Use of mid-arm and chest circumferences to predict birth weight in rural north India

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Abstract

Study objective – To determine the most appropriate surrogate indicator and its cut off point for identifying low birthweight babies in northern India.

Study setting – A secondary level hospital at Ballabgarh. The patients were from nearby rural and urban areas and mostly belonged to lower and middle socio-economic strata.

Participants – These comprised 733 singleton newborns delivered in the hospital between April and December 1991.

Design – Birth weight, arm circumference, and chest circumference were measured in all the newborns. Different cut off points for each index were identified and their validity was tested. Based on the regression equations, a simple chart was drawn up and was used to predict weights for different arm and chest circumferences in the hospital and community settings.

Main results – Cut off points for arm and chest circumferences of 8.5 cm and 29.5 cm respectively gave a sensitivity and specificity of around 80%. When the chart based on the regression equations was tested in both the hospital and the community, chest circumference was found to be the better of the two indicators.

Conclusion – Chest circumference seems to be the most appropriate surrogate measure for birth weight. Cut off points of 29.5 cm and 27.5 cm seem to be satisfactory for predicting birth weight below 2500 g and 1800 g respectively. The birthweight prediction card using chest circumference was effective in predicting birth weight.

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The decline in the infant mortality rate in India from 110/1000 livebirths in 1981 to 73/1000 live births in 1993 has been achieved mainly by immunisation and diarrhoea control strategies.¹ Though these have reduced postneonatal mortality, neonatal mortality has not fallen correspondingly. To reduce neonatal mortality, identification and timely referral to care of low birthweight infants is important. However, in developing countries most babies are delivered at home by illiterate, traditional birth attendants and weighing at birth may not be possible. In these circumstances surrogate measures for birth weight need to be identified. Such a measure should be simple to use (even for illiterate people), valid (it should identify low birthweight babies correctly), and must be

robust under field conditions. With the help of this measure, the birth attendant should be able to recognise low birthweight babies and refer them to appropriate health facilities.

Many studies have reported a high correlation between birth weight and other anthropometric measurements in newborns.^{2,3} A WHO collaborative study identified arm and chest circumferences as the most appropriate indicators.⁴ The study also identified cut off points, with the caveat that a single cut off point may not be valid globally. Each region/country will need to identify the cut off points most suitable for them. This study aimed to identify the most appropriate indicator and its cut off point for identifying low birthweight babies in northern India.

Methods

The study was conducted at a secondary level hospital at Ballabgarh (Comprehensive Rural Health Services Project) under the administrative control of the Centre for Community Medicine, All India Institute of Medical Sciences. All the singleton live births occurring in the hospital in the period April to December 1991 were included in the study. There are around 1100 deliveries each year at this hospital, about 60% of which are booked in the hospital's antenatal clinic. The patients are from the nearby rural and urban areas and mostly belong to lower and middle socio-economic strata.

Birth weight was recorded on a beam balance scale that could measure down to the nearest 100 g. A trained investigator measured the arm circumference and chest circumference of all the newborns. About 20% of these measurements were verified by the principal investigator. The arm circumference was measured at the mid point between the olecranon process and acromion. The chest circumference was measured at just below the level of the nipples in the expiratory stage.

DEVELOPMENT OF SURROGATE MEASURES

The correlation coefficients were calculated between these indices and birth weight. To select the best index cut off points for predicting low birth weight (≤ 2500 g), the frequency distribution curves of arm and chest circumferences for low birthweight and normal birthweight babies were drawn. Based on these curves, cut off points for each index were identified. The validity (sensitivity, specificity, positive predictive value and negative predictive

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Table 1 Validity of arm and chest circumference at different cut off points as surrogate measures for low birth weight (<2500 g) in newborns in northern India

Cut off point	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Birth weight (g) Mean (SD)
Arm circumference (cm)					
7.5	0.220	0.992	0.918	0.766	2127 (283)
8.0	0.463	0.956	0.805	0.821	2360 (290)
8.5	0.771	0.813	0.615	0.901	2538 (291)
9.0	0.912	0.530	0.430	0.940	2733 (309)
Chest circumference (cm)					
27	0.229	0.996	0.959	0.769	2100 (173)
28	0.410	0.991	0.944	0.812	2340 (182)
29	0.693	0.936	0.807	0.887	2368 (300)
30	0.873	0.765	0.590	0.940	2632 (221)
31	0.960	0.490	0.420	0.970	2820 (302)

value) of these indices was calculated for different cut of points.

