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Cross-sectional anthropometry: what can it tell us about the health of young children?

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Abstract

It has become common practice in health surveys to collect anthropometric measurements from young children. These datasets comprise one-point-in-time measurements for a number of children, and are very different in character from longitudinal data such as those collected during growth monitoring. This paper explores the nature of cross-sectional data, their applications and their limitations, using sample data from Burundi, Uganda and Zimbabwe. Methods of analysis which treat the data as continuous or dichotomous are compared. The conclusion is that cross-sectional data can make a valuable contribution to health research provided their application and interpretation are properly understood.

The collection of body measurements, or anthropometry, has become a basic tool for monitoring the health of young children. The reliability of weight gain as an indicator of child health is widely recognized, and major episodes of illness are almost invariably associated with loss of weight. Prolonged growth faltering precedes most child deaths.

Growth monitoring usually involves weighing individual children during a series of visits to a health facility so that weight increases can be tracked over time. Health workers throughout the world record weights of infants and children on growth charts which compare their progress with the expected range for their age. Having less than the expected range of weight or weight gain indicates failure to thrive and the need for special care. Weight, rather than length or height, is the preferred measure for growth monitoring of infants as height increases more slowly and is difficult to measure accurately in small children, but height for age also is taken into account when the health status of both infants and young children is assessed.

In recent years it has become increasingly common to use survey techniques to collect a single round of anthropometric measurements from a large number of children. In some instances this may be a practical exercise to identify children most in need of nutritional supplementation when there is a critical food shortage, or to determine the prevalence of poor growth attainment. For example, Beaton et al. (1990:17) recommend one-time screening in emergency situations to identify individuals requiring immediate attention in order to survive, and in non-emergency situations, individual one-time screening can be used to identify children in need of immediate nutrition or health intervention. In other instances cross-sectional anthropometry is collected to support health-related research, as in the case of the Demographic and Health Surveys (DHS), which also gather information on a wide range of other health issues and socio-economic, demographic and environmental characteristics. In these cases the anthropometric measurements are intended as an indicator of a child's nutritional and health status.

Cross-sectional data, however, are very different from data collected longitudinally over time to monitor the growth of individuals, and cannot be interpreted in the same way. Indeed, because there is only one measurement for each child, some would argue that one-off, cross-sectional measurements are of little value other than as a rough method of identifying cases for intervention in emergency situations.

This paper considers the nature of cross-sectional height and weight data for children aged up to five years, and compares their use and interpretation with that of longitudinal data. Approaches to the analysis of cross-sectional data also are discussed. Examples are drawn from three DHS cross-sectional data sets, for Burundi, Uganda and Zimbabwe, to give an appreciation of cross-national similarities. These surveys were carried out between 1987 and 1989 as part of the first round of DHS. The choice of countries was primarily because of the availability of DHS I data, their regional proximity and several common features[1].

Measuring growth attainment

Child growth is determined primarily by food intake, genetic potential and the experience of infection, and may be affected by other factors, such as stress and exercise levels (Ferro-Luzzi 1984; Mata 1985:165; *Nutrition Reviews* 1988:217; Tomkins and Watson 1989:30). Height and weight are thus measures of growth attainment rather than nutritional status, since more information is required to distinguish the effects of nutrition from other factors. For example, in the short term some forms of micro-nutrient deficiency may not manifest as impaired growth (see Fidanza 1991). Although malnutrition is a major cause of short stature, it also may be inherited or due to congenital dwarfism, chromosomal disorders, inter-uterine growth retardation, hormonal deficiencies or chronic diseases (Ebrahim 1978:7). Genetic variation in size between children of the same age is expected within any population (Mora 1985:270), and there is usually a normal distribution of height and weight across samples of children of any given age. Within any given population healthy children of different ages are expected to be of different sizes, and some variation also is expected between children of the same age. At the same time, all healthy children are expected to increase progressively in dimensions and weight until they reach adulthood.

It is therefore essential to understand thoroughly the nature of child growth before drawing conclusions about nutrition or health from cross-sectional anthropometry. On the one hand, even with clinical assessment, it is virtually impossible to determine from one-time measurement the relative contributions of nutrition, genetics, infection and other factors to the growth attainment of an individual child. Nevertheless, it is possible to make some judgements about nutrition and health at the population level from large samples of cross-sectional measurements.

Because there are obvious ethnic variations between adults, many people find it difficult to accept the fact that children of different ethnicities have the potential to achieve similar levels of growth attainment in the first few years of life. Research has shown, however, that ethnic differences become established at puberty rather than in early childhood (Falkiner 1986:125). Eveleth and Tanner (1976) concluded from an examination of data from some 50 studies that, before puberty, greater differences exist between ethnic groups living in different environments than between different ethnic groups in the same environment. They also found

[1]Africans constitute the majority of the population in all three countries, with each having at least two major ethnic groups. All three have a substantial population growth rate with a large proportion of the people dependent on subsistence or semi-subsistence cultivation. Each has experienced colonialism, and each suffered major civil conflict at some time in the decade preceding the survey, which had an impact on living standards and health services.

that environmental differences can affect the timing and magnitude of adolescent growth spurts. There was little difference in height between 16-year-old boys and girls in African tribal groups, whereas Afro-American boys had already experienced their adolescent growth spurt and were 9 to 10 cm taller than 16-year-old Afro-American girls.

Similarly, Habicht et al. (1974) concluded from their study of well-nourished children from different ethnic backgrounds that nutrition generally has a much greater effect on growth attainment in the first few years of life than does ethnicity. They found that the effect of ethnicity was so small compared to that of nutrition and environment that it was reasonable to use height and weight standards drawn from well-nourished white populations to compare with samples of children from other populations. In most developing countries poor growth attainment is due to both malnutrition and repeated infection rather than to malnutrition alone. It is widely recognized that there is a synergy between malnutrition and infection which increases their effect when they occur together (see various research reports in Tomkins and Watson 1989). Differences between populations therefore justify the use of cross-sectional anthropometry at the population level as a proxy for the extent of nutrition and infection, but not for one without the other.

The evaluation of growth attainment requires the use of a reference standard which allows for normal variation at any age. The same standard may be used for both cross-sectional and longitudinal anthropometry, at either the individual or the population level. The World Health Organization / National Center for Health Statistics / Center for Disease Control (WHO/NCHS/CDC) reference data are widely recommended for this purpose and for evaluating the efect of nutritional programs (Waterlow et al. 1977:490; WHO 1986:937; Behrens 1991). There are a number of other internationally recognized reference standards, such as the Harvard data, which were collected before the WHO/NCHS/CDC data, and some countries have developed their own standards. This paper refers only to the WHO/NCHS/CDC data, which have become the most popular reference. These data were compiled from two samples of well-nourished American children during the 1970s. The complete set of tables comprises the mean weights and heights for every 10th centile, and the 3rd, 5th, 95th and 97th centiles, across the normal distributions for each month of age up to 18 years, separately for males and females.

One limitation of the WHO/NCHS/CDC reference data is that heights and weights below the 10th centile or above the 90th centile were estimated (WHO 1983:61). That is, values below the 10th centile were not derived from observations. In countries such as Burundi, Uganda and Zimbabwe many children cluster at the lower extremes of the reference tables, but the WHO/NCHS/CDC reference values for these groups are not actual population means. Despite this, the WHO/NCHS/CDC reference values are widely used even for populations with a high prevalence of poor growth attainment, because limited funds and lack of time usually prevent the development of a local standard. As will be shown here, the important thing is not the source of the reference data but the way in which they are used.

