Community and International Nutrition

Length Screens Better than Weight in Stunted Populations[1,2,3]

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ABSTRACT Stunting (low length-for-age) is the most widespread manifestation of growth retardation worldwide. Yet, most nutrition programs use weight-for-age for screening of at-risk children. This study tested whether weight-for-age was an effective screening tool in a severely stunted rural Guatemalan population, using data from the INCAP longitudinal supplementation trial ($n = 400$). Stunting was defined as length-for-age <–2 SD of the National Center for Health Statistics standards at 3 y of age. Sensitivity and specificity analyses and receiver operating characteristics curves were used to compare weight indicators (weight-for-age, weight velocity and weight-for-length) with length (length-for-age and length velocity) and arm and head circumferences measured during early infancy. Length indicators were clearly superior to weight in predicting stunting (Z_{da} test), and velocities were consistently worse than attained growth. Length-for-age at 6 mo had the best performance, followed by length-for-age at 3 mo, and weight-for-age at 6 and at 3 mo. Velocities, weight-for-length and circumferences were all poor predictors of stunting. Using the cutoff of <–1 SD, length-for-age at 3 mo was the best screening indicator for the early detection of growth faltering. Thus, the current use of weight-for-age, which results in large proportions of at-risk children being missed by screening, greatly limits the potential for impact of nutrition interventions. J. Nutr. 125: 1222–1228, 1995.

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- *nutrition assessment* • *anthropometry*
- *Guatemala* • *humans* • *malnutrition*

Guatemala and most countries in Latin America are characterized by a high prevalence of stunting (low height-for-age) and little or no wasting (low weight-for-height) (INCAP/OPS 1992). Yet most primary health care programs in the region use weight indicators to select beneficiaries for nutrition interventions. Currently the most popular screening indicators are attained weight, weight velocity and weight-for-height using the Nabarro wall chart (Nabarro and McNab 1980).

Weight, expressed in relation to age (weight-for-age), is by far the most widely used of the three, because of its simplicity and the availability of scales in most health centers. Weight, however, is an imperfect indicator of malnutrition because it does not discriminate between wasting and stunting. In populations such as Guatemala where stunting is highly prevalent and wasting is almost nonexistent, the use of weight to estimate prevalences of malnutrition grossly underestimates the magnitude of the problem. National estimates in 1988 showed prevalences of malnutrition of 34 compared with 58% when weight-for-age and height-for-age were used, respectively (INCAP/OPS 1992). Whether weight is an efficient screening tool in such situations to predict the risk of stunting is questionable.

The present study examined this issue by comparing the performance of weight with other anthropometric measurements of young infants in predicting stunting at 3 y of age in a rural Guatemalan population. The main objective was to

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identify the best screening indicator for the early identification of children at risk of stunting. The screening indicators compared were weight (attained and velocity), weight-for-length, length (attained and velocity), and head and arm circumferences. All indicators were measured when children were 3 and 6 mo old, and velocities between 3 and 6 mo were calculated. Sensitivity and specificity analysis, and receiver operating characteristics (ROC) curves were used to compare the performance of the different anthropometric indicators in predicting stunting at 3 y of age.

The research focused on early indicators (measured at 3 and 6 mo of age), because we showed in a separate study that up to 37% of the total growth deficit seen at 36 mo of age in this population was due to growth retardation in the first 6 mo of life (Rivera and Ruel 1993). Among a subsample of children who had adequate birth weight (>–1 SD) and low weight-for-age at 3 y of age (<–2 SD), we found a deficit of 3.7 kg in weight at 3 y, compared with the median of the National Center for Health Statistics (NCHS) reference population (WHO 1979). Of this deficit, 19.3% (690 g) was due to growth retardation during the first 3 mo of life, and an additional 17.4% (620 g) was due to growth retardation between 3 and 6 mo of age. Moreover, the impact of food supplementation in preschool children was shown to be far greater during the first year of life, compared with later ages (Schroeder et al. 1995). Early screening also has the advantage of allowing for longer-term interventions, thereby increasing the potential for impact.

The main purpose of the present study was to identify the most effective screening tool to detect at-risk children as early as possible in the first year of life. Assuming that at-risk children benefit most from interventions, effective screening followed by immediate, well-designed action should improve the impact and cost-effectiveness of primary health care programs and reduce the prevalence and severity of stunting in Guatemala.

