Research / Recherche

Use of a simple anthropometric measurement to predict birth weight

WHO Collaborative Study of Birth Weight Surrogates[1]

Low-birth-weight babies are most at risk of infant mortality. Unfortunately, in many developing countries it is not possible to weigh babies accurately because of the lack of robust scales. This article describes the results of a WHO Collaborative Study to investigate whether birth weight can be predicted accurately using chest circumference and/or arm circumference. The implications of the results for paediatric practice in developing countries are discussed.

Introduction

A significant proportion of infant deaths in developing countries result from exogenous causes, with the most susceptible babies being those of low birth weight. In addition, low-birth-weight babies who do survive may suffer physical and mental growth impairment. It is therefore essential to identify low-birth-weight babies as early as possible so that appropriate measures can be taken to minimize the risk to them.

Unfortunately, in developing countries it is often not possible to weigh babies at birth, because either there are no scales or the available scales are not sufficiently robust to withstand constant use in the field.

To overcome these problems, several workers have attempted to identify suitable surrogates for birth weight (*1–4*). Such surrogates must be highly correlated with birth weight; in particular, they must identify low-birth-weight babies accurately and be easily measurable using a simple, robust measuring instrument. Also, a suitable surrogate should be consistently accurate over the first few days of life, since in rural areas a baby may not be seen by a health worker until it is a few days old. Many of the surrogates that have been proposed are anthropometric indices such as head circumference, foot length, and symphysis fundal height. These surrogates have met with varying degrees of success, but have often been prone to measurement error or have led to an unacceptably high level of false-positive diagnoses.

Two anthropometric measures that have been reported to be successful in predicting low birth weight are mid-arm and chest circumferences (*1, 3, 4*); however, the studies involved were carried out on relatively small samples in one centre. If the use of a surrogate is to be widely recommended it has to be appropriate across national and ethnic boundaries. This article reports the results of a WHO Collaborative Study to compare the performance of mid-arm and chest circumferences as predictors of low birth weight in a number of countries and recommends standards for the identification of low-birth-weight babies.

---

[1] This report was prepared by Dr I. Diamond and Dr J. McDonald, Department of Social Statistics, University of Southampton, Southampton, England, and Dr R. Guidotti, Maternal and Child Health and Family Planning, World Health Organization, Geneva, Switzerland, as part of the WHO Collaborative Study of Birth Weight Surrogates, on behalf on the following collaborating investigators:

Dr S. Alexaniants and Dr G.G. Okojev, Yerevan; Dr Huang Xinghui and Dr Ma Yaling, Beijing; Dr E. Coutinho, Salvador; Dr J.T. Pereyre, Santiago; Dr R. Sala, Havana; Dr N. Tarfari, Addis Ababa; Dr A. H. Guinena, Gaza; Dr K.F. Abdalla, Amman; Dr M. Sass, Szeged; Dr H.D. Tandon, New Delhi (Centre A); Dr A.N. Gupta and Dr G.I. Dhall, Chandigarh; Dr M.M. Kapur, New Delhi (Centre B); Dr S.I. Kim, Seoul; Dr K. Rogo, Nairobi; Dr S. Janjua and Dr R. Farid, Islamabad; Dr M.H. Hassonah and Dr Y.B. Edrees, Riyadh; Dr Correa, Dakar; Dr Jiang Dixian and Dr Shi Zhuzhong, Shanghai; Dr O. Vioegas and Dr K. Singh, Singapore; Dr S. Chutivongse, Bangkok; Dr A. Celenk and Dr R. Darendeliler, Istanbul; Dr I. Evsiukova and Dr T. Savelyeva, St. Petersburg; and Dr Nguyen Can, Hanoi.

Requests for reprints should be sent to Dr I. Diamond, Department of Social Statistics, University of Southampton, Southampton SO9 5NH, England.

Reprint No. **5368**

Methods

The study was undertaken in 22 centres throughout the world (see Table 1). The aim was to collect data on a consecutive sample of 400 births, although there was some variability in the sample size between centres. To ensure comparability, we collected data from each centre according to a detailed protocol. Three main measurements were made for each baby: birth weight, mid-arm circumference, and chest circumference. In addition, the baby's sex and gestational age at birth were recorded.

Birth weight was measured using the scales that were currently available in the study centre. To identify the position of the mid-arm, the length of the infant's left arm from the top of the shoulder to the elbow tip was measured. This measurement was divided by two and the appropriate point on the arm marked before the circumference was measured. The chest circumference was defined at the level of the nipples during the end phase of expiration. Both arm and chest circumferences were measured to the nearest mm using a specially designed tape measure; all measurements were recorded within 3–4 hours of birth.