Since the interpretation of any given height or weight depends on the age of the child, the growth reference curves were transformed into age-standardized normalized growth curves so that children of different ages could be compared. Using these curves, which are considered to be normal (Gaussian) curves at each age, the growth attainment of a particular child can be expressed in three ways: as centiles of the reference distribution, as percentages of the reference median and as standard deviations (SDs) from the reference median. All three indices can be applied to both longitudinal and cross-sectional data. SDs, also known as Z-scores, are the most widely used of the three indices. Their derivation and use is described in detail in Dibley, Goldsby et al. (1987); Dibley, Staehling et al. (1987).

The standardized measurements used most commonly for children are height-for-age (Ht/A), weight-for-age (Wt/A) and weight-for-height (Wt/Ht)[2]. Other measurements not discussed here include Head Circumference (HC), Mid Upper Arm Circumference (MUAC), Skinfold Thickness (SFT) and Body Mass Index (BMI) and various other dimensions discussed in Fidanza (1991).

To allow for normal genetic variation in growth attainment, the convention is to select a cut-off point, below which all children are considered to have low attainment. Cut-off points of minus 2SDs below the reference median in the case of Z-scores (or 80 per cent of the reference median Wt/A and 90 per cent of the reference median Ht/A if percentages are preferred) are widely used to identify cases for intervention or to assess the prevalence of poor growth attainment in developing countries. Children whose height-for-age is very low or below a chosen cut-off point are said to be 'stunted'; very low weight-for-age is 'underweight'; and very low weight-for-height is described as 'wasted'.

Low height-for-age generally indicates long-term past malnutrition. Height deficiencies are usually related to intermittent or continuous inadequate nutritional intake and frequent infection, especially during the first two years of life (Graitcer et al. 1981:292). Low Ht/A is therefore considered a good indicator of chronic malnutrition. It is a very common condition in poorer countries.

Low weight-for-age is associated with current or acute malnutrition or infection. A child who has previously received adequate nutrition, but is currently experiencing a short-term episode of reduced food intake or infection, would typically have normal Ht/A and low Wt/A. When used on its own, Wt/A is a better indicator for children up to age one year than for older children, because weight is obviously related to height. In some African countries up to 50 per cent of young children are stunted, but half of them are within the normal range for Wt/A, and otherwise healthy apart from their small stature.

Older children who have low height-for-age may also have low weight-for-age, even if they are not currently malnourished. In this case, if only one cross-sectional measurement is available, Wt/A alone does not distinguish acute (short-term) malnutrition from low weight associated with smallness of stature or chronic (long-term) malnutrition (Waterlow et al. 1977:491). This limitation of Wt/A applies particularly to cross-sectional data, but less to longitudinal surveys, where repeated measurements are taken and trends can be observed.

Weight-for-height is a more robust indicator, particularly for cross-sectional data, since it allows for stunting. Wasting is considered the best indicator of present malnutrition, and hence is the best proxy for nutritional status. Between ages one and ten years Wt/Ht is nearly independent of age, although when children of the same height who are aged less than one year are compared, the older child tends to be heavier (Waterlow et al. 1977:491).

It is important to note that the choice of cut-off point is optional. Different cut-offs may be selected to suit particular purposes or conditions. For example, in the case of one-time assessment to select candidates for emergency nutritional supplementation the cut-off point may be adjusted to identify the number of children that can be fed with the available budget. The minus 2SDs cut-off point and 80 or 90 per cent of the reference median have become so widely used that their real meaning tends to be forgotten. They do not signify a rigid distinction between one group of children who are adequately nourished and healthy and

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[2]Children up to two years of age commonly have their length measured, as they are placed in a supine position against a measuring board. Older children usually stand upright so that their height is measured rather than their length. For simplicity this paper refers to the 'height-for-age' (Ht/A) and 'weight-for-height' (Wt/Ht) of children of all ages, in preference to the more precise, but cumbersome, 'length-for-age' or 'weight-for-length' for those up to two years of age and 'height-for-age' and 'weight-for-height' only for older children. Similarly, the terms 'length','height' and 'stature' can be treated as interchangeable.

another group who are not. Rather, they are rough boundaries. Above the cut-off point the health and nutrition of most children, but not all, is probably adequate. Below the cut-off point the health and nutrition of many, but not all, is probably a cause for concern.

WHO (1986) argues convincingly that the most commonly used cut-off points, minus 2SDs and 80 per cent of the reference median, may be unrealistic and of limited use. One obvious limitation is that different scales of measurement may focus on different cases. For example, 80 per cent of the reference median weight-for-age is roughly equivalent to a Z-score of minus 2SDs, but the relative proportions of children diagnosed as underweight by the two indicators vary according to age (Waterlow et al. 1977:494).

Keller and Fillmore (1983) found that 27 per cent of a sample of children aged between one and two years had a weight-for-height minus 2SDs or below, but only 15 per cent were below 80 per cent of the reference median. Similarly, Mora (1985) used different data to demonstrate that the actual cases identified by cut-off points for the various indices may differ. It is thus evident that, in the absence of supporting data to indicate trends over time, cut-off points should never be regarded as making a definitive statement about nutrition and health.

The use of international reference standards based on well-nourished American populations also has led to some debate. One school of thought is that local standards should to be developed, since some countries find it unacceptable, as well as possibly inappropriate, to compare children in developing countries unfavourably with standards drawn from an alien population (WHO 1986:4). Since it is usually impracticable to develop a local standard because of time and cost constraints, such an argument serves only to direct attention away from the more important issue of how to use the reference values correctly.

Recent work by the WHO Working Group on Infant Growth (1995) has shown that the growth of populations of infants fed according to current WHO recommendations is less than expected on the basis of the WHO/NCHS/CDC reference values. The American children from whom the WHO/NCHS/CDC reference values were derived were mainly bottlefed, whereas WHO recommends exclusive breastfeeding for the first four to six months, after which children should receive appropriate and adequate complementary weaning foods but continue to receive breastmilk up to age two years or more. Relative to the reference values, the mean weight-for-age for samples of breastfed children declined continuously from two to 12 months to a low of almost -0.6 SDs, but thereafter gradually increased and approached the reference median. Differences were smaller for height-for-age and weight-for-height. On the basis of this the Working Group has now recommended a new reference which reflects current health and feeding recommendations (WHO Working Group on Infant Growth 1995:173).

Although this would improve the validity of the WHO/NCHS/CDC reference values for breastfed children, it does not mean that they cannot be used in their present form. Waterlow et al. (1977:490) argued that the reference values should be used only as a yardstick and not a target. WHO (1986:4) suggested that if attainment of the reference standards is unrealistic they could serve as a hindrance to practical planning, and recommended that local 'norms' should be set, such as 95 per cent rather than 100 per cent of the international reference value.

As discussed above, poor growth attainment in young children is usually caused by malnutrition and infection as a result of socio-economic disadvantage, rather than by differences in genetic potential (Habicht et al. 1974; Pelletier 1991). This is a compelling argument in favour of using the WHO/NCHS/CDC reference values as at least an approximate target for children in all countries until another standard becomes available, since the difference due to breastfeeding is only small. The most important thing is to draw attention to the fact that substantial shortfalls in child growth attainment at the population level indicate socio-economic disadvantage and a need for nutrition and health interventions.

