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Accuracy and utility of newborn foot length screening tools to identify small babies by mothers in Sidama Region, Ethiopia

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ABSTRACT

Background Simple, low-cost anthropometric screening tools like foot length (FL) can be used to screen for small babies (low birth weight (LBW) or preterm) delivered at home or in facilities where functional weighing scales are unavailable. This study aimed to evaluate the accuracy and utility of newborn FL screening tools to help identify small babies by mothers.

Methods A mixed-method study was conducted at selected health facilities from 15 May to 6 July 2024. The consecutive sample included 396 mother–newborn dyads. Mothers screened newborns using laminated cards and plastic tools with colour codes (green/red) based on a 73 mm FL cut-off. In-depth interviews were also conducted with purposively selected participating mothers. The screening tools' diagnostic accuracy was evaluated by receiver operating characteristic curve analyses.

Results The mean maternal age was 26.9 years. There were 61 (15.4%) LBW and 48 (12.3%) preterm babies. Using the laminated card, mothers classified 39.4% of newborns as having a short foot, while 33.1% were classified as such using the plastic tool. The plastic tool showed LBW identification accuracy of 0.82 area under receiver operating characteristic curve (AUC): 0.82 (95% CI 0.77 to 0.87) compared with the laminated card AUC: 0.75 (95% CI 0.69 to 0.81). For preterm identification, both tools performed similarly (AUC: 0.73–0.74). Compared with the laminated card (81.9% sensitivity and 68.4% specificity), the plastic tool (86.9% sensitivity and 76.7% specificity) would miss fewer LBW babies and reduce unnecessary referrals. The qualitative findings also suggested that a smooth surface, footprint picture, colour codes and heel holder can increase acceptability and utilisation of the FL screening tools.

Conclusion FL screening tools made from plastic or card with colour codes can be used by mothers to help identify LBW and preterm babies. Area-specific cut-off points, a smooth surface with a footprint picture and a heel holder, should be considered while designing colour-coded FL screening tools.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ A significant number of newborns in low-income countries are not weighed at birth, especially those delivered at home.
⇒ Foot length measurement can be used as a screening tool to identify small babies.
⇒ Previous studies showed that foot length measurement has high accuracy when used by health professionals.
⇒ There is limited information about designing simple foot length-based screening tools that can be used by mothers.

WHAT THIS STUDY ADDS

⇒ Mothers or family members can identify small babies delivered at home by using foot length screening tools.
⇒ The plastic tool has 86.9% sensitivity, 76.7% specificity and 0.82 (area under receiver operating characteristic curve: 0.82) overall accuracy to identify low birth weight (LBW) babies when used by mothers.
⇒ The laminated card has 81.9% sensitivity, 68.4% specificity and 0.75 overall accuracy to identify LBW by mothers.
⇒ Utilisation of the tools can be improved by considering design characteristics such as a smooth surface with a footprint picture, a 90° heel holder and colour codes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Mothers or other family members could be incorporated into strategies for screening and identifying small babies born at home using simple tools.
⇒ Further research is needed to understand how these tools can be contextualised to enable early identification of small babies delivered at home.

INTRODUCTION

The UN Sustainable Development Goal 3 states targets by 2030 to reduce neonatal mortality below 12 per 1000 live births and under-5 mortality to below 25 per 1000 live births.[1 2] Yet, many developing countries including Ethiopia still have high neonatal deaths and a long way to go to reach the SDG targets.[3]

In Ethiopia, a neonatal mortality rate of 33 deaths per 1000 live births was reported by the national survey conducted in 2019. This was higher than the global target of 17 deaths per 1000 live births and the target of 27 deaths per 1000 live births for Sub-Saharan Africa. It was also far from the national target of reducing newborn mortality to 10 per 1000 live births and under-5 mortality to 30 per 1000 live births for the year 2019/2020.[3 4] Ethiopia's second Health Sector Transformation Plan also aims to reduce the neonatal mortality rate to 21 per 1000 live births. Achieving this goal requires the proper identification of infants born LBW and preterm.[5]

A major cause of neonatal mortality is complications associated with small babies (preterm birth or LBW) and congenital anomalies. LBW babies (weight below 2.5 kg at birth) are either preterm (born before 37 completed weeks of gestation) or small for gestational age (birth weight below the 10th percentile for gestational age and sex). LBW is also associated with increased risk of post-neonatal mortality and infant and childhood morbidity.[6 7]

This reinforces the importance of birth weight as an indicator for infant survival, future growth and overall child development. In addition, it underlines the importance of early identification of LBW and preterm babies in order to improve their outcomes by initiating timely and appropriate interventions. However, many deliveries occur at home in places where accurate weight measurement and gestational age assessment are difficult to obtain. As a result, newborns born at home, especially in rural areas, are often not weighed at birth.[8] In addition to deliveries taking place outside of equipped health facilities, a lack of functional weighing scales and a lack of health professionals with the required training and skills are challenges in these settings. Furthermore, in these areas, mothers often lack adequate prenatal care for precise gestational age assessment.[4 9 10]

Identification of small vulnerable infants who are born at home is one of the WHO recommendations for home initiation of newborn care.[11 12] Alternative anthropometric measures have been explored as proxies for identifying LBW and preterm infants, and in countries where home delivery rates are likely to remain high for some years, their potential for translation into practice warrants continued examination. These include foot length (FL), mid-upper arm circumference (MUAC), head circumference and chest circumference. Among these, FL has shown promise as an easy-to-measure parameter that does not require extensive expertise or disturb the baby significantly.[13–16] Our systematic review and meta-analysis indicated that FL performed best for identifying preterm infants, with 82% sensitivity and 89% specificity at a 7.3 cm optimal cut-off point. The review also identified that FL screening tools can be made by simple and easily available equipment; do not require special training to use; have minimal risk of exposing infants to hypothermia; have low interobserver variability and can be used outside health facilities.[17]

