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RESEARCH ARTICLE

Identification of anthropometric surrogate measurements and their cut-off points for the detection of low birth weight and premature newborn babies using ROC Analysis

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Abstract

Despite the fact that health facilities in Ethiopia are being built closer to communities in all regions, the proportion of home deliveries remains high, and there are no studies being conducted to identify low birth weight (LBW) and premature newborn babies using simple, best, alternative, and appropriate anthropometric measurement in the study area. The objective of the present study was to find the simple, best, and alternative anthropometric measurement and identified its cut-off points for detecting LBW and premature newborn babies. A health facility-based cross-sectional study was conducted in the Dire Dawa city administration, Eastern Ethiopia. The study included 385 women who gave birth in health facility. To evaluate the overall accuracy of the anthropometric measurements, a non-parametric receiver operating characteristic curve was used. Chest circumference (AUC = 0·95) with 29·4 cm and mean upper arm circumference (AUC = 0·93) with 7·9 cm proved to be the best anthropometric diagnostic measure for LBW and gestational age, respectively. Also, both anthropometric measuring tools are achieved the highest correlation ($r = 0{\cdot}62$) for LBW and gestational age. Foot length had a higher sensitivity (94·8 %) in detecting LBW than other measurements, with a higher negative predictive value (NPV) (98·4 %) and a higher positive predictive value (PPV) (54·8 %). Chest circumference and mid-upper arm circumference were found to be better surrogate measurements for identifying LBW and premature babies in need of special care. More research is needed to identify better diagnostic interventions in situations like the study area, which has limited resources and a high proportion of home deliveries.

Key words: **Anthropometric measurement: LBW: Non-parametric: ROC analysis**

Introduction

Over the last three decades, child mortality has decreased dramatically worldwide. However, it is still a long way from eliminating preventable deaths among newborns and children under the age of five, in accordance with Sustainable Development Goal (SDG) 3.2[1,2]. Birth weight (BW) is an indicator of a newborn's current and future health status[3]. Low birth weight (LBW < 2500 g) and prematurity are major causes of neonatal mortality and morbidity, and continue to be a global problem and one of the most serious public health issues[4–8]. LBW and premature newborn babies are at a higher risk of death in the first 28 days of life. Those who survive are more likely to have stunted growth, a lower IQ and an increased risk of developing chronic conditions such as obesity

Abbreviations: AUC: area under curve; BW: birth weight; CC: chest circumference; CI: confidence interval; DHS: Demographic and Health Survey; DOR: diagnostic odds ratio; EMDHS: Ethiopia Mini Demographic and Health Survey; FL: foot length; GA: gestational age; HC: head circumference; LBW: low birth weight; MUAC: mid-upper arm circumference; NICU: neonatal intensive care unit; NPV: negative predictive value; PPV: positive predictive value; ROC: receiver operating characteristics; WHO: World Health Organization

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and diabetes in adulthood[9–11]. LBW is an important indicator of progress towards the World Health Organization's (WHO) global nutrition goal[12–14]. Every year, 20·6 million babies are born worldwide, and 14·6 % of these babies are born with a LBW (<2500 g)[15]. Africa has been home to about a quarter of all LBW newborns, with East and West Africa bearing the lion's share[16]. Ethiopia, like other East African countries, has higher LBW and premature babies, with the highest neonatal death rate in the world (32·5 deaths per 1000 live births)[17–19] and also the proportion of births attended by qualified health workers is low. Most LBW and premature babies are unlikely to be identified and referred for further life-saving care[17]. The Ethiopia Mini Demography Survey (EMDHS) found that 30·8 % of mothers in Dire Dawa city administration still give birth at home[20]. This implies that there are newborn deaths in the community who do not receive medical care due to LBW or prematurity. As a result, it is critical to assess the best simple anthropometric measurement to identify LBW and premature newborn babies in communities; however, identification of newborns with LBW and premature neonates is difficult in developing countries, including the study area, due to a lack of studies on identifiable alternative and simple anthropometric surrogate measurements[21–25]. Identifying anthropometric measurements are considered to be reliable, sensitive indicator and an important screening tool for the detection of newborns with LBW and premature babies[3]. As a result, it is necessary to identify anthropometric measurements that are simple and use portable, inexpensive equipment in order to identify LBW and premature babies in the community immediately after giving birth at home.

It is also used as a complement study to other studies to establish standard guidelines for assessing LBW and premature babies by themselves for home deliver mothers, and uses as alarming the families to visit health facilities in any outbreak occurs, like corona.

As a result, we assumed that the tape measure is lightweight and portable, and that it can be used at home easily. Therefore, the primary goal of the present study was to identify the simple, best, and alternative anthropometric surrogate measurement and identify its cut-off point for detecting LBW and premature newborn babies in the study area.