Weight charts based on international reference standards have been used very successfully throughout the world to measure the progress of individual children in both developed and developing countries. Weight charts, however, indicate growth trends. The following section of this paper explores the application of the WHO/NCHS/CDC international reference standard to cross-sectional anthropometric data when only a single set of measurements is available for each child.

Anthropometric patterns and correlations in cross-sectional data

As discussed above, an obvious limitation of data from one-off cross-sectional anthropometric surveys is that they cannot be used to draw firm conclusions about the health status of individual children because they give no indication of growth trends. This is especially so in countries where large proportions of otherwise healthy children are stunted. For example, whereas a child who has normal height-for-age and low weight-for-age would probably be a cause for concern, a child who is minus 2SDs below the reference median for both Wt/A and Ht/A at the time of survey could be a previously healthy child who has become ill and is losing weight rapidly; a previously unhealthy child who is experiencing a period of healthy weight gain; or a genetically small child who has been consistently stunted and underweight with respect to the reference median since birth. Only a series of measurements over time can provide sufficient information to allow reliable judgements to be made at the individual level.

Since sample surveys are designed to portray population rather than individual characteristics, this limitation is somewhat irrelevant. A more important question is whether limitations at the individual level prevent the drawing of valid conclusions about growth patterns at the population level. The answer is that cross-sectional data are as useful as longitudinal data for population-level analysis, and in several respects are superior.

One major advantage of one-off cross-sectional surveys compared with longitudinal studies is that data can be gathered from relatively large samples at relatively little cost. It is therefore possible to explore mean growth attainment at different ages, using data for a large number of children at one point in time rather than data for a small number of children at different points in time. Greater sample sizes give cross-sectional data the advantage of being more likely to be nationally representative. Cross-sectional surveys also are able to collect data on a wider range of topics, such as detailed information on socio-economic, demographic and environmental characteristics of respondents, which can be related to patterns of growth attainment. To demonstrate the validity of cross-sectional anthropometry at the population level the next section compares the patterns depicted when sample means for one–month age groups are compared with the reference values.

Patterns of distribution

The DHS samples for Burundi, Uganda and Zimbabwe are large enough to depict nationally representative patterns. The survey respondents were women aged 15-49, and the target population for weighing and measuring were all children aged from three months to 36 months in Burundi, all children from birth to 60 months in Uganda and all children aged from three months to 60 months in Zimbabwe, at the time of the interview. Table 1 gives details of the sample of measured children. A smaller percentage were missed in Burundi, as the target age limit was lower and young children are more likely to be with their mothers.

Table 1
Selected characteristics of measured children

	Burundi		Uganda		Zimbabwe	
	%	N	%	N	%	N
Child's age (months)						
0-5	12.1	*230*	13.2	*486*	7.5	*177*
6-11	22.3	*424*	13.1	*485*	10.6	*251*
12-17	16.6	*317*	12.5	*461*	11.9	*281*
18-23	15.1	*287*	10.1	*373*	10.8	*254*
24-29	18.3	*349*	9.7	*357*	11.6	*274*
30-36	15.6	*298*	9.2	*339*	9.8	*232*
36-47			17.4	*644*	18.1	*428*
48-60			14.8	*546*	19.7	*465*
	100.0	*1905*	100.0	*3691*	100.0	*2362*
Child's sex						
Male	50.7	*967*	49.3	*1821*	50.2	*1185*
Female	49.3	*939*	50.7	*1870*	49.8	*1177*
	100.0	*1906*	100.0	*3691*	100.0	*2362*
Mother's age (years)						
15-19	0.8	*16*	8.7	*320*	5.2	*122*
20-24	18.6	*354*	25.2	*931*	23.3	*550*
25-29	31.3	*596*	28.0	*1035*	26.5	*627*
30-34	24.4	*465*	18.3	*675*	21.8	*515*
35-39	15.8	*300*	12.7	*468*	14.1	*333*
40-44	6.3	*119*	5.5	*203*	6.4	*150*
45-49	2.8	*54*	1.6	*59*	2.8	*65*
	100.0	*1904*	100.0	*3691*	100.0	*2362*
Mother's education						
None	80.3	*1530*	42.0	*1548*	18.5	*436*
Primary	17.1	*326*	50.2	*1854*	64.6	*1527*
Secondary +	2.6	*50*	7.8	*288*	16.9	*399*
	100.0	*1906*	100.0	*3690*	100.0	*2362*
Mother working for money						
No	96.0	*1828*	91.8	*3377*	80.7	*1905*
Yes	4.0	*77*	8.2	*302*	19.3	*457*
	100.0	*1905*	100.0	*3679*	100.0	*2362*
Husband's education						
None	59.5	*1028*	17.2	*606*	11.3	*243*
Primary	35.3	*610*	61.6	*2174*	60.1	*1290*
Secondary +	5.2	*89*	21.2	*748*	28.6	*615*
	100.0	*1727*	100.0	*3528*	100.0	*2148*
Place of residence						
Rural	97.0	*1847*	8.9	*330*	76.7	*1811*
Urban	3.0	*58*	91.1	*3361*	23.3	*551*
	100.0	*1905*	100.0	*3691*	100.0	*2362*
Drinking water source						
Well	55.8	*1063*	48.6	*1795*	49.0	*1150*
Piped	1.4	*26*	6.7	*248*	38.1	*893*
Surface,other	42.8	*816*	44.6	*1648*	12.9	*303*
	100.0	*1905*	100.0	*3691*	100.0	*2346*
Toilet facility						
None	4.1	*78*	16.9	*624*	42.4	*1000*
Flush	1.3	*24*	2.6	*97*	25.9	*611*
Pit, other	94.6	*1804*	80.5	*2970*	31.7	*749*
	100.0	*1906*	100.0	*3691*	100.0	*2360*

Note: Total number of cases may vary because of non-response.

Figures 1, 2 and 3 show the height-for-age, weight-for-age and weight-for-height distributions for Burundi, Uganda and Zimbabwe. Although the age range of children for whom data are available varies between the three countries, only children aged 3-36 months are included in these figures, so they are exactly comparable.

Figure 2: DISTRIBUTION OF WEIGHT / AGE, AGES 3-36 MONTHS

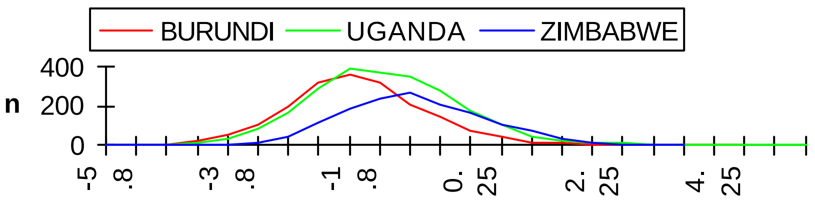
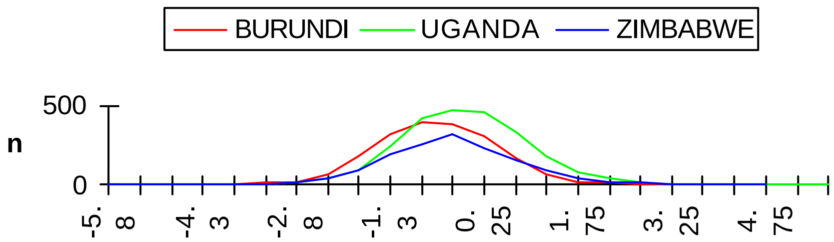


Figure 3: DISTRIBUTION OF WEIGHT / HEIGHT, AGES 3 - 36 MONTHS



It is apparent that the distributions for all three indicators in each country are close to a normal curve in shape, but those for Ht/A and Wt/A are noticeably displaced to the left of the reference median. That is, there is the expected normal variation in weight and height across the population, but the level is low in relation to the reference median. The patterns thus indicate that a large proportion of the sample has failed to achieve the reference median height and weight for their age. Zimbabwe appears slightly advantaged in both Ht/A and Wt/A compared to Burundi and Uganda, which is consistent with its better economic status.