Different studies have demonstrated the potential of FL measurement in identifying LBW and preterm babies.[13 18] However, most studies assessed the accuracy of these anthropometric measurements when used by health professionals in clinical settings. Some studies also recommend the need to design simple FL screening tools that can be used to identify high-risk newborns at community level.[18–20]

Despite the availability of research evidence that describes the potential use of FL for early identification of LBW and preterm babies,[17] information regarding simple FL screening tool designs and the performance of the tools when used by mothers is limited. To address these gaps, we used a participatory human-centred design process, including interviews with community-based mothers and health workers, to develop and test six prototype screening tools. A further phase of field testing, assessment and selection resulted in two simple colour-coded FL screening tools (a laminated card and a plastic tool with a 90° heel holder). The hospital setting provided a managed environment to access sufficient mother–baby dyads with which to collect baseline information about the performance of the tools when used by mothers, prior to evaluating its applicability in the community. Based on these identified research gaps and our preliminary tool development work, it was essential to formally assess how these tools perform when used by mothers themselves. Therefore, the aim of this study was to evaluate the accuracy and utility of simple newborn FL screening tools for the identification of LBW and preterm babies by mothers.

METHODS AND MATERIALS

Study setting and design

A facility-based mixed method study including quantitative and qualitative approaches was conducted at Hawassa University Comprehensive Specialized Hospital (HUCSH) and Bushulo Mother, Newborn and Child Health Specialty Center & Primary Health Care (Bushulo PHC) from 15 May 2024 to 6 July 2024. These facilities are in Hawassa city, the administrative city of Sidama region, located 273 km from Addis Ababa. Both facilities offer specialised care for newborns and are equipped with Neonatal Intensive Care Units (NICU).

Study population and eligibility criteria

This study included all mother and newborn dyads delivered at HUCSH and Bushulo PHC or those referred to the NICU of these facilities during the data collection period. Mother and newborn dyads were excluded if the mother refused to participate in the study, if her baby was already 24 hours old, if the newborn had congenital anomalies that could compromise measurement, or if the mother's clinical condition prevented her participation in the study within the first 24 hours postpartum.

Sample size and sampling technique

The sample size was calculated by using Buderer's formula[21] considering: LBW prevalence of 14% (pre): 95% confidence level: clinically acceptable width of 10%

(d) and expected sensitivity (SE) of 84%: specificity (Sp) of 73% to identify LBW babies using FL and 10% non-response rate.[20] Based on this, the largest sample size, 406, was obtained using the following formula.

$$n \text{ for } Se = \frac{\left(Z_{\frac{a}{2}}\right)^2 (Se)(1-\text{Se})}{pre \times (d)^2} +$$

$$n \text{ for } Sp = \frac{\left(Z_{\frac{a}{2}}\right)^2 (Sp)(1-\text{S}p)}{(1-Pre) \times (d)^2}.$$

A consecutive sampling technique was employed to select mother–newborn dyads for the study.

Data collection

Both quantitative and qualitative data collection methods were employed in this study. For the quantitative data collection, we used interviewer-administered questionnaires, medical record review and FL screening by using the newly designed tools. The quantitative data collection tool contained items to assess the sociodemographic characteristics, medical and reproductive history of the mother and neonatal characteristics including birth weight and FL. An electronic form of this tool was developed using KoboToolbox and deployed to the KoboCollect mobile phone application.

We evaluated the diagnostic performance of two FL-based screening tools (laminated card and plastic tool with 90° heel holder). The screening tools were designed and prototyped by the study team following a systematic approach. Initially, we conducted a systematic review to identify potential anthropometric measurements used for detecting LBW and preterm babies in Africa. Based on these findings, we performed a feasibility study to test various prototypes suitable for our context. The final FL screening tools incorporated results from the feasibility study and consisted of two designs: a 2D laminated card and a 3D-printed plastic tool with a 90° heel holder. A comprehensive description of the design process, technical specifications, production challenges and cost analysis can be found in a separate manuscript. Both tools had colour codes that were used to classify a baby's FL based on whether the tip of a baby's longest toe was in the red or green area. The red area indicated a short foot and risk of being LBW or preterm. Initially, the prototypes were assessed for feasibility and acceptability at the community level. Based on the findings from the feasibility study, the study team selected and modified three anthropometric screening tools (MUAC and the two FL-based screening tools) for further testing. When deciding which tools to trial, initial engagement with mothers showed that MUAC was not a popular or easily used method and so we decided to focus on the laminated card and the plastic FL screening tools for this hospital-based study (figure 1). Both tools have a printed outline of an infant foot shape on top of the red and green-coloured surface. The length of the red band on the screening tool was determined from the pooled estimate of FL cut-off points (73 mm) from a systematic review we performed on studies conducted in Africa.[17]

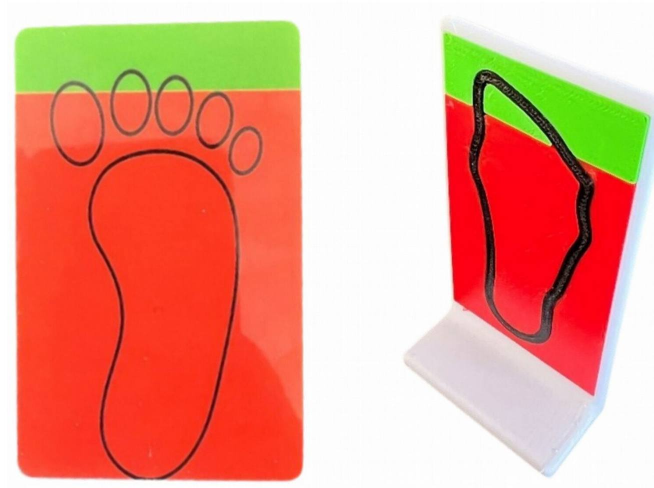

Figure 1 FL screening tools; laminated card (left) and plastic tool with 90° heel holder (right). FL, foot length.

