JMCH Journal of Maternal and Child Health (2024), 09(01): 97-104
Masters Program in Public Health, Universitas Sebelas Maret

Research
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Newborn Calf Circumference to Identify Low Birth Weight Neonates

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Received: 14 November 2023; Accepted: 14 December 2023; Available online: 16 January 2024

ABSTRACT

Background: The absence of birth weight records for infants remains a prevalent issue in developing countries, including Indonesia. The timely identification of low birth weight (LBW) and premature neonates, particularly those born outside well-equipped healthcare facilities is vital within the critical first 48 hours of life. This study aimed to ssess the potential utility of calf circumference in identifying low birth weight infants.

Subjects and Method: A cross-sectional study was conducted on 100 neonates aged between 0 – 48 hours old who were treated at Dr. Moewardi General Hospital, Surakarta from May 2022 to August 2022. The dependent variable was neonates birth weight. The independent variables was calf circumference. Calf circumference was measured using non elastic but flexible measuring tape, with measurement precision up to the nearest 0.1 cm. The cut-off point of calf circumference was determined with the ROC curve.

Results: Calf circumference significantly correlates with birth weight ($p<0.001$), with $r=0.969$. The calf circumference cut-off value of 10.35 cm in LBW had an AUC of 0.99, a sensitivity of 98.0%, a specificity of 98.0%, and a positive predictive value of 98.0%, a negative predictive value of 98.0%. The calf circumference cut-off value was 8.85 cm for LBW neonates, which had an AUC of 0.93, with a sensitivity of 83.9%. specificity 85.7%, positive predictive value 98.7%, negative predictive value 28.6%.

Conclusion: Calf circumference in newborns can be used to identify neonates with low birth weight.

Keywords: calf circumference, birth weight, low birth weight, anthropometry.

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Cite this as:
Atriadewi HS, Hafidh Y, Andarini I (2024). Newborn Calf Circumference to Identify Low Birth Weight Neonates. *J Matern Child Health*. 09(01): 97-104. https://doi.org/10.26911/thejmch.2024.09.01.09.

BACKGROUND

Premature birth is a pressing global health concern, with approximately one million children under five years old succumbing to its complications each year, especially those born before 37 weeks of gestation (Walani, 2020). Indonesia ranks fifth among nations with a high prevalence of premature births, totaling 675,700 annually (March of Dimes PMNCH Save the Children WHO, 2012).

Early diagnosis and identification of low birth weight (LBW), very-low birth weight (VLBW), and premature infants, particularly in resource-limited settings, are imperative within the initial 48 hours of life (Chukwudi et al., 2018). Timely identification facilitates cost-effective interventions like kangaroo mother care (KMC), exclusive breastfeeding, and early infection risk management (Keshmiri et al., 2019; Sivanandan and Sankar, 2023). However, restricted availability to precision weighing equipment causes problems in economically under-developed locations, particularly rural ones with undertrained medical staff. Furthermore, the lack of regular antenatal care makes measuring gestational age difficult (Katz et al., 2015).

Many nations have implemented anthropometric measurements as an alternative for birth weight screening in primary and community health clinics to reduce the global mortality rate of preterm and LBW infants (Conde-Agudelo and Díaz-Rossello, 2016; Fitri, 2017). This approach mentioned before evaluates the relationship between particular anthropometric cut-offs, birth weight, and gestational age (Goto, 2011). A study in South Kalimantan at 2012 explored anthropometric measurements, such as calf circumference, head circumference, and chest circumference, to detect LBW. Chest circumference with a cut-off of 30.7 cm exhibited 83% sensitivity and 85% specificity, while calf circumference with a cut-off of 10.3 cm demonstrated 94% sensitivity and 66% specificity in detecting LBW (Putra et al., 2020).

Despite this progress, Indonesia lacks comprehensive data on anthropometry related to neonatal gestational age and birth weight, including LBW and VLBW. Consequently, this study aims to investigate the role of anthropometry, with a specific focus on calf circumference, as a screening tool for LBW infants. Given the persistent high incidence of LBW in Indonesia and the country's ethnic diversity, this research aims to contribute valuable insights for early LBW detection and intervention, ultimately improving infant outcomes in the region.

SUBJECTS AND METHOD

1. Study Design

This research used a cross-sectional design. It was performed in Dr. Moewardi General Hospital, Surakarta, Indonesia from May 2022 to August 2022.