Results

A small number of observations from each centre were deleted since they were clearly unreliable, probably because they were misrecorded, but in general the data satisfied all the reliability checks. The main problem with respect to data quality was digital preference, i.e., there was a tendency for weights to be recorded in round hundred grams and circumferences in whole centimetres. This was to be expected, particularly for anthropometric measures, where measurement is more difficult and the range of possible values smaller.

The effects of this digital preference on the analysis need to be considered. A major aim is to identify cut-off points below which a baby is diagnosed to be at risk for conditions associated with low birth weight. Observations subject to digital preference will comprise those rounded up and rounded down. If the cut-off point is at a whole centimetre, there will be no false-negative diagnoses, since measurements that are rounded up will still be associated with an at-risk diagnosis. On the other hand, a number of false positives may occur because of rounding down. The observed predictive power of a positive test is therefore likely to be underestimated a little. This should be borne in mind when assessing the success of an anthropometric measure as a predictor of low birth weight.

Some summary statistics for the data are shown in Table 1. Clear differences can be seen between the centres in terms of the means and tenth centiles of both birth weight and the anthropometric measures. The values confirm the expected regional differences, since centres in South Asia, such as Delhi and Chandigarh, have on average the lowest values, whereas those in Europe, such as St. Petersburg, Szeged, and Yerevan have among the highest.

This variation is important for policy formulation. Any health initiative is bounded by available resources. A cut-off point that identifies the infants most at risk in Yerevan, for example, would clearly identify a much higher proportion in New Delhi. Although levels of infant mortality are higher in New Delhi, there will be many healthy babies who would be small relative to those in Yerevan. It may therefore, be necessary, to identify separate cut-off points for different regions.

The correlations between birth weight, arm circumference and chest circumference are high (Table 2), ranging from 0.60 to 0.95. In 18 of the 22 centres, the correlations between birth weight and chest circumference were greater than those for arm circumference. Possibly this is because chest circumference could be more easily and reliably measured than arm circumference, which exhibited greater measurement errors, resulting in a relatively low correlation.

To identify the relationship between birth weight and the anthropometric measures, we performed a number of regression analyses to examine the following: whether there was one global relationship that held across all centres or if a separate model was necessary for each centre, and whether chest circumference, arm circumference or a combination of the two was the best predictor of birth weight. The results demonstrated that the best model in each centre was birth weight predicted by chest circumference. If the chest circumference was known, use also of arm circumference did not significantly improve the prediction of birth weight. However, one global regression equation was not sufficient and a different regression equation had to be estimated for each centre. The magnitude of the estimated regression coefficients varied between those for Islamabad and Chandigarh, where an increase of 1 cm in chest circumference predicted birth weight increases of 260 g and 156 g, respectively. All other centres fell between these two extremes.

To be of practical use in developing countries, the marked relationships across all birth weights and chest circumferences must also hold for the prediction of low birth weight. Cut-off points for chest circumference and end-points for birth weight need to be defined for this purpose.

