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ORIGINAL ARTICLE

Mid-arm and Chest Circumferences for Estimating Low Birthweight

by

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Abstract

A prospective study was conducted to assess the diagnostic performance of mid-arm and chest circumferences on low birth weights in 1033 singleton newborn infants. The proportion of low birth weight was 11.7%. Strong correlations on birth weight (P<0.001) were found for mid-arm (r=0.85) and chest (r=0.86) circumferences. A mid-arm circumference of ≤ 9,5 cm was considered as cut-off level for low birth weight, with a sensitivity of 0.818, specificity 0.956 and positive predictive value 0.712. Whereas that of chest circumference was ≤ 29.5 cm with a sensitivity of 0.785, specificity 0.895 and positive predictive value 0.497. Receiver operating characteristic (ROC) curves were used to compare their diagnostic accuracy. The area under these two ROC (± SE) were 0.954 ± 0.011 for mid-arm and 0.945 ± 0.012 for chest circumferences, respectively. Both areas showed significant differences with the area under chance line. No statistically significant difference was found between the area under ROC of mid-arm and chest circumferences.

The results showed that mid-arm and chest circumferences as simple and reliable measurements can be used in estimating low birth weight, in areas where the accurate weighing of newborn infants is not feasible.

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Introduction

Birth weight is generally recognized as one of the determinants of infant's mortality and morbidity [1.2], as well as the child's mental and physical development [3]. The most susceptible infants are those with a low birth weight (birth weight less than 2500 gram). Therefore, it is important to weigh every newly born infant accurately for appropriate measures to minimize the risk to the baby.

In rural areas, almost 84% of deliveries occur at home and are attended by traditional birth attendants [4]. Weighing newborns at birth may not be possible due to a lack of scales or the available scales are not sufficiently robust to withstand constant use in the field. In these conditions, suitable surrogates for birth weight are needed. Some studies [5.6.7.8] have reported anthropometric indices as proxies of birth weight.

The objectives of this study are to present the performance of mid-arm and chest circumferences as indicators in predicting low birth weight infants and the comparison of their diagnostic accuracy by using receiver operating characteristic (ROC) curves.

Materials and Methods

Birth weight, mid-arm and chest circumferences were measured during the period of August 1989 to December 1990 in newborn infants delivered at the Dr. Sardjito Hospital. The infants were materials of multicenter study on maturity in newborn infants coordinated by the Indonesian Pediatric Association. Strict criteria about gestational age was applied to liveborn singleton for inclusion into this study.

Specific training was given to certain nurses who recorded the measurements. All measurements were obtained within 4 hours after birth. Weight was taken to the nearest 0.01 kg using a Berkel scale calibrated daily with a 1 kg standard weight. To identify the mid-arm, the length of infant's left arm from the top of the shoulder to the elbow tip was measured. The value was divided by two and the appropriate point on the arm marked before the circumference was measured. Chest circumference was obtained at the level of the nipples during quiet respiration. Both circumferences were measured to the nearest 0.1 cm using a specially designed tape measure and performed prior to weighing in order to reduce measurement bias.

Data Analysis

Statistical methods of linear regression, correlation and step wise regression were applied to determine measurements correlated with birth weight. Sensitivity, specificity and predictive values were calculated on different cut-off levels of both circumferences to obtain the diagnostic performances for predicting low birthweight infants. Sensitivity was defined as the proportion of low birthweight infants detected at a cut-off level. Specificity was the proportion of not low birthweight who were correctly classified as such. Predictive value positive/negative was the probability of low birthweight/not with a positive/negative test result. Epi Info version-5 program was used for these statistical analysis.

Receiver operating characteristic (ROC) curves of mid-arm and chest circumferences were constructed. ROC curve was a graphical representation of the reciprocal relationship between sensitivity and specificity over all possible diagnostic cut-off values. It was formed by plotting the true positive rate in the vertical axis and the false positive rate in the horizontal axis [9]. The area under ROC curve which denoting to a single quantitative index of diagnostic accuracy and its standard error can be obtained by the Dorfman & Alf approach. Statistical testing of the discrimination ability was calculation of a critical ratio with area under chance line [10.11]. In case both had statistically significant differences, comparison of the difference at mid-arm and chest discrimination ability from the same set of subjects was conducted [11,12]. The critical ratio value in p value less than 0.05 (two tailed test) was considered statistically significant difference.

