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The Utility of Infancy Weight Curves for the Prediction of Linear Growth Retardation in Preschool Children

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ABSTRACT. Simondon, K. B., Simondon, F., Cornu, A. and Delpeuch, F. (ORSTOM, Institut Français de Recherche Scientifique pour le Développement en Coopération, Tropical Nutrition Units of Dakar, Senegal; Brazzaville, Congo and Montpellier, France). The utility of infancy weight curves for the prediction of linear growth retardation in preschool children. Acta Paediatr Scand 80: 1, 1991.

Routine weight measurements, recorded on health cards of 95 Congolese infants, were collected during a cross-sectional survey as the children were aged 1 to 5 years. The subjects were divided into two groups according to height-for-age (more or less than −2 SD of NCHS reference) at the time of the survey. Adjustment of a mathematical function to the infancy weight curves allowed comparison of groups using the means of the function's parameters: The stunted children had been significantly lighter than the healthy group during infancy. Predictive values of estimated weights and quarterly weight gains were assessed by discriminant analysis and cut-off points were computed. The weight gain between 3 and 6 months of age predicted stunting just as well as weight at age 1 year did. Sensitivity and specificity were at 77% and 74%, respectively. These results suggest that good prediction of stunting is possible from first-year weight measurements. *Key words: infancy, weight, growth monitoring, protein-calorie malnutrition, modelling, prediction.*

Linear growth retardation, also named chronic malnutrition or stunting (1), is very prevalent in less developed countries and weight monitoring programmes aiming at early detection of growth failure are an important part of local health care systems. Weight monitoring is the first component of "GOBI", the strategy for promotion of child health defined by UNICEF and composed of: Growth monitoring, Oral rehydration, Breast feeding and Immunization. According to WHO, all preschool children should be weighed monthly, but the effectiveness of this programme is thought to be unsatisfactory (2, 3). Gopalan & Chatterjee (2) recommend restriction of monitoring to high-risk children. Little is known about how to identify at-risk subjects.

The objective of the present study is to define a group of children at risk of linear growth retardation, on the basis of their weight curves from the first year of life. Thus, growth monitoring could concern all children prior to age one year, and only the at-risk children thereafter.

SUBJECTS AND METHODS

Subjects. The data were taken from the 1987 National Nutrition Survey in the People's Republic of Congo, Central Africa (4). A sample of 2 429, randomly selected children below 5 years of age were included, using a stratified cluster sampling design, and investigated at household level. The items recorded dealt with anthropometric measurements, nutritional habits, morbidity and socioeconomic status. Length was measured with a locally made wooden board and recorded to the nearest millimeter. Weighing was done on a SECCA balance and recorded to the nearest 20 g. Weight measurements recorded at local health centres during infancy were copied from the children's health cards, when these were available in their homes, and the corresponding ages noted. For weighing, most Congolese health centres use Salter Spring balances.

In 834 children health cards were available showing at least one weighing during infancy. Only 95 children had been monitored from birth up to age one year. These were selected for the present study. The number of readings ranged from 7 to 11, and birthweight was known for 79% of the children. The children's ages at the time of the survey ranged from 12 to 60 months with a mean of 28.0 months. Fourty-six children were aged 1 to 2 years, 24 children were aged 2 to 3 years and 25 children were aged 3 to 5 years. The majority of the children (94%) lived in the southern part of the country, 57% in large villages (more than 2000 inhabitants) and 37% in smaller villages.

Growth modelling. The statistical analysis of the growth data gave rise to some methodological problems, because measurement ages and spacing of measurements differed between children. Modelling of growth by adjustment of a mathematical function to the individual growth curves permitted comparison between curves and estimation of weight at any timepoint, independently of measurement ages. The infancy component of the Karlberg model (5) was selected from the models proposed for early childhood, according to criteria of goodness of fit and independence of parameter estimates (6). This three-parameter non-linear model is as follows:

$$Y = A + B(1\text{-}\exp(-C \cdot t)),$$

where t is age (here in months) and Y is the anthropometric variable (here weight in kilograms). A, B and C are the parameters, which are constants for a particular child but allowed to vary between children. According to the function, birthweight is estimated by A and "final" weight by $(A+B)$. The curvature is estimated by $\exp(C)$. The fitting was achieved, child by child, by the non-linear regression programme BMDP 3R using Gauss–Newton iterations. Thus, the serial weight data for each child was reduced to three parameters.

Analyses. The aim of the analysis was to relate the infancy weight curves to the nutritional status of the children at the time of the survey, as they were aged one to five years. Children were separated into two groups, stunted or healthy according to height-for-age at the time of the survey. Linear growth retardation was defined by a height-for-age lower than −2 standard deviations of the NCHS reference population mean, as recommended by WHO. Standard scores were computed using a programme written by the Centers for Disease Control (7).