In all three countries the curve for weight-for-height is closest to the reference median. The modes for both Uganda and Zimbabwe are close to zero, with that for Burundi displaced slightly more to the left, with a mode of approximately minus 0.75 SDs. This pattern reflects the high-risk nature of low Wt/Ht, which usually indicates growth faltering. Whereas children may remain stunted or underweight for long periods of time, often throughout their lives, wasting tends to be a more transient condition because wasted individuals are likely to deteriorate further and die, or else to recover and gain weight.

Table 2
Percentage of singleton children stunted, underweight or wasted [a]

	Stunted %	Underweight %	Wasted %	N
Burundi	47.9	37.9	5.7	*1906*
Uganda	43.8	25.3	2.3	*2386*
Zimbabwe	29.9	12.6	1.2	*1514*

[a]Defined as 2SDs or more below the reference median.

Table 2 gives the percentages of children in Figures 1,2 and 3 who would be classified as stunted, underweight and wasted when minus 2SDs is used as the cut-off point. It can be seen that stunting is the most prevalent condition among children aged 3- 36 months in all three countries. Fewer children are underweight, and only a very small percentage are wasted. It is interesting to note that in these data sets virtually all of the underweight children were also stunted, signifying that they were suffering from both chronic and acute malnutrition. As is the case in most countries, wasting is uncommon, but most prevalent among children aged 12 - 23 months, the age at which weaning usually occurs. Even in this age group the percentages with this condition are small: 10.1 per cent in Burundi, 3.8 per cent in Uganda and 1.9 per cent in Zimbabwe.

Since, as discussed above, weight-for-height is the best indicator of present malnutrition, the low prevalence of wasting limits the extent to which anthropometric indicators can be used as proxies for current nutritional status. Because there tend to be fewer wasted children at any point in time, much larger samples would be needed to explore the correlates of this condition. The remainder of this paper therefore focuses only on patterns and correlates of Ht/A and Wt/A in the three countries.

As the cross-sectional data in Figures 1,2 and 3 show approximately the normal distribution expected in any population, it is reasonable to compare the means for each age with the reference median. Figures 4, 5 and 6 depict the mean Z-scores for Ht/A and Wt/A separately for males and females in relation to the reference values, which are represented as a straight line index. All measured children are included in these figures, that is, ages 3-36 months for Burundi, birth to 60 months for Uganda and 3-60 months for Zimbabwe.

Figure 4a: Burundi: mean height-for-age in standard deviations from reference median, males and females aged 3-36 months

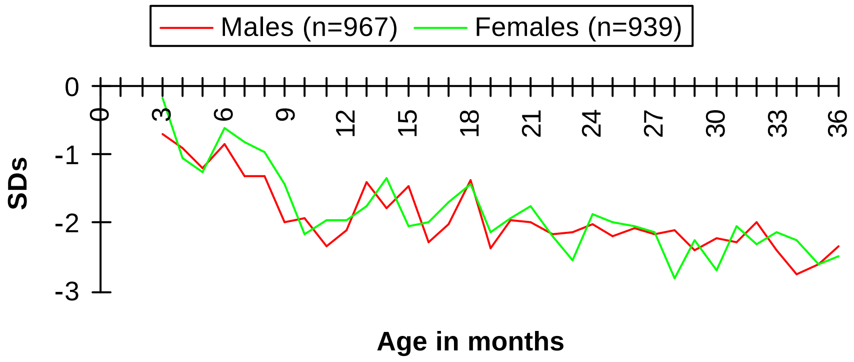


Figure 4b: Burundi, mean weight-for-age in standard deviations from reference median, males and females aged 3-36 months

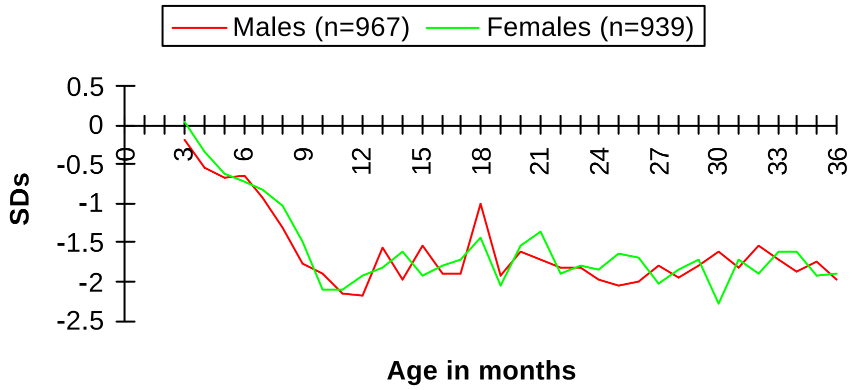


Figure 5a. Uganda: mean height-for-age, males and females aged 0-60 months (standard deviations)

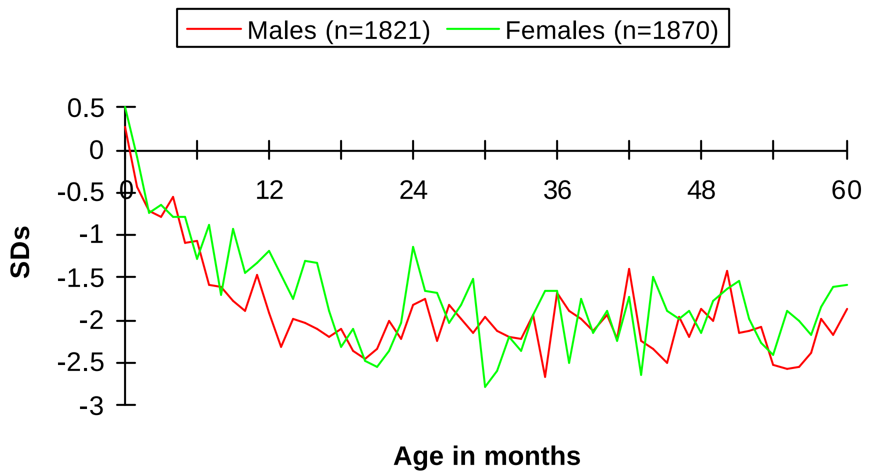


Figure 5b. Uganda: mean weight-for-age, males and females aged 0-60 months (standard deviations)