Methods and materials

Study setting and design

A health facility-based cross-sectional study design was carried out on 381 single healthy newborn babies of both sexes. The study was carried out in Dire Dawa city administration, Eastern Ethiopia. The city administration is divided into nine urban kebele and thirty-eight rural kebele. Dire Dawa's current population is 445 000 in 2022, with a 4·46 % population growth. Various nations and nationalities living in Dire Dawa city administration speak a variety of Ethiopian languages.

Sample size determination

The required sample size was obtained using Buderer's formula[26], $n = (Z_1 - \alpha/2)^2$*SN (1−SN)/L^2*P and $n = (Z\alpha/2)$ 2*Sp (1−Sp)/L^2*(1−P) with the following assumptions: sensitivity 80 %, LBW prevalence 21 %[27], anticipated sensitivity of CC = 84·2 %, anticipated specificity of HC = 90 %, P = 0·05[28] (37), d is the margin of error of 0·05, α is the size of critical region = 5 %, $1-\alpha$ = confidence level = 95 %, $Z_1 - \alpha/2$ = standard normal deviate corresponding to the specified size of critical region α = 1·96 and adding 5 % non-response rate, the last sample size was 385.

Study participants

During the study period, all mothers and their newborns delivered at governmental health facilities were screened for inclusion. Newborns aged less than 24 h with who did not have major congenital malformations and/or birth injuries such as scalp swellings and limb fractures, and who were not less than 1·0 kg and very sick needing oxygen therapy were included in the study.

Newborns with uncertain gestational age (GA), with poor health conditions were excluded from the study in order to allow them get emergency care. In addition, mothers who were refused to participate in the study were excluded from the study. After being briefed on the purpose of the study, informal written consent was obtained from the parent/guardian for participation of their newborns, or a witnessed thumb print was provided for those who were illiterate.

Data collection tool and procedure

Information on mother's demographics, pregnancy and delivery history were obtained verbally from the mother or guardian, and any additional information were retrieved from the antenatal card and delivery records. Specific information on the mother's demographic characteristics obtained included age, telephone number, place of residence, home address (with land marks), educational status, occupation, ethnicity, religion, marital status and household income. Variables on mother's pregnancy and delivery history included gravidity, parity, last menstrual period (LMP), expected date of delivery, mode of delivery, date and time of delivery, baby's weight, sex, Apgar scores and gestational age. The GA was used to determine whether the newborn was term or preterm and was assessed by the mother's LMP and/or ultrasound report.

Anthropometric measurements (weight, Chest Circumference (CC), Mid-Upper Arm Circumference (MUAC), Head Circumference (HC) and Foot Length (FL)) were taken immediately following recruitment by the trained midwives and recorded on the study-specific data collections forms within 24 h after birth. The BW was measured with a calibrated digital scale (Salter digital toddler/Baby scale, model WS034, UK) to the nearest 10 g. The birth weights were cross-checked during the examination and were consistent with the recorded birth weights. The scale was often zeroed to ensure an accuracy of the measurement. The HC was with the tape measure placed directly over the supraorbital ridges anteriorly and the maximum occipital prominence posteriorly to ensure that the tape measure was placed level on each side. For CC, the measurement was taken at the level of the nipple in the final phase of expiration.

The date of the LMP was sourced from the mother to estimate expected date of delivery and GA of the newborn. Medical records were reviewed for early ultrasound findings and estimated date of delivery. If this were not recorded, the information was requested from the mother. Premature birth was defined as GA <37 weeks. Standard operating procedures have been developed for all study procedures. The study was conducted in accordance with the Helsinki Declaration and the requirements of good clinical practice[29].

Six hospital-based midwives and two senior midwives (clinical supervisor) were trained by the principal investigator for 3 d, on how to measure the newborns' FL, head, chest, thigh and MUACs.

Data quality control

For each measurement, two readings were done by two trained midwives interchangeably and the average was taken as a gold standard against which midwives measurements were compared to assess the accuracy of midwives measurements. Routine calibration of instruments were made to ensure accurate results by the equipment. The supervisors performed two repeat measurements for each test for one in every thirty study participants to check for reliability.

We calculated the technical error of measurement (TEM) for each anthropometric measurement to assess inter-observer variability between supervisors and data collectors. We also calculated %TEM (TEM/mean*100), a measure of TEM coefficient of variation, because comparing TEMs directly is difficult due to the positive relationship between TEM and measurement size. The difference between the data collectors' measurements and the gold standard was then computed (measurement error).

Statistical analysis

The mean difference in each anthropometric measurement between LBW and NBW babies was assessed using independent *t* test. A Pearson correlation coefficient (*r* values) and the coefficient of determination (R^2 values) between the results and each anthropometric measurement. The receiver operating characteristic (ROC) non-parametric curve (using De Long's method) was conducted separately for each measure and the area under the curve (AUC) was calculated to determine which measure best predicted BW and premature baby. Sensitivity and specificity were calculated to obtain operative cut-offs that can be used to identify LBW and premature infants. The Youden's J^{th} statistic (Youden's index) was used to identify the maximum value of the index for selecting the optimum cut-off point. At each cut-off point, the positive predictive value (PPV) and the negative predictive value (NPV) were calculated. Positive likelihood ratio (+LR), negative likelihood ratio (−LR) and diagnostic odds ratio (DOR) were determined at each cut-off point. A *P*-value less than 0·05 was considered statistically significant.