The infancy weight curves of stunted and healthy children were compared globally using the parameter estimates. For comparison of means we used Student's t-test. The mean weight curves of the two groups were constructed according to the model, using the means of the parameters in each group. The velocity curves were constructed by differentiation of the growth model:

$$(dY/dt = B \cdot C \cdot \exp(-C \cdot t)).$$

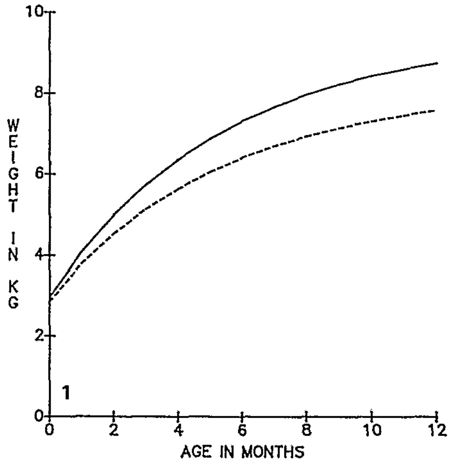
Quarterly weight gains (increments) were estimated between birth and age 12 months using the difference between weight estimates at the end of each interval.

Table 1. *Parameter estimates of infancy weight curves*

Groups refer to childhood nutritional status

	Stunted $n=22$		Healthy $n=73$	
	Mean	SD	Mean	SD
Parameter A (kg)	2.845	0.685	2.962	0.503
Parameter B (kg)	5.620	1.435	6.715	1.381*
Parameter C (kg/mo)	0.210	0.096	0.191	0.059

*$p<0.005$.



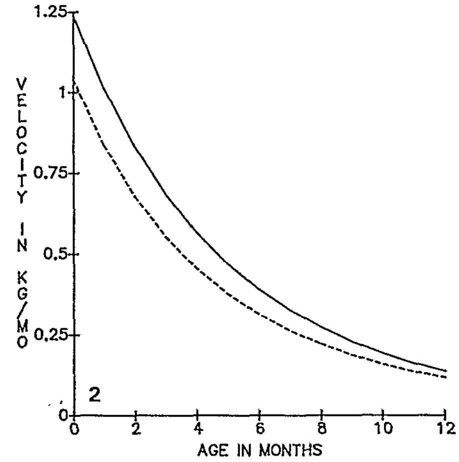


Fig. 1. Mean infancy weight curves of stunted and healthy children.

Fig. 2. Mean infancy velocity curves of stunted and healthy children.

Two discriminant analyses were carried out stepwise in order to assess the discriminating power of weights and quarterly weight gains. First, the 12, monthly birthday weights were tested together with classical risk factors of linear growth retardation (mother's height, mother's weight, birthweight) and sex. Social status or income were not included despite current association with linear growth retardation, because they can hardly be measured by health workers on a routine basis. Second, the predictive power of weight gains was tested. In this discriminant analysis the four estimated quarterly weight gains were entered. These were tested along with sex, birthweight and mother's height and weight.

The sensitivity of the selection procedure was defined as the proportion of infants classified at high risk among those who became stunted during childhood. Specificity was defined as the proportion of infants classified at low risk among those who did not become stunted. The positive predictive value (PPV) was defined as the proportion of infants who did develop linear growth retardation at later ages, among all the high-risk infants, while the negative predictive value (NPV) was the proportion of infants who did not develop linear growth retardation, among all the low-risk infants.

RESULTS

The mean height-for-age at the time of the survey was −2.7 SD in the stunted group ($n=22$) and −0.9 SD in the healthy group ($n=73$). Few infants were significantly stunted before age one year, and prevalence was almost constant between 1 and 5 years in this sample, as in the whole survey. Thus, little catch-up growth seemed to occur before age five years.

Table 1 contains estimates of the parameters in the two groups. B was significantly greater in the healthy group ($p<0.005$), while A and C did not differ. Thus, weight curves of infants who developed linear growth retardation during childhood differed from those of other infants. The mean weight curves of the stunted and the healthy group are given in Fig. 1. Weight for the healthy group was higher at all ages, and the difference progressively increased because of its higher growth rate (Fig. 2).

The discriminating power of the observed differences in weights and weight gains was assessed using stepwise discriminant analysis. Two analyses were carried out. Among the 12 monthly weights, the most predictive was the weight at age 12 months. Knowledge of weights at earlier ages did not improve the prediction. Neither did the initial risk factors like birthweight or mother's height. Only the knowledge of the sex of the infant improved the prediction. The prediction provided by weight at age 12 months and sex had a sensitivity of 77% and a specificity of 76%. At a prevalence of 23%, the selection procedure had a PPV of 50% and a NPV of 92%. The function resulting from the discriminant analysis was used to calculate cut-off points for weight at age 12 months for boys and girls separately. Boys lighter than 8.80 kg and girls lighter than 7.35 kg belonged to the at-risk group, comprising 35% of the sample.

Using the growth curve in this cross-sectional fashion is not very satisfactory. Therefore, weight gains (increments) were tested in a second discriminant analysis. The most predictive weight gain was the one between ages 3 and 6 months. Together with sex, it was as predictive as weight at age 12 months (sensitivity = 77% and specificity = 74%). PPV and NPV were at respectively 47% and 92%. The cut-off points for boys and girls were 1.59 kg and 1.15 kg during the quarter. The proportion of at-risk infants was still 35%.