Four health professionals (nurses and midwives) received training and performed the quantitative data collection. All eligible mothers were informed about the study and requested for their consent to participate. Then, the quantitative data collectors interviewed the selected mothers to complete the background and maternal information.

A Standard Operating Procedure with an illustrated flow diagram was used to explain the process of using the screening tools to mothers. The data collectors provided the screening tools to the selected mothers and observed the screening process. Finally, they recorded the screening result as normal/long or short feet based on the mothers' response after completing each procedure. The data collectors also observed the mother while she was performing the FL screening procedure. Then, they recorded their observation using a checklist of items containing questions on whether the mother performed each step based on their explanation of the screening procedure. After completing the interview and FL screening, the data collectors reviewed the medical records to collect information on the clinical characteristics of the mother–newborn dyads.

The qualitative data collection used in-depth interviews (IDIs) with purposively selected mothers who participated in the quantitative data collection and a focus group discussion (FGD) with the data collectors. The purposive selection of mothers for the IDIs was conducted to ensure the inclusion of participants from diverse backgrounds, including various age categories, educational levels, residential areas and those with both normal birth weight and LBW or preterm babies. Guided questions and discussion topics were used to capture the experience and insights of participants. The IDIs were conducted by two qualitative data collectors immediately before the selected mothers were discharged. The FGD with the data collection team was conducted after completing the hospital-based data collection and was led by the principal investigators. Audio recordings were used during the interviews and FGD.

The overall data collection process was supervised by the investigators. They closely followed the day-to-day data collection activities and provided daily feedback before commencing the next day's data collection.

Measurements

Digital infant weight scales were used to measure birth weights. Weight measurements were recorded to the nearest 10 g. LBW is defined as a baby who is born weighing less than 2500 g. Preterm birth is delivery of a baby before 37 weeks of gestation.

FL refers to the length measured from the most prominent posterior point of the mid heel to the tip of the longest toe of the right foot using the two FL screening tools. After the data collectors explained the procedure, screening of the newborn FL was performed by the mothers using the plastic tool and the laminated card.

Data analysis

The quantitative data set was exported from the KoboToolbox server in SPSS format and imported to Stata V.16 for analysis. After data cleaning, descriptive statistics including means and SD or frequencies and percentages were computed for the measured variables.

The colour codes (green and red) on the FL screening tools were used to classify newborns with or without a short foot based on the 73 mm cut-off.[17] Sensitivity, specificity, positive predictive value and negative predictive value were calculated to evaluate the validity of screening results reported by the mothers against the classification based on birth weight and gestational age (which were considered as reference standards). The overall accuracy of the screening tools was evaluated by using receiver operating characteristic curve analysis. The area under receiver operating characteristic curve (AUC) was used to evaluate the overall accuracy of the FL screening tools used by mothers in identifying LBW and preterm babies. P value <0.05 and 95% CIs were used to determine statistically significant difference.

Audio records of the qualitative interviews were first translated to English and transcribed. Thematic analysis was conducted beginning with thorough data familiarisation and followed by comprehensive initial coding. Two independent researchers coded all transcripts separately to ensure analytical precision and minimise bias. The researchers then together reviewed and refined the codes, identifying emerging patterns.

Ethical consideration

Ethical clearance for this study was obtained from the Institutional Review Board of College of Medicine and Health Sciences, Hawassa University (Reference number: IRB/084/16). Informed consent was also received from each study participant (mothers) before data collection. Personally identifiable information was not collected to ensure confidentiality of the study participants.

Patient and public involvement

There was no involvement of patients or the public in the design, conduct, reporting or dissemination plans of our research.

RESULTS

Background characteristics

Of the total 406 mother newborn dyads approached, 396 participated in the study; yielding a 97.3% response rate. The mean age of mothers included in this study was 26.9 years with an SD of ±5.1 years. The average family size was five per household.

Mothers within the age range of 25–29 years accounted for 162 (40.9%) and those within the age range of 20–24 years were 93 (23.5%). Three hundred thirty-one (83.6%) of the mothers lived in urban areas. Nearly all (99.5%) mothers participating in this study were married. Mothers with elementary level education were 122 (30.8%), followed by 107 (27.02%) with secondary level education. There were 175 (44.2%) housewife mothers, and 75 (19.0%) government-employed women in the study. More than half, 232 (58.6%) of the participants in this study had four to six family members (table 1).

Maternal and newborn characteristics

One-third, 120 (30.3%) of the mothers were primigravida. For 136 (34.3%) of the mothers participating in the study, the study baby was their first live birth. A total of two live births were reported by 115 (29.0%) mothers, while 70 (17.7%) mothers had three live births. Of those who had two or more live births, only 15 (5.8%) reported that they had LBW babies in the past (table 2).

Almost all, 390 (98.48%) mothers in this study had at least one antenatal care (ANC) visit during their pregnancy, 234 (60.0%) reported 4–7 ANC visits and 106 (27.2%) reported 8 or more ANC visits. Iron folic acid supplements were received by 374 (94.4%) of the mothers (table 2).

Almost all 392 (99.0%) mothers in this study gave birth in health facilities. Husbands accompanied 361 (91.2%) of the mothers during the current delivery. In addition, 248 (62.6%) mothers in this study reported that they were accompanied by family members in their household, and 246 (62.1%) were accompanied by their relatives. Three hundred seventy-four (94.4%) newborns were single births and 210 (53.0%) were female (table 2).