Results

In total, 385 newborns were enrolled in the study, with 341 meetings the statistical assumptions of hypotheses and remain 44 newborns' data being excluded. The mean differences between the data collectors were very small (for CC: 0·003 cm (SD 0·1); for FL: 0·05 cm (SD 0·17); for MUAC: 0·01 cm (SD 0·12); for HC: 0·01 cm (SD 0·05)). These findings were confirmed by the values of TEMs and %TEMs (for CC: TEM 0·005 kg (%TEM 0·007 %); for FL: 0·018 cm (0·010 %); for MUAC: 0·011 cm (0·013 %); for HC: 0·004 cm (0·004 %)).

Table 1 shows the demographics of mothers and their newborns. The mean age of the mothers was 28·1 (+5·3 SD) years and the majority (71·7 %) were city dwellers. The mean BW of the newborns was 2700 g (SD = 870 g). The median GA was 38 weeks (SD +1·3 weeks) (Table 1).

The mean for each measurement for newborns with LBW was 6·54 ± 0·59 cm for FL, 28·2 ± 1·89 cm for CC, 31·3 ± 1·95 cm for HC and 7·1 ± 0·68 cm for MUAC (Table 2).

There was a statistically significant difference between LBW and NBW infants. It shows that all anthropometric variables had a significant, linear, positive correlation with BW and GA ($P < 0·001$). CC had the highest correlation coefficient (*r*) with BW ($r = 0·72$), while FL had the lowest ($r = 0·53$). The anthropometric measurements were correlated with the GA with a significant *P*-value, the maximum coefficient correlation with the GA was observed for CC ($r = 0·62$) and MUAC ($r = 0·59$) and HC ($r = 0·52$) (Table 3).

ROC-AUC analysis, CC and MUAC proved to be the best anthropometric diagnostic measure for LBW with the highest area under the receiver's operating curve (AUC = 0·95, 95 % CI 0·93, 0·97) and (AUC = 0·94, 95 % CI 0·92, 0·96) with a

Table 1. Demographic and clinical characteristics of participants (*n* 385)

Variables	Summary statistic (Mean ± SD, or number (%))
Residence	
Urban	276(71·7)
Rural	109(28·3)
Age (years)	
18–24	150(39)
25–34	201(52·2)
35–44	34(8·8)
Educational status	
Illiterate	123(31·9)
Primary education (1–8)	133(34·3)
Secondary education (9–12)	93(24·2)
College diploma and above	36(9·4)
Sex of neonate	
Male	203(52·7)
Female	182(47·3)
Mother's age in years, mean (SD)	28·18 ± 5·3
Birth weight (g), mean (SD)	2·700 ± 0·87
Low birth weight, *n* (%)	80(20·8)
Chest circumference in cm, mean (SD)	31·7 ± 3·09
MUAC in cm, mean (SD)	8·7 ± 1·4
Foot length in cm, mean (SD)	7·5 ± 1·0
Head circumference in cm, mean (SD)	33·4 ± 2·2
Premature newborn	85(22·3)

MUAC, mid-upper arm circumference.

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Table 2. Comparison of mean values of anthropometric variables for the different weight categories

Parameters		Frequency	Mean ± SD	*P*	95 % CI
FL	LBW	102	6·54 ± 0·59	<0·0001	7·39, 7·6
	NBW	283	7·84 ± 1·0		
CC	LBW	102	28·2 ± 1·89	<0·0001	31·7, 32·04
	NBW	283	33 ± 2·37		
HC	LBW	102	31·3 ± 1·95	<0·0001	33·2, 33·6
	NBW	283	34·2 ± 1·79		
MUAC	LBW	102	7·1 ± 0·68	<0·0001	8·69, 8·8
	NBW	283	9·2 ± 1·1		

FL, foot length; CC, chest circumference; HC, head circumference; MUAC, mid-upper arm circumference; NBW, normal birth weight.
Significant at $P < 0·05$.

lower AUC for HC of 0·89 (95 % CI 0·86, 0·892). When predicting premature birth, MUAC and CC were estimated with the highest area under the receiver operating curve (AUC = 0·93, 95 % CI 0·9, 0·95) and (AUC = 0·92, 95 % CI 0·9, 0·95) found (Table 4).

The corresponding ROC curves for FL, CC, HC and MUAC as surrogates for birth weights below 2500 g and <37 weeks are shown in Figs. 1 and 2.