2. Population and Sample

The population of this study were neonates aged 0-48 hours who were treated at the neonatal care unit. We used a consecutive sampling technique. We excluded patients suffering from major congenital anomalies, extremely low birth weight (birth weight <1000 grams) and/or gestational age <28 weeks (extremely preterm), and severe asphyxia.

3. Study Variables

The independent variable of this study was calf circumference, while the dependent variable in this study was the birth weight of neonates.

4. Operational Definition of Variables

Calf circumference was defined by measurement at the most noticeable portion of the cruris region in the proximal 1/3 of the calf. Birth weight of neonates was defined by the weight of baby aged 0 days to less than 48 hours.

5. Study Instruments

The calf circumference was measured using non-elastic but flexible measuring tape, with measurement accuracy to the nearest 0.1 cm. The measurements were performed by the researcher (assisted by the resident on duty at that time) by semiflexing the lower left leg then wrapping the tape around the most prominent place on the lower left leg of the newborn baby. Measurements were made twice, then the average was calculated. Results will be presented in units of measurement in cm, with 1 (one) decimal place after the comma.

The baby's birth weight was measured using a baby scale available in the neonatal care room which has been calibrated with an accuracy of 50 grams. Body weight measurements were performed on the same day as calf circumference measurements. The results will be presented in birth weight values (units in grams) then categorized into low birth weight (LBW) 2500-4000 grams, very low birth weight (VLBW) 1500-2500 grams, extremely low birth weight (ELBW) 1000- 1500 grams.

5. Data analysis

We analysed all the data statistically with SPSS-based statistical software (version 26). Chi-square test was applied for bivariate analysis, and p<0.05 was considered statistically significant. The cut-off point of calf circumference was determined with ROC curve.

6. Research Ethics

This study was approved by the Ethics Committee of Dr. Moewardi General Hospital, Surakarta, Indonesia with the number was 761/VI/HREC/2022. This study was approved by the Ethics Committee of Dr. Moewardi General Hospital, Surakarta, Indonesia.

RESULTS

There were 100 neonates who were treated in the neonatal care unit of Dr. Moewardi General Hospital during the study period. 52% of subjects were male. The study subjects were dominated by neonates with gestational age of >37 weeks (64.0%), followed by 36.0% who had gestational age of <37 weeks. The average subject birth weight was 2489.48 grams (Mean= 2489.48; SD= 680.99) with a minimum weight of 1275 g and a maximum weight of 4000 g, and the average subject calf circumference was 10.38 cm (Mean = 10.38; SD 1.66) with a minimum length of 7 cm and a maximum length of 14 cm (Table 1).

Table 1. Sample characteristics

Baseline	Total (n=100)		Sex (Male)		Sex (Female)		p
	Mean	SD	Mean	SD	Mean	SD	
Birth weight (g) [b]	2489.48	680.99	2628.42	663.55	2338.96	674.20	0.050
Calf circumference (cm) [b]	10.38	1.66	10.73	1.66	10.01	1.58	0.037*

Note: [a]Chi-Square test; [b]Mann Whitney test; *Significant at p<0.05

Based on Figure 1, the scatterplot data distribution of the relationship between calf circumference and newborn baby weight forms a linear line from bottom left to top right, which means that the longer the calf circumference, the heavier the birth weight of the baby.

Based on Table 2, the relationship between calf circumference and birth weight in male neonates has a value of r=0.98, which exhibited a positive and very strong relationship (r=0.80-1.00) between calf circumference and birth weight in male neonates. The p-value ≤0.001 (p <0.01), indicated a statistically significant relationship.

Similarly, in female neonates, the relationship between calf circumference and birth weight has a value of r=0.95, which demonstrated a positive and very strong relationship (r=0.80-1.00) between calf circumference and birth weight in female neonates. The p-value ≤0.001 (p <0.01), implied a statistically significant relationship.

