

Estimating Stunting from Underweight Survey Data

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INTRODUCTION

Child growth is widely used to assess adequate nutrition, health and development of individual children, and to estimate overall nutritional status and health of populations. Compared to other health assessment tools, measuring child growth is a relatively inexpensive, easy to perform and non-invasive process.

Two of the internationally recommended indicators most commonly used are *child stunting* (low height-for-age) and *underweight* (low weight-for-age). While stunting reflects a failure to reach linear growth potential due to suboptimal health and/or nutritional conditions, underweight reveals low body mass relative to chronological age, which is influenced by both, a child's height and weight. Underweight thus cannot distinguish between a child that is small in weight relative to his/her height and a child that is low in height relative to his/her age, but who may be normal in weight-for-height (WHO, 1995).

While the limitations of underweight are known, it is the indicator most often applied due to the ease of measuring weight. The common problems encountered when assessing stunting are: 1) A length/height board is needed, that is usually expensive; it can be bulky and heavy to carry; 2) Measuring length/height requires two observers: one to take and record the measurement, the other to help positioning the child to facilitate an accurate measurement; 3) Newborns' legs cannot be fully straightened, making measuring length particularly difficult in this age group; and 4) Training observers in standard measuring techniques for length/height is critically important and requires time.

Underweight is the single indicator used in many countries because of the simplicity of collecting only one measurement. Furthermore, the availability of electronic scales at affordable prices has made weighing easier and faster. While digital reading increases accuracy and precision of the measurement, these scales offer also the flexibility to measure the mother with the infant, which reduces stress to the child. Measuring children's length, in turn, is known to induce anxiety and cause stress to young children (and their mothers).

According to a recent global survey of national child growth charts, 97% of countries use growth charts for underweight, while only 41% monitor stunting (de Onis et al., 2004a). This selective assessment may have deleterious effects e.g. in Latin American, where most countries have close to a twofold prevalence of stunting compared to underweight (ACC/SCN, 2004), the use of weight-based indicators can underestimate the magnitude of malnutrition (Ruel et al., 1995). On the other end of the growth distribution, if children's length and height is not assessed, food supplementation may lead to increasing rates of overweight, as a stunted child of normal-to-high weight-for-height who receives surplus food is at risk of becoming overweight or obese (Uauy and Kain, 2002).

At the Millennium Summit in 2000, representatives from 189 countries committed themselves to give highest priority to sustaining development and eliminating poverty (UN, 2000). Goal number 1 (eradication of extreme poverty and hunger) has the specific target to halve the prevalence of child underweight in preschool-aged children between 1990 and 2015 (UN, 2004). Underweight will thus remain a major indicator and is likely to continue as sole indicator assessed in many countries.

Experts concluded that, in the absence of high wasting levels, underweight and stunting can provide similar information (WHO, 1995; Waterlow, 1992). The objective of this analysis was to derive simple regression equations to predict child stunting from underweight prevalence, and to test, whether the frequently cited strong correlation between underweight and stunting is reflected by the empirical data.

METHODS

Prevalence data on child stunting and underweight were derived from the World Health Organization (WHO) Global Database on Child Growth and Malnutrition (www.who.int/nutgrowthdb, 2004). The methodology of this database, established in 1986 with the objective to collect and standardize child growth data, has been described elsewhere (de Onis and Blössner, 2003).

Stunting and underweight were defined as the percentage below -2 standard deviation (SD) from

the median of the National Centre for Health Statistics (NCHS)/WHO reference population. Given that $\% < -2$ SD are derived by comparing weight and length/height to the age and sex-specific reference data, made that the variables were controlled for age and sex.

From the extracted 16,288 data records, based on surveys conducted between 1961 and 2003, we selected those referring to sexes combined (10,316 records), because: i) no systematic differences by sex were expected and ii) most survey data were available for sexes combined. Countries were grouped following the UN regions and subregions classification (UN, 2003), and records without prevalence estimates for both underweight and stunting were deleted.

We considered five age groups: 1, 2, 3, 4 and 0-4.99 years (i.e. 12-23 months, 24-35 months, 36-47 months, 48-59 months, and 0-59 months, respectively). The data from age groups 0-5 and 6-12 months were excluded given: i) the commonly observed low quality of length data collected in infants due to difficulties in fully straightening their legs and ii) the distinct pattern of growth in terms of mean z-scores of height-for-age and weight-for-age observed in these age groups (Shrimpton et al., 2001).