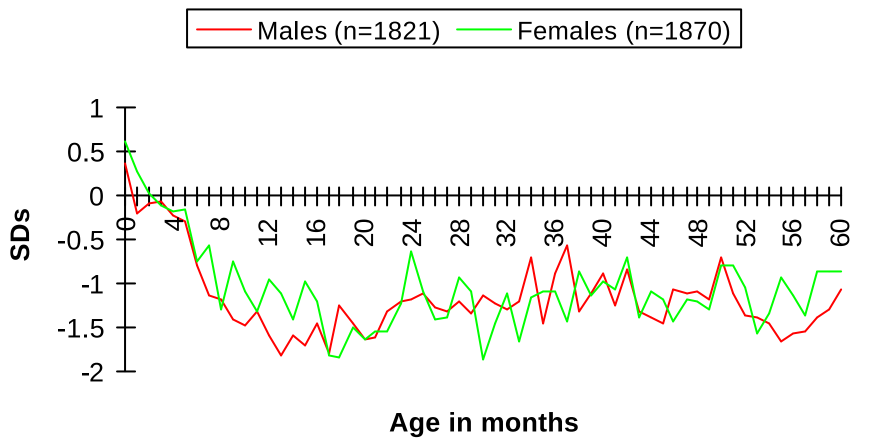


Figure 6a. Zimbabwe, mean height-for-age, males and females aged 3-60 months (standard deviations)

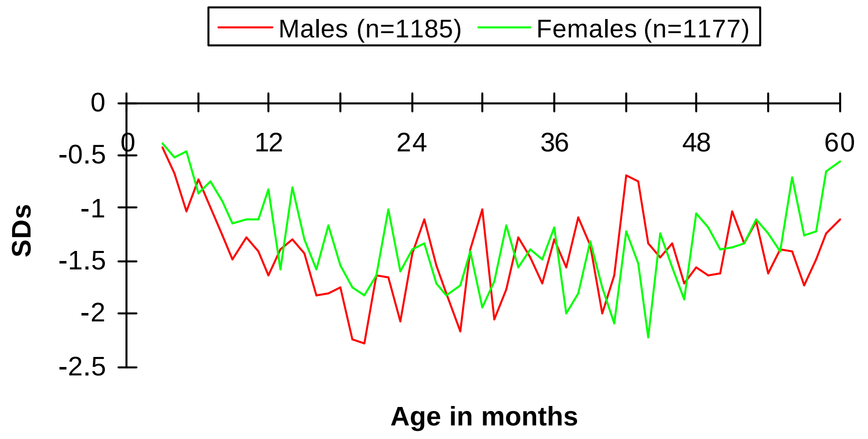
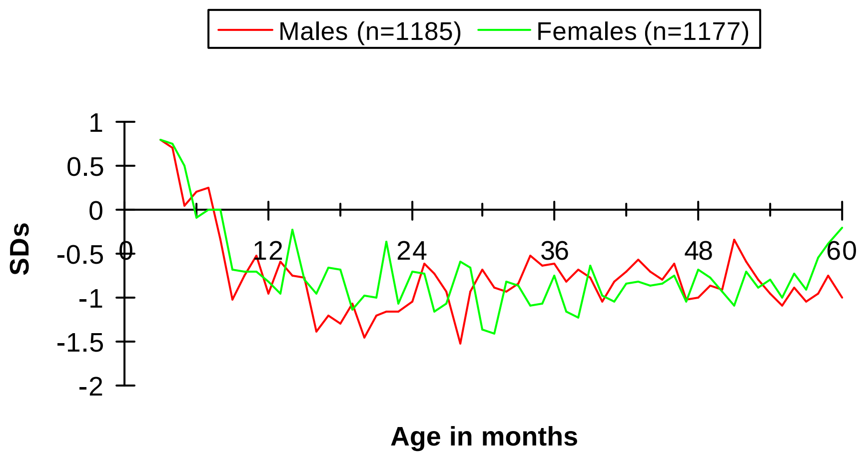


Figure 6b. Zimbabwe: mean weight-for-age, males and females aged 3-60 months (standard deviations)



A strikingly consistent pattern can be seen. In each country the means for both Ht/A and Wt/A start out close to or even above the reference median, but deteriorate sharply over the succeeding 12 months or more as age increases. The curves are similar in all three countries, even though there is some fluctuation as a consequence of relatively small samples at each age[3].

It is obvious from the jagged nature of the plotted curves that they are synthetic trend lines comprising mean values from many different cases, in contrast to a real trend line of longitudinal data from a single case. The synthetic nature of such curves should be borne in mind even when cross-sectional samples are so large that the curves appear smooth. But even though they are synthetic, the implications of these patterns are considerable. They signify that at birth and at very young ages these samples are comparable with the reference values; that is, with well nourished populations of American children. In the succeeding months, however, they grow more slowly than the reference population, and the mean values slip ever further below the reference values until around 24 months, when they begin to level out. The cause of this inferior growth attainment at the population level is obviously not due to any ethnic differences in growth potential, or the distance from the reference values would be more or less the same at all ages. Rather, it is a result of socio-economic disadvantage, manifesting as malnutrition and infection.

Clearly, cross-sectional data are valuable for, and ideally suited to, portrayals of this nature, but the information they give is not the same as that yielded by longitudinal data. To identify similar patterns of mean growth attainment with age from longitudinal data, it is necessary to treat observations at each age as individual cases, and to calculate means for the observations at each age; that is, effectively to convert longitudinal observations into cross-sectional observations. However, since longitudinal data include a time dimension, they depict a growth history. This is different from a cross-sectional snapshot, which, as a composite of data from children of different ages at one point in time, may not equate with either the sample mean growth history or the growth history of any individual child.

The extent to which longitudinal data mirror actual historical trends in growth depends on the age distribution of the sample. For example, ten-year longitudinal data for a cohort of Zimbabwean children who were all born in 1975 might show very poor mean growth attainment at ages one to five years, because of social disruptions and nutritional deprivation in the period before independence was achieved in 1980. However, if such data were from a continuing longitudinal survey of children born between 1975 and 1985, better growth attainment of children born after 1980 might cancel out the poor growth of children born during the war, and so reduce evidence of historical trends in nutrition. To some extent cross-sectional data also are able to reflect historical trends such as periods of food shortage, in that some cohorts have poorer mean growth attainment than others. Such events would tend to become increasingly less evident as they recede into the past and there is opportunity for ‘catch-up’ growth to occur.

It is thus necessary to consider the distribution of birth dates and ages in both longitudinal and cross-sectional samples in order to be sure what they depict. It must also be remembered that, as mentioned above, longitudinal observations are likely to be based on a relatively small sample of children compared with most cross-sectional surveys, and so are less likely to be nationally representative.

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[3]The sample size at each one month of age ranges from a maximum of 97 children aged 11 months in Uganda to a minimum of 23 aged 44 months in Burundi, with an average of 30 to 40 children at each age.

Correlations

The identification of the correlates of poor growth attainment is important for planning effective health policy. Health planners need such information to plan and set priorities for intervention strategies to improve child health, and to assess the effect of interventions. At the population level cross-sectional data can be used to plan long-term health and nutrition interventions. In this case, poor growth attainment is regarded as a proxy for inadequate diet, infectious disease and detrimental socio-environmental factors (Beaton et al. 1990:18). Cross-sectional surveys are the preferred approach to collecting such data because large, representative samples and information on a range of topics can be obtained in a short time and generally more cheaply than setting up and implementing long-term longitudinal studies.