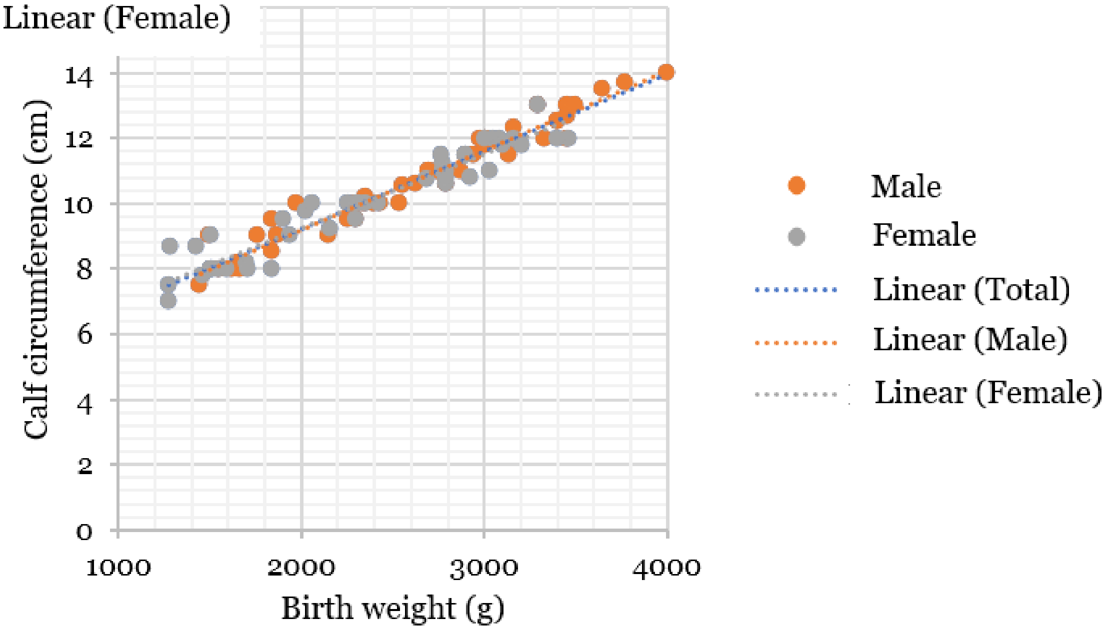

Figure 1. Scatterplot of Correlation Between Birth Weight and Calf Circumference

Table 2. Correlation Between Birth Weight and Calf Circumference

Varaible	N	Birth Weight Correlation Coefficient (r_s)	p
Calf circumference			
Male	52	0.98	<0.001**
Female	48	0.95	<0.001**
Total	100	0.97	<0.001**

Note: [b]Spearman Rank Test; *Significant at p<0.05; * Significant at p<0.01

In the total sample, the relationship between calf circumference and birth weight obtained a value of r=0.97, displayed a positive and very strong relationship (r=0.80-1.00) between calf circumference and the baby's overall birth weight. The p-value ≤0.001 (p <0.01), suggested a statistically significant relationship.

Based on Figure 2 and Table 3, the area under curve (AUC) value of LBW is 0.99 and a cut-off value for calf circumference of 10.35 cm with a sensitivity of 98.0% and a specificity of 98.0%. The positive predictive value (PPV) is 98.0% and negative predictive value (NPV) is 98.0%.

Based on Figure 3 and Table 3, the AUC of VLBW is 0.927 with a cut-off value for calf circumference of 8.85 cm with a sensitivity of 83.9% and a specificity of 85.7%. The PPV was 98.7% and NPV was 28.6%.

