Development and Validation of a Simple Device to Estimate Birthweight and Screen for Low Birthweight in Developing Countries

Nikorn Dusitsin, MD, MS, Sumana Chompootaweep, MD, MS, Piyalamporn Poomsuwan, MS, Kanchana Dusitsin, MD, Prasertsri Sentrakul, MD, MS, and Pisake Lumbiganond, MD, MS

ABSTRACT

Low birthweight (<2500 g) is the major factor associated with the death of infants within the first 4 weeks of life. The mean birthweight of newborn babies of a certain geographic area reflects the quality of maternal and child health care service as well as the degree of socioeconomic development of that particular region. Hence, birthweight is being used increasingly as an indicator for health and socioeconomic planning. However, in a developing country such as Thailand, two-fifths of the babies are delivered at home and are not weighed because scales are not available. To solve this problem in rural areas, a circular nomographic chart was developed with which the birthweight can be computed from a newborn baby's chest and mid-arm circumferences. Preliminary trials comparing these charts with standard baby scales showed a high degree of accuracy with sufficient sensitivity and specificity. (*Am J Public Health*. 1991;81:1201–1205)

Introduction

Low-birthweight (<2500 g) is the major factor associated with the death of infants within the first 4 weeks of life. The mean birthweight of newborn babies of a certain geographic area may reflect the quality of maternal and child health care service as well as the degree of socioeconomic development of that particular region.[1–4] However, in a developing country such as Thailand, two fifths of the babies are delivered outside hospitals and are not weighed because scales are not available.[5] Anthropometric parameters such as chest circumference,[6] mid-arm measurement,[7] and foot length[8] have been used to identify low birthweight and a newborn at risk. The World Health Organization has studied the chest and arm circumferences in correlation with birthweight, aiming to develop chest or arm bands that would indicate that the birthweights are above or below a specified cutoff point (i.e., 2500 g). However, no effort has been made to correlate anthropometric parameters with actual birthweight. This study uses multiple parameters of chest and arm circumferences and the length of a newborn to estimate birthweight and to validate this new method in various centers throughout Thailand.

Methods

The Training Data Set

The training data set undertaken at the Department of Pediatrics, Lerdsin Hospital, from January to March 1985, involved 402 newborn babies, 197 male and 205 female. The duration of pregnancy at the time of delivery ranged from 36 to 40 weeks according to Nägele's formula. The measurements taken within 24 hours of birth included chest circumference at nipple line in centimeters, arm circumference, midway between the acromion process and the tip of elbow in centimeters, crown-to-heel length in centimeters, and weight in grams.

Measuring Instruments

The measuring instruments consisted of a tailor's metric measuring tape, tested against a standard ruler, and a baby metric beam balance (SECA, made in Germany), tested for accuracy with standard weights. All measurements were performed by the same pediatrician throughout the study.

Sample Size

The sample size was calculated after Lachin[9] to estimate the sample size for the correlation (r) .85, setting $\alpha = .05$ and the power of test at .80 (for a two-tailed test).

Data Analysis

Stepwise multiple regression analysis was employed to formulate the best linear prediction equation.[10] The least squares method was used for fitting the "best" straight line to a given set of data in order to relate two variables.

Testing Data Set

The testing data set of body weight and chest and arm circumferences of 3222 newborn infants from eight hospitals in north, northeast, central, and south Thai-

Nikorn Dusitsin and Prasertsri Sentrakul are with the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand. Sumana Chompootaweep and Piyalamporn Poomsuwan are with the Institute of Health Research, Chulalongkorn University. Kanchana Dusitsin is with Lerdsin Hospital, Ministry of Public Health, Bangkok. Pisake Lumbiganond is with the Faculty of Medicine, Khon-Kaen University, Thailand.

Requests for reprints should be sent to Nikorn Dusitsin, MD, Department of Obstetrics & Gynaecology, Faculty of Medicine, Chulalongkorn University, Rama IV Road, Bangkok 10330, Thailand.

This paper was submitted to the journal July 23, 1990, and accepted with revisions February 20, 1991.