Table 1: **Summary statistics for birth weight and anthropometric measures**

Study centre	Birth weight (g)		Chest circumference (cm)		Arm circumference (cm)		
	Mean ± S.D.	10th centile	Mean ± S.D.	10th centile	Mean ± S.D.	10th centile	*n*
Asia							
Bangkok	2986 ± 415.6	2411	31.9 ± 1.9	29.5	10.5 ± 0.9	10.5	430
Beijing	3175 ± 543.1	2400	33.8 ± 2.4	30.0	10.4 ± 1.0	9.0	400
Chandigarh	2850 ± 530.6	2102	31.1 ± 1.9	28.8	9.9 ± 1.0	9.9	400
Hanoi	2866 ± 524.0	1999	30.4 ± 2.7	26.6	9.8 ± 1.1	8.3	427
Islamabad	3209 ± 437.4	2722	32.9 ± 2.1	30.0	10.8 ± 0.8	10.0	103
New Delhi (A)	2798 ± 540.7	2065	30.3 ± 2.4	27.0	9.2 ± 1.0	3.0	334
New Delhi (B)	2634 ± 478.6	2040	29.6 ± 2.5	35.1	9.0 ± 0.9	8.0	260
Seoul	3187 ± 402.5	2648	32.4 ± 1.7	30.2	10.3 ± 0.8	9.2	187
Shanghai	3244 ± 422.8	2755	32.9 ± 1.8	30.7	10.8 ± 0.9	9.8	400
Singapore	3163 ± 446.9	2615	32.0 ± 1.9	29.8	10.1 ± 0.8	9.1	404
Africa/Middle East							
Addis Ababa	2901 ± 592.8	2160	32.2 ± 2.8	28.9	11.0 ± 1.3	9.4	430
Dakar	2964 ± 629.1	1950	30.0 ± 3.1	29.3	9.7 ± 1.4	7.8	140
Gaza	3285 ± 422.6	2590	32.3 ± 2.1	29.9	10.4 ± 1.0	9.2	529
Nairobi	2957 ± 600.5	2355	30.8 ± 2.5	28.0	10.4 ± 1.2	9.0	400
Riyadh	3199 ± 321.4	2655	33.2 ± 1.8	31.0	10.8 ± 0.8	10.3	400
Latin America							
Havana	3253 ± 528.6	2633	33.1 ± 1.8	31.0	11.3 ± 1.1	10.0	442
Salvador	3394 ± 454.6	2710	33.3 ± 1.9	30.5	11.0 ± 0.0	10.0	100
Santiago	3224 ± 510.2	2596	32.9 ± 2.1	30.0	10.8 ± 1.0	9.6	317
Europe							
Istanbul	3205 ± 597.6	2491	33.3 ± 2.7	32.0	10.5 ± 1.1	9.2	290
St. Petersburg	2336 ± 430.3	2900	34.0 ± 1.7	34.0	11.3 ± 0.9	10.0	401
Szeged	3279 ± 461.4	2680	31.3 ± 2.0	29.0	10.5 ± 0.9	9.5	1000
Yerevan	3295 ± 503.9	2700	33.8 ± 2.4	30.0	11.5 ± 1.2	10.0	400

The following end-points for birth weight were considered: 2000 g, 2500 g, and 3000 g, as well as the tenth centile for gestational age in each centre. The choice was dependent on criteria such as the proportion of babies identified to be at risk and the need for easily interpretable and comparable standards. The tenth centile for gestational age was excluded primarily because of the impracticality of using it in rural areas of developing countries, where gestational age is usually very difficult to ascertain accurately. The choice between the other end-points depends largely on the proportion of babies identified at risk. In centres other than those in South Asia the proportion of babies weighing below 2000 g at birth was very low, whereas for an end-point of 3000 g the corresponding proportion was particularly high. Therefore, we adopted the standard WHO end-point of 2500 g, and babies below this were defined as having low birth weight.

Table 3 shows the sensitivities, the predictive powers of a positive diagnosis, and the percentages diagnosed to be at risk for chest circumferences less than 28 cm, 29 cm, and 30 cm. The aim was to maximize simultaneously the sensitivity and the predictive power of a positive test. It is always possible to choose a cut-off point for an anthropometric measure below which all the low-birth-weight babies lie, and thus have a sensitivity of 100%; however, such a cut-off point will clearly lead to a large number of false-positive diagnoses. Since any health system has finite resources, it is neither possible nor desirable to provide special care for a large proportion of babies.

At chest circumferences (cut-off points) of 29 cm and 30 cm both the sensitivity and predictive positive values were high. At circumferences above or below these values, the proportion diagnosed to be at risk is either extremely high or low, respectively;

Table 2: **Correlation coefficients between birth weight, arm circumference, and chest circumference**

Study centre	Birth weight/ arm circumference	Birth weight/ chest circumference	Arm circumference/ chest circumference	*n*
Asia				
Bangkok	0.81	0.85	0.78	430
Beijing	0.83	0.88	0.81	400
Chandigarh	0.95	0.95	0.96	400
Hanoi	0.94	0.95	0.91	427
Islamabad	0.64	0.74	0.70	103
New Delhi (A)	0.83	0.87	0.80	334
New Delhi (B)	0.77	0.94	0.75	260
Seoul	0.60	0.75	0.60	187
Shanghai	0.83	0.88	0.84	400
Singapore	0.84	0.86	0.84	404
Africa/Middle East				
Addis Ababa	0.92	0.94	0.90	430
Dakar	0.88	0.93	0.91	201
Gaza	0.86	0.85	0.84	529
Nairobi	0.89	0.89	0.90	400
Riyadh	0.77	0.81	0.67	400
Latin America				
Havana	0.73	0.72	0.72	442
Salvador	0.77	0.84	0.79	100
Santiago	0.80	0.88	0.78	317
Europe				
Istanbul	0.90	0.93	0.87	315
St. Petersburg	0.74	0.80	0.75	401
Szeged	0.80	0.81	0.79	1000
Yerevan	0.72	0.78	0.70	400

for example, at a chest circumference of 31 cm fully 60% of the babies in Chandigarh would be diagnosed as low birth weight.