The point with the highest Youden index was selected to represent the optimal cut-off value with the highest overall accuracy for predicting LBW and preterm birth. A result of the Youden index showed that the optimal limit values of anthropometric indicators with a sensitivity of >80 % when predicting the LBW 6·9 cm for FL, 29·4 cm for CC, 33·1 cm for HC and 7·7 cm for MUAC goods. In the premature infant prediction, the optimal cut-off points were 7·1 cm for FL, 30·1 cm for CC, 33·7 cm for HC and 7·9 cm for MUAC (Table 5). FL had the highest sensitivity (94·8 %) and HC has the highest specificity (94·8 %) for the detection of LBW. MUAC had the highest sensitivity (89·3 %) and CC has the highest specificity (95·3 %) for the detection of premature infants (Table 5). On the other hand, FL ≤ 6·9 cm had a sensitivity of 94·8 % and MUAC ≤ 7·9 cm had a sensitivity of 89·3 %, which means that 5·2 % babies with low births and 10, 7 % premature babies would not be recognised by this screening.

With a cut-off value of <33·1 cm, HC had the highest PPV of 78·4 % (95 % CI 73·5 %, 82·6 %) for the identification of LBW newborns. Although FL had the highest NPV of 98·4 % (95 % CI 97·9 %, 98·7 %) with a cut-off value of <6·9 cm. With a cut-off value of <29·4 cm, CC had the highest PPV of 81·9 % (95 % CI 77·3 %, 85·7 %) for the identification of premature newborns. Although MUAC had the highest NPV of 96·6 % (95 % CI 95·9 %, 97·1 %) with a cut-off value of <7·9 cm. All other measurements had high NPVs of 91 % or more (Table 5).

The likelihood ratios and the diagnostic odds ratios for all measures and for LBW as well as for premature births are shown in Table 6. CC had a significantly higher + LR than any other reading and FL had the lowest LR, but it was not significantly different from LR from CC and MUAC. DOR was highest for FL (80), followed by MUAC (77·7). In addition, +LR = 7·7 suggests that babies with MUAC ≤ 7·7 cm are almost eight times more likely to have LBW than babies with MUAC > 7·7. On the other hand, the +LR = 15·8 indicates that newborns with CC ≤ 30·1 cm were almost sixteen times more likely to have premature babies than newborns with CC > 30·1 cm (Table 6).

Discussion

There is a need for alternative methods of identifying LBW neonates and GA in a resource-poor environment with high neonatal mortality rates and limited access to equipment to accurately estimate BW and GA. The present study found that the prevalence of LBW and premature birth occurred at a rate of 20 % and 22·3 %, respectively.

Table 3. Pearson correlation of anthropometric variables with BW and GA

Variable	Correlation coefficient, *r* (95 % CI)	r^2	*P*
Birth weight			
Foot length (FL)	0·53(0·44–0·61)	0·28	<0·001
Chest circumference	0·72(0·66–0·79)	0·53	<0·001
Head circumference (HC)	0·63(0·55–0·71)	0·4	<0·001
Mid-upper arm circumference (MUAC)	0·65(0·58–0·73)	0·43	<0·001
Gestational age			
Foot length (FL)	0·48(0·39–0·57)	0·48	<0·001
Chest circumference	0·62(0·55–0·7)	0·39	<0·001
Head circumference (HC)	0·52(0·43–0·6)	0·27	<0·001
Mid-upper arm circumference (MUAC)	0·59(0·51–0·67)	0·35	<0·001

BW, birth weight; GA, gestational age.
Significant at $P < 0·05$.

Table 4. AUC analysis for identification of birth weight and gestational age

Parameters	AUC (95 % CI)	*P*
LBW (<2500 g)		
FL	0·941(0·917, 0·965)	<0·0001
CC	0·952(0·93, 0·974)	<0·0001
HC	0·896(0·863, 0·929)	<0·0001
MUAC	0·945(0·921, 0·969)	<0·0001
Gestational age (<37 weeks)		
FL	0·914(0·886, 0·943)	<0·0001
CC	0·929(0·904, 0·954)	<0·0001
HC	0·87(0·834, 0·905)	<0·0001
MUAC	0·932(0·907, 0·957)	<0·0001

AUC, area under curve; LBW, low birth weight; FL, foot length; CC, chest circumference; HC, head circumference; MUAC, mid-upper arm circumference.
Significant at $P < 0·05$.