MATERIALS AND METHODS

Data and sample. Data from a longitudinal supplementation trial conducted between 1969 and 1977 in the Eastern part of rural Guatemala were used. Two villages were randomly allocated to receive a high energy, high protein drink (Atole), and two other villages were assigned to a low energy, nonprotein drink (Fresco). A detailed description of the study is presented elsewhere (Habicht and Martorell 1992). The sample used for the present analysis includes all children who had anthropometric data (weight, length, arm circumference and head circumference) at 3, 6 and 36 mo (n = 400).

Data collection and measurement procedures. Children were measured at a central site every 3 mo during their first 2 y of life and every 6 mo thereafter, until their seventh birthday. Anthropometrists were trained and standardized to take all measurements, using standard techniques (Habicht 1974). Recumbent length was measured to the nearest millimeter using locally made measuring boards, and weight was measured to the nearest 10 g using beam scales. Mid-upper arm and head circumferences were measured to the nearest millimeter using flexible steel tapes.

Weight and length velocities for the period between 3 and 6 mo were computed by subtracting the values at 3 mo from the values at 6 mo of age. Monthly weight and length gains were derived by dividing the 3-mo period velocities by the actual interval between measurements. Length and weight data were transformed to Z-scores, using the NCHS reference values (WHO 1979).

Analytical methodology. Stunting was defined as length-for-age <–2 SD from the median of the NCHS reference standards at 36 mo of age. The ability of each indicator studied to discriminate stunted from nonstunted children was estimated using the normalized distance (da) between their sensitivity (stunted) and specificity (nonstunted) distributions (Habicht et al. 1982). A t test was used to determine whether the discriminating ability of the indicator was statistically significantly greater than zero (Habicht et al. 1982).

Receiver operating characteristics curves were plotted to visualize differences in sensitivity and specificity distributions between indicators and to see whether lines were parallel. The curves were plotted on double probability paper to obtain straight lines. Each line represents the discriminating ability of a particular indicator to differentiate between stunted and nonstunted children. The diagonal line, also called the indifference line, represents the line where there is no discriminating ability (i.e., the indicator is not better than chance alone). The further away from the indifference line, the better the performance of the indicator is for screening. Comparisons between indicators were done using a modified Z test, which compared the normalized distances of the indicators (Brownie et al. 1986). A Bonferroni correction was applied when multiple comparisons were made (Neter and Wasserman 1974).

A second approach used was to calculate, for the most popular indicators (weight-for-age, weight-for-length, weight velocity and length-for-age), the sensitivity, specificity, positive predictive value, percentage of false positives and percentage of false negatives at the cutoff points generally used in public health programs. Length-for-age, weight-for-age and weight-for-length <–1 SD and –2 SD from the median of the NCHS standards, and monthly weight gain less or equal to zero and 0.5 kg were compared.

Analyses were performed to verify whether the results were similar for the two intervention groups, i.e., the group that received Atole (high protein, high energy drink; $n = 208$) and the group that received Fresco (nonprotein, low energy drink; $n = 192$). The first approach was to do the analyses separately for each group. Results showed that the ranking of indicators remained identical and that the indicators normalized distance values were similar. Secondly, a multivariate model was used to test whether there was a statistically significant interaction term between treatment group and nutritional status indicators at 3 or 6 mo on length at 3 y. The interaction term was not statistically significant for any of the indicators studied, suggesting that the predictive ability of the indicator was the same for both supplementation groups. Thus, children from the Atole and Fresco groups were pooled for all analyses.

Analyses were performed using the PC-SAS statistical program, version 6.04 (SAS Institute, Cary, NC). Probability values <0.05 were considered statistically significant.

RESULTS

Figure 1 illustrates for this sample how estimates of malnutrition prevalence differ when weight-for-age rather than length-for-age is used. At all ages, prevalences estimated by weight-for-age were markedly lower than when length-for-age was used. No information was available on length at birth for this sample, but at 3 mo of age, already 20% of the children were stunted, and almost twice as many were stunted at 6 mo of age. At 3 y of age, 62% of all children were stunted, whereas only 35% were underweight (low weight-for-age).