Subregions with at least 20 survey records were included in the analysis. These were: Eastern Africa, Middle Africa, Northern Africa, Southern Africa, Western Africa, Eastern Asia (excluding Japan and Taiwan), South-central Asia, South-eastern Asia, Western Asia, Caribbean, Central America, Southern America. Due to insufficient data no regression analysis was possible for: Eastern Europe, Northern Europe, Southern Europe, Western Europe, Northern America, Australia/New Zealand, Melanesia, Micronesia and Polynesia.

First, a simple univariate regression equation using least squares method was derived for 48 sub-region and age group (1, 2, 3, 4 years) combinations. Stunting was assumed to be normally distributed across underweight with constant variance, and mean values of % stunted were assumed to be linearly related to % underweight. Residual plots were examined to ensure assumptions were not violated, and hypothesis tests for the slope were carried out. The regression equations provided an estimate of the dependent variable (% stunting) as a linear function of the independent variable (% underweight), with the standard error (SE) of the slope indicating the variability of the estimate, a measure of precision, and the p-value reflecting the level of

significance (using Student's t-test) of the null hypothesis $H_0: \beta = 0$ (i.e. slope equals zero). The r^2 , being defined as the proportion of the variability in the % stunted explained by % underweight from the linear regression, measured how well the regression line represents the data points. Sufficient strength of the correlation between underweight and stunting was defined *a priori* as r^2 of at least 0.70. Meaning that no more than 30% of the variation would be unexplained and due to other factors.

After checking residual plots for outliers, five survey records were deleted: Seychelles, Eastern Africa, 1988-89; Dominican Republic, Caribbean, 1976; Guyana, Southern America, 1971; Nepal, South-central Asia, 1978; and Singapore, South-eastern Asia, 1970-77. These country surveys' results reflected untypical situations compared to the remainder of countries in the respective regions. For example, Seychelles' thriving tourist industry has led to rapid economic growth, e.g. the national per caput gross domestic product grew from US\$ 800 in 1976 to US\$ 6500 in 1999. Prevalences of stunting and underweight were lower compared to all other countries in the region. Thus including the Seychelles' estimates made the trend line steeper and had a considerable impact on the intercept. In the residual plots it appeared a clear outlier and thus all age groups of this survey were removed from the analysis. This left us with a total of 4247 records, i.e. 604, 632, 535, 526 and 1950 for the age groups 1, 2, 3, 4, and 0-4.99 years, respectively. To obtain information on precision of the predictive models, the 95% confidence bands were constructed for each subregional regression equation using the standard formula (Kleinbaum et al., 1988).

Given that age disaggregated estimates are not always derived, we examined whether the overall % of underweight, covering 0-59 months, would predict equally well the % stunting as the records stratified by 1, 2, 3, and 4 year olds. To further examine whether correlation analysis results were related to time trends when surveys were conducted, the overall regions were evaluated by grouping data into year ranges. Using the results obtained, we attempted to validate the equations for the age group with the most consistent and strongest association per subregion against country survey data of the WHO Global Database that have subsequently become available between January and June 2004.

RESULTS

All regions and age group combinations

showed a highly significant, direct and linear relationship between % underweight and % stunting. There was no evidence against the model assumptions. The correlation coefficients for the different subregions and age groups were found to be highest in the 12-23 months age group, which was thus selected for further analysis. This age group showed also more homogenous slopes, ranging from 0.581 in Western Africa (SE: 0.079) to 1.349 in Central America (SE: 0.095) compared to the other age groups (e.g. 4 year age group, ranging from 0.515 in Eastern Africa (SE: 0.120) to 1.791 in Central America (SE: 0.230). Table 1 presents the regression equations by subregions for the 1 year olds, including the SE of the slope, the p-value and the r^2 . The units of analysis are the individual study records for each subregion.

Among the 1 year olds, the Pearson's correlation coefficient "r" (square-root of r^2) – measuring the degree of association– ranged from 0.691 (Western and Middle Africa) to 0.929 in Central America. The African subregions seemed to have a similar association of underweight and stunting which is reflected in the parallel regression lines (Fig. 1), but the strength of the correlation was low with the coefficient of determination r^2 ranging from 0.477 in Middle Africa to 0.698 in Northern Africa. Sufficiently strong correlation equations, according to the pre-defined criteria were found for all subregions in Asia with correlation strength ranging from 0.703 in South-eastern Asia to 0.779 in Western Asia. In Latin America and the Caribbean the correlation of stunting on underweight shows

equally good predictive power with r^2 ranging from 0.725 to 0.863.