TABLE 1—Mean ± Standard Deviation for Weight, Chest, and Arm Circumferences, and Body Length of the Study Samples

Measurement	Male (n = 197)	Female (n = 205)	Total (n = 402)
Weight (g)	3079.1 ± 424.0	2941.9 ± 427.4	3009.0 ± 430.7
Chest (cm)	32.8 ± 1.8	32.2 ± 1.8	32.5 ± 1.8
Arm (cm)	10.7 ± 1.0	10.6 ± 1.0	10.6 ± 1.0
Length (cm)	49.5 ± 2.0	48.6 ± 1.9	49.0 ± 2.0

TABLE 2—Stepwise Regression for Birthweight Estimation

Step	Variable Entered	Coefficient	SE[a] of Coefficient	Error[b]	R^2 (%)[c]
1	Chest	207.2	5.4	199.8	78.5
	Constant	−3725.2			
2	Chest	149.6	8.3	183.3	82.0
	Arm	134.4	15.4		
	Constant	−3281.5			
3	Chest	104.8	9.0	167.0	85.1
	Arm	131.5	14.0		
	Length	57.4	6.3		
	Constant	−4607.0			

[a]SE = standard error.
[b]Standard error of estimate.
[c]R^2 = Coefficient of determination.

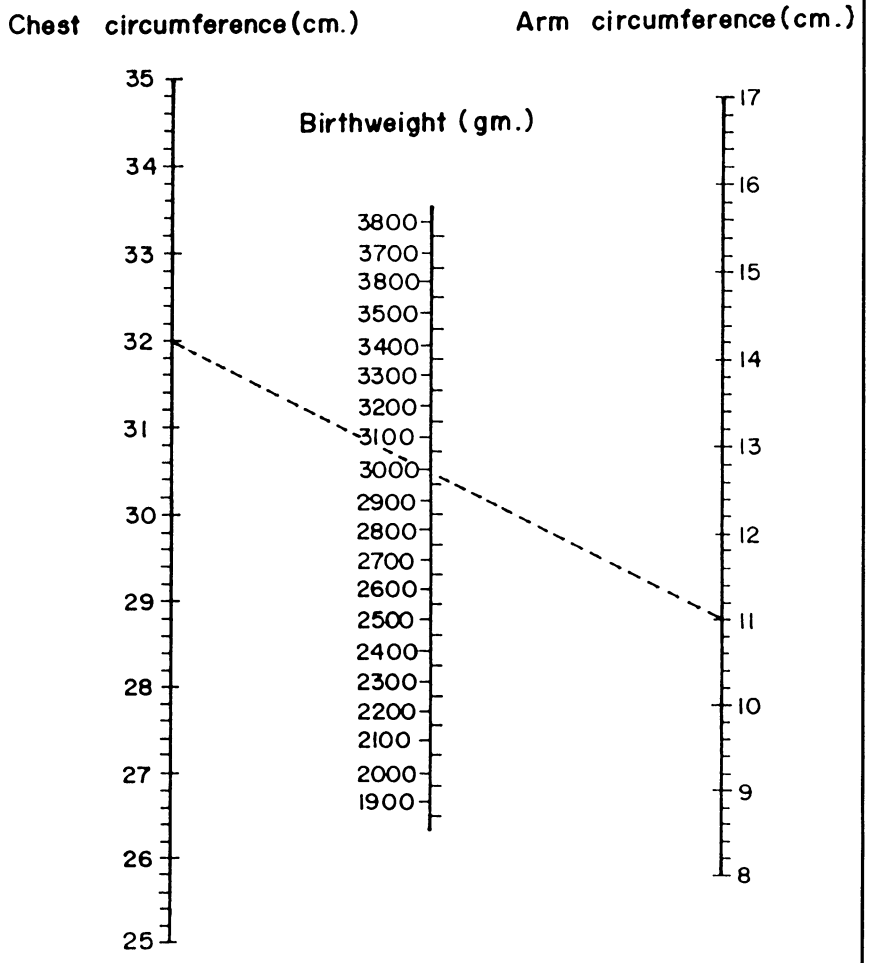

FIGURE 1—The Birthweight Estimation Nomogram

land was used for analysis. Measurements were taken within 24 hours of birth. The study population was derived from two sets of data. The first set consisted of 1612 newborn babies from the project "Low Birth Weight Newborn Babies of High Risk Mothers" at Chulalongkorn University Hospital, and at regional maternal and child health hospitals in Chiengmai, Nakornsawan, Rajburi, Yala, and Masharaj Hospital at Nakorn-srithamaraj. This was a case-control study, with a 1:2 ratio of low birthweight (LBW) to normal birthweight infants.

The second set of data consisted of 1610 newborn babies from Lerdsin Hospital and the Khon-Kaen University Hospital in Bangkok.

The first set was collected by nurses, using standardized measuring methods, and the second set was obtained by the doctors responsible for the project.

A diagnostic test was employed to reveal sensitivity and specificity of positive predictive values, negative predictive values, and accuracy of the new device in comparison with the gold standard (a baby metric beam balance) in screening for LBW infants.

Results

The data from the study of 402 newborn babies are summarized in Table 1. The correlation coefficients (r) of weight versus chest and arm circumferences and body length were 0.89, 0.82, and 0.78, respectively.

Although the combined chest and arm circumferences and length gave the best correlation with birthweight ($r = .92$), measuring the length of a newborn baby is usually impractical and may be subject to relatively large error. We therefore chose the second best equation (Table 2), using the combined chest and arm circumferences to estimate birthweight ($r = 0.90$, $r^2 = 82.0\%$, and standard error (SE) = ±183.3 g). Based on this equation, a nomogram was constructed (Figure 1) and, subsequently, a circular birthweight estimation device was developed (Figure 2).