The birth weight of newborns was distributed by mean and SD of 3108.94 (±666.9) g. Mean and SD of gestational age was 38.83 (±2.3) weeks (online supplemental table 1). Three hundred forty-one babies (87.7%) were born full term, while 48 (12.3%) were born preterm. There were 335 (84.6%) babies with normal birth weight and 53 (13.4%) with LBW (figure 1).

Table 1 Background characteristics of the mothers

Variable	Frequency	Percentage
Age		
<20 years	23	5.8
20–24 years	93	23.5
25–29 years	162	40.9
30–34 years	83	21.0
35 years and above	35	8.8
Residence		
Urban	331	83.6
Rural	65	16.4
Marital status		
Single	1	0.3
Married	394	99.4
Widowed	1	0.3
Mother's education		
No formal education	6	1.5
Elementary education (grade 1–8)	122	30.8
Secondary education (grade 9–12)	107	27.0
Certificate and diploma	58	14.7
Degree	92	23.2
Masters	11	2.8
Mother's occupation		
Student	14	3.5
Farmer	3	0.8
Merchant	96	24.2
Government employee	75	19.0
NGO employee	10	2.5
Daily labourer	6	1.5
House wife	175	44.2
Other	17	4.3
Health professional (n=161)		
Yes	28	17.4
No	133	82.6

Almost all, 389 (98.2%) of the mothers gave birth in the two facilities selected for this study and 54 (13.6%) of the infants were admitted to NICU. Caesarean section delivery accounted for 224 (56.6%), and 172 (43.4%) were spontaneous vaginal deliveries. There were 49 (12.6%) mothers who had multiple medical complications during delivery, of whom 18 (4.6%) had pre-eclampsia and 7 (1.8%) had oligohydramnios. Based on the information recorded on mothers' clinical charts, different methods of estimating gestational age were indicated. The gestational age of 243 (62.5%) mothers was estimated by ultrasound and for 136 (35.0%) mothers by LMP method. Fundal height and New Ballard Score were used to estimate gestational age of 5 (1.3%) mothers each (table 3).

Table 2 Maternal and newborn characters

Characteristics	Frequency	Percentage
Total pregnancies		
One	120	30.3
Two	101	25.5
Three	73	18.4
Four	57	14.4
Five and above	45	11.4
Total live births		
One	136	34.3
Two	115	29.0
Three	70	17.7
Four	45	11.4
Five and above	30	7.6
History of LBW babies (n=260)		
Yes	15	5.8
No/don't know	264	94.2
Attended ANC for current pregnancy		
Yes	390	98.5
No	6	1.5
Number of ANC for current pregnancy (n=390)		
1–2 times	14	3.6
3 times	36	9.2
4–7 times	234	60.0
8+ times	106	27.2
Received IFA during current pregnancy		
Yes	374	94.4
No	22	5.6
Current place of delivery		
Health facility	392	99.0
Home	4	1.0
Birth companion*		
Husband	361	91.2
Household family members	248	62.6
Friends	154	38.9
Relatives	246	62.1
No one	1	0.2
Number of newborns from current pregnancy		
Single	374	94.4
Twins	19	4.8
Multiple	3	0.8
Sex of the screened newborn		
Male	186	47.0
Female	210	53.0

*Multiple responses.
ANC, antenatal care; IFA, iron folic acid; LBW, low birth weight.

FL screening to identify LBW and preterm babies

In this study, there were 61 (15.4%) LBW and 48 (12.3%) preterm babies based on the birth weight and gestational

Table 3 Review of medical records from the mother or the newborn card

Variable	Frequency	Percentage
Gave birth at the selected facilities		
Yes	389	98.2
No	7	1.8
Newborn admitted to NICU		
Yes	54	13.6
No	342	86.4
Mode of delivery		
SVD	172	43.4
CS	224	56.6
Medical complication during current delivery (n=389)		
No complication	340	87.4
Pre-eclampsia	18	4.6
Oligohydramnios	7	1.8
APH	6	1.5
Premature rupture of membranes	6	1.5
Placenta previa	4	1.0
Other*	14	3.6
Method used to estimate GA		
Ultrasound	243	62.5
LMP	136	35.0
Fundal height	5	1.3
New Ballard Score	5	1.3

*Breech presentation, retained placenta, seizure, diabetes mellitus, anaemia, hepatitis infection, HIV infection, malaria.
APH, acute postpartum haemorrhage; CS, caesarean section; GA, gestational age; LMP, last menstrual period; NICU, neonatal intensive care unit; SVD, spontaneous vaginal delivery.

Table 4 Mothers' performance and preference on the FL screening tools

Variable	Frequency	Percentage
Mother's performance of using laminated card		
Hold the baby properly	368	92.9
Positioned the heel correctly	270	68.2
Hold the feet firmly to the surface	320	80.8
Mark the toe tip correctly	337	85.1
Hold the feet straight	301	76.0
None of the above	6	1.5
Heel positioned incorrectly on laminated card (n=126)		
Too high	30	23.8
Too low	94	74.6
Other	2	1.6
Mother's performance of using plastic tool with 90° heel holder		
Hold the baby properly	386	97.5
Positioned the heel correctly	296	74.7
Hold the feet firmly to the surface	350	88.4
Mark the toe tip correctly	332	83.8
Hold the feet straight	302	83.8
None of the above	5	1.3
Mother's first preference tool		
FL screening tool with laminated card	183	46.2
FL screening plastic tool with 90° heel holder	212	53.5
None	1	0.3

FL, foot length.

age on mother's clinical records. Thirty-six (9.2%) of the babies were both LBW and preterm, while 68 (17.5%) were either preterm or LBW. Mothers classified 156 (39.4%) newborns as having short feet and 240 (60.6%) as having a normal/long foot by using the laminated card screening tool. Using the plastic tool, mothers classified 131 (33.1%) as short and 265 (67.0%) as normal/long feet (online supplemental figure 1).