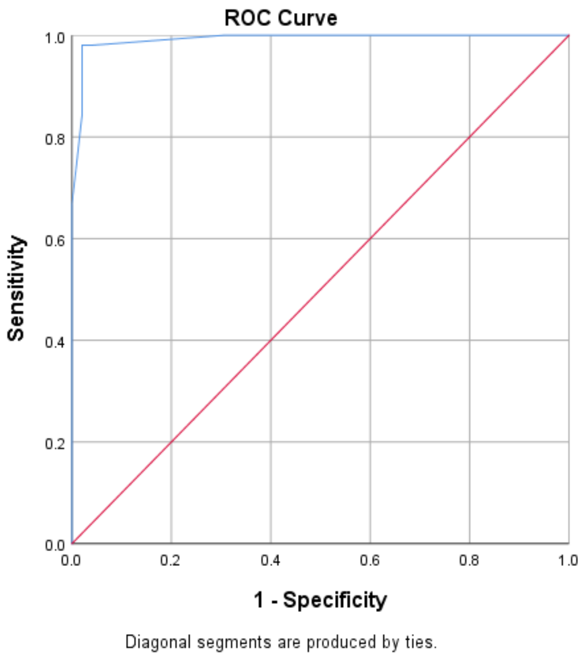

Figure 2. ROC Curve of Calf Circumference Based on VLBW

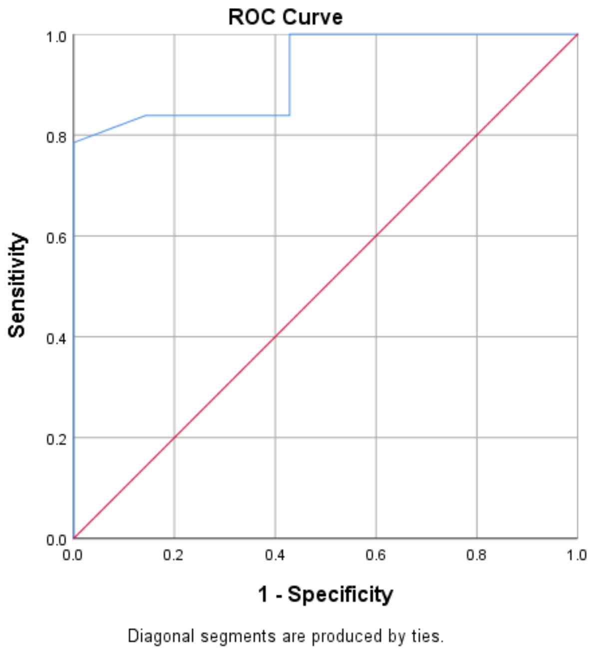

Figure 3. ROC Curve of Calf Circumference Based on ELBW

Table 3. Cut-off Result of Calf Circumference to Identify LBW

Examination	Calf circumference						
	AUC	Cut-off	Sensitivity	Specificity	NDP	NDN	p
LBW	0.992	10.35	98.0%	98.0%	98.0%	98.0%	<0.001*
VLBW	0.927	8.85	83.9%	85.7%	98.7%	28.6%	<0.001

Based on Table 4, the cut-off proportion of calf circumference as an alternative measure for birth weight is better in predicting LBW cases compared to VLBW cases. In comparing calf circumference as an alternative measure for birth weight to detect LBW and LBW, an AUC analysis was performed based on the ROC curve, sensitivity, specificity, predictive value and likelihood ratio (LR). Calf circumference has a better AUC value in predicting LBW compared to VLBW (0.992 compared to 0.93). When analyzed further, calf circumference for LBW prediction had a higher sensitivity and specificity (98.0%) (Table 3).

The likelihood ratio is a value that describes the relationship between test results and the actual probability of occurrence of the observed case. An alternative measure is considered to have good performance if it has LR+ > 10 and LR- < 0.1. The calf circumference for identifying LBW also has better LR+ and LR- values when compared to identify LBW (Table 5).

Table 4. The Crosstabulation Calf Circumference and Birth Weight

Calf circumference	LBW		Calf circumference	VLBW	
	No	Yes		No	Yes
≥10.35 cm	50	1	≥8.85 cm	78	1
<10.35 cm	1	48	<8.85 cm	15	6

Table 5. The likelihood ratio value of calf circumference

Examination	Calf Circumference	
	Likelihood Ratio+	Likelihood Ratio -
LBW	48.04	0.02
VLBW	5.87	0.19

DISCUSSION

Table 1 reveals a statistically significant difference in calf circumference (p=0.037) between males and females, with a p-value of less than 0.05. The data indicates that male neonates tend to have larger calf circumferences compared to female neonates. This observation suggests a consistent trend of higher measurements in male infants.

Figure 1 illustrates a scatterplot displaying the relationship between calf circumference and newborn baby weight. The plot exhibits a linear pattern from the bottom left to the top right, implying that as calf circumference increases, so does the baby's birth weight. This linear trend in data distribution indicates a strong positive relationship between calf circumference and birth weight.

Surprisingly, our study revealed that both male and female neonates exhibit a strong positive relationship (correlation coefficients ranging from 0.80 to 1.00) between calf circumference and birth weight. This intriguing finding suggests that gender does not influence the connection between calf circumference and birth weight, despite our initial observation that male neonates tend to have larger measurements than female neonates. In our research, we also utilized ROC curves, as depicted in Figure 2 and Figure 3, along with data presented in Table 3, to determine a crucial cutoff value for calf circumference when assessing newborns for the risk of LBW. Our analysis identified a cutoff value of 10.35 cm. This means that a calf circumference measurement greater than 10.35 cm has a sensitivity of 98.0%, indicating that it can accurately identify 98.0% of neonates weighing over 2500 grams. Furthermore, our study found a specificity value of 98.0% for measuring calf circumference. This high specificity implies that there is a substantial probability of correctly identifying neonates with a body weight below 2500 grams (LBW) among those with a calf circumference measurement below 10.35 cm.