Results

A total of 1033 single healthy newborn infants were included in this study. They consisted of 547 male and 486 female infants. The proportion of low birthweight was 11.7% .

Some summary statistical data of the samples are presented in Table I. The extraneous factors on birth weight in the table are sex and parity. The correlations between birthweight/BW, and mid-arm/AC (r= 0.85) and chest/CC (r=0.86) circumferences are high ($p < 0.001$). The scatter diagrams of birthweight on mid-arm and chest circumferences are shown in Figure 1 & 2. The regression equation of mid-arm circumference on predicting birth weight is BW = 72.47 + 273.472 AC, and that of chest circumference is BW = -1820.1 + 151.706 CC.

Stepwise regression analysis of birth weight on mid-arm and chest circumferences in BW = -1364.386 + 146.696 AC + 88.249 CC. Table II & III contain the sensitivity, specificity and predictive values on some cut-off points for mid-arm and chest circumferences for diagnosis of low birthweight. A cut-off level for the surrogate of low birthweight is chosen considering the high sensitivity, specificity as well as predictive value positive. It revealed that increase in sensitivity will result in the expense of specificity and predictive value positive. A cut-off value of ≤ 9.5 cm and ≤ 29.5 cm were proposed for mid-arm and chest circumferences, respectively.

ROC curves of mid-arm and chest circumferences in detecting low birth weight infants are shown in Fig. 3. The chance line represents no apparent accuracy. The area under ROC of mid-arm circumference was 0.954 ± 0.011 (SE). It was significantly different than the area under chance line (critical ratio = 42.056; two tailed $p<0.0001$). The area under ROC of chest circumferences was 0.945 ± 0.012 (SE), which was also significantly different as compared to the area under chance line (critical ratio = 39.097, two tailed $p< 0.0001$). No statistically significant difference in diagnostic accuracy was seen between mid-arm and chest circumferences (critical ratio = 0.849, two tailed p = 0.396).

Table I. *Summary statistical data of the samples (n = 1033)*

	mean	sd	median	10 centile	25 centile
1. Overall sample					
Birthweight/BW (gr)	2970.6	459.6	3000	2450	2750
Arm circumference/AC (cm)	10.6	1.3	11	9	10
Chest circumference/CC (cm)	31.5	2.4	32	28.9	30

	BW	AC	CC
2. Stratified by sex (means ± SD)			
Male (n = 547)	3015.1 ± 496.9	10.6 ± 1.4	31.4 ± 2.5
Female (n = 486)	2920.5 ± 408.4	10.6 ± 1.1	31.5 ± 2.1
3. Stratified by parity			
1 (n = 249)	2876.7 ± 460.9	10.4 ± 1.4	31.0 ± 2.5
2 (n = 645)	2990.1 ± 442.0	10.6 ± 1.2	31.6 ± 2.2
3 (n = 92)	2978.0 ± 475.1	10.6 ± 1.4	31.7 ± 2.6
≥ 4 (n = 47)	3085.9 ± 558.4	10.8 ± 1.3	32.0 ± 2.1

4. Correlation coefficients (95% confidence interval)	
BW - AC	0.85 (0.83 - 0.88)
BW - CC	0.86 (0.84 - 0.88)
AC - CC	0.89 (0.86 - 0.91)

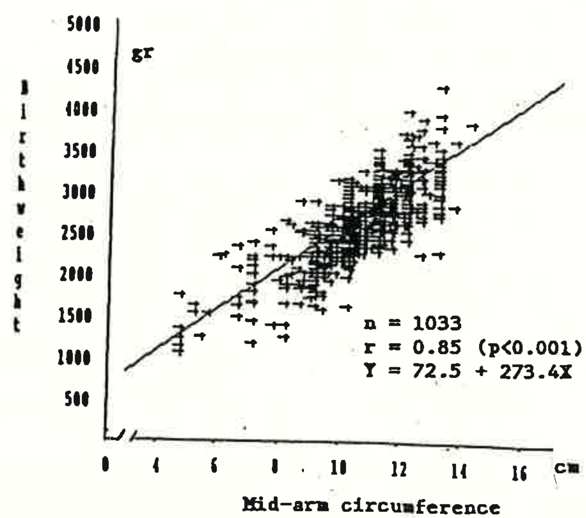

Figure 1. *Scatter diagram and regression of birthweight on mid-arm circumference*