To identify the cut off point which provides the best compromise between sensitivity and specificity, receiver operating characteristic (ROC) curves were drawn. A ROC curve is simply a graph of pairs of true positivity (sensitivity) and false positivity (1-specificity) rates that correspond to each possible cut off point for the diagnostic test result. The upper left hand corner of the graph denotes a perfect test – that is, one which is 100% sensitive and specific. It follows that the point which falls closest to this upper left hand corner is the “best” cut off point for a diagnostic test.⁵

The scatter diagrams between birth weight and both arm and chest circumferences showed linear relationships. Therefore a model with simple linear regression was calculated for both. Based on the regression equations, a line was plotted on a graph with birth weight on the X axis, arm circumference on Y1 axis and chest circumference on Y2 axis. The two lines almost coincided, especially for weights below 3000 g, so a chart was drawn with which the weight could be predicted by measuring either the arm or chest circumference.

TESTING THE SURROGATE MEASURE

This chart was then tested in 42 newborns in the hospital and 30 newborns in the community. Trained female para-health workers, who were unaware of the purpose of the study, took the arm and chest circumference measurements

and the weight in these neonates. These women are responsible for delivering the maternal and child care to the community under the government health system of India. Another person, who was unaware of the actual weight of the neonate, then used the chart to predict the birth weight by both arm and chest circumference. The actual and the predicted birth weights were then calculated and compared.

In developing countries, it is useful to be able to identify babies whose birth weight is below 2000 g as these infants are not only at higher risk but, where health care resources are limited, their numbers are more manageable (around 9%). However, current thinking among paediatricians is that a birth weight of 1800 g is probably more useful as a cut off point as this corresponds to 34 weeks' gestation when the sucking reflex develops in the fetus. Because of this, similar analyses were undertaken for birth weights of 2000 g and 1800 g.

Results

A total of 733 singleton newborns was included in the study. The mean (SD) values for birth weight, arm circumference, and chest circumference were 2678 (454) g, 8.862 (0.84) cm, and 30.35 (1.992) cm respectively. The prevalence of low birth weight (<2500 g) was 28.9%, while 9.3% of newborns weighed <2000 g. The chest circumference ($r=0.8164$) had a higher correlation coefficient than arm circumference ($r=0.7510$).

For arm circumference, the two curves of low birth weight and normal birth weight intersect at about 8.5 cm, and the overlap is between 7 cm and 10 cm. If the cut off point is taken at 7 cm the index will be highly specific but have low sensitivity, and with a cut off point at 10 cm it will be highly sensitive but with low specificity. The actual sensitivity, specificity, and positive and negative predictive values at different cut off points are given in table 1. A cut off point for arm circumference at 8.5 cm provides the best compromise between the sensitivity and specificity.

For chest circumference, the curves intersect at 29.4 cm and the overlap occurs between 27 cm and 33 cm. The sensitivity, specificity, and predictive values are given in table 1. It is also evident from this that a cut off point at about 29.5 cm for chest circumference would have the best results (sensitivity 78%, specificity 90.3%). The same conclusions can be drawn

Figure 1 Receiver operating characteristic curves of mid-arm circumference and chest circumference measurements in newborns used for screening for birth weight <2500 g.

Birth weight prediction card

Figure 2 Birthweight prediction card to be used to identify babies at risk.

from the ROC curve of the two indicators shown in figure 1.

