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Bone Maturation in Children Recovered from Malnutrition

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Since growth is conditioned by the adequacy of nutrition, it is not surprising that skeletal development may be affected detrimentally by limited nutrition.

In the literature, one finds early reports to this effect based on the gross assessment of 'bone age', established by comparison of radiographs of selected sites, with corresponding age-sex specific norms [7]. Although this approach results in estimates which may be considerably affected by measurement error, the results obtained through its application have, nevertheless, suggested that retardation in bone development begins early in life, manifesting itself in a pattern that is quite uniform among populations of widely different ethnic extraction but with a similar background of deficient nutrition [2, 8, 11]. Furthermore, the retardation in bone age reported for these populations in terms of net time deviations from the norm closely parallel similar estimates of time lags established on the basis of either height or weight [8].

The problem of skeletal growth retardation has been studied using different alternative methods, all of which attempt to reduce the large measurement errors commonly associated with the comparison technique described previously [3, 5]. In our case, we have evaluated bone development on the basis of age-sex specific counts of ossification centers, determined from left hand-wrist radiographs, and following the methodology described by Garn and Rohmann [5]. The counting of ossification centers present is complemented with radiogrammetric measurements of the external and internal diameters at the midshaft of the second metacarpal bone, which permits estimation of cortical thickness [3]. By using this approach, we have been able to assess bone development, with sufficient sensitivity and a good reliability, from birth to 5 years of age for different population groups in the rural highlands of Guatemala [9, 10, 12].

Results from a longitudinal study of 5 years' duration [10], evaluated in terms of bone development using the methods described, suggest that improvement of the usual diet of a village through the daily administration of a high quality protein supplement (Incaparina) resulted in better age-sex specific ossification status (greater number of centers present) and improved bone growth (more centers appearing during fixed time intervals) for the children of the supplemented village in comparison with children from similar villages without food supplements [9, 10].

Parallel studies conducted with 96 children hospitalized for protein-calorie malnutrition at the Roosevelt Hospital in Guatemala City revealed that the ossification status of these children does not differ from that of ambulatory children from control villages in the Guatemalan highlands [6]. On the other hand, radiogrammetric measurements of second metacarpal cortical thickness in village and hospitalized Guatemalan children revealed no systematic reduction in outer bone diameter at midshaft, but a significantly larger inner diameter was found in the hospitalized children. This indicates a reduction of cortical bone at the endosteal surface [4]. The difference in cortical bone between the hospitalized and the village children becomes more apparent if the bone diameter measurements are used to calculate midshaft cortical area, and the results expressed in terms of percent cortical area [4].

Another series of studies on the bone development of children, also conducted in Guatemala, evaluated radiogrammetric results for 84 children with protein-calorie malnutrition who died and were autopsied at the Roosevelt Hospital during the period from August 1964 to November 1965.

Preliminary analyses of the results from these studies indicate that there is no significant difference between the number of ossification centers present in these children and the number of centers present in either their village, or hospitalized, age-sex specific counterparts. The cortical thickness of the second metacarpal of the autopsied cases was, however, less than the cortical thickness of the second metacarpal of both the village and the hospitalized children. In this case, the percent cortical area of the autopsied cases was substantially less than that of comparable living children. In the necropsy series, it was also possible to carry out direct measurements of midshaft diameters on the second metacarpal bone removed at the time of autopsy; the results from such measurements closely parallel the previously described radiogrammetric results.

Table I. Percent ash content of the second metacarpal bone in children dying from protein-calorie malnutrition at the Roosevelt Hospital in Guatemala during August 1964–November 1965

Age, years	Males			Females		
	n	$\bar{x}$	s	n	$\bar{x}$	s
<1	11	42.3	13.3	3	51.7	12.7
1	9	48.8	10.1	16	52.8	9.4
2	7	51.3	4.1	6	53.3	7.0
3	2	58.5	1.0	2	59.0	5.6
4	4	59.8	10.8	–	–	–
5 and over	6	53.5	3.3	3	56.0	2.0
Total	39	49.7	10.7	30	53.5	8.4

In 69 of the 84 cases included in the necropsy series, it was also possible to carry out ash determinations; the results are presented in table I. These determinations suggest that the children dying from protein-calorie malnutrition have a dried, defatted bone ash content that does not differ from reported normal values [1, 13]. In other words, the bone loss evidenced by reduced cortical thickness really represents a loss of total bone; in this event, the detrimental effect of early malnutrition may well produce irreversible damage to the skeletal structure, such as thinning of the bone and changes in the epiphyses [6]. A sequence of these events may be permanently recorded in the bone as lines of arrest (Harris' lines), which are commonly visible in hand-wrist radiographs of children from areas where malnutrition is common. The real biological significance of these lines, however, still remains unclear. On the other hand, the thinning of the bone results in decreased breaking strength and a generally reduced compression strength [6]; the changes in the epiphyses may produce a reduction in the length of bones which may well be irreversible, thus contributing to the small body size which uniformly characterizes the populations of regions where malnutrition is prevalent [8]. In any case, the available evidence suggests that conditions of poor nutrition result in skeletal changes which may permanently affect the normal functions of the individual.

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