When using the laminated card, 368 (92.9%) mothers demonstrated appropriate baby holding, with correct heel positioning among 270 (68.2%) and accurate toe tip marking among 337 (85.1%). For the plastic tool, proper baby holding was observed among 386 (97.5%), correct heel positioning among 296 (74.7%) and accurate toe tip marking among 332 (83.84%). The plastic tool was preferred by 212 (53.5%) mothers, while 183 (46.2%) preferred the laminated card (table 4).

Based on the information from the IDIs, the ease of using the FL screening tools was generally appreciated, though preferences varied among mothers regarding the specific design of the tools, as illustrated by their comments.

> The plastic tool with the heel holder is easier to use and more comfortable to hold and appropriately measure the newborn foot, compared to the laminated card, which lacks clear guidance and requires extra caution to place the foot correctly.

Although the plastic tool was appreciated by most of the respondents, they also suggested some areas of improvement like adding side supports and that incorporating a smoother design would make it easier to use and more comfortable for the baby. Some mothers preferred the laminated card's smoothness, easiness and attractiveness.

> I choose the laminated card because of its shape, picture of baby's foot, and comfortability to use.

There were improvements suggested for the laminated card too. Some mothers reported that the laminated card could be improved by adding a structure to support the heel for better accuracy during measurement.

> The laminated card is not comfortable for measurement, because the foot slides when trying to put my baby's foot.

Concerns were also raised about the durability of the laminated card, which was seen as susceptible to damage if exposed to moisture or fluid.

Data collectors also observed that the plastic tool with heel holder was easier for most mothers. They suggested making the surface smoother and modifying the footprint picture on the plastic tool for future use.

Diagnostic accuracy of FL screening tools

Compared with their birth weight classification, mothers were able to identify LBW babies at a sensitivity of 81.9% (78.2%–85.7%) and specificity of 68.4% (63.8%–72.9%) by using the laminated card screening tool. As measured by the AUC value, the laminated card showed an overall accuracy of 0.75 (0.69–0.81). The sensitivity and specificity of the plastic tool to identify LBW babies when used by the mothers were 86.9% (83.6%–90.2%) and 76.7% (72.5%–80.9%), respectively. The screening result of mothers using the plastic tool also showed an overall accuracy of AUC of 0.82 (0.77–0.87) to identify LBW babies (figure 2 table 5).

Based on the classification of gestational age as preterm (<37 weeks) and full term (>37 weeks), the laminated card FL screening tool showed a sensitivity at 79.2% (75.1%–83.2%) and specificity of 66.8% (62.2%–71.5%) to identify preterm babies. The laminated card FL screening has an AUC of 0.73 (0.67–0.79) to identify preterm babies. The sensitivity and specificity of the plastic tool to identify preterm babies when used by the mothers were 75.0% (70.7%–79.3%) and 73.9% (69.5%–78.3%), respectively. The screening result of mothers using the plastic tool also showed a good level of accuracy in identifying preterm babies with an AUC of 0.74 (0.68–0.81) (figure 3 Table 5).

Comparing the performance of the screening tools to identify LBW babies, there was no significant difference across different groups of mothers (online supplemental table 2).

Feasibility of FL screening tools

Mothers' experience of using the newborn FL screening tools to measure their babies was characterised by a mixture of positive emotions, curiosity, concerns and evolving acceptance. For many, the opportunity to measure their own newborn's FL brought a sense of happiness and fulfilment. One mother expressed her feelings;

> There is nothing that makes mothers happy than measuring her baby by herself and knowing the body weight condition.

However, several mothers raised questions about the connection between FL and body weight. The concept of using FL to infer body weight appeared novel and unclear to many of the mothers, who questioned the universality of such a measurement, given the natural variation in body proportions from one baby to another.

Despite initial fears and worries that the tools might harm their babies, mothers realised that the tools did not cause any harm after completing the procedure.

> I was afraid at first. But after I measured my baby's foot length, I am happy to experience this.

This transition from fear to comfort and reassurance was emphasised by most of the respondents. The

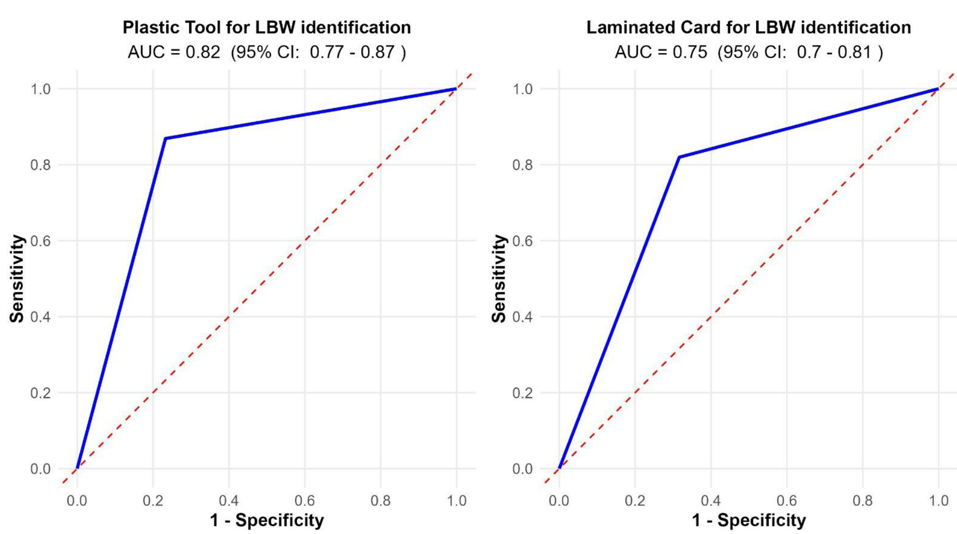

Figure 2 ROC curve for plastic tool with 90° heel holder (left) and laminated card (right) screening tools in identifying LBW babies. AUC, area under receiver operating characteristic curve; LBW, low birth weight; ROC, receiver operating characteristic.