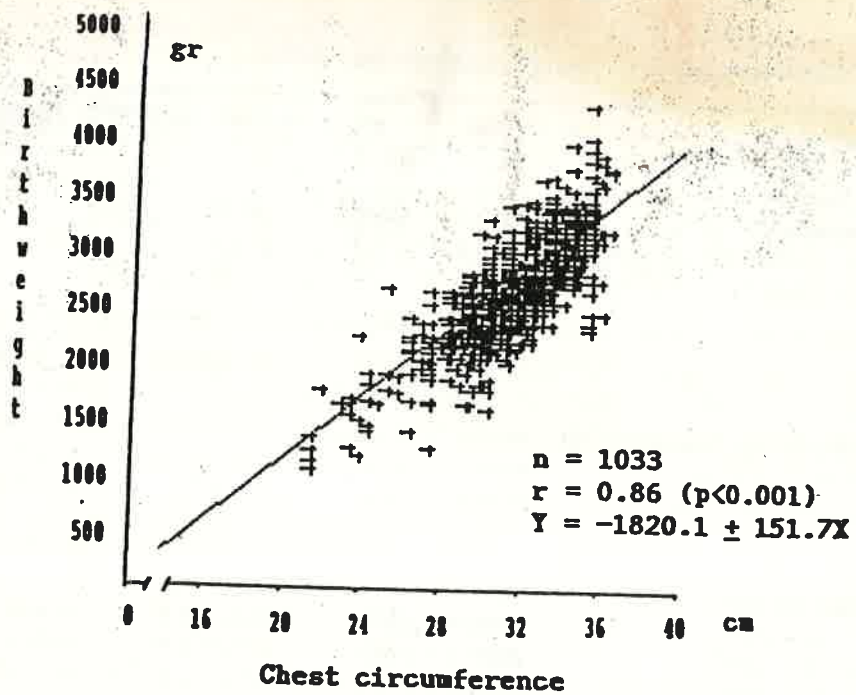

Figure 2. *Scatter diagram and regression of birthweight on chest circumference*

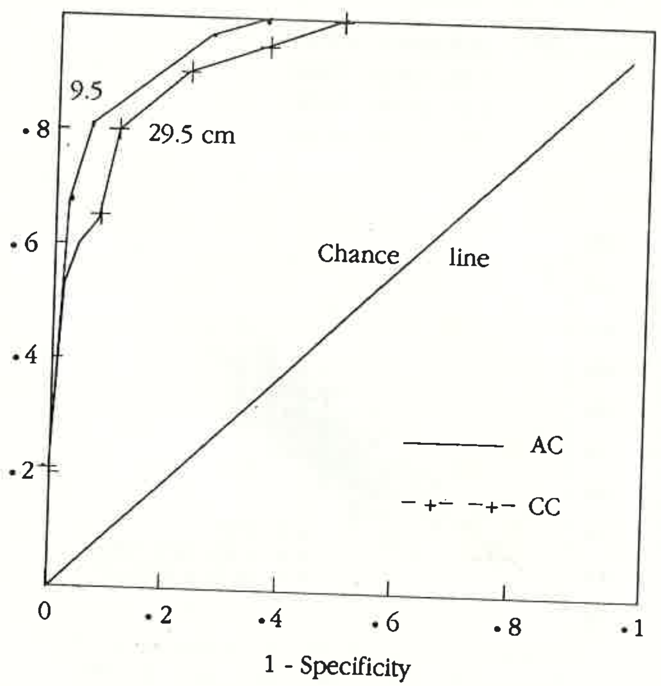

Figure 3. *Receiver operating characteristic curve of mid-arm and chest circumferences in detecting low birthweight infant*

Table II. *Prediction of low birthweight by mid-arm circumference (n = 1033, low birthweight 11.7%)*