The intercepts (α -values) were generally high for all subregions in Africa, i.e. between 14.2 and 26.1, varied for the Asian subregions between 1.2 and 13.2, and appeared comparable across subregions in Latin America and the Caribbean, ranging from 4.5 to 7.9 (see Fig. 1-3).

Given the similar association of underweight and stunting in the African subregions, it was considered adequate to pool all subregional data and perform one overall regression analysis for the African region. The resulting equation was: $\times \% \text{ stunting} = 21.199 + 0.5884 \times \% \text{ underweight}$. The r^2 for this overall correlation was 0.4365, and the

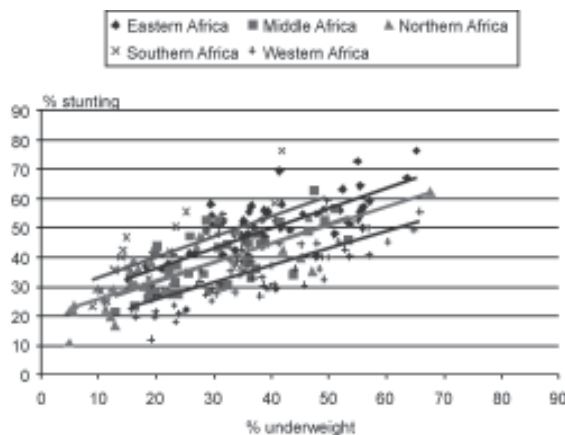


Fig. 1. Correlation of underweight and stunting in the subregions of Africa

Table 1: Correlation and regression analysis results of the prevalence of stunting on underweight by region in age group 12-23 month-olds

Region	# Data records	Countries	% stunting= $\alpha + \beta \times x^1$	SE (β)	p-value	r^2
<i>Africa</i>						
Eastern Africa	62	14	$22.433 + 0.684 \times x$	0.083	<0.0001	0.530
Middle Africa	38	9	$18.292 + 0.671 \times x$	0.117	<0.0001	0.478
Northern Africa	26	6	$19.627 + 0.623 \times x$	0.084	<0.0001	0.698
Southern Africa	23	5	$26.050 + 0.698 \times x$	0.155	<0.0001	0.490
Western Africa	61	16	$14.211 + 0.581 \times x$	0.079	<0.0001	0.477
<i>Asia</i>						
Eastern Asia	33	5	$13.209 + 0.924 \times x$	0.096	<0.0001	0.751
South-central Asia	112	13	$10.231 + 0.803 \times x$	0.046	<0.0001	0.736
South-eastern Asia	61	10	$1.237 + 0.984 \times x$	0.083	<0.0001	0.703
Western Asia	55	14	$7.078 + 0.853 \times x$	0.063	<0.0001	0.779
<i>Latin America and the Caribbean</i>						
Caribbean	27	9	$4.482 + 0.891 \times x$	0.098	<0.0001	0.767
Central America	34	8	$5.764 + 1.349 \times x$	0.095	<0.0001	0.863
Southern America	72	13	$7.884 + 1.231 \times x$	0.091	<0.0001	0.725

¹ α = intercept, β = slope and x = % underweight (Regression equation: % stunting = intercept + slope $\times$ % underweight)