The mean and standard deviations (SD) of chest and arm circumferences of 3222 newborn babies in various study centers are shown in Table 3. The mean of chest circumferences was about 31 cm, and arm circumferences was about 10 cm.

The differences of means between the weight obtained by standard scales and the estimated weight obtained by the new device (Figure 2) are also shown. The differences appear to be within ±187 g.

The diagnostic values of the new device, when the arbitrary point for picking LBW infants is set at 2500 g, are shown in Table 4. The sensitivity was lowest (56.9%) at Nakornsawan and highest (94.5%) at Chulalongkorn hospital. The specificity was lowest (86.1%) at Khon-Kaen and highest (98.6%) at Yala. The accuracy varied from 83.2% to 95.7%.

If the arbitrary point for defining LBW neonates is set at 2600 g on the new device, the sensitivity at all centers increased, ranging from 71.3% to 97.3%, the specificity ranged from 78.4% to 97.2%, and the accuracy ranged from 79.8% to 92.3%, as shown in Table 5. If the arbitrary point was set at 2700 g, the sensitivity increased to 100% at Chulalongkorn Hospital but the specificity declined to 58.7% at Khon-Kaen Hospital (Table 6).

These results showed that the optimum arbitrary point of all data combined for defining LBW neonates when using the new device should be 2600 g and can be confirmed by the receiver operating characteristic curve shown in Figure 3. The curve became steeper when the arbitrary point was changed from 2500 g to 2600 g, which means that the sensitivity increased markedly while only a small degree of specificity was lost. However, the curve became linear when the arbitrary point was 2700 g, which indicates a very small increase in sensitivity but marked loss of specificity.

Discussion

Birthweight of infants estimated from the Chulalongkorn birthweight estimation device differed by only ±187.4 g from weight obtained by a standard scale. This difference is not clinically significant unless the birthweights are below 2000 g.

The sensitivity and specificity of the new device varied when arbitrary points of LBW infants were set at 2500, 2600, and 2700 g. There was less variation in accuracy, however. The optimum arbitrary point on the new device, as determined by a receiver operating characteristic curve, was found to be 2600 g. The sensitivity increased to 100% when the arbitrary point was 2700 g, but the specificity was low, indicating that there would be an increased number of falsely identified LBW infants.