The choice between 29 cm and 30 cm as a cut-off is not an easy one. At a chest circumference of 29 cm the predictive powers of a positive test tend to be very high — in five centres (Addis Ababa, Bangkok, Beijing, Chandigarh, and Salvador) all those diagnosed at risk were low birth weight; however, the sensitivities were rather low. With a cut-off point of 30 cm the sensitivities are higher but the predictive values are lower — implying a number of false-positive diagnoses.

The solution we propose is to recommend two cut-off points — 29 cm and 30 cm. Babies with a chest circumference <29cm would be diagnosed as "highly at risk" and health workers instructed to refer them to a health centre immediately; in contrast, those with a chest circumference of 29–30 cm would be diagnosed as "at risk" and health workers instructed to monitor carefully their progress. The practical implications of these results are discussed below.

Discussion

The early identification of low-birth-weight babies is an important prerequisite of any initiative to reduce infant mortality. In many less developed countries, widespread accurate measurement of birth weight is not practicable; easily measurable surrogates for birth weight are therefore needed. This article considered arm and chest circumference as surrogates

Table 3: **Predictions of birth weight below 2500 g using the chest circumference data**

	Chest circumference:								
	<28 cm			<29 cm			<30 cm		
Study centre	% sensitivity	% predicted positive	% at risk	% sensitivity	% predicted positive	% at risk	% sensitivity	% predicted positive	% at risk
Asia									
Bangkok	39	100	4	59	100	8	85	72	16
Beijing	35	100	4	57	100	7	78	82	11
Chandigarh	22	100	6	60	100	16	93	89	29
Hanoi	59	100	20	85	93	31	98	74	46
Islamabad	43	100	3	56	80	5	86	46	13
New Delhi (A)	43	97	22	66	90	37	88	78	57
New Delhi (B)	63	93	23	88	78	39	98	60	66
Seoul	11	100	1	33	60	8	44	25	9
Shanghai	23	75	1	46	86	2	77	63	4
Singapore	25	100	2	50	88	4	79	44	12
Africa/Middle East									
Addis Ababa	36	100	7	54	100	10	80	96	16
Dakar	75	98	24	94	93	32	199	74	33
Gaza	49	92	5	71	94	6	88	70	11
Nairobi	58	93	10	77	83	15	94	63	24
Riyadh	4	100	1	21	100	2	42	63	4
Latin America									
Havana	15	100	5	15	80	1	59	61	6
Salvador	33	50	2	100	50	6	100	43	8
Santiago	36	100	3	45	84	4	81	56	10
Europe									
Istanbul	39	94	5	55	96	7	68	87	10
St. Petersburg	42	100	1	50	86	2	58	70	3
Szeged	49	59	5	85	42	10	96	24	13
Yerevan	45	90	2	68	73	4	79	49	8

and found that both are linked very strongly to birth weight.

We recommend the use of chest rather than arm circumference as a surrogate for birth weight for two reasons. First, it is simpler to measure — identification of the nipple line is easier, making measurement more operationally feasible than that of mid-arm circumference. Second, our findings suggest that measurement of both arm circumference and chest circumference is of little additional value in predicting low-birth-weight babies.

A global cut-off point for chest circumference does not permit the joint goals of high sensitivity and accurate diagnosis. While high predictive values can be obtained at low cut-off points for chest circumferences <29 cm, the numbers of babies identified to be at risk in some centres would be rather low since almost all babies have chest circumferences greater than this value. Therefore, both 29 cm and 30 cm should be used as cut-off points, with <29 cm being diagnosed, in general, as "highly at risk" and those between 29 cm and 30 cm as "at risk". It should be noted that in some areas of the world, particularly South Asia, it may be desirable to use 29 cm as the standard cut-off point for chest circumference because of the high proportion of small (but healthy) babies born there. The final choice of cut-off point will also reflect the resources available for the care of low-birth-weight babies. In this context a lower end-point for birth weight, e.g., 2250 g or

2000 g, may be desirable and the analyses of our data suggest that the sensitivities and predictive powers would remain high for these end-points.

How should these results be used in developing countries? In areas where the accurate, early weighing of neonates is not feasible, community health workers should be trained to measure the chest circumference. Those babies diagnosed to be at risk through complications associated with low birth weight could then be either given specialized home care or referred to the nearest health centre for appropriate treatment. The tape measures used to measure chest circumference should be colour coded to overcome problems of illiteracy: a three-colour tape could be used to identify babies at high risk, at risk, and at low risk.

Where community health workers are likely to be absent at the time of birth, it is important that the mothers are given a colour-coded tape measure and instructed in its use. This tape measure should be part of a delivery kit containing, for example, soap, a razor blade, a bandage, and a dressing, each of which would promote a healthy delivery.