Table 5 Diagnostic accuracy of FL screening and measurement result against birthweight and gestational age classification

FL result	Small	LR+/LR−	NPV (95% CI)	PPV (95% CI)	Sp (95% CI)	Sn (95% CI)	Normal
Against birth weight classification (small/LBW and normal)							
Laminated card							
Short	50	106	81.9 (78.2 to 85.7)	68.4 (63.8 to 72.9)	32.1 (27.4 to 36.6)	95.4 (93.4 to 97.5)	9.96
Normal	11	229					
Plastic tool							
Short	53	78	86.9 (83.6 to 90.2)	76.7 (72.5 to 80.9)	40.5 (35.6 to 45.3)	96.9 (95.3 to 98.7)	21.94
Normal	8	257					
Against gestational age classification (small/preterm and normal/ full term)							
Laminated card							
Short	38	10	79.2 (75.1 to 83.2)	66.8 (62.2 to 71.5)	25.2 (20.8 to 29.5)	95.8 (93.8 to 97.8)	7.7
Normal	113	228					
Plastic tool							
Short	36	89	75.0 (70.7 to 79.3)	73.9 (69.5 to 78.3)	28.8 (24.3 to 33.3)	95.4 (93.4 to 97.5)	8.4
Normal	12	252					

FL, foot length; LR+, likelihood ratio for positive; LR−, likelihood ratio for negative; NPV, negative predictive value; PPV, positive predictive value; Sn, sensitivity; Sp, specificity.

experiences of mothers using newborn FL screening tools revealed a journey from initial scepticism and fear to acceptance. One mother expressed her reaction about the measurement result.

> My baby is premature, so I suspected she may be underweight. I haven't seen this previously on my children. The measurement also laid on the red color of the tools. I was saddened by this, because I am not sure what I should do.

Several mothers stated that they would be able to measure their baby's FL correctly in the future if they had access to the tools. They emphasised the importance of practical demonstrations and the opportunity to practice using the tools to build their confidence and competence. Mothers also raised that they might forget how to use the tools or the tools might be lost if they received them too early.

> The card is a small object, and it can disappear easily. But if it is given while I am approaching to delivery, it may not be forgotten, and it won't lost.

Moreover, some mothers suggested that using pictures in the instructions could enhance understanding and measurement skills, particularly for those with limited literacy.

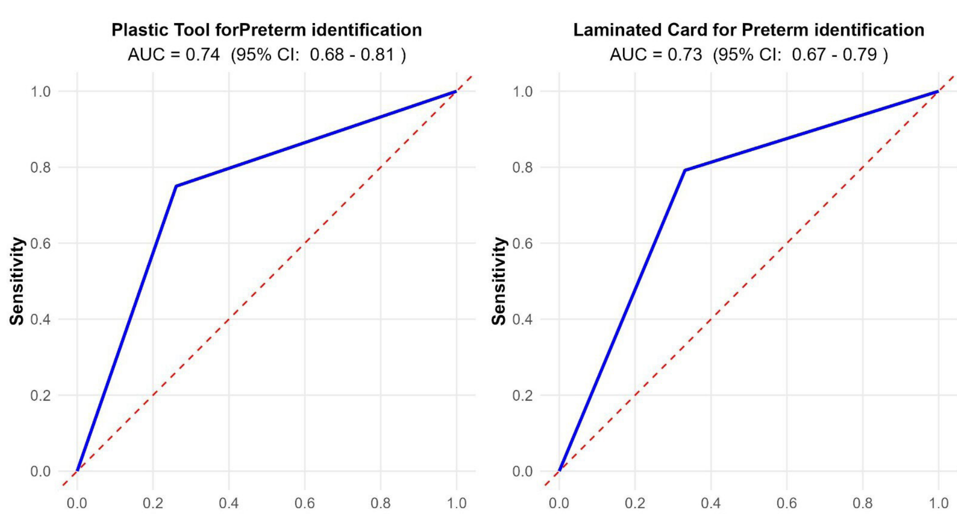

Figure 3 ROC curve for plastic tool with 90° heel holder (left) and laminated card (right) screening tools in identifying preterm babies. AUC, area under receiver operating characteristic curve; ROC, receiver operating characteristic.

> I understand more because the instructions are explained through pictures. So, showing the measurement procedures using pictures might help to improve mothers' awareness and skills, especially those living in rural areas.

Most mothers mentioned no cultural concerns that might prevent the use of the screening tools, stating that measuring FL has nothing to do with the culture. However, some mothers mentioned cultural expectations that prevent newborn babies from being taken out of the home. This cultural belief could limit their ability to access healthcare services and receive the tools. Mothers also expressed that these tools can be good for those who prefer (or have) to deliver at home.

> Mothers in rural areas might refuse to allow anyone to touch their baby out of fear of the evil eye as they assume exposing a newborn babies will make them sick.

Data collection team members also raised concerns related to mothers' ability to understand the explanation of the measurement procedure and misconceptions that might contradict the intention of using these screening tools. They mentioned that some mothers required additional assistance after they explained the procedure. They also expressed concern about mothers' ability to recall if they were provided with the tools and an explanation too far ahead of their delivery date. In addition, they highlighted the need to clarify that the tool is not intended to replace procedures of newborn measurement during facility delivery.

