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Population morbidity screening—practical methodology for small populations

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SUMMARY During a study of the health status of children in rural Nigerian communities a gross lack of fit was observed between the sample and the growth attainment standards derived from local longitudinal data. The degree of misfit was greater in children over the age of 3 years and deteriorated with age thereafter. A very high incidence of tuberculosis seemed to be responsible for the deviation in the sample.

A simple practical methodology is presented, suitable for dealing with small samples: this is an application of the established Z value analysis which may easily be used by a wide variety of personnel.

Assessment of the health status of populations is commonly made by studying fertility, mortality rates, and age/sex structure. These are clumsy, however, and changes affecting only a part of the population may be obscured by the mass of the remainder. Alternatively, morbidity data may be frequently derived from health service utilisation statistics. The first method relies on total population data, and the second on the self selected population who use the health services. It is known that growth attainment is influenced by health, and also that the growth achieved in children is the most sensitive indicator of the health status of any population.[1] There are methods of measuring the relative growth of individuals, and for many parameters very accurate data is available on the distribution of values within a normal population. Although cross sectional surveys of growth attainments of large populations have been used to assess health or health change, there has to date been no easily available method of assessing the morbidity of a small population, particularly of children. This paper presents a statistical methodology which corrects this deficiency.

Methods

Data was originally collected during a survey in western Nigeria, which had been devised to assess the impact of a health service on the health status of children. A representative random sample of children under 5 years was obtained, based on the geographical location of residence.[2]

Altogether 833 children were included in the survey. Clinical examinations were performed by N B, height and weight measurements were undertaken by trained field workers, and laboratory and Mantoux tests were performed by medical students. The clinical data collected included age, weight, height, skinfold thickness, and various stigmata of malnutrition—pedaloedema, skin flaking, mental depression, irritability, fine or straight hair, or both, and delay in motor development.

To achieve maximum cooperation from the children and improve the accuracy of the readings, the decision to weigh or measure standing was taken according to developmental ability rather than the exact age of the child. Nearly all children aged under 1 year were weighed hanging and measured for supine length, whereas most children over 24 months were weighed and measured standing. The methods used were:

(a) Hanging weight using a standard harness and spring balance[3] standardised with a 5 kg weight before each session and corrected to zero before each reading.

(b) Standing weight using a good quality bathroom scale, standardised to a hospital balance before each session and standardised again using one person of known weight when set up for the session. All children were weighed naked.

(c) Supine length was measured using a flat board

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with a fixed headpiece and an inset slide with an erect foot plate. A standardised metre rule was screwed to the flat board.

(d) Standing height was measured using the procedure as laid down by Weiner and Laurie.[4] A fixed 1·5 metre rule was set into a flat foot board and arranged on a flat surface.

Children were, in addition, examined clinically for major congenital malformations or congenital diseases that might contribute to poor health (such as sickle cell disease) and these children were excluded from the analysis.

Mantoux tests were carried out on all children over 12 months of age and the results were available for 561 children in this age group. A total of 157 children were tested with 10 IU purified protein derivative, but most (484) received the international diagnostic standard of 1 IU. Readings of induration were calculated by taking the average of two diameters as measured with a transparent ruler. Children were not excluded from analysis on the basis of either a Mantoux result or a clinical diagnosis of tuberculosis.

During the following 12 months, further investigation of the tuberculosis status of children was carried out. For the purposes of the analysis presented here, the diagnosis of tuberculosis was clinical, there being no radiology facilities available. A modification of the World Health Organisation diagnosis protocol was used, the criteria for diagnosis being the presence of at least one of the following:

(i) Reaction to 1 IU purified protein derivative of more than 10 mm in diameter

(ii) Two or more of the following:
Cough of more than two months' duration.
Weight loss.
Evening fever or night sweats.
Anorexia.
Doughy abdomen.

(iii) Severe malnutrition with one of:
Persistent cough.
Evening fever or night sweats.
Doughy abdomen.

(iv) A chronically sick child with a totally negative Mantoux reaction living in a house with an active case was presumed to be an anergic case.

Children in categories (ii), (iii), and (iv) who failed to respond to treatment with isonicotinic acid hydrazide and thiacetazone were reinvestigated. They were excluded as cases if they were found to have another chronic condition which would confound the data.

Statistical analysis. Data on weight for age was recorded in kg, and that for supine length and height in cm. All were charted against the rural Nigerian growth standards developed by Janes, according to the sex of the child.[5] These standards were assumed at the time to be appropriate.