The Chulalongkorn birthweight estimation device appears promising as an appropriate substitute for obtaining the birthweight of newborns in places where scales are not readily available. While the theoretical error was ±183.3 g, the prac-

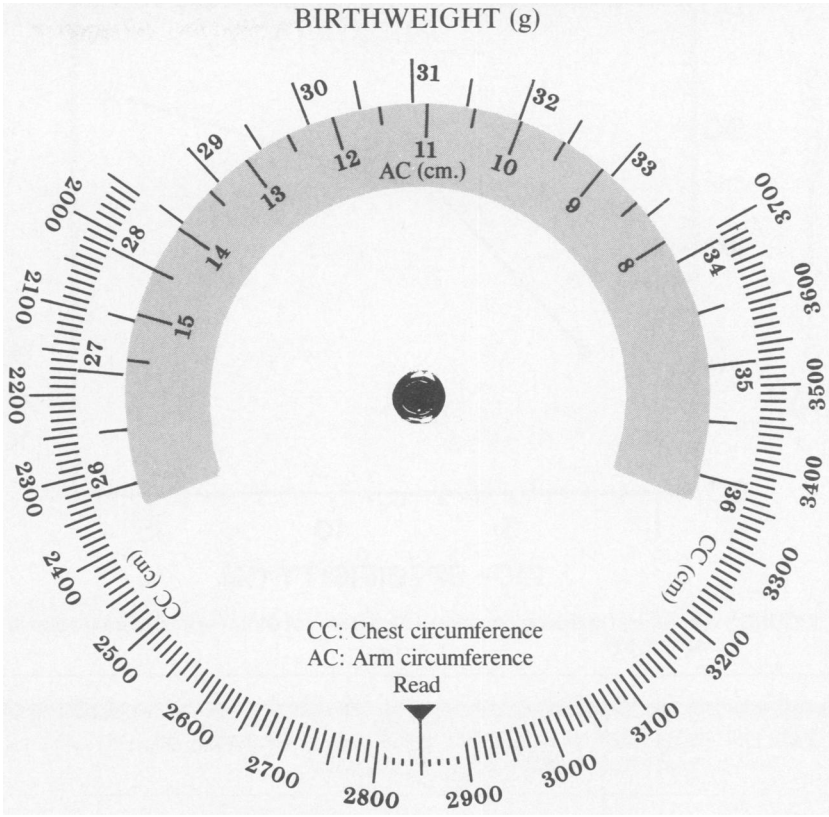

FIGURE 2—Chulalongkorn University Birthweight Estimation Device

TABLE 3—Mean ± Standard Deviation of Arm and Chest Circumferences and Weight of Newborn Babies

Location	n	Chest (cm)	Arm (cm)	Scale Weight	Estimated Weight	Difference of Mean
LS	606	32.3 ± 1.8	9.9 ± 0.9	2996.0 ± 378.7	2854.5 ± 331.4	141.5
KK	1004	31.6 ± 1.6	9.9 ± 0.7	2974.2 ± 360.8	2786.8 ± 321.0	187.4
CU	260	30.9 ± 2.2	9.9 ± 0.9	2828.6 ± 482.7	2668.6 ± 438.7	159.9
CM	339	31.3 ± 2.2	10.0 ± 1.0	2768.6 ± 482.6	2747.4 ± 440.5	21.2
NS	215	31.5 ± 2.3	10.6 ± 1.2	2887.5 ± 532.2	2861.4 ± 501.9	26.1
RB	215	31.4 ± 2.4	10.3 ± 1.2	2779.6 ± 554.8	2790.0 ± 501.5	8.7
YL	300	31.3 ± 2.4	10.8 ± 1.4	2759.2 ± 544.3	2857.1 ± 542.6	−97.9
NT	276	31.8 ± 2.5	10.7 ± 1.2	2797.6 ± 515.3	2925.2 ± 531.3	−127.6

Note. LS = Lerdsin General Hospital; KK = Khon-Kaen University Hospital; CU = Chulalongkorn University Hospital; CM = Chiengmai MCH Hospital; NS = Nakornsawan MCH Hospital; RB = Ratchaburi MCH Hospital; YL = Yala MCH Hospital; NT = Nakorn-srithamaraj MCH Hospital.