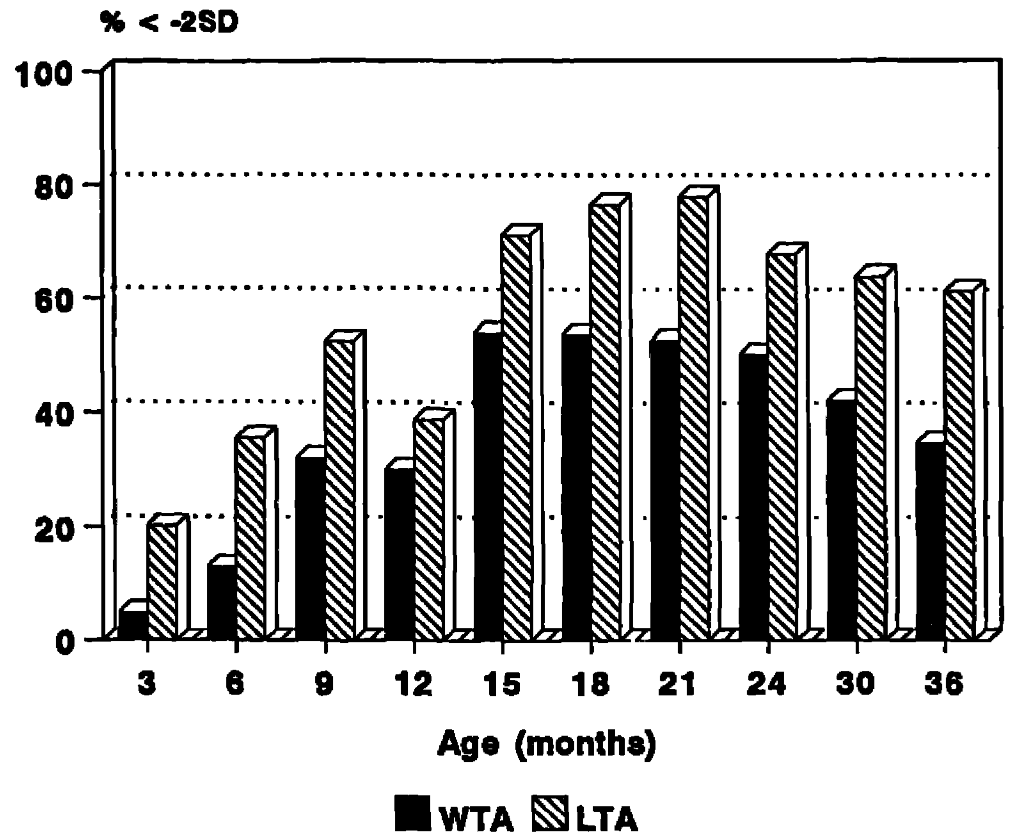

FIGURE 1 Prevalence of malnutrition among a sample of Guatemalan children, estimated by weight-for-age (WTA) and length-for-age (LTA) <–2 SD from the median of the National Center for Health Statistics population.

The mean values for the different indicators of risk at 3 and 6 mo of age are presented in **Table 1** for stunted and nonstunted children at 36 mo. Normalized distances and their *t* tests are also presented

TABLE 1

Descriptive statistics of the various indicators compared for stunted and nonstunted Guatemalan children at 36 mo of age

	Stunted (LTA[1] <–2 SD) ($n = 250$)		Nonstunted (LTA ≥–2 SD) ($n = 150$)				
Indicator	Mean	SD	Mean	SD	da (A)[2]	Vda (A)[3]	*t* test[4]
LTA Z-scores (6 mo)	–2.08	0.85	–1.07	0.68	1.30	0.012	13.07
LTA Z-scores (3 mo)	–1.61	0.86	–0.76	0.69	1.09	0.012	10.85
WTA Z-scores (6 mo)	–1.24	0.94	–0.46	0.81	0.89	0.011	8.77
WTA Z-scores (3 mo)	–0.68	0.86	–0.08	0.74	0.74	0.011	7.38
Head circumference (3 mo)	38.55	1.42	39.25	1.17	0.54	0.011	5.34
Head circumference (6 mo)	41.20	1.61	41.95	1.20	0.53	0.010	7.65
Arm circumference (6 mo)	12.71	1.10	13.20	0.97	0.48	0.011	4.65
Weight velocity (3–6 mo)	1.27	0.48	1.51	0.51	0.45	0.011	4.66
Length velocity (3–6 mo)	5.20	1.63	5.71	1.34	0.35	0.010	3.39
Arm circumference (3 mo)	12.03	1.12	12.31	0.97	0.26	0.010	2.63
WTLT Z-scores (3 mo)	0.81	0.93	0.81	0.78	0.13	0.010	0.00
WTLT Z-scores (6 mo)	0.53	0.95	0.46	0.95	0.09	0.019	0.71