Calculating a simplified Z score

To calculate a simplified Z score the growth attainment measure (such as height) for each child is plotted on a graph of the appropriate standard data. The child is given a standard deviation score according to its relation to the standard mean. All those children with a particular SD score are grouped together to evolve a frequency table of scores around the mean, and this is converted to percentages. Table 1 illustrates how this percentage distribution is calculated.

The percentage distribution can now be compared to the Gaussian distribution around the mean. Different subsamples within the sample may also be tested against either the Gaussian distribution or against each other using simple statistical tests such as χ^2 or Student's t test (Table 2). Should the aggregate sample figures show an approximately

Table 1 *Calculating the percentage distribution for weight for age in the town Osu*

	> Mean +2 SD	*> Mean +1 SD*	*> Mean*	*<Mean*	*<Mean −1 SD*	*<Mean −2 SD*
Standard deviation score	+c	+b	+a	−a	−b	−c
Sample frequency No (%)	15 (9·4)	23 (14·4)	52 (32·5)	34 (21·3)	27 (16·9)	9 (5·6)

Table 2 *Height (in SD) in the town of Osu, Nigeria (n=138)*

	> Mean +2 SD	*> Mean +1 SD*	*> Mean*	*<Mean*	*<Mean −1 SD*	*<Mean −2 SD*
Standard deviation score	+c	+b	+a	−a	−b	−c
Sample frequency	10	10	20	26	29	43
Percentage sample frequency	7·2%	7·2%	14·4%	18·8%	21%	31·2%
Expected Gaussian distribution	2·3%	13·6%	34·4%	34·4%	13·6%	2·3%

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Gaussian distribution around the population mean, one may conclude that the standard data is appropriate for the sample.

It is important that statistically significant samples that represent the clinical situation are defined. Care must be exercised, therefore, in deciding age groups for disaggregation, since large numbers of finely divided age categories may produce samples too small for statistical analysis. On the other hand, re-grouping samples of dissimilar characteristics together may mask a true difference. Where samples are very small, it may be necessary to reduce the numbers of stratifications on either side of the mean before analysis. A continuum of data may be obtained by amalgamating standard deviation scores for supine length and standing height.

Results

The sampling achieved in the study is shown in Table 3. An initial inspection of the graphic data for weight seemed to show a reasonably close fit with the norms. It was apparent, however, from the first tabulation of standard deviation scores that our sample did not give a reasonable distribution around the mean: the aberration was much more apparent for height than for weight, which was why it was initially missed when studying weight for age data only.

The standard deviation scores were disaggregated in yearly age groups and it was then possible to determine the shift of the mean of the sample against the standard by age (Fig. 1). The difference between the sample and population mean increased with age, becoming equivalent to more than one standard deviation by the age of 4 years. This became highly statistically significant ($P<0.01$) at age 3 years for height and age 4 years for weight, although it reached a significance of $P<0.05$ even at age 1 year. It was therefore clear that this was not a Gaussian population as fitted to the rural population standards.

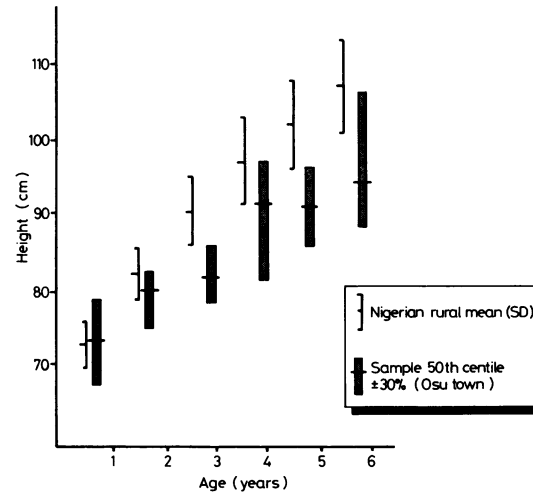

Fig. 1 *Height attainment by age.*

One of the pointers to further investigation in the Nigerian study was the lack of correlation of the proportions of the population with low weight for age with the incidence of pronounced malnutrition. Table 4 shows that the three towns with the most severe malnutrition did not have concomitantly high proportions of very low weight for age children. It was also found that height and weight analysed by standard deviations against age produced similar but not identical trends (Figs. 1 and 2). The greater numbers of children below the mean for height than for weight was due to nutritional oedema in severely malnourished children masking the true degree of weight growth failure.