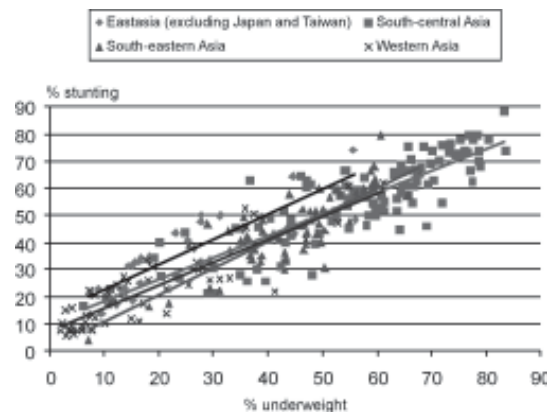


Figure 2. Correlation of underweight and stunting in the subregions of Asia

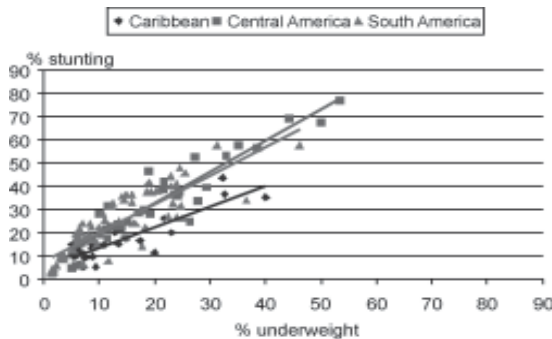


Fig. 3. Correlation of underweight and stunting in the subregions of Latin America and the Caribbean

SE of the slope 0.046 (p -value < 0.001). Hence, when pooling the African subregions the correlation attenuated the strength of the association compared to the single subregions, and % underweight explained less of variability of % stunting in the region as a whole.

A separate analysis was conducted to compare the 0-4.99 years age group with that of the 12-23 months age group. The slopes for the overall age group varied in the subregions from 0.631 (SE: 0.060) to 2.189 (SE: 0.944) and r^2 was ≥ 0.70 in 5 subregions compared to 7 subregions in the 12-23 months age group. Given that selecting the 0-4.99 age group, did not show any substantial improvement to the inference made from the 1 year age group, it was not further considered.

In order to obtain the 95% confidence bands for the slopes the estimated underweight prevalence in 1 year olds was entered into the regression equation. In a hypothetical example of 15% underweight in a country of Central America, the equation would be (see Table 1): % stunting =

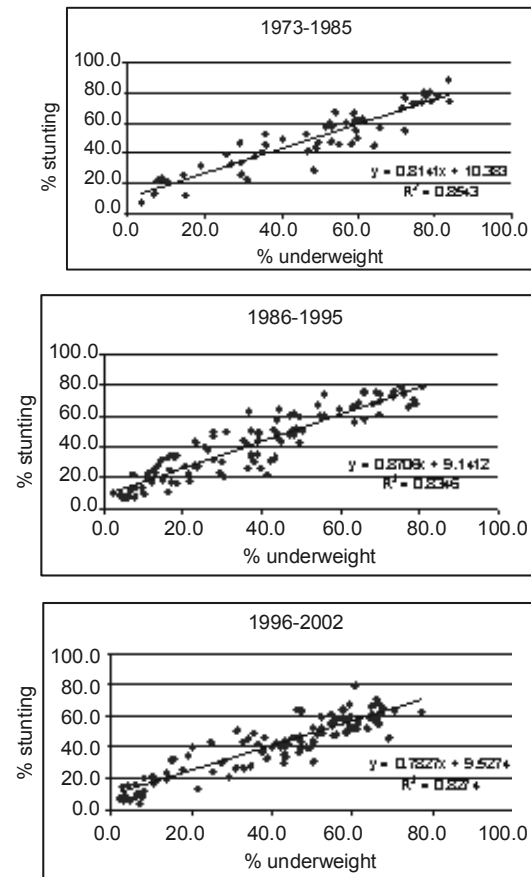


Fig. 4. Correlation of underweight and stunting over time periods in Asia

$5.764 + 1.349 \times 15\% = 26\%$. Given that the $SE(\beta) = 0.095$, hence the lower slope $\beta_{lo} = 1.349 - 1.96 \times 0.095 = 1.163$; and the upper slope $\beta_{up} = 1.349 + 1.96 \times 0.095 = 1.535$. Using the upper and lower $\hat{a}$ the confidence limits would be 23.2% ($5.764 + 1.163 \times 15$) and 28.8% ($5.764 + 1.535 \times 15$). Provided that the 15% underweight estimate is presented with a 95% CI: 12.3% — 17.5%, a conservative range can be obtained by using the upper and lower confidence limits as well as the upper and lower bounds of the slope (derived above). In this example the lower range would be: $5.764 + 1.163 \times 12.3 = 20.1\%$ and the upper range: $5.764 + 1.535 \times 17.5 = 32.6\%$.

There seemed to be a constant strong association across time periods in Asia (see Fig. 4), whereas the magnitude of the association became weaker over time in Latin America and the Caribbean (see Fig. 5).