[1]Abbreviations used: LTA, length-for-age; WTA, weight-for-age; WTLT, weight-for-length.

[2]$da(A) = \bar{A}_1 - \bar{A}_0/\sqrt{(1/2\,[s_1^2(A) + s_0^2(A)])}$, where 1 = nonstunted and 0 = stunted (Brownie et al. 1986).

[3]$Vda(A) = da(A)^2\,[1/\delta_A^2\,(1/n_0 + b_A^2/n_1) + (1/2(1 + b_A^2)^2\,(1/n_0 + b_A^4/n_1))]$, where $\delta_A = \bar{A}_1 - \bar{A}_0/s_0(A)$ and $b_A = s_1(A)/s_0(A)$ (Brownie et al. 1986).

[4]*t* test $= \bar{A}_1 - \bar{A}_0/\sqrt{(s_1^2/n_1) + (s_0^2/n_0)}$ (Habicht et al. 1982).

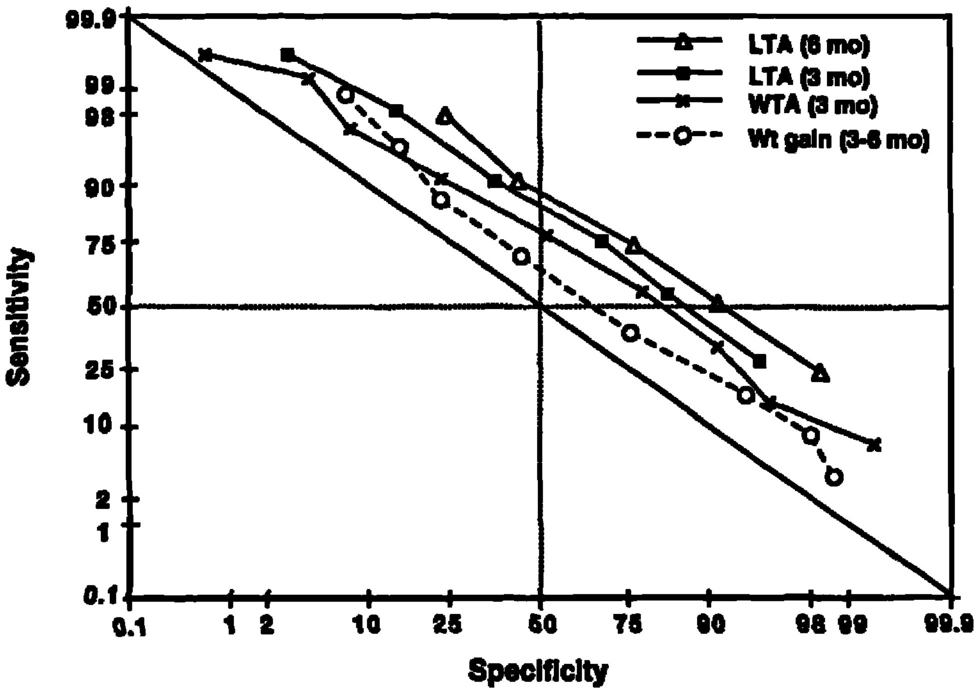

FIGURE 2 Receiver operating characteristics curves comparing the performance of four screening indicators to predict stunting at 3 y of age among a sample of Guatemalan children. LTA = length-for-age; WTA = weight-for-age.

for each anthropometric measurement. The indicators are listed in descending order of their discriminating ability.

The attained length indicators had greater discriminating ability, followed by attained weight, head circumference and arm circumference. Velocities (both weight and length) performed poorly, and weight-for-length at 3 or 6 mo were the worst indicators. Except for weight-for-length, all indicators were significantly different from zero ($P < 0.05$), meaning that their discriminating ability was greater than chance alone.