One important limitation of cross-sectional data in the context of health surveys, however, is that, unlike longitudinal surveys, they do not support assessment of the direct effect of a particular episode of illness on growth attainment. The DHS surveys for Burundi, Uganda and Zimbabwe asked mothers if their children had suffered from diarrhoea in the preceding 24 hours or two weeks, and if they had suffered from a cough, respiratory problems and fever in the past four weeks. Analysis of the data showed no consistent statistically significant associations between reports of illness and stunting, underweight or wasting. This is partly because the questions about illness relied on the respondent’s perception of illness rather than on clinical diagnosis, and no attempt was made to assess the severity or duration of the episode. On the other hand, even such limited reports of illness would probably show some association with growth trends in longitudinal data.

The main reason for the limited associations in the cross-sectional data is that illness usually has a very direct effect on growth. Growth may slow or stop when children are sick, but resume when they recover. The assessment of the impact of illness on growth attainment thus requires knowledge of individual growth trends, which cannot be determined from a single measurement. For this reason cross-sectional measurements are unlikely to reflect a consistent relationship with reports of illness, whereas a series of measurements obtained at different points in time are very likely to demonstrate a direct causal relationship between episodes of illness, especially diarrhoea, and growth.

On the other hand, it is reasonable to use cross-sectional data to analyse the correlation of socio-economic, demographic or environmental factors with poor growth attainment. Since the association is less direct, population-level patterns are likely to reflect an association with these factors. Even so, the method of analysis selected can affect the results. In particular, the use of a cut-off point to classify cases may blur the association because the causes of the growth attainment of children in the two groups are not uniform.

As discussed above, cut-off points may be an essential tool to facilitate practitioners’ judgements about a particular child’s condition, and as a quick way of identifying cases for intervention programs. They also are obviously convenient to distinguish groups of cases, and to summarize data in written reports. However, it has become common practice to use cut-off points to transform Z-scores or percentages of the reference median into dichotomous dependent variables so that odds ratios can be estimated with logistic regression models. In many such studies the only other presentation of the anthropometric data is in cross-tabulations, also using cut-off points (for example, Choudhury and Bhuiya 1993; Katz 1995; Timaeus and Lush 1995).

Given the nature of cross-sectional data and their limitations at the individual level, analysis based on cut-off points should be used only in conjunction with other analytical techniques which give a picture of growth attainment patterns across the whole sample. Pelletier et al. (1994:2085S, 2087S) consider that relative-risk analysis is an unreliable basis for comparing the predictive value of various anthropometric indicators. They point out that the results are highly sensitive to the choice of cut-off points, and that categories are not strictly comparable across indicators

One argument advanced by some researchers who favour cut-off points and dichotomous variables is that their data are too unreliable to use at the individual level (for example, Gaminiratne 1991). However, this approach still makes the questionable assumption that the data are sufficiently reliable to allow meaningful classification to either side of a cut-off point, and that there are real differences between the children on either side. Moreover, even when cases are reclassified into groups, the statistical procedures for analysing growth attainment operate on individual cases. Yip and Scanlon (1994:2044S) comment:

> In reality , the risk of undesirable outcomes including mortality does not change drastically when crossing the magic cutoff point. The only certain part of risk prediction in using the distribution of specific health or nutrition parameters as a guide, such as weight-for-age, is that the farther away from the central part of a distribution the greater the likelihood of true disease or poor outcomes.

In view of this, a better approach to the analysis of cross-sectional data is to treat anthropometric indicators as continuous variables, and to focus on patterns of covariation rather than on the odds of being in one discrete category rather than another. Linear regression is a suitable analytical technique for this purpose, with categorical independent variables converted into dichotomous dummy variables. This approach is consistent with the recommendation of Yip and Scanlon (1994:2045S) that it is important to look at the characteristics of the entire population when determining factors associated with adverse outcomes. Examples of authors who have used Z-scores or percentages as continuous variables include Sommerfelt (1991), Desai (1992) and Thomas (1993).

To demonstrate the difference between the two approaches, logistic regression models which treat Ht/A and Wt/A as dichotomies are compared here with linear regression models which treat Ht/A and Wt/A as interval variables. The conventional Z-score cut-off point is used in the logistic regression models, that is, above minus 2SDs and minus 2SDs or more below the reference median. The data are for Burundais children aged 3-36 months. Table 3 lists the variables tested for inclusion in both models, and their reference categories in the logistic regression models. Duration of breastfeeding, ownership of a refrigerator, immunization status and some other variables were not tested because there was no significant association in bivariate tabulations. In the linear regression models categorical variables were converted into dummy variables. Tables 4 and 5 present the results of the analysis.

The very low r^2 values in the linear regression model are to be expected, because Z-score data are age standardized. Moreover, several important factors which have a direct bearing on growth, such as genetic potential, experience of illness and food intake, were either not available in the data sets or lacked sufficient detail to be used. When the raw, unstandardized heights and weights of these children were regressed against age, 72 per cent of the variation in height and 61 per cent of the variation in weight were explained by variation in age. The models in Tables 4 and 5 therefore relate only to that portion of the variation which is not accounted for by age standardization. The inclusion of child's age in these models is to explore variation in Z-scores as age increases, as opposed to absolute variation in height and weight as age increases. The use of child's age squared in addition to child's age in both approaches is simply a device to fit the curvilinear pattern of variation with age, as depicted in Figure 4.

Table 3
Burundi: Variables tested in models and reference categories for logistic regression

Child's age	*Interval*	Mother's education	None
Antenatal tetanus	No	Mother's literacy	No or weak
Antenatal care	No	Husband's education	None
Dead sibling	No	Husband's literacy	No or weak
Birth order	*Interval*	Husband's occupation	Agriculture
Preceding birth interval	24-35 months	Water source	Well
Succeeding birth interval	None	Distance to water	*Interval*
Electricity	No	Toilet facility	Pit latrine
Sex of child	Male	Number in household	*Interval*
Mother's age	*Interval*	No. of children under 5yrs	*Interval*
Region	Central Plateau	Immunization	None
Residence	Rural	Heard of oral rehydration	Yes

It must be appreciated that the two models presented here look at growth attainment from different perspectives. The logistic regression model in Table 4 looks at the odds of cases in various categories being 2SDs or more below the reference median. That is, an odds ratio of less than one indicates lower odds relative to the reference category for that variable, and a value greater than one indicates higher odds. The linear regression model in Table 5 looks only at covariation of the dependent and independent variables. A negative B value indicates that a factor is negatively associated with growth attainment, while a positive value indicates the reverse.

It can be seen from Tables 4 and 5 that in both approaches similar variables are significantly associated with Ht/A and Wt/A. In the linear regression model, however, the use of dummy variables to represent individual categories of a single variable allows a wider range of factors to remain significant, including electricity in house, no soap in house and having a dead sibling. Child's age, region, and preceding or succeeding birth interval feature in both models for Ht/A. However, only Imbo region is significant in the linear regression model, while seven categories of husband's occupation are replaced by a dummy variable indicating that the husband has secondary education.

The strength of the association of birth interval with growth attainment is evident in the appearance of three out of the four categories in the linear regression model. The positive rather than negative association of a short succeeding birth interval probably reflects a bias towards older ages and a slight catch-up effect in growth among the few children in this very young sample who actually have a succeeding birth interval.