It would be expected that a child falling in one standard deviation group for height would fall in the same, or only one standard deviation group in either direction, for weight, and vice versa. The cross hatched portion of Fig. 3 shows the acceptable overlap. The half hatched areas are marginally acceptable. Thus, in this population it can be seen

Table 3 *Sampling achieved*

Town	*Age (months)*						*Total*	*Proportion of relevant childhood population surveyed*
	0–11	*12–23*	*24–35*	*36–47*	*48–71*	*72+*		
Ipetumodu	42	33	26	35	58	3	197	2·2%
Abata Egba	15	19	14	12	33	44	137	26·0%
Ibodi	14	17	13	10	23	3	80	22·0%
Sekona	34	16	8	30	31	40	159	11·7%
Osu	27	27	24	16	50	2	146	8·6%
Famia	13	13	12	6	19	28	91	21·9%
Total	145	125	97	109	215	120	811	6·15%

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that 18·9% fall well outside the cross hatched area, with a further 13·3% in marginal zones. All but 3 of these 32 children fell on one side of the graph, again depicting an abnormal deficiency of height attainment compared with weight. A further factor was the negative correlation between the incidence of oedema and the rate of Mantoux positivity.

The four populations ultimately separated out in this study are shown in Fig. 4 and Table 5.

(1) An optimal group under the age of 1 year who

Table 4 *Inverse relation of weight for age and nutritional oedema in different towns*

Town	*Percentage of sample with:*		
	More than 2 clinical signs of malnutrition	*Weight less than 2 SD below rural mean*	*Pronounced nutritional oedema*
Famia	46·8	10·8	42·7
Abata Egba	79·9	9·6	34·7
Ibodi	56·3	17·5	29·7
Sekona	28·7	16·8	15·0
Ipetumodu	47·0	16·3	14·6
Osu	40·3	6·3	12·0

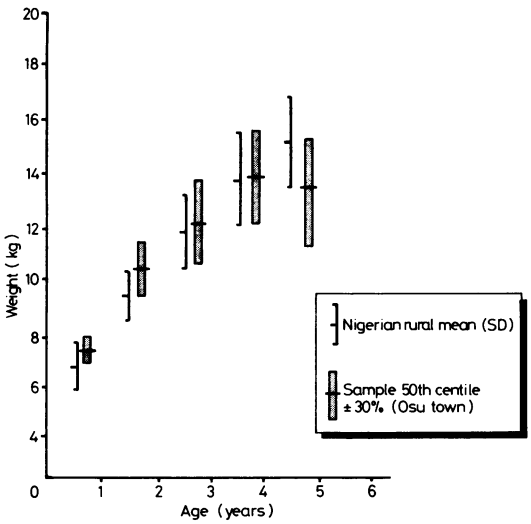

Fig. 2 *Weight attainment by age.*

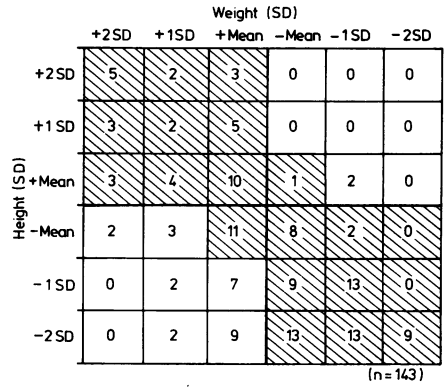

Fig. 3 *Height against weight in standard deviations.*

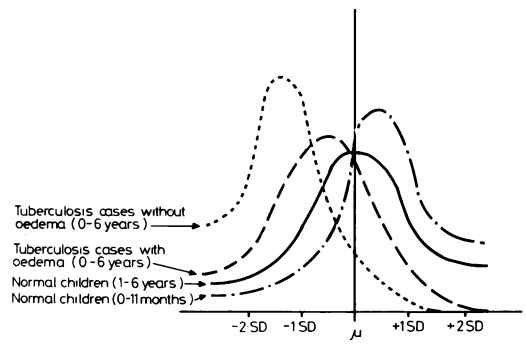

Fig. 4 *Distribution of different sub-samples around the rural Nigerian mean in Osu.*

Table 5 *Percentages of difference clinical groups in Osu according to standard deviations from the mean (Derivation of Fig 3)*

	>Mean +2 SD	*>Mean +1 SD*	*>Mean*	*<Mean*	*<Mean −1 SD*	*<Mean −2 SD*	*No (n=96)*
Tuberculous patients with oedema	0	5	20	37	25	10	19
Tuberculous patients with oedema	0	0	7	21	50	21	14
Non-tuberculous children over 1 year	11	11	32	29	11	7	28
Non-tuberculous children under 1 year	17	14	43	11	11	3	35
Overall percentage (equal weighting)	7	7·5	25·5	24·5	24·5	10·25	

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fitted the elite rather than the rural mean for Nigerian children for both height and weight.