TABLE 4—Diagnostic Values for Detecting Low Birthweight Babies (<2500 g) When the Arbitrary Point Is Set at 2500 g on the New Device

Diagnostic Values	LS	KK	CU	CM	NS	RB	YL	NT
Sensitivity	79.4	88.1	94.5	75.5	56.9	65.3	65.8	57.4
Specificity (%)	97.6	86.1	93.0	96.1	96.5	97.5	98.6	98.4
Accuracy (%)	95.7	86.2	93.5	89.4	83.2	86.7	87.4	84.4
+PV (%)	79.4	37.0	—	—	—	—	—	—
−PV (%)	97.6	98.8	—	—	—	—	—	—

Note: +PV, positive predictive value; −PV, negative predictive value; Positive and negative predictive values of case-control study cannot be calculated, since estimates of prevalence of low birthweight were not available.
LS = Lerdsin General Hospital; KK = Khon-Kaen University Hospital; CU = Chulalongkorn University Hospital; CM = Chiengmai MCH Hospital; NS = Nakornsawan MCH Hospital; RB = Ratchaburi MCH Hospital; YL = Yala MCH Hospital; NT = Nakorn-srithamaraj MCH Hospital.

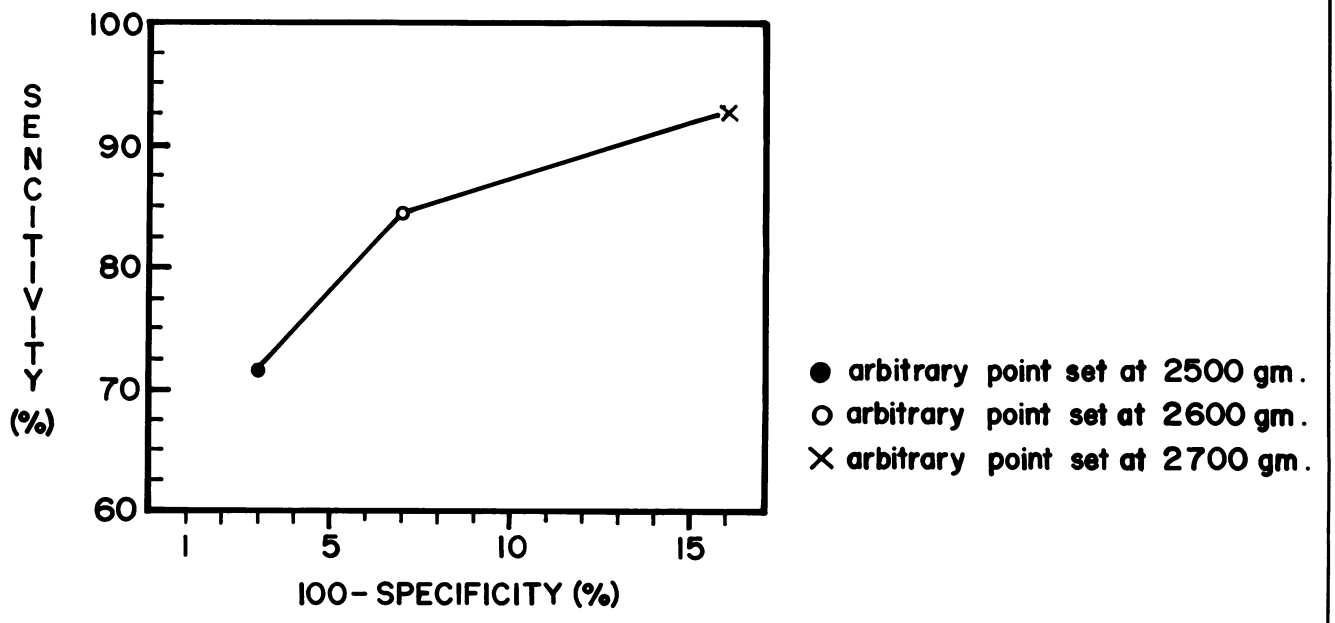

FIGURE 3—Receiver Operating Characteristics Curve of Birthweight Determination in Diagnosing Low Birthweight (All Data Combined, N = 3222)