Receiver operating characteristics curves illustrating differences between selected indicators are shown in **Figure 2**, and statistical comparisons are presented in **Table 2**. Only a few selected comparisons were made, the others being irrelevant in light of the results presented in Table 1. The ROC curves were generally parallel, and length-for-age at 6 mo of age was the furthest away from the indifference line, meaning that it had the greatest specificity at all levels of sensitivity. Thus length-for-age at 6 mo was the best indicator and was significantly superior to length-for-age at 3 mo of age. Comparisons between attained length and weight indicators at a given age show that length consistently performed better than weight (Table 2). Velocities, on the other hand, generally were significantly worse than their associated attained indicators.

Table 3 presents the characteristics of a subset of indicators at the cutoff points most commonly used in primary health care programs. Again, the length indicators showed the best combinations of high sensitivities and specificities. Using the cutoff point of −1 SD below the median of the NCHS population at 3 mo of age, 75% of the children at risk of being stunted at 3 y were correctly identified (sensitivity), and 67% of the nonstunted children were correctly identified as not at-risk (specificity). Among the children screened at-risk at 3 mo, 79% were truly at-risk (positive predictive value) and would have needed an intervention. Of all children screened, 15% would have been missed (false negatives) and 12% would have received the intervention without being at-risk (false positives). Thus, length-for-age <−1 SD at 3 mo of age provided the smallest rate of misclassification of all the indicators compared in Table 3, with a relatively high combination of sensitivity and specificity.

Table 3 also shows that for a given indicator, lowering the cutoff point always reduces the sensitivity and increases the specificity, and thus increases the percentage of children missed (false negatives) and reduces the percentage of false positives. The attained

TABLE 2

Comparison of indicators for screening Guatemalan children at risk of being stunted at 36 mo of age

Indicators compared: A	B	$Z_{da}(A - B)$ test[1,2]
LTA[3] at 6 mo	LTA at 3 mo	2.82*
WTA at 6 mo	WTA at 3 mo	2.29
LTA at 3 mo	WTA at 3 mo	3.97*
LTA at 6 mo	WTA at 6 mo	4.51*
LTA at 3 mo	WTA at 6 mo	1.95
WTA at 3 mo	Weight velocity (3–6 mo)	2.04
WTA at 6 mo	Weight velocity (3–6 mo)	4.41*
LTA at 3 mo	Length velocity (3–6 mo)	4.43*
LTA at 6 mo	Length velocity (3–6 mo)	7.99*

[1] Z_{da} (A − B) = da(A) − da(B)/$\sqrt{}$(var da(A) + var da (B) − 2cov [da(A), da(B)]) (Brownie et al. 1986).
[2] Using the Bonferroni correction, P values <0.05/9 (0.005) were considered significant (indicated by an asterisk).
[3] Abbreviations used: LTA, length-for-age; WTA, weight-for-age.

TABLE 3

Performance of weight and length indicators at selected cutoff points, for the prediction of stunting at 36 mo of age among a sample of Guatemalan children

Indicator	Se[1]	Spe[2]	V+[3]	Missed (FN)[4]	Non-needy (FP)[5]	Total misclassified[6]	Screened at-risk[7]
				%			
Length-for-age							
<–1 Z-score							
At 3 mo	75	67	79	15	12	27	59
At 6 mo	90	41	72	6	22	28	79
<–2 Z-score							
At 3 mo	27	95	90	46	2	48	19
At 6 mo	52	91	90	30	3	33	36
Weight-for-age							
<–1 Z-score							
At 3 mo	34	90	85	41	3	44	25
At 6 mo	58	77	81	26	9	35	45
<–2 Z-score							
At 3 mo	6	99	94	58	0.2	58	4
At 6 mo	19	97	91	50	1	51	13
Weight-for-length							
<–1 Z-score							
At 3 mo	2	98	62	60	0.7	61	2
At 6 mo	4	93	50	59	3	62	5
<–2 Z-score							
At 3 mo	0.3	100	100	61	0	61	2
At 6 mo	0	100	0	62	0.4	62	0.4
Weight change							
3–6 mo							
≤0.0 kg/mo	0.1	99	75	62	0.2	62	1
<0.5 kg/mo	70	44	68	19	21	40	65