In the logistic regression model for Wt/A only child's age, region and preceding birth interval are significant. As before, a wider range of factors appear in the linear regression model, including electricity in the house, and no soap in the house, along with two regions, rather than one, and three birth interval categories. A comparison of the two approaches for Uganda and Zimbabwe, which is not shown here, yielded comparable results, with similar variables in both models, and an even wider range of significant categories in the linear regression model.

Table 4
Burundi: Relative risk of being 2SD or more below reference median

	Estimate	S.E.	Odds	N
HEIGHT/AGE				
Base	-0.4257	0.8755	1.00	*1769*
Child's age	0.1375	0.0269	1.15	
Child's age2	-0.0020	0.0007	1.00	
Husband's occupation				
Agriculture			1.00	*1416*
Prof./Tech./Cler.	-1.0480	0.4085	0.35	*42*
Retailing	-0.2321	0.2032	0.79	*124*
Manufacturing	-0.0606	0.1793	0.94	*161*
Never worked	0.8010	0.7708	2.23	*26*
Region				
Central Plateau			1.00	*988*
Mumirwa	-1.1320	0.8662	0.32	*216*
Mugamba	-1.5260	0.8726	0.22	*171*
Imbo	-0.0421	1.0280	0.96	*126*
Depressions	-1.3570	0.8632	0.26	*268*
Preceding birth interval				
24-35 mths			1.00	*657*
0-23 mths	0.2758	0.1640	1.32	*267*
No previous birth	0.3127	0.1625	1.37	*272*
36 + mths	-0.1418	0.1296	0.87	*573*
WEIGHT/AGE				
Base	-0.1803	1.0780	1.00	*1769*
Child's age	0.2588	0.0291	1.30	
Child's age2	-0.0056	0.0007	0.99	
Region				
Central Plateau			1.00	*988*
Mumirwa	-2.8200	1.0650	0.06	*216*
Mugamba	-2.8410	1.0680	0.06	*171*
Imbo	-1.9710	1.2030	0.14	*126*
Depressions	-2.8000	1.0630	0.06	*268*
Preceding birth interval				
24-35 mths			1.00	*657*
0-23 mths	0.4359	0.1656	1.55	*267*
No previous birth	-0.1442	0.1639	0.87	*272*
36 + mths	-0.0603	0.1332	0.94	*573*

Table 5
Burundi: Multiple regression estimates of covariation with growth attainment

HEIGHT/AGE		B	T	Sign. T
Child's age		-0.0419	-0.137	0.000
Electricity		0.9302	0.031	0.002
Succeeding interval < 24 mths		0.5909	0.042	0.000
Birth order		0.0315	0.020	0.041
Imbo		0.3719	0.030	0.003
Preceding interval < 24 mths		-0.2539	-0.027	0.007
No soap in house		-0.2059	-0.025	0.014
Preceding interval 36 mths +		0.1742	0.024	0.014
Dead sibling		0.1659	0.022	0.030
Husband secondary educated		0.3549	0.022	0.031
Constant		-1.3049	-0.145	0.000
Adj r^2	0.123			
N	1903			
WEIGHT/AGE		B	T	Sign. T
Child's Age		-0.0336	-0.115	0.000
Electricity		0.9669	0.044	0.000
Imbo		0.3696	0.037	0.000
Depressions		0.2311	0.033	0.001
Preceding interval < 24 mths		-0.1896	-0.026	0.009
Succeeding interval < 24 mths		0.3607	0.031	0.002
Succeeding interval 24-35 mths		0.3004	0.029	0.003
No soap in house		-0.1609	-0.024	0.019
Constant		-1.0048	-0.174	0.000
Adj r^2	0.092			
N	1903			

The linear regression model thus conveys more information about the factors significantly associated with growth attainment, while avoiding the necessity of classifying cases to either side of a cut-off point. Although odds ratios derived from logistic regression models are attractive and easily understood, the requirement of a dichotomous dependent variable means that the analysis must be compromised.

Longitudinal data can give a better picture of patterns of correlation and covariance, provided sufficient socio-economic or other variables are available to make the exercise worthwhile. To extract maximum value from longitudinal data, observations for each case should be viewed as trends rather than as individual points, using mean increase in weight or height between particular ages rather than age standardized indices. It can be seen from Figures 4, 5 and 6 that mean growth attainment over time relative to the reference values may not be very informative, unless the means are for short time periods of a few months.

The predictive value of anthropometric indicators can be explored with the relative operating characteristic (ROC) method, as recommended by Brownie, Habicht and Coghill (1986). This method is used in nuclear medicine to compare scanning diagnoses and for comparing the sensitivity and specificity of medical tests, but also is suited to the analysis of normally distributed epidemiological indices. Pelletier et al. (1994) used ROCs in addition to logistic regression to relate nutritional status at an earlier point in time to the risk of subsequent mortality. This approach also could be used to relate nutritional status at two points in time when longitudinal data are available.

Conclusion

The preceding analysis of cross-sectional anthropometric data for Burundi, Uganda and Zimbabwe demonstrates that such data can yield valuable information on patterns of child growth attainment at the population level. Cross-sectional data are particularly useful for depicting national and regional patterns, and for identifying differences between subgroups, such as between males and females. They also can show strong associations with certain socio-economic, environmental and demographic factors. This is essential information for the planning and monitoring of child health interventions, since growth is an essential component of child health. Where large proportions of children have poor growth attainment, child health can be considered to be below the desired standard.

Although they have only very limited value at the individual level, cross-sectional data are useful at the population level, and may even have advantages compared to longitudinal data. For example, a relatively large sample of cross-sectional data may give a more representative portrayal of growth attainment patterns at a given point in time than a series of longitudinal measurements for a small sample. Distributions of the sample may be usefully compared with normal distributions from reference populations, and mean growth attainment at each age provides a useful indication of trends at the population level. Figures 4,5 and 6 provide important information on infant and child growth patterns in Burundi, Uganda and Zimbabwe, indicating clearly that the high prevalence of stunting and underweight in these countries is largely due to slower rates of growth in children up to 18 months compared with the reference population.

It is important to remember, however, that because the growth patterns in cross-sectional data are composite patterns based on many individuals, they depict synthetic trends which may not equate with the observed growth pattern of any particular child. This is in contrast to longitudinal data sets which comprise a collection of observed trends over time.

Cross-sectional data are generally unsuitable for research on the association between growth attainment and recent morbidity in children, because it is not possible to determine a causal association from a single measurement and because morbidity reporting in surveys usually relies on maternal recall rather than exact diagnosis. If there is follow-up to identify subsequent mortality, cross-sectional data may support some research on the association of anthropometric status and mortality, but again a series of measurements, as in a longitudinal survey, would be more useful. Longitudinal data also give a better picture of seasonal variations in nutrition since they show common patterns in the growth trends of individual children.

Aside from these obvious limitations, the biggest problem associated with cross-sectional anthropometric data is the tendency of some users to misunderstand the nature and interpretation of a set of one-off measurements. This has led to a lack of appreciation in some quarters of the utility of such data for evaluating population health, and also to the practice of focusing on cut-off points in data analysis. In the absence of information on growth trends, and because of the possibility of inaccurate measurement, this focus endows cross-sectional data with a spurious accuracy which invites criticism from those accustomed to assessing growth trends at the individual level. As shown in the preceding analysis, techniques which focus on patterns of covariation rather than cut-off points are more appropriate to such data and avoid this criticism.