Many mothers recognised that acceptance of the tools could be improved by providing education to increase their awareness. One mother stated that;

> The baby's foot length measurement is unusual; but it can be changed by providing information and creating awareness about measuring baby's foot length; then the community can accept it.

DISCUSSION

This study evaluated the diagnostic accuracy and utility of two colour-coded FL screening tools (laminated card and a plastic tool with a 90° heel holder) for identifying LBW and preterm infants by their mothers. The laminated card showed AUC of 0.75 (95% CI 0.69 to 0.81) for LBW identification and 0.73 (95% CI 0.67 to 0.79) for preterm identification. The plastic tool showed slightly higher accuracy with AUCs of 0.82 (95% CI 0.77 to 0.87) and 0.74 (95% CI 0.68 to 0.81) for LBW and preterm identification, respectively. For LBW detection, the laminated card yielded a sensitivity of 81.9% and specificity of 68.4%, while the plastic tool had a sensitivity of 86.9% and specificity of 76.7%. In identifying preterm infants, the laminated card showed 79.2% sensitivity and 66.8% specificity, compared with 75.0% sensitivity and 73.9% specificity for the plastic tool.

Both the plastic and the laminated card FL screening tools in this study showed lower overall accuracy for identifying LBW babies when compared with the AUCs reported by other studies conducted in different African countries.[15 17–21] Similarly, the overall accuracy of the FL screening results to identify preterm babies in this study was lower than other similar studies.[19 20 22 23] However, importantly, most previous studies have used trained data collectors with health-related backgrounds to measure FL, whereas the FL screening in this study was performed by lay mothers; and taking that into account, the findings are promising for potential use at community level. Some differences could also be due to variations in the FL measurement process between studies. Furthermore, our study applied an FL cut-off point from the meta-analysis the study team conducted prior to this study, while the other studies measured the actual FL and computed optimal cut-off points specific to their study populations.

The qualitative study found that the screening tools are easy to use by mothers and mothers reacted positively to using the tool to screen their own newborn. The role of healthcare providers in creating awareness was emphasised repeatedly throughout the mothers' testimonies, suggesting that successful acceptance of these tools by the community would depend on clear communication and culturally sensitive education.

The accuracy of the plastic FL screening tool with 90° heel holder in this study was comparable with the study conducted to assess the accuracy of FL measurement performed by trained community volunteers in Papua New Guinea.[24] Similar to the FL screening tool with 90° heel holder in this study, that study used a plastic ruler stuck to the inside of a cardboard box to support the sole and heel during measurement.

The accuracy of both tools in this study was higher than the accuracy of mothers and family members using a foot-length card in Nepal.[25] The possible reasons for the difference could be due to differences in the methods of explaining the procedure to the mothers in study settings. Unlike the pictorial chart used to explain the FL screening procedures in this study, the Nepal study used audio recordings to inform the participants about how to perform the measurement. In addition, this study was hospital-based while the other was conducted in the community.

The method of information dissemination also emerged as a critical factor in the qualitative study. Mothers reflected positive opinions about the benefits of using pictures to illustrate the screening procedure. However, the proper timing and method of distributing the tool and the information will require further study.

Even though it was not statistically significant, the plastic tool showed slightly better accuracy than the laminated card FL screening tool. Similarly, the plastic tool performed better when compared with the accuracy of FL screening tools in previous community-level studies.[24 26] This suggests that the 90° heel holder used for positioning the heel contributes to improved accuracy.[27] It also implies that FL screening tools with a heel holder can reduce the variation of performance characteristics, whether measurements are taken by clinically trained staff or community volunteers, field workers or caregivers.[28 29]

The qualitative findings also support the advantage of using the heel holder to ease the screening procedure. However, mothers and data collectors suggested making the surface of the tool smoother and using the footprint picture from the laminated card to improve the performance of the plastic tool with heel holder. It seems clear that combining the strengths observed in the two tools would be important in any design revision to produce a better FL screening tool.

The strengths of this study include the use of two simple FL screening tools designed with colour codes and that the tools have not previously been tested in the study area. In addition, and importantly when considering future options for use at community level, this study evaluated the performance of these new screening tools when used by mothers to identify LBW and preterm babies. Furthermore, the feasibility of the proposed FL screening tools was assessed by integrating qualitative assessment in the study.

However, this study was not free of limitations. The first limitation in this study was the gestational age estimation methods, other than early ultrasound, used for most study participants. The other limitation was the fact that the study was conducted at a hospital setting. The result could be different had it been performed at a household level due to the difference in lighting conditions and the time gap between mothers receiving the screening procedure explanation and delivery. In community settings, especially rural households, variations in lighting might compromise the precision of FL measurements compared with standardised hospital illumination. Additionally, when mothers receive screening instructions during antenatal visits weeks before delivery rather than in the hospital, their recall and application of proper measurement technique may vary significantly. Finally, the cut-off point used in this study was not derived specifically from the local population in the study setting but from a systematic review of relevant data from across Africa.

In conclusion, FL screening tools made from plastic or card can be successfully used for screening of small babies that are likely to be LBW and preterm, by mothers and family members. These colour-coded screening tools have potential use at community level and have no literacy requirements. While birth weight represents a precise physical measurement, GA in this study relied on various methods of estimation beyond early ultrasound for most participants, introducing inherent measurement variability. This methodological constraint is significant because FL may correlate differently with physical growth parameters than with gestational maturity. Consequently, while these tools show promise for community-level identification of vulnerable infants requiring additional care, their application should acknowledge the greater certainty in identifying low birth weight compared with making definitive conclusions about gestational age without additional clinical validation. We recommend future studies to evaluate the performance of these FL screening tools at community level by considering design characteristics such as smooth surface with footprint picture, heel holder and area-specific cut-off points in designing the colour codes. Furthermore, future studies should assess the optimal timing and method of introducing the tools to pregnant mothers.