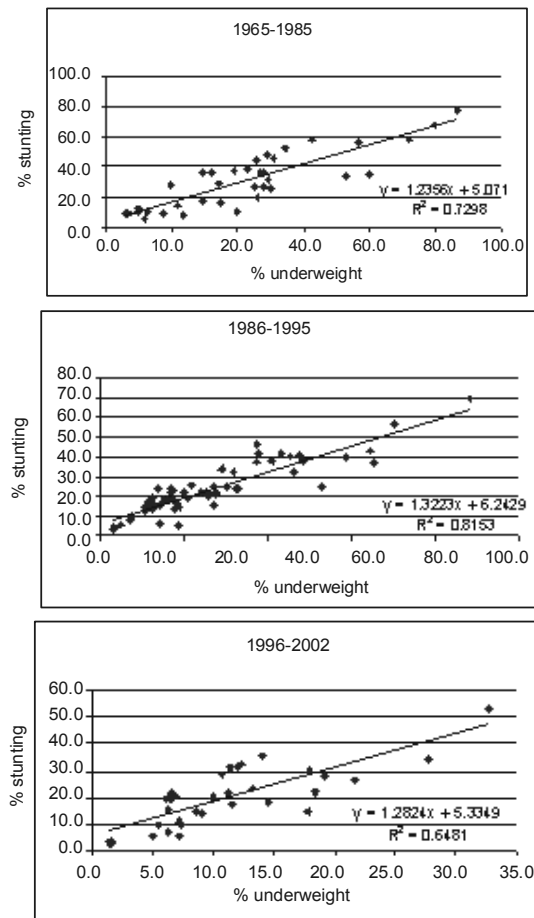


Fig. 5. Correlation of underweight and stunting over time periods in Latin America and the Caribbean

Table 2: Observed % stunting in 12-23 months old children compared to the estimated prevalence of stunting using the regional specific regression models

Country	UN subregion	Year of survey	% underweight	% stunting observed	% stunting estimated (CI ^a)	Δ
Iran, Islamic Rep. of	South-central Asia	1998	11.4	18.4	19.4 (18.4-20.0)	1.0
India (Chhattisgarh)	South-central Asia	1998-99	72.6	67.0	68.5 (62.0-75.1)	1.5
Dominican Republic	Caribbean	2002	6.3	12.1	10.1 (8.9-11.3)	-2.0
Maldives	South-central Asia	2001	35.6	36.3	38.8 (35.6-42.0)	2.5
Azerbaijan	Western Asia	2001	8.9	17.3	14.7 (13.6-15.8)	-2.6
Guatemala	Central America	2000	30.4	49.8	46.8 (41.1-52.4)	-3.0
Cuba	Caribbean	2000	5.0	5.3	8.9 (8.0-9.9)	3.6
Timor Leste	South-eastern Asia	2003	51.8	48.1	52.2 (43.8-60.7)	4.1
Malaysia	South-eastern Asia	1999	22.2	17.7	23.1 (19.5-26.7)	5.4
India (Uttaranchal)	South-central Asia	1998-99	48.2	56.6	48.9 (44.6-53.3)	-7.7
India (Goa)	South-central Asia	1998-99	25.6	22.9	30.8 (28.5-33.1)	7.9
Guatemala	Central America	2002	30.2	57.1	46.5 (40.9-52.1)	-10.6
Guyana	Southern America	2000	16.0	13.5	27.6 (24.7-30.4)	14.1

^aConfidence interval derived using the SE(β) to obtain upper and lower slope estimates

^bDelta value = estimated % stunting - observed % stunting

To validate the equations we examined the differences between observed and estimated % of stunted children. Table 2 presents data of 13 new surveys from subregions for which there was a sufficiently strong correlation (i.e. $r^2 \geq 0.70$). Percentage of underweight and stunting observed refer to 12-23 months, sexes combined. Next to the % stunting observed are listed for each survey record the predicted estimates with confidence intervals based on SE(β) and the delta value, i.e. the difference between the two. Survey records are listed in ascending order of absolute delta values.