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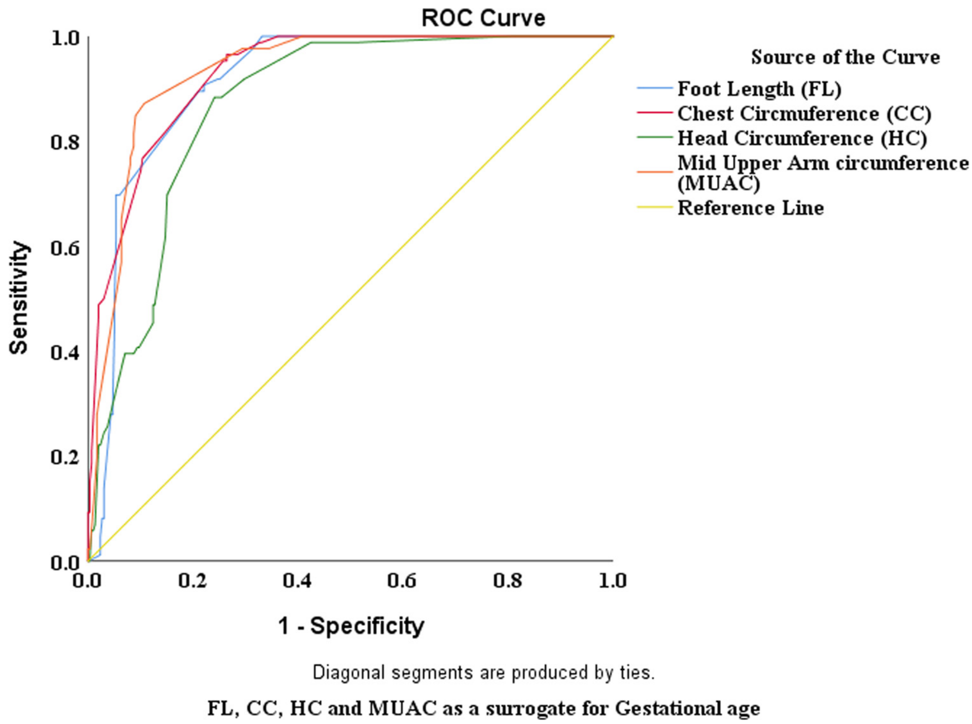

Fig. 1. The ROC curve of FL, CC, HC and MUAC for predicting gestational age.

In the present study, we found that all four anthropometric parameters (FL, CC, HC and MUAC) appeared to be useful diagnostic tools for identifying LBW and premature babies, however, CC and MUAC were found to be the best anthropometric diagnostic measure than FL and HC. Our findings are consistent with those of a WHO inter-laboratory study and a meta-analysis[21,25]. In the present study, the CC cut-off point for identifying LBW was 29·41 cm, which was lower than in previous Nepalese studies (30·8 cm), Uganda (31 cm), Vietnam (30·4 cm) and Mekelle, Ethiopia (30·1 cm)[28,30,31], and comparable to the proposals of the WHO inter-laboratory study (with an interpretation of <29 cm high at risk and between 29 and 30 cm at risk)[21]. We identified the cut-offs of MUAC for identifying of LBW were 7·7 cm, similar to the results from the WHO inter-laboratory study, but lower than those of the study from Vietnam (with 9·0 cm) and

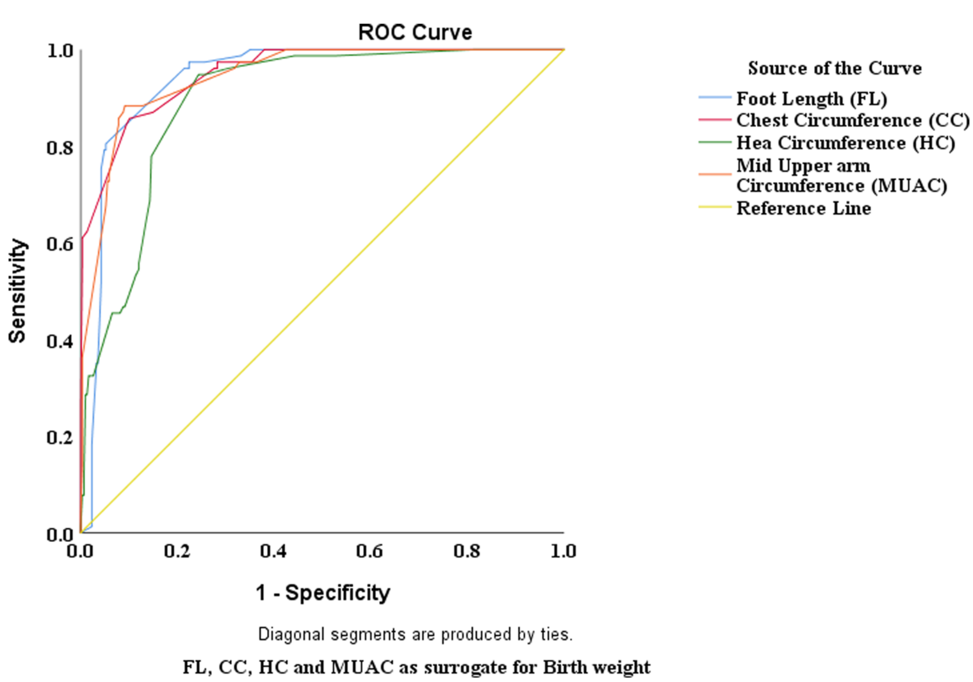

Fig. 2. The ROC curve of FL, CC, HC and MUAC for predicting birth weight of newborn babies.