During the examination, we also calculated the NPV, which was determined to be 98.0%. This implied that if the calf circumference measurement is greater than 10.35 cm, there is a 98.0% likelihood of the baby weighing over 2500 grams. Conversely, if the calf circumference is less than 10.35 cm, there is a 98.0% probability that the baby will have a bodyweight below 2500 grams (LBW). These findings underscore the utility of calf circumference measurements as a reliable indicator for assessing birth weight, irrespective of gender.

In our subsequent examination of VLBW neonates using calf circumference measurements, we determined a cutoff value of 8.85 cm. This cutoff exhibited a sensitivity of 83.9%, indicating that 83.9% of neonates with a body weight greater than 1500 grams could be accurately identified by assessing a calf circumference measurement exceeding 8.85 cm. The specificity value for calf circumference measurements in this study was 85.7%. This high specificity suggests that there is a strong likelihood of correctly identifying neonates with a body weight below 1500 grams (VLBW) among those with a calf circumference measurement below 8.85 cm, at an accuracy rate of

85.7%. Furthermore, during our examination, we calculated the PPV, which stood at 98.7%. This signifies that if the calf circumference measurement surpasses 8.85 cm, there is a 98.7% probability that the baby's weight exceeds 1500 grams (non-VLBW). Conversely, the Negative Predictive Value (NPV) was determined to be 28.6%, indicating that if the calf circumference measures less than 8.85 cm, there is a 28.6% chance that the baby will have a bodyweight below 1500 grams (VLBW). These findings emphasize the valuable role of calf circumference measurements in assessing birth weight for VLBW neonates, providing clinicians with a reliable tool for identifying at-risk infants.

The findings of our study align with previous research conducted in South Kalimantan by Kusharisupeni et al. (2013). Their study recommended the use of calf circumference as a straightforward and suitable parameter for identifying low birth weight infants, especially in remote areas. In their research, a calf circumference cut-off of 10.3 cm demonstrated a sensitivity of 94% and specificity of 66% for detecting LBW neonates, with an impressive AUC value of 89% (95% CI= 0.83 to 0.95) (Kusharisupeni et al., 2013).

Our results also harmonize with a study conducted by Putra et al. (2020), which focused on a maternity clinic in Jakarta. This study found a significant relationship between calf circumference and upper arm circumference with birth weight ($p<0.001$), with correlation coefficients (r values) of 0.529 and 0.674, respectively. The study determined a cut-off value for calf circumference of 10.62 cm, with an AUC of 0.90, a sensitivity of 66.7%, and a specificity of 97.9%. Additionally, the PPV was 8.2%, the NPV was 98.9%, the likelihood ratio (+) was 31.7, and the likelihood ratio (-) was 0.03. Notably, this research indicated that calf circumference performed better as a surrogate measure for birth weight in identifying low birth weight neonates when compared to measurements of upper arm circumference (Putra et al., 2020).

According to Diamond and McDonald's (1993) criteria, alternative measurements must meet at least four criteria: a strong correlation with birth weight, accurate detection of birth weight, measurements that are easy to perform, and simple but stable equipment.

This study underscores the strong correlation between calf circumference and birth weight, revealing that calf circumference serves as a valuable predictor. Interestingly, when considering the likelihood ratio values, calf circumference demonstrates greater accuracy in detecting LBW cases compared to VLBW cases.

An examination of the likelihood ratio analysis in Table 5 reveals that calf circumference's LR+ (positive likelihood ratio) is 48.04, and its LR- (negative likelihood ratio) is 0.02. These values indicate that calf circumference fulfills the criteria for a reliable substitute measure, particularly in predicting LBW cases.

A notable advantage of our research lies in the identification of two distinct cutoff values: one for LBW and the other for VLBW. The LBW cutoff, set at 10.35 cm, can prove especially valuable in remote or resource-constrained areas where advanced facilities and infrastructure may be limited. However, it's essential to acknowledge a limitation of this study. The sample size for subjects falling into the VLBW category was relatively small. This limitation may have influenced the study's results, potentially contributing to its higher accuracy in detecting LBW cases compared to VLBW cases.

AUTHOR CONTRIBUTION

Hambrah Sri Atriadewi is the lead author who conducted the research, conducted data analysis, and wrote the manuscript. Yulidar Hafidh examined the background and discussion of the research. Ismiranti Andarini formulated the research framework.

ACKNOWLEDGMENT

The author gratefully acknowledged the study participants who had volunteered to participate in this study.

FUNDING AND SPONSORSHIP

This research was funded independently.

CONFLICT OF INTEREST

In this study, there was no conflict of interest.

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