	Sensitivity	Specificity	Predictive +	Predictive -
AC ≤ 8 cm	30.6	99.5	88.1	91.5
≤ 8.5 cm	36.4	99.3	80.0	95.1
≤ 9 cm	68.6	97.4	78.3	95.9
≤ 9.5	81.8	95.6	71.2	97.2
≤ 10 cm	97.5	76.1	36.5	99.6
≤ 10.5 cm	99.2	67.9	29.8	99.8

Table III. *Prediction of low birthweight by chest circumference (n = 1033, low birthweight 11.7%)*

	Sensitivity	Specificity	Predictive +	Predictive -
CC ≤ 28 cm	52.9	98.3	81.0	94.0
≤ 28.5 cm	58.6	96.8	71.1	94.6
≤ 29 cm	66.9	92.7	55.1	95.5
≤ 29.5 cm	78.5	89.5	49.7	96.9
≤ 30 cm	90.1	80.8	38.4	98.4

Discussion

The early identification of low birth weight is an important factor for appropriate care during the neonatal period and proper planning of services to reduce infant mortality. Since a widespread accurate measurement of birthweight is still not available in the rural community, early measurable surrogates are desired. This study shows that mid-arm and chest circumferences are associated strongly to birthweight, with correlation coefficient of 0.85 and 0.86, respectively.

Receiver operating characteristic curve is used to select proper mid-arm and chest circumferences cut-off levels for diagnosing low birthweight infants. High sensitivity and specificity balance is chosen arbitrarily to the nearest level from left-top corner of the curve graph. Cut-off levels of ≤ 29.5 cm for mid-arm and of ± 29.5 cm for chest circumferences are chosen. These values shows that about 20% of low birthweights would not be diagnosed and the false positive rates will be about 5% and 10% for mid-arm and chest circumferences, respectively. The predictive value of low birthweight infants would be 0.7 in mid-arm and 0.5 in chest circumferences. When these cut-off levels are applied in population containing higher proportion of low birthweight infants (> 11.7%), the predictive value will increase.

Landicho et al. [5] proposed cut-off levels of ≤ 9 cm and ≤ 30 cm for mid-arm and chest circumferences in defining newborns at risk of having low birth weight in Guatemala. It gave sensitivity of 0.84, specificity of 0.83 and predictive positive value of 0.67 for mid-arm, and 0.94, 0.87, 0.58 for chest circumference, respectively. The proportion on low birthweight was 43.2%. This cut-off value of mid-arm had been used to study its relationship with risk of death during the first 14 days of life in the community with a good results [6]. Bhargava et al. [7] considered mid-arm of ≤ 8.7 cm and chest circumference of ≤ 30 cm for identifying neonates with a birthweight of 2500 gr or less in a population with 40% of low birthweight in India. The predictive positive value of these cut-off levels was 0.75. Diamond et al. (1991) [8] preferred to use chest than mid-arm circumferences in predicting of low birthweight in Egypt, partly perhaps due to more replicable measurement. A cut-off level between 29 - 30 cm was reported as a study results with 14% proportion of low birth weight infants. The sensitifity was 0.45-0.74 and the predictive positive value was 0.79-0.9.

It is recommended to use of either mid-arm or chest circumferences to identify low birthweight infants. Both tests can be applied in parallel or serially. Parallel testing is used to increase the sensitivity, in which a positive results of each test consider evidence of low birth weight. Serial testing maximizes specificity, in this case mid-arm circumference with the higher specificity is performed first in order to get fewer infants retested [9].

The limitations of this study should be emphasized when applied in the community. Although circumference measurement is an ease and simple technique, training to acquire skill should be performed to health cadres and traditional birth attendants. It will lead to minimize measurement error, improve of accuracy and consistency. To overcome the situation in which measurement could not be performed at birth, the mothers should be trained to use the tape to measure their infants. It will be beneficial to know the relationship between mid-arm and chest circumferences with birthweight on the subsequent days after birth.

The implication of this study is that routine measurement of mid-arm and chest circumferences in rural community can be used for weight estimation at birth in neonatal assessment as well as in epidemiological surveys.

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