(2) Among the older children there was a group that fitted the rural standards.

(3) There was a second group of older children who had tuberculosis without nutritional oedema.

(4) The third, older group that had tuberculosis with considerable nutritional oedema.

Using this method it was possible to show that it was the overlapping of these four populations that produced the picture that we found.

Discussion

The interpretation of the high numbers of positive (10 mm+) Mantoux results was initially problematic, as there were no local data on avian or bovine tuberculosis, nor had such high values been found previously.[6 7] In addition, there were appreciable numbers of severely sick children with totally negative reactions for whom we could not initially prove a certain diagnosis. No children were therefore excluded from the analysis on the basis of either Mantoux result or a clinical diagnosis of tuberculosis. It was only after prolonged follow up and further investigation of the population that it became possible to define the proportions of the tuberculosis epidemic present in the community. Preliminary details of tuberculosis in Nigeria have been reported in 1977 (N Bankole—Annual Scientific Meeting of the Paediatric Association of Nigeria) and 1978,[2] and it is anticipated that the detailed analysis will be available shortly. It was the presence of these sick children in the sample that stimulated the statistical analysis presented here.

A portion of the loss of height attainment as measured would have been due to the increased lordosis characteristic of children with muscle wasting, in this case due to malnutrition and chronic disease. Since the lordosis is itself another reflection of the poor state of health of these children, it does not invalidate the findings. The variation between supine and upright measurements of the same child may vary up to 2 cm, depending on both the child and the technician.[1] This differential should have been minimised by the present analysis which used separate standards for supine and upright measurements, and compared children in standard deviation groupings, rather than by absolute measurements: one standard deviation for height varied from 2·5 cm at 1 year of age to 5 cm at 6 years, and differences in measurement between patients would not alone, therefore, account for the gross deviation of more than one standard deviation from the mean by the age of 3 years. The lordosis may, however, be partly responsible for the apparently earlier downward shift in height relative to weight, as this would not have been apparent in measuring supine length which was used for any child who could not stand. On the other hand, the height of all those children, who were measured standing would have been affected by any lordosis present. There would have been no such complication in weighing children of different ages. There have been many longitudinal studies of the various growth parameters.[8]

Cross sectional studies have been used commonly for the assessment of the health of samples but the traditional method of analysis requires very large numbers of cases of identical ages, which are then compared to standard data. They are a useful tool, but cumbersome to use and not applicable to small populations.

Growth parameters that are the most reliable indicators of previous health are height, head circumference, and chest circumference. Although weight attained is useful and frequently measured, it may also be confounded by recent or concurrent acute illness, or sudden changes in diet. Weight is not, therefore, the ideal measure to use in population screening. Technical problems, however, in ensuring accurate recording of other parameters in large field surveys may preclude their reliability (especially with regard to head and chest circumference). The complications of an increased lordosis due to muscle imbalance has already been discussed in relation to standing height. It is therefore ideal to use at least two growth parameters in a population screening exercise—preferably those for which there are standards against which distribution may be calculated. Differing results on different parameters may immediately indicate the direction of further research.

Although it is well known that different populations have different means, for instance for weight achievement at a given age, it has not been clearly ascertained what is the ideal for any one population. It is not clear, for instance, to what degree genetics and environment play a part in these growth achievements.

The validity of having different weight charts for different populations from the same genetic pool is dubious, the implication being that to be 'non-elite' actually is equivalent to being unhealthy. The World Health Organisation has developed a series of standard deviations progressing to minus four standard deviations from a mean which is close to the Nigerian rural norm,[9] and one wonders again how valid these standard deviations are.

In the United Kingdom we normally use the Tanner norms of child development.[10] More work needs to be done to determine whether groups of children in the UK who do not fit the Tanner norms

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are from different genetic groups, or whether they have poor health due to poor nutrition, poor environment, infectious disease, or low socioeconomic status.

These are the types of questions which it is hoped that this method of analysis will open up. The answers to the questions are far more complicated, but once a problem population has been defined it is hoped that the exact cause may be found.

It is often easy to assume that methods of analysis devised in less well automated societies are irrelevant to our needs in the 'developed West'. We are ignorant, however, of problems as they affect different groups in our own back yards. Times have changed and health is not necessarily improving. If it is, we should be able to confirm it. If it is not, we must have easily available tools with which to diagnose 'ill-health' and acquire an awareness of degrees of suboptimal health.

This paper presents a sensitive health indicator which should be easily usable by persons with even limited medical skills.

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