TABLE 5—Diagnostic Values for Detecting LBW Babies (<2500 g) When the Arbitrary Point is Set at 2600 g on the New Device

Diagnostic Values	LS	KK	CU	CM	NS	RB	YL	NT
Sensitivity (%)	87.3	95.2	97.3	89.5	80.6	76.2	81.6	71.3
Specificity (%)	92.9	78.4	85.6	93.8	93.7	96.5	95.7	97.2
Accuracy (%)	92.3	79.8	88.9	92.3	89.3	89.0	91.0	88.4
+PV (%)	59.1	—	—	—	—	—	—	—
−PV (%)	98.4	—	—	—	—	—	—	—

Note. +PV, positive predictive value; −PV, negative predictive value; Positive and negative predictive values of case-control study cannot be calculated, since estimates of prevalence of low birthweight were not available.
LS = Lerdsin General Hospital; KK = Khon-Kaen University Hospital; CU = Chulalongkorn University Hospital; CM = Chiengmai MCH Hospital; NS = Nakornsawan MCH Hospital; RB = Ratchaburi MCH Hospital; YL = Yala MCH Hospital; NT = Nakorn-srithamaraj MCH Hospital.

TABLE 6—Diagnostic Values for Detection of LBW Babies (<2500 g) When the Arbitrary Point is 2700 g on the New Device.

Diagnostic Values	LS	KK	CU	CM
Sensitivity (%)	92.1	98.8	100.0	93.9
Specificity (%)	80.5	58.7	74.3	81.8
Accuracy (%)	81.7	62.0	81.5	85.8
+PV (%)	35.6	—	—	—
−PV (%)	98.9	—	—	—

Note. +PV, positive predictive value; −PV, negative predictive value; positive and negative predictive values of case-control study cannot be calculated, since estimates of prevalence of low birthweight were not available.
LS = Lerdsin General Hospital; KK = Khon-Kaen University Hospital; CU = Chulalongkorn University Hospital; CM = Chiengmai MCH Hospital.

tical error was ±187.4 g when compared with standard weighing scales.

The diagnostic test revealed the value of the new device. The optimum arbitrary point for screening an LBW infant was 2600 g, at which the sensitivity was 97.3%, the specificity was 97.2%, and the accuracy was 92.3%. This new device is inexpensive and convenient and is a good example of appropriate technology for primary health care. Use of the device should be encouraged throughout developing countries such as Thailand. □

Acknowledgments

The authors are grateful to Assistant Professor Supudda Pawanarit of the Department of Mathematics, Faculty of Science, for valuable suggestions concerning the mathematical formulas used in this study. They also wish to thank Dr. Prathan Kanchanalai, Head of the Department of Pediatrics, Lerdsin Hospital, Dr. Dittee Choengcharoen of Siriraj Hospital, and Associate Professor Chitr Sitthi-amorn of Chulalongkorn University for helpful advice. The authors also thank Associate Professor Wongkulapat Snidvongs for assistance in preparing the manuscript.

References

1. Petterson R, Regnstrom N, Sterky G, Taube A. *Birthweight Distribution and Socioeconomic Variables.* Geneva: World Health Organization; 1978. Sarec Report No. R2:45.
2. Mahner J. *Birthweight as a New Development Indicator.* Geneva: World Health Organization; 1978. Sarec Report No. R2:33.
3. Rao MVS. Social-economic indicators for development planning. *Int Soc Sci J.* 1975; 23:132.
4. Panpiamrat K. *Indicator for Poverty at the Umphur level: Concepts and Calculation Method.* [In Thai]. Rural Thailand 2526: Office of National Economic and Social Development Board; 1982.
5. Chaturachinda K, Hiranraks A, Auamkul N, Amornvichet P, Kanchanasinith K, Piy-