The cut off points similarly identified for a birth weight of 2000 g were 8 cm for arm circumference (sensitivity 80.9%; specificity 90.5%) and 28 cm for chest circumference (sensitivity 90%, specificity 93.1%). For birth weight 1800 g, these corresponded to 8 cm for arm circumference (sensitivity 85%, specificity 89.2%) and 27.5 cm for chest circumference (sensitivity 95%, specificity 94%).

The linear regression equation for chest circumference was birth weight (kg) = $0.186 \times \text{chest circumference (cm)} - 3.0$. For the arm circumference, the equation was birth weight = $0.405 \times \text{arm circumference} - 0.914$.

A birthweight prediction chart based on these equations was tested in the hospital and community settings. In the hospital, the results indicated that chest circumference was an effective surrogate for birth weight. The predicted mean birth weight in relation to chest circumference was 2631 g and that in relation to arm circumference was 2824 g as compared to the actual mean birth weight of 2619 g. The sensitivity and specificity for identifying birth weight below 2500 g were 80% and 85.2% for chest circumference and 13.3% and 88.9% for arm circumference respectively. When the chart was tested in the community, the sensitivity and specificity were similar. However, there were no newborns with a weight below 2000 g in this group.

Discussion

The objective of the study was to find surrogate measures for birth weight that could be used by birth attendants and health workers in north India to identify low birthweight neonates. Such an indicator needs to be highly sensitive so that a good proportion of "at risk" neonates will be referred to a higher centre. At the same time, greater specificity is required so that

unnecessary referrals do not burden the referral centres.

In the present study, the cut off point for arm circumference was found at 8.5 cm and that for chest circumference at 29.5 cm. The sensitivity and specificity for these indicators were around 80%. Studies in other parts of India have reported cut off points for arm circumference representing 2500 g as 8.7 cm,⁶ 8.5 cm,⁷ and 9 cm,⁸⁻¹⁰. Thus, the cut off point for arm circumference that would identify newborns with a birth weight <2500 g was between 8.5 cm and 9 cm in all studies.

A chest circumference of 29.5–30 cm was found to be the best indicator for identifying newborns with a weight below 2500 g in the present study. Other studies have also reported a cut off point between 29.5 and 30 cm.^{6,9,10} The WHO collaborative study recommended a cut off point of 30 cm.⁴

Estimates of the cut off point for arm circumference most appropriate for identifying newborns weighing <2000 g have varied between 7.5 and 8.5 cm.^{6,9} We identified the cut off point at 8 cm. The cut off point for 1800 g was estimated to be represented by between 27 and 27.5 cm for chest circumference and 7.5 and 8 cm for arm circumference. Bhargava *et al* and Singh *et al* reported that a chest circumference of 27.5 cm corresponded to a birth weight of 2000 g, which was similar to findings in the present study.^{6,9}

In this study we also tried to devise a simple chart from which the birth weight could be predicted, based on the measurement of arm or chest circumference. This graph was based on the regression equation derived from the data. When tested in another sample of newborns, this chart was seen to be useful only for chest circumference. We therefore recommend that the chart with chest circumference only (fig 2) be used for predicting birth weight. One of the possible reasons for the poor performance of arm circumference as a surrogate measure was a proportionately higher inter-observer variation in its determination.

In the community, deliveries are conducted by illiterate birth attendants. If our objective is to identify all the babies who are at high risk (low birthweight babies and those who are preterm), we need to devise a measuring tape that can be used by these birth attendants. The tape could be designed so as to differentiate three groups as follows: those weighing <2500 g (green), 1800–2500 g (yellow), and <1800 g (red). The cut off points identified in this study can be used for this purpose.

CONCLUSIONS:

Chest circumference is the most appropriate surrogate measure for birth weight. The cut off points of 29.5 cm and 27 cm seem to be satisfactory for predicting birth weights below 2500 g and 1800 g respectively. The birthweight prediction card using chest circumference was effective in predicting birth weight.

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