Table 5. Sensitivity, specificity, positive predictive values (PPVs) and negative predictive values (NPVs) with 95 % CIs for each outcome and anthropometric measured within 24 h of life (*n* 385)

Outcome	Youden's index	Sensitivity (95 % CI)	Specificity (95 % CI)	PPV (95 % CI)	NPV (95 % CI)
LBW (<2500 g)					
FL < 6·9 cm	0·753	94·8(93·2, 96·09)	80·5(77·9, 82·9)	54·86(51·7, 57·9	98·4(97·9, 98·7)
CC < 29·4 cm	0·756	89·9(87·8, 91·7)	85·7(83·3, 87·8)	61·1(57·4, 64·6)	97·1(96·5, 97·6)
HC < 33·1 cm	0·704	75·6(72·8, 78·2)	94·8(93·2, 96·0)	78·4(73·5, 82·6)	93·9(93·3, 94·5)
MUAC < 7·7 cm	0·792	90·9(88·9, 92·6)	88·3(86·1, 90·2)	69·04(65·2, 72·5)	97·1(96·5, 97·6)
Gestational age (<37 weeks)					
FL < 7·1 cm	0·686	77·9(75·2, 80·4)	90·7(88·7, 92·4)	70·6(66·3, 74·5)	93·4(92·7, 94·1)
CC < 30·1 cm	0·695	74·2(71·3, 76·8)	95·3(93·8, 96·5)	81·9(77·3, 85·7)	92·7(92·0, 93·4)
HC < 33·7 cm	0·621	70·2(67·2, 73·02)	91·9(90·03, 93·5)	71·3(66·7, 75·4)	91·4(90·7, 92·2)
MUAC < 7·9 cm	0·765	89·3(87·2, 91·1)	87·2(84·9, 89·2)	66·9(62·9, 70·2)	96·6(95·9, 97·1)

J^{th}, Youden index; HC, head circumference; FL, foot length; MUAC, mid-upper arm circumference.
Significant at $P < 0·05$.

Table 6. Likelihood ratios and diagnostic odds ratio for the different anthropometric measurements for predicting LBW at selected cut-off points

Parameter	+Likelihood ratio (95 % CI)	−Likelihood ratio (95 % CI)	Diagnostic OR
LBW (<2500 g)			
FL < 6·9 cm	4·8(4·28, 5·52)	0·06(0·05, 0·08)	80
CC < 29·4 cm	6·29(5·39, 7·3)	0·12(0·1, 0·14)	52·14
HC < 33·1 cm	14·54(11·13, 18·99)	0·26(0·23, 0·29)	56
MUAC < 7·7 cm	7·77(6·55, 9·22)	0·1(0·08, 0·13)	77·7
Gestational age (<37 weeks)			
FL < 7·1 cm	8·38(6·86, 10·19)	0·24(0·22, 0·27)	35
CC < 30·1 cm	15·79(11·91, 20·92)	0·27(0·24, 0·3)	58·48
HC < 33·7 cm	8·67(7·01, 10·72)	0·32(0·29, 0·36)	27·1
MUAC < 7·9 cm	6·98(5·93, 8·21)	0·12(0·1, 0·15)	58·1

LBW, low birth weight; HC, head circumference; FL, foot length; MUAC, mid-upper arm circumference.
Significant at $P < 0·05$.

from Turkey (with 9 cm)[21,31,32]. The present study's cut-off point for identifying LBW with FL was 6·98 cm, which is less than the results from Mekelle, Ethiopia (7·5 cm), Ugandan (7·9 cm) and Tanzanian studies (8 cm)[30,32,33].

Our finding indicated that CC (AUC = 0·95, 95 % CI 0·93, 0·97) have high correlation coefficient with BW. Similar finds from Bangladesh, Pokhara and Mekele, Ethiopia[28,34,35], who reported a good correlation between CC and BW. The present study found high correlation coefficient and supports that the WHO inter-laboratory comparison recommendation to use CC as an alternative measurement for detecting LBW[36]. The probability of this recommendation may be due to its high sensitivity in diagnosing LBW and the simplicity of the procedure, since the nipple line is an obvious landmark for measurement and is therefore less susceptible to inter-observers or intra-observers variability. It is also easier to measure because the nipple line is easier to see; this makes the measurement more operationally feasible. The delivery process does not result in any significant soft tissue changes on the breast.