apinyo P. *A Nationwide Study of Birthweight in Thailand.* Presented at the Fourth Fertility Research Investigators' Meeting; September 28–29, 1985; Asia Hotel, Pattaya, Thailand.
6. Bhargava SK, Ramji S, Kumar A, Mohan M, Marwah J, Sachder HPS. Mid-arm and chest circumferences at birth as predictors of low birth weight and neonatal mortality in the community. *Br Med J.* 1985; 291:1617–1619.
7. De Vaquera MV, Townsend JW, Arroyo JJ, Lechtig A. The relationship between arm circumference at birth and early mortality. *J Trop Pediatr.* 1983;29:167–174.
8. Daga SR, Daga AS, Patole S, Kadam S, Mukadam Y: Foot length measurement from foot print for identifying newborn at risk. *J Trop Pediatr.* 1988;34:16–19.
9. Lachin JM. Introduction to sample size determination and power analysis for clinical trials. *Controlled Clin Trials.* 1981;2:93–113.
10. Draper NR, Smith H. *Applied Regression Analysis.* New York: Wiley; 1966.

Oral Rehydration Program Evaluation by Quality Assurance Sampling in Rural Haiti

June N. Pierre-Louis, MPH

ABSTRACT

An oral rehydration program in rural Haiti was evaluated by quality assurance sampling. The quality assurance sampling method and its application are described. The indicators measured were knowledge of the oral rehydration salts packet, knowledge of preparation of the solution from the packet, oral rehydration therapy use, and knowledge of preparation of the solution from salt and sugar. Coverages of the first two indicators were adequate, coverages of the latter two were inadequate. The method is a useful low-cost approach to evaluation of program coverage. (*Am J Public Health.* 1991;81:1205–1207)

Introduction

Oral rehydration therapy (ORT) is a cost-effective treatment for diarrheal disease.[1] While the scientific basis for oral rehydration is established, and programs are in place, many programs have not been evaluated at the local level.

In rural Haiti local programs typically target populations of less than 50,000.[2] To meet the need for a low-cost, population-based survey method, quality assurance sampling (QAS), a small sample method,[3] was used to evaluate a local ORT program in Haiti. The QAS method and its application in Haiti are described.

Methods

Study Population

Freres is a rural area located 20 km from Port-au-Prince, the capital of Haiti. The population (13,750 in 1987) lives on dirt roads within one km of a partly paved main road which bisects the area. Freres is targeted by a primary health care program managed by a private hospital in the area. The program maintains a census of the target population.

Promotion of ORT takes place at community meetings and on the radio. Health workers teach mothers to prepare the solution of oral rehydration salts (ORS) from a packet, and from salt and sugar, and to use ORT when their children under three years of age have diarrhea.[2]

Indicators

Widely accepted indicators of program outcome were selected by managers and funders of oral rehydration programs in Haiti and included: ORT use, knowledge of the packet, knowledge of preparation of the solution from the packet, and from salt and sugar.[4,5] The use rate was defined as the proportion of episodes of diarrhea in children under three years of age receiving ORT, whether the solution was prepared from the packet or salt and sugar.[4] The rate of knowledge of preparation of the solution was defined as the proportion of mothers of children under age three knowing the correct quantities of ingredients in a solution prepared from the packet or from salt and sugar.

The survey questionnaire is given in the Appendix.

Quality Assurance Sampling Method

The QAS method was first used for quality control in manufacturing. Product quality was assessed based on the probability of observing a particular proportion of defective items in a sample relative to a null hypothesis stating a proportion of defective products. This probability is determined by the binomial distribution. The goal of the QAS method is hypothesis testing rather than parameter estimation. The major advantage of QAS is the sample size which is small.

Address reprint requests to June N. Pierre-Louis, MPH, Division of Nutritional Sciences, Cornell University, Ithaca, NY 14853. The author was affiliated with Institut Haitien de l'Enfance, Delmas, Haiti. This paper, submitted to the Journal December 1, 1989, was revised and accepted for publication January 23, 1991.