DISCUSSION

Longitudinal studies are necessary in order to understand malnutrition better. They are costly in time and money and therefore often deal with small samples. Retrospective studies, like the present one, can be carried out on a large scale in countries where growth monitoring is common and weight-recording cards are kept at home. The present survey covered a relatively small number of monitored children because the growth monitoring programme has only recently been introduced in the Congo. It is further limited by the fact that routine measurements taken by health workers are likely to be less accurate than those obtained in prospective surveys. However, a previous study in Brazzaville, Congo, showed good congruence between weight measurements taken during the survey and recent health centre measurements.

The sample studied here is not representative of Congolese children since it is composed of children attending the growth monitoring centres. According to the National Survey, these are typically middle-class children, likely to be less at risk of growth retardation. Yet, prevalence of linear growth retardation did not differ between the selected subsample (23%) and the total sample of the National Survey (27%, $p > 0.05$).

It might seem paradoxical to use weight for the prediction of height deficiency. However, weight-for-age is the only nutritional index used in growth monitoring programmes because it is too difficult to measure recumbent length on a routine basis. The results obtained here indicate that linear growth retardation can be effectively predicted using weight.

Weight curves of healthy and nutritionally at-risk infants have previously been compared by Kim & Pollitt (8) using a growth model. The nutritionally at-risk infants were taken from the Bacon Chow Study in Taiwan and the healthy infants were taken from the Berkeley Growth Study in California. Velocities of the former were lower from age 3 months to age 8 months. Weight gains were not assessed. The critical issue was whether this drop in weight velocity after age 3 months was associated with a higher developmental risk. The present study shows that differences in infancy weight growth, especially after age 3 months, also exist within a

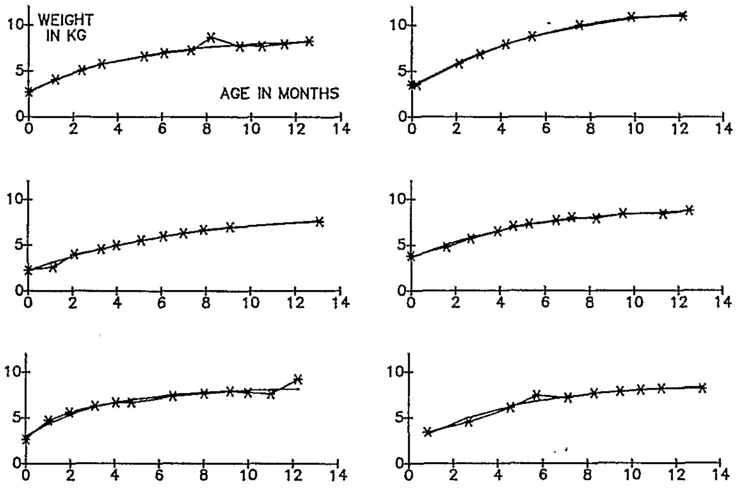


Fig. 3. Stimated infancy weight curves and raw data of six, randomly selected children.

nutritionally at-risk population, and that low weight gains at that age are closely associated with linear growth retardation later on.

Prediction of growth retardation by cross-sectional measurements of weight and height at different ages has previously been tested in a sample of 239 Mexican children by Scholl et al. (9). Weight at age one year had the same predictive power as in the present investigation (sensitivity = 73% and specificity = 72%) on growth failure at age 3 years. Length at age one year was less specific (sensitivity = 76% and specificity = 63%). The authors stated that "neither age related weight nor length adequately identifies growth failure from birth up to age 6 months".

An important finding of the present study is that early prediction of linear growth retardation can be provided by the weight gain between ages 3 and 6 months. Unless effectively treated, one-half of the selected at-risk infants will develop linear growth retardation, while only 8% of the non-selected infants will become stunted. Weight gains from the second half of infancy have poor discriminating power, probably because all children slow down at that time.

The results presented here were obtained using estimated weights and weight gains. A comparison of estimated curves and raw weight data is given in Fig. 3. The model described the general growth pattern very well, but irregularities, due to measurement errors or temporary weight losses, were ignored. Therefore, predictions using raw weight data are not likely to perform so well. Furthermore, systematic under- and over-estimations at any of the ages under consideration would influence estimated weight gains more than estimated weights. However, very little bias was observed using the Karlberg model on this data (6).

In conclusion, the cut-off points should be considered merely as examples since they are likely to vary substantially between samples and populations. The predictive values obtained are very promising but need validation on large samples of raw infancy weight data from the Congo and other countries. It is especially important to determine whether weight gains permit earlier detection of at-risk infants than weights do, since early detection would improve the effectiveness of interventions.

Age at the onset of linear growth retardation, and the relationship between gains in weight and in recumbent length during infancy, are important topics for further studies.

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