[1]Sensitivity (Se) = percentage of all malnourished children at 36 mo of age who are correctly identified as malnourished by the screening test.
[2]Specificity (Spe) = percentage of all well-nourished children at 36 mo of age who are correctly identified as well-nourished by the screening test.
[3]Positive predictive value (V+) = percentage of those screened as malnourished by the test who are really malnourished at 36 mo of age.
[4]False negatives (FN) = percentage of all children tested who are incorrectly classified as well-nourished by the screening test (% missed).
[5]False positives (FP) = percentage of all children tested who are incorrectly classified as malnourished by the screening test (% non-needy).
[6]Total misclassified = sum of FN and FP.
[7]Screened at-risk = percentage of all children tested who are classified as at-risk by the screening test.

weight indicators generally had poor sensitivity and high specificity. This means that using attained weight for screening would result in a large proportion of at-risk children being missed. Using the common cutoff point of –2 SD, between 51 and 58% of all at-risk children would remain undetected.

Weight-for-length again performed poorly, showing extremely low sensitivity and a large percentage of misclassification. The cutoff points of –1 and –2 SD correspond roughly to the yellow and red areas of the Nabarro wall chart, which are usually considered as the areas of risk. Using these cutoff points, <5% of all at-risk children would be correctly screened.

Monthly weight gain as currently defined by WHO (no gain or weight loss) (OMS 1986) also had an extremely low sensitivity and a very poor performance in general. Changing the cutoff point to 0.5 kg per mo between 3 and 6 mo of age, however, provided a much better test (sensitivity, specificity and positive predictive value of 70, 44 and 68%, respectively). The total percentage of misclassification, however, was higher than the one seen for attained length at 3 mo.

DISCUSSION

Attained length was the best screening indicator to predict stunting at 3 y of age in our sample of severely stunted Guatemalan children. At both 3 and 6 mo, the attained length indicators had higher sensitivity than did attained weight, for all levels of specificity. Velocities performed less well than their corresponding attained indicators, and weight-for-length, arm circumference and head circumference were poor predictors of stunting.

It may seem obvious that length indicators would have a greater predictive power than weight in a population where stunting is the main manifestation of growth retardation. Yet, we are unaware of any primary health care program that uses length for screening, or of any attempts to validate the usefulness of different anthropometric indicators for screening (Ruel 1995).

The present research showed that weight indicators were generally poor predictors of stunting and had low sensitivity, which results in a large proportion of at-risk children being missed by screening (false negatives). Because nutrition interventions such as education and food supplementation do not present any risk for those who are not needy (false positives), tests with high sensitivity rather than high specificity are desirable. Where resources are scarce, tests with high specificity and high positive predictive value also need to be considered, to prevent leakage resulting from treating those who are not needy and to minimize the cost per beneficiary.

Interestingly, the weight indicators generally had high positive predictive value and thus could be considered efficient relative to cost effectiveness. Because of their low sensitivities, however, a large proportion of at-risk children would be missed and only a small percentage of all children tested would be considered eligible for interventions. In many cases, this percentage would be far below the capacities of the programs in place. This situation occurred in Guatemala, where a nongovernmental organization providing food assistance used the Nabarro (weight-for-length) chart to screen potential beneficiaries. The small percentage of malnourished children identified by the screening test led policy makers to conclude that malnutrition was not an important problem in Guatemala and that food aid should be suspended. These conclusions are appalling for a country showing the highest rates of stunting in all of Latin America (PAHO/WHO 1990).

Considering that most malnutrition in the world, and particularly in Latin America, is reflected in stunting as opposed to wasting (Victora 1992), our findings have important implications for screening for nutrition interventions.