There were too few data points available from the same regions to conduct an agreement analysis. The 13 study records nevertheless provide an idea what the results would be in a group of selected country settings when applying the regression equations. In 8 out of 13 data records the regression model estimated a higher prevalence of stunting. This overestimation could be as high as 14.1% for Guyana in Central America. In the opposite direction the underestimation could be as low as -10.6% in Guatemala, South America. This underscores the finding, that the regression equation may not be appropriate for the subregions of Latin America and the Caribbean. For the subregions of Asia, the highest underestimate was -7.7% for the Indian state of Uttaranchal and the highest overestimate was 7.9% for the Indian state of Goa. In summary, only for 5 out of the 13 survey records used in the validation exercise the observed % stunting were within the confidence interval derived using the regression equations.

DISCUSSION

Child stunting and underweight are biologically related indicators of abnormal growth. Under physiologic conditions any weight increase is usually associated with an increase in length or height. Given the numerous practical problems in measuring children's length and height, the objective of this analysis was to develop a simple predictive model using the most widely available indicator, i.e. % underweight. The positive and significant correlations between underweight and stunting observed in all regions proves their close relationship. The assumption, in turn, that regressing stunting on underweight yields similar slope and regression coefficients across regions was not confirmed.

While in the subregions of Africa, particularly sub-Saharan Africa (i.e. Southern, Middle, Eastern and Western Africa), underweight explained at most 53% of the variability in stunting, in Latin America and the Caribbean underweight explained more than 72% and in Asia at least 70%. In Africa one could argue that this is due to high prevalences of wasting in the region—between 5% and 10% (WHO, 2004). But this does not explain why the correlation was consistently strong in the Asian subregions, as this region has also high wasting prevalences—up to 14% in South-central Asia—(WHO, 2004).

In Africa specific regional circumstances that contribute to malnutrition and need to be taken into account include: Malaria incidence, HIV/AIDS, and political and social instability. The observed change over time in the association between the two indicators in Latin America and the Caribbean may well be a consequence of the transition that is being experienced in several countries of that region (Uauy et al., 2001). Asia, in turn, might be a special case when one considers the very high levels of underweight, stunting, and wasting found in this region. With the exception of China, which follows a separate trend due to rapid economic development, the majority of the countries struggle with prevailing poverty and high rates of malnutrition even though there is an overall declining trend (de Onis et al., 2004b). Additionally, throughout Asia low birth weight (LBW) continues to be an important public health problem, and one could question if the stable relationship between underweight and stunting does not stem from the early timing of malnutrition, i.e. during the intrauterine period.

These results confirm that the patterns of malnutrition, as measured by underweight and

stunting, in the subregions are distinct, as reported earlier by de Onis et al. (1993). As a new finding, the present analysis suggests that the relationship between the two nutritional indicators is also distinct for each subregion.

An important point of consideration is that the two indicators describe different physiological and biological processes (WHO, 1995; Waterlow, 1992); and the observed distinct slopes and intercepts for each subregion indicate that additional factors, probably with specific regional and/or local contexts, influence this association. Among Honduran children, for example, researchers found that important determinants of stunting were: mother/caretaker's and father's schooling, source of water, the geographic location, and the "possession score" for ownership of items such as a radio, television, refrigerator, stereo system, and electric iron (Nestel et al., 1999). The predictors for underweight, in turn, were: micronutrient status, diarrhoea, maternal/caretaker's schooling, type of toilet, and possession score. In the Democratic People's Republic of Korea, by comparison, only maternal mid-upper arm circumference showed a significant association with stunting (not significant were maternal weight, haemoglobin and the child's birth weight) (Shrimpton R, 2004).

The Demographic and Health Surveys comparative studies on children's nutritional status presented national data by bio-demographic and socioeconomic characteristics and found consistent pattern of underweight and stunting. Correlates for both indicators were about similar, for example, in children whose birth order was 6 or higher, who were born after a short birth interval (<24 months), whose mothers had received no formal schooling, who lived in households without a radio, who drank well or public tap or surface water. Very few countries showed exceptions to this pattern (Sommerfelt and Stewart, 1994). While Zere and McIntyre (2003) by looking at the living standards and measurement survey in South Africa found that income-related inequalities were strongest in stunting.

If local factors have such a strong influence on the relationship of underweight and stunting, then one could conclude that only national regression equations should be developed provided there are sufficient data. Victora et al. (1998) have made such an attempt with data from Brazil. However, only few countries will ever be able to derive equations of sufficient strength, and in order to do so they first need to measure children's length and height, which somewhat defeats the purpose.