The utility of cross-sectional anthropometric surveys can be enhanced in several ways. Where possible, second rounds of measurements should be collected from the same children at a later time period, ideally a year or two, thus effectively adding the advantages of longitudinal measurement to a cross-sectional data set. This would allow analysis of growth trends which could be more effectively related to morbidity and health care than can a single measurement. If a second round of measurements is not feasible an attempt should be made to collect birth weights for all measured children. This helps to distinguish those children who were born small from those who have suffered most growth faltering, and allows the calculation of mean growth rates.

If it is not possible to collect a second round of measurements from the same children, a series of comparable cross-sectional samples at, say, five-yearly intervals would help countries to monitor population-level growth trends. A common problem is lack of comparability between different surveys, because of inadequate sample sizes, different measurement techniques or because they are carried out in different regions. Every effort should be made to co-ordinate survey designs to maximize comparability.

Some of the second and third-round DHS surveys collected the heights and weights of mothers in addition to anthropometry of children. This is useful to identify disadvantaged mothers, particularly since adult BMI is a good indicator of nutritional status. However, it would be unwise to use mother's measurements to infer a child's genetically determined growth potential. Mock et al. (1994) found significant but weak correlations between maternal and child anthropometry. Although the specificity generally exceeded 80 per cent, the sensitivity of maternal BMI as a predictor of child anthropometry was very low, below 20 per cent for most indicators. The main value of collecting mothers' measurements in addition to those of children is to identify disadvantage at the household level. While it is a useful addition to a survey and adds another dimension to the analysis, maternal anthropometry is no substitute for a second round of measurements for research on child growth attainment.

Even without a subsequent round of measurements, a single cross-sectional survey can contribute useful information on growth patterns and differentials at the population level. It is, however, essential to understand thoroughly the nature of such data and how their use and interpretation varies from that of longitudinal data. Researchers who have this understanding will find cross-sectional anthropometry a valuable addition to their tool kit for identifying the determinants of the health of young children in developing countries.

References

Behrens, R.H. 1991. Biomedical methods for the assessment of nutritional status in the individual and in communities. Pp. 35-42 in *The Health Transition, Methods and Measures,* ed. John Cleland and Alan G.Hill. Canberra: Australian National University.

Brownie, C., J.-P. Habicht and B.Coghill. 1986. Comparing indicators of health or nutritional status. *American Journal of Epidemiology* 124,6:1031-1044.

Choudhury, Abu Yusuf and Abbas Bhuiya. 1993. Effects of biosocial variables on changes in nutritional status of rural Bangladeshi children, pre- and post-monsoon flooding. *Journal of Biosocial Science* 25,3:351-357.

Desai, Sonalde. 1992. The impact of family size on children's nutritional status: insights from a comparative perspective. Working Paper No 46. New York: Population Council.

Dibley, Michael J., James B.Goldsby, Norman W.Staehling and Frederick Trowbridge. 1987. Development of normalized curves for the international growth reference:historical and technical considerations. *American Journal of Clinical Nutrition* 46:736-748.

Dibley, Michael J., Norman W.Staehling, Phillip Nieburg and Frederick Trowbridge. 1987. Interpretation of Z-score anthropometric indicators derived from the international growth reference. *American Journal of Clinical Nutrition* 46:749-762.

Eveleth, Phyllis B. and J.M. Tanner. 1976. *Worldwide Variation in Human Growth,* London: Cambridge University Press.

Falkner, Frank. 1985. Monitoring growth. Pp.123-137 in *Nutritional Needs and Assessment of Normal Growth,* ed. M.Gracey and F.Falkner. New York: Raven Press.

Ferro-Luzzi, Anna. 1984. Environment and physical growth. Pp.169-198 in *Genetic and Environmental Factors During the Growth Period*, ed. C.Susanne. New York: Plenum.

Fidanza, F. 1991. *Nutritional Status Assessment*. London: Chapman and Hall.

Gaminiratne, K.H.W. 1991. Socio-economic and behavioural influences on child undernutrition in Sri Lanka. PhD thesis, Australian National University, Canberra.

Habicht, Jean-Pierre, Reynaldo Martorell, Charles Yarbrough, Robert M.Malina and Robert E.Klein. 1974. Height and weight standards for preschool children: how relevant are ethnic differences in growth potential? *Lancet* April:611-615.

Katz, Joanne. 1995. Sample-size implications for population-based cluster surveys of nutritional status. *American Journal of Clinical Nutrition* 61:155-160.

Keller, W. and C.M.Fillmore. 1983. Prevalence of protein-energy malnutrition. *World Health Statistical Quarterly* 36:129-140.

Mata, Leonardo J. 1985. Environmental factors affecting nutrition and growth. Pp.165-184 in *Nutritional Needs and Assessment of Normal Growth,* ed. M. Gracey and F. Falkner. New York: Raven Press.

Mora, J.O. 1985. Pitfalls of anthropometry. Pp. 270-273 in *Proceedings of the XIII International Congress of Nutrition,* ed. T.G. Taylor and N.K. Jenkins. London: John Libbey.

Nutrition Reviews. 1988. Parental health beliefs may cause failure to thrive. 46,6:217-219.

Pelletier, David L. 1991. Issues in the collection, analysis and interpretation of anthropometric data in sample surveys. Pp. 1073-1099 in *Proceedings of the Demographic and Health Surveys World Conference, Washington, DC August 5-7, II*. Washington DC: IRD/Macro International.

Pelletier, David L., Jan W. Low, F. Catherine Johnson and Louis A.H. Msukwa. 1994. Child anthropometry and mortality in Malawi: testing for effect modification by age and length of follow-up and confounding socio-economic factors. *Journal of Nutrition* 124,10S:2082S-2105S.

Timaeus, Ian and Louisiana Lush. 1995. Intra-urban differentials in child health. *Health Transition Review* 5,2:163-190.

Thomas, Duncan. 1993. Testing for sectoral differences in child anthropometric status in Zimbabwe:a comment. Center Paper No. 468. New Haven: Economic Growth Center, Yale University.

Tomkins, Andrew M. and Fiona Watson. 1989. *Malnutrition and Infection:A Review*. London: London School of Hygiene and Tropical Medicine.

Waterlow, J.C., R.Buzina, W.Keller, J.M.Lane, M.Z.Nichaman and J.M.Tanner. 1977. The presentation and use of height and weight data for comparing nutritional status of groups of children under the age of 10 years. *Bulletin of the World Health Organization* 55,4:489-498.

World Health Organization (WHO). 1983. *Measuring Change in Nutritional Status*. Geneva.

World Health Organization (WHO). 1986. Use and interpretation of anthropometric indicators of nutritional status. Report of a WHO Working Group. *Bulletin of the World Health Organization* 64,6:929-941.

World Health Organization (WHO) Working Group on Infant Growth. 1995. An evaluation of infant growth: the use and interpretation of anthropometry in infants. *Bulletin of the World Health Organization* 73,2:165-174.

Yip, Ray and Kelly Scanlon. 1994. The burden of malnutrition: a population perspective. *Journal of Nutrition* 124,10S:2043S-2046S.