MUAC (AUC = 0·93, 95 % CI 0·9, 0·95) was the highly sensitive tool for detecting premature births in newborns. This is comparable to the findings in Jimma, Ethiopia[22]. The FL ($r = 0·53$) had the lowest correlation, the highest sensitivity (94·8 %) and the highest NPV of 98·4 % for the detection of LBW among all parameters analysed in the present study. This study is similar to the results in Mekelle, Ethiopia[28]. But in a study carried out in Uganda, it correlated strongly with BW ($r = 0·76$ and AUC = 0·97) and had a sensitivity of 94 % and a specificity of 83 % in the detection of LBW[30]. The study also implied that measuring FL exposes the baby is less, which reduces the risk of hypothermia and technically easier. These are both important points that require further study of this anthropometric measurement as it is the least studied of the others. This study contradicts a study carried out in Jimma, Ethiopia[22], in which MUAC (95·2 %) had the highest sensitivity for the detection of LBW. The possible reason may be due to different ethnicity has different visceral fat and muscular composition, it may be due to dietary practice and genetically factors.

Our study showed that HC with a cut-off value of <33·1 cm had the highest PPV of 78·4 % (95 % CI 73·5 %, 82·6 %) for identification of LBW newborns. Although FL had the highest NPV of 98·4 % (95 % CI 97·9 %, 98·7 %) with a cut-off value of <6·9 cm. With a cut-off value of <29·4 cm, CC had the highest PPV of 81·9 % (95 % CI 77·3 %, 85·7 %) for the identification of LBW newborns. Although MUAC had the highest NPV of 96·6 % (95 % CI 95·9 %, 97·1 %) with a cut-off value of <7·9 cm. All other measurements had high NPVs of 91 % or more.

The strengths of the present study were as follows: This is the first study in the study area and it used as a baseline for grand study. Also it used as a complement study to other studies to set standard guideline for assessing LBW and premature babies by themselves for those home deliver mothers and it uses as alarming the families to visit health facilities if any outbreak is occur like corona. However, our study was not without limitations. First, our study participant was from health facilities and not included mothers who delivered at their home. Secondly, a sample size was small and it is difficult to the generalised the entire population. Thirdly, a preterm birth is assessed by <37 weeks rather than early ultrasound, however, mothers do not remember their LMP, and Ethiopian health facilities do not routinely perform prenatal ultrasound, which may lead to errors in estimating GA.

Conclusion

Anthropometric parameters can be viewed as a useful tool to identify LBW. In the present study, four newborn anthropometric measurements (CC, FL, MUAC and HC) were used as a diagnostic tool to identify LBW and premature babies. All anthropometric measuring instruments correlate significantly with LBW and premature babies. However, CC possibly had better sensitivity for the identification of LBW newborns and premature babies than the other parameters examined. Furthermore, large scale and meta and systematic analysis research is needed to identify better diagnostic measures for LBW and premature neonate birth from study conducted in Ethiopia in order to set the standard anthropometric measurement.

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E. S. and A. B.: Study concept and design, statistical analyses, interpretation of data, and drafting of the manuscript, writing, review and editing the manuscript text. A. O. and Y. S.: drafting of the manuscript and editing the manuscript text.

The authors have declared that no competing interests exist.

Ethical clearance was obtained from the Ethical Review Board of Dire Dawa University, College of Health Science with reference number IRB 205/21. A declaration of approval was presented to all selected facilities. Written informed consent was obtained from all mothers for their participation in the study. In addition, the informed consent was obtained from mothers/parents for participation of their newborns.

The datasets used and/or analysed during the present study are not publicly available due to limitations of ethical approval involving the study participants data and anonymity, but are available from the corresponding author on reasonable request.

