagnostic accuracy of neonatal foot length to identify preterm and low birthweight infants: a systematic review and meta-analysis. *BMJ Glob Health* 2020;5:e002976.
30 Elizabeth NL, Christopher OG, Patrick K. Determining an anthropometric surrogate measure for identifying low birth weight babies in Uganda: a hospital-based cross sectional study. *BMC Pediatr* 2013;13:1–7.
31 Mullany LC, Darmstadt GL, Khatry SK, *et al*. Relationship between the surrogate anthropometric measures, foot length and chest circumference and birth weight among newborns of Sarlahi, Nepal. *Eur J Clin Nutr* 2007;61:40–6.
32 Ceesay SM, Prentice AM, Cole TJ, *et al*. Effects on birth weight and perinatal mortality of maternal dietary supplements in rural Gambia: 5 year randomised controlled trial . *BMJ* 1997;315:786–90.