In situations where community health workers cannot visit the mother until a few days after the birth, it is important to know whether the relationship between birth weight and chest circumference remains the same. The study was not able to answer this question comprehensively and further research is therefore necessary.

Résumé

Utilisation d'un paramètre anthropométrique simple pour estimer le poids de naissance

Le poids de naissance est à la fois un indicateur de santé important et un prédicteur de la survie de l'enfant. Sa mesure est par conséquent importante tant sur le plan clinique que pour la planification des programmes de santé maternelle et infantile. Malheureusement, dans un grand nombre de régions du monde, il est impossible de peser l'enfant en raison du manque de balance. Le présent article a pour but de décrire les résultats d'une étude collective menée par l'OMS en vue de rechercher si le poids de naissance peut être estimé avec précision en mesurant, au lieu du poids, le périmètre brachial ou le périmètre thoracique de l'enfant.

L'étude a été réalisée dans 22 pays de localisation géographique variée. Les données ont été recueillies conformément au protocole commun, et trois mesures principales ont été réalisées sur chaque enfant: poids de naissance, périmètre brachial à mi-bras et périmètre thoracique. Le sexe et l'âge gestationnel à la naissance ont également été notés.

Le coefficient de corrélation entre, d'une part, le poids de naissance et, d'autre part, les périmètres thoracique et brachial fluctue entre 0,60 et 0,95. Dans 18 des 22 centres le coefficient de corrélation du poids de naissance avec le périmètre thoracique était plus élevé qu'avec le périmètre brachial. Une analyse plus approfondie a révélé que, dans tous les centres, le meilleur modèle consistait à estimer le poids de naissance au moyen du périmètre thoracique seul et que l'inclusion du périmètre brachial dans le modèle n'améliorait pas significativement l'estimation du poids de naissance.

Pour que cette forte corrélation entre le poids de naissance et le périmètre thoracique ait un intérêt pratique il faut qu'elle persiste quand les poids de naissance sont faibles. Il est donc nécessaire de définir des valeurs limites des périmètres thoraciques et des seuils correspondants des poids de naissance. Il est apparu que 29 cm et 30 cm de périmètre thoracique étaient des valeurs extrêmement utiles à cet égard. Il n'a pas été facile de fixer cette valeur limite à 29 ou 30 cm. En effet pour 29 cm, la valeur prédictive d'un test positif était extrêmement élevée dans cinq des centres (Addis Abeba, Bangkok, Beijing, Chandigarh et Salvador); toutefois la sensibilité était relativement basse. Inversement, en prenant comme limite 30 cm, la sensibilité était élevée alors que la valeur prédictive était faible – d'où un très grand nombre de faux-positifs.

La solution proposée consiste à recommander à la fois les seuils de 29 cm et 30 cm. Pour les enfants dont le périmètre thoracique est inférieur à 29 cm on portera un diagnostic de "risque très élevé" assorti des mesures appropriées, tandis que lorsque le périmètre thoracique est 29–30 cm le diagnostic porté sera "à risque", la série de mesures à prendre et la prise en charge étant différentes.

On préférera le périmètre thoracique au périmètre brachial comme équivalent du poids de naissance, le premier étant plus facile à mesurer et la connaissance du deuxième apportant peu d'informations supplémentaires par rapport à la première mesure.

Lorsqu'il n'existe pas de balance l'agent de santé communautaire pourrait être entraîné à mesurer le périmètre thoracique du nouveau-né, la mesure étant réalisée au moyen d'un mètre à

ruban comportant trois repères de couleur correspondant chacun à un degré de risque. On pourrait ainsi tourner la difficulté pour les personnes qui ne savent ni lire ni écrire, repérer le degré de risque chez les nourrissons, et appliquer les stratégies de prise en charge prévues en conséquence.

References

1. **Gueri, M. et al.** The arm circumference at birth and its relations to other anthropometric parameters. *Archivos latinoamericanos de nutricion*, **27**: 403–410 (1977).
2. **Jelliffe, E.F.P. & Jelliffe, D.B.** The arm circumference as a public health index of protein–calorie malnutrition of early childhood. *Journal of tropical pediatrics*, **15**: 179–188 (1969).
3. **Ramachandran, P. & Kumar, A.** *Use of some anthropometric indices for assessment of "at risk neonate"*. Hyderabad, India, National Institute of Nutrition, 1986.
4. **De Vaquera, M.V. et al.** The relationship between arm circumference at birth and early mortality. *Journal of tropical pediatrics*, **29**: 167–174 (1983).