References

1. Estimation UNI-aGfCM (2020) Levels & Trends in Child Mortality: Report 2020, Estimates Developed by the UN Inter-Agency Group for Child Mortality Estimation.
2. Estimation UNI-aGfCM (2020) Levels and Trends in Child mortality: Report 2020. Fund UNCs New York.
3. Bhargava S, Ramji S, Kumar A, *et al.* (1985) Mid-arm and chest circumferences at birth as predictors of low birth weight and neonatal mortality in the community. *Br Med J (Clin Res Ed)* **291**, 1617–1619.
4. Dubois L & Girard M (2006) Determinants of birthweight inequalities: population-based study. *Pediatr Int* **48**, 470–478.
5. Goldenberg RL & Culhane JF (2007) Low birth weight in the United States. *Am J Clin Nutr* **85**, 584S–590S.
6. do Carmo Leal M, da Gama SG, da Cunha CB (2006) Consequences of sociodemographic inequalities on birth weight. *Rev Saude Publica* **40**, 466–473.
7. Mahumud RA, Sultana M & Sarker AR (2017) Distribution and determinants of low birth weight in developing countries. *J Prev Med Public Health* **50**, 18.
8. Hug L, Lee S, Sharrow D, *et al.* (2020) Levels & Trends in Child Mortality Report 2019. Estimates Developed by the UN Inter-Agency Group for Child Mortality Estimation. 2019.
9. Christian P, Lee SE, Donahue Angel M, *et al.* (2013) Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low-and middle-income countries. *Int J Epidemiol* **42**, 1340–1355.
10. Gu H, Wang L, Liu L, *et al.* (2017) A gradient relationship between low birth weight and IQ: a meta-analysis. *Sci Rep* **7**, 1–13.
11. Jornayvaz FR, Vollenweider P, Bochud M, *et al.* (2016) Low birth weight leads to obesity, diabetes and increased leptin levels in adults: the CoLaus study. *Cardiovasc Diabetol* **15**, 1–10.
12. McGuire S & World Health Organization (2015) Comprehensive implementation plan on maternal, infant, and young child nutrition. Geneva, Switzerland, 2014. *Adv Nutr* **6**, 134–135.
13. WHO (2014) *Comprehensive Implementation Plan on Maternal, Infant and Young Child Nutrition*. Geneva, Switzerland: WHO.
14. WHO. *Global Targets 2025. To Improve Maternal, Infant and Young Child Nutrition*.
15. Blencowe H, Krasevec J, de Onis M, *et al.* (2019) National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: a systematic analysis. *The Lancet Global Health* **7**, e849–e860.
16. World Health Organization (WHO) (2019) UNICEF-WHO Low Birthweight Estimates: Levels and Trends 2000-2015. World Health Organization.
17. Tessema ZT & Tesema GA (2020) Pooled prevalence and determinants of skilled birth attendant delivery in East Africa countries: a multilevel analysis of Demographic and Health Surveys. *Ital J Pediatr* **46**, 1–11.
18. UN, United Nations (2021) *Population Division of the Department of Economic and Social Affairs. World Population Prospects, Ethiopia Infant Mortality Rate from 1950-2021*.
19. Sheehan L (2021) *Life Expectancy Project: Technical Report*. Dublin: National College of Ireland.
20. ICF, E.a., Central Statistical Agency (CSA) [Ethiopia] and ICF (2019) *Ethiopia Mini Demographic and Health Survey 2019*. Addis Ababa, Ethiopia and Rockville, Maryland, USA: ICF, E.a., Central Statistical Agency (CSA) [Ethiopia] and ICF.
21. Diamond I, McDonald J & Guidotti R (1993) Use of a simple anthropometric measure to predict birth weight. *Bull World Health Organ* **71**, 157–163.
22. Gidi NW, Berhane M, Girma T, *et al.* (2020) Anthropometric measures that identify premature and low birth weight newborns in Ethiopia: a cross-sectional study with community follow-up. *Arch Dis Child* **105**, 326–331.
23. Marchant T, Penfold S, Mkumbo E, *et al.* (2014) 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* **14**, 1–6.
24. Raymond EG, Tafari N, Troendle JF, *et al.* (1994) Development of a practical screening tool to identify preterm, low-birthweight neonates in Ethiopia. *Lancet* **344**, 524–527.
25. Goto E (2011) Meta-analysis: Identification of low birthweight by other anthropometric measurements at birth in developing countries. *J Epidemiol* **21**, 354–362.

26. Buderer NMF (1996) Statistical methodology: I. Incorporating the prevalence of disease into the sample size calculation for sensitivity and specificity. *Acad Emerg Med* **3**, 895–900.
27. Sema A, Tesfaye F, Belay, Y, *et al.* (2019) Associated factors with low birth weight in Dire Dawa City, Eastern Ethiopia: a cross-sectional study. *BioMed Res Int* **2019**, 1–8
28. Hadush MY, Berhe AH & Medhanyie AA (2017) Foot length, chest and head circumference measurements in detection of low birth weight neonates in Mekelle, Ethiopia: a hospital based cross sectional study. *BMC Pediatr* **17**, 1–8.
29. Association WM (2001) World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *Bull World Health Organ* **79**, 373.
30. Elizabeth NL, Christopher OG & Patrick K (2013) Determining an anthropometric surrogate measure for identifying low birth weight babies in Uganda: a hospital-based cross sectional study. *BMC Pediatr* **13**, 1–7.
31. Thi HN, Khanh DKT, Thu HLT, *et al.* (2015) 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* **10**, e0142420.
32. Arisoy AE & Sarman G (1995) Chest and mid-arm circumferences: identification of low birth weight newborns in Turkey. *J Trop Pediatr* **41**, 34–37.
33. Marchant T, Jaribu J, Penfold S, *et al.* (2010) Measuring newborn foot length to identify small babies in need of extra care: a cross sectional hospital based study with community follow-up in Tanzania. *BMC Public Health* **10**, 1–9.
34. Dhar B, Mowlah G, Nahar S, *et al.* (2002) Birth-weight status of newborns and its relationship with other anthropometric parameters in a public maternity hospital in Dhaka, Bangladesh. *J Health Popul Nutr* **20**, 36–41.
35. Sreeramareddy CT, Chuni N, Patil R, *et al.* (2008) Anthropometric surrogates to identify low birth weight Nepalese newborns: a hospital-based study. *BMC Pediatr* **8**, 1–6.
36. World Health Organization (WHO) (1993) Use of a simple anthropometric measurement to predict birth weight. *Bull World Health Organ* **71**, 157–163.