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REFERENCES

1 Requejo JH, Bhutta ZA. The post-2015 agenda: staying the course in maternal and child survival. *Arch Dis Child* 2015;100 Suppl 1:S76–81.
2 World Health Organization. Health in 2015- from MDGs to SDGs. Available: https://www.who.int/data/gho/publications/mdgs-sdgs [Accessed 29 Aug 2024].
3 EFDR. Ethiopia voluntary national review 2022. Planipolis. Available: https://planipolis.iiep.unesco.org/en/2022/ethiopia-voluntary-national-review-2022 [Accessed 29 Aug 2024].
4 Central statistical agency (CSA)[Ethiopia] and ICF. Ethiopia mini demographic and health survey 2019. 2021.
5 Ministry of Health. Health sector transformation plan II (HSTP II) 2020/21 - 2024/25 (2013 EFY-2017 EFY). 2021.
6 Ashorn P, Black RE, Lawn JE, *et al*. The Lancet Small Vulnerable Newborn Series: science for a healthy start. *The Lancet* 2020;396:743–5.
7 Blencowe H, Krasevec J, de Onis M, *et al*. National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: a systematic analysis. *Lancet Glob Health* 2019;7:e849–60.
8 Blanc AK, Wardlaw T. Monitoring low birth weight: an evaluation of international estimates and an updated estimation procedure. *Bull World Health Organ* 2005;83:178–85.
9 Deribew A, Tessema GA, Deribe K, *et al*. Trends, causes, and risk factors of mortality among children under 5 in Ethiopia, 1990-2013: findings from the Global Burden of Disease Study 2013. *Popul Health Metr* 2016;14:42.
10 Haileamlak A. Why is the Under-5 Mortality Rate in Ethiopia Slipped Back? *Ethiop J Health Sci* 2017;27:314.
11 Sivanandan S, Sankar MJ. Kangaroo mother care for preterm or low birth weight infants: a systematic review and meta-analysis. *BMJ Glob Health* 2023;8:e010728.
12 Vogel JP, Ramson J, Darmstadt GL, *et al*. Updated WHO recommendations on antenatal corticosteroids and tocolytic therapy for improving preterm birth outcomes. *Lancet Glob Health* 2022;10:e1707–8.
13 Goto E. Meta-analysis: identification of low birthweight by other anthropometric measurements at birth in developing countries. *J Epidemiol* 2011;21:354–62.
14 Tikmani SS, Brown N, Inayat A, *et al*. Diagnostic accuracy of foot length measurement for identification of preterm newborn in rural Sindh, Pakistan. *BMJ Paediatr Open* 2024;8:e002316.
15 Tikmani SS, Brown N, Inayat Ali A, *et al*. 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. *BMJ Open* 2024;14:e089153.
16 Tikmani SS, Mårtensson T, Khalid S, *et al*. Assessing the diagnostic accuracy of postnatal clinical scoring methods and foot length measurement for estimating gestational age and birthweight of newborns in low- and middle-income countries: a systematic review and meta-analysis. *BMJ Paediatr Open* 2024;8:e002717.
17 Belay FW, Fikre R, Alemayehu A, *et al*. Feasibility and diagnostic accuracy of neonatal anthropometric measurements in identifying low birthweight and preterm infants in Africa: a systematic review and meta-analysis. *BMJ Paediatr Open* 2024;8:e002741.
18 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.
19 Dagnew N, Tazebew A, Ayinalem A, *et al*. Measuring newborn foot length to estimate gestational age in a high risk Northwest Ethiopian population. *PLoS One* 2020;15:e0238169.
20 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.
21 Buderer NMF. Statistical Methodology: I. Incorporating the Prevalence of Disease into the Sample Size Calculation for Sensitivity and Specificity. *Acad Emerg Med* 1996;3:895–900.
22 Sintayehu E, Sintayehu Y, Oumer A, *et al*. Identification of anthropometric surrogate measurements and their cut-off points for the detection of low birth weight and premature newborn babies using ROC Analysis. *J Nutr Sci* 2023;12:e32.
23 Stevenson A, Joolay Y, Levetan C, *et al*. A Comparison of the Accuracy of Various Methods of Postnatal Gestational Age Estimation; Including Ballard Score, Foot Length, Vascularity of the Anterior Lens, Last Menstrual Period and Also a Clinician's Non-Structured Assessment. *J Trop Pediatr* 2021;67:fmaa113.
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 Hodgins S, Rajbhandari B, Joshi D, *et al*. Community-based cluster randomized controlled trial: empowering households to identify and provide appropriate care for low-birthweight newborns in Nepal. *BMC Public Health* 2020;20:1274.
26 Lee AC, Mullany LC, Ladhani K, *et al*. Validity of Newborn Clinical Assessment to Determine Gestational Age in Bangladesh. *Pediatrics* 2016;138:e20153303.
27 Pratinidhi AK, Bagade AC, Kakade SV, *et al*. Action-oriented colour-coded foot length calliper for primary healthcare workers as a proxy for birth weight & gestational period. *Indian J Med Res* 2017;145:347–52.
28 Marchant T, Penfold S, Mkumbo E, *et al*. The reliability of a newborn foot length measurement tool used by community volunteers to identify low birth weight or premature babies born at home in southern Tanzania. *BMC Public Health* 2014;14:859.
29 Hirve SS, Ganatra BR. Foot tape measure for identification of low birth weight newborns. *Indian Pediatr* 1993;30:25–9.