In interpreting the findings, one also needs to consider the difference in nutritional status by regions at one year of age, the age group examined in this analysis. Children born with LBW and/or intrauterine growth retardation (IUGR) are known to only catch up partially in growth during the first one or two years of life, and after that maintain their achieved place in the distribution (Martorell et al., 1998). Incidence patterns of LBW vary by geographical regions, and approximately 15 million LBW babies are born in Asia every year (de Onis et al., 1998). Regions with high prevalence of LBW are likely to experience high prevalences of underweight and stunting. IUGR has an important impact on morbidity in early life, particular in increasing the child's risk of diarrhoeal diseases and pneumonia (Ashworth, 1998). These diseases, in turn, are known to affect child malnutrition and early growth. Other important factors at the individual level with a high impact on impaired child growth are a low rate and short duration of breastfeeding.

Like in any analysis, the development of predictive models depends primarily on the quality and quantity of data used. Although the WHO Global Database on Child Growth and Malnutrition is probably the most comprehensive collection of child malnutrition prevalence estimates, the survey data included in this analysis nevertheless varied based on different survey methodology and rigor applied, neither are deemed representative for the regions. Particularly, the above-mentioned problems in collecting accurate and precise length and height data could have lead to measurement errors that biased the correlation. The number of survey data points for some subregions was small and the inclusion of data records in the analysis was limited to those with estimates of both % underweight and % stunting.

That the age group of one year olds showed the strongest correlation is not surprising, considering that this is the time when underweight reaches its peak—paralleling the nutritional change that young children experience during the weaning and post-weaning phase—after which growth velocity follows the normal pattern (Shrimpton et al., 2001).

The results of this analysis demonstrate that, generally speaking, underweight cannot be recommended as a proxy for stunting. Regression equations may be applied where child stunting is unavailable only in those subregions with a sufficiently strong and stable correlation, i.e. in the subregions of Asia, or else may be developed on a national level. It is recommended to always present

confidence limits to reflect uncertainty of the estimates when using these simplified equations to derive a stunting prevalence. However, the only way to get a valid estimate of the prevalence of child stunting, is to actually measure length and height and assess these indices relative to the age and sex of the child.

The forthcoming launch of the WHO child growth standards in 2006 is expected to give a fresh impetus to growth monitoring, and these results contribute to a timely appeal for the collection of comprehensive data on children's height and weight to derive informative indicator estimates of nutritional status. In order to better understand the etiology and potential causes of child malnutrition, it is important to look at different indicators. Stunting, in particular, because of its capacity to measure cumulative inadequate health outcomes, is an ideal indicator of health inequity. Knowing where high levels of child stunting (and underweight) are located will facilitate appropriate action and preventive measures to avoid further deprivation. Length and height data will additionally enable the calculation of the body mass index (BMI)-for-age, an indicator that is expected to become crucial in monitoring child and adolescent overweight.

The legacy of malnutrition is a huge obstacle to overall national development. Further research is needed on the factors that determine change in malnutrition prevalence over time. Child stunting provides additional vital information to underweight; etiologically it is different from underweight, and its causal factors are highly associated with chronic poverty and deprivation. In order to tackle poverty we need to establish the causes of child stunting and define the best approaches to prevent and control it early in life.

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ABSTRACT Percentage of stunting in children is more informative than % underweight as the latter cannot distinguish between wasting (low weight-for-height) and stunting (low height-for-age). Yet, stunting is less often assessed than underweight due to practical problems in measuring length and height. Given that experts commonly cite a high correlation between child underweight and stunting, we developed a methodology to estimate child stunting on a population level, and examined its strength and weaknesses. Extracted survey data of the WHO Global Database on Child Growth and Malnutrition with both underweight and stunting estimates formed the basis of this analysis. We developed simple regression models using least squares method based on 604 records from 122 countries. The explanatory variable was % underweight (weight-for-age <2 standard deviations of the NCHS/WHO reference population). The analysis focused on children 12-23 months old, sexes combined, since this age group showed the strongest correlations across regions and had similar slopes. Resulting regression equations showed sufficient ($r^2 \geq 0.70$) and consistent strength over time only in the regions of Asia. Empirical data reflect the expected relationship between child underweight and stunting prevalences in few regions only. Reason for this lack of correlation could be distinct determining factors related with a specific regional and/or local context. We conclude that the best way to get reliable estimates of child stunting is to measure length and height.

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