Our results demonstrated that the screening indicators currently used in primary health care programs are tremendously inefficient in identifying children at risk of stunting. Weight-for-length was shown to be a particularly poor predictor of stunting, which suggests that the widespread use of the Nabarro chart in Latin America should be reconsidered. Weight velocity, which is widely used in primary health care programs to monitor children's progress, was also found to be a poor predictor of the risk of stunting. Using the criteria recommended by WHO of no weight gain or weight loss over a 1-mo period to characterize risk (OMS 1986), the indicator identified only 1% of all children as being at risk. When the criterion of 0.5 kg was used, however, the indicator performed better. This suggests that cutoff points would have to be adjusted according to the expected growth rates characteristic of different age groups, in order to improve the performance of the weight velocity indicator. This was done by Piwoz et al. (1994), who showed that monthly weight gain was useful for predicting weight-for-age at 12 mo when the age-specific 50th percentile of expected weight gain was used as the cutoff point. Introducing age-specific cutoff points, however, would not be a practical solution for public health programs where simplicity must be maintained. Moreover, the ROC curves showed that over the entire range of cutoff points, weight velocity performed significantly more poorly than attained weight or length. A limitation of our data, however, was that monthly weight gain was derived from data for a 3-mo period. Similar analyses should be repeated using monthly data for a more accurate test of the validity of the WHO criteria.

Attained weight at 6 mo of age was the next best indicator after attained length at 3 and 6 mo. Weight at 6 mo performed relatively well, particularly with the cutoff point of −1 SD. Because screening by weight is so popular in primary health care, it may be wise to continue to use it in situations where a change to screening with length would not be a viable alternative. However, screening at 6 mo, as opposed to 3 mo, would delay the delivery of interventions and reduce the potential for impact. Interventions to promote exclusive breast-feeding for at least the first 4–6 mo may be particularly important in this population to reduce morbidity from diarrheal diseases and to prevent some of the growth faltering occurring between 3 and 6 mo of age. Maternal supplementation may also be more effective if implemented during the peak period of lactation (3 mo) rather than at later ages.

An important objective of the study was to identify an indicator for the early identification of at-risk children, using the actual health care system. In Guatemala, more than 70% of all births are attended at home by midwives, and thus information on birth weight and length is usually not available. The first official contact of young infants with the health system is when they attend the health center for immunization, well-baby clinic or food distribution activities. Thus, the earliest possible time to detect young infants at risk of stunting is at ~3 mo of age. It is important to recognize that a large proportion of infants identified as at-risk at this age are probably infants who suffered intrauterine growth retardation but were not detected at birth because of the limitations of the current system. We have shown that at 3 mo, length-for-age is a highly sensitive and specific screening indicator. Thus, the opportunity to accurately screen these children upon their first visit to the health care system should not be missed.

Our results showed that with the right indicator, i.e., length-for-age, up to 75% of all children at risk of stunting by 3 y of age were correctly screened at 3 mo of age. Of those children identified at risk at 3 mo of age, 79% were truly at risk and could have benefited from an intervention. Only 15% of the at-risk children were missed by the screening test, and 12% were incorrectly classified as being at risk (false positives). With this indicator, up to 60% of all children in poor communities would be considered eligible for nutrition interventions upon screening at 3 mo of age. If screening is repeated at 6 mo among the healthy group (two-stage screening), another 20% would be added to the number of children to be treated (analyses not shown). In situations in which such high percentages of children need to be treated, one may question the relevance of individual screening. It may be that screening poor communities and including all children below a certain age (adjusting the cutoff point to available resources) would be more efficient than using sophisticated screening tools (Beaton 1993, Ruel et al. 1995, Schroeder et al. 1995).

Our findings may not apply to other regions of the world where stunting is less severe, or where both wasting and stunting are prevalent (Victora 1992), or in populations where growth retardation occurs later in life. In our sample, up to 70% of the children were stunted at 3 y of age, and, although at-birth length data were not available, we suspect that a large proportion of children suffered intrauterine length retardation. Thus, similar analyses should be repeated in populations that differ in the nature or the timing of growth retardation.

Another important consideration, which could not be addressed with available data, is how measurement errors in usual primary health care conditions would affect the performance of the indicators reviewed. It is important to note that our data were collected under controlled research conditions by well-trained and standardized anthropometrists. Whether measurement errors in usual field conditions would affect the ranking of the indicators compared in this research should be tested in the future. Of all indicators, velocities would be the most affected by measurement errors, because the errors of the two measurements tend to cumulate (Briend and Bari 1989). Thus, it is likely that velocities would not improve their ranking as screening indicators.

Finally, the present study focused on indicators for screening children at risk of stunting. The question of whether these children are also those who will benefit the most from interventions was not addressed here. A comparison of benefit and risk indicators is presented elsewhere (Ruel et al. 1994).

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