The total weight of mineral in the human infant

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There is at present no satisfactory method by which the severity of protein deple-
tion in malnourished children can be measured. Although there are numerous methods
for the estimation of body composition, these rely to a greater or lesser extent on a
constant ratio between some of the four main body constituents: water, protein, fat
and mineral. In infantile malnutrition the assumption of any such ratio is unjustified,
since variations in each of the constituents may be large and independent of changes
in the others. Of the four, only water can be measured independently by a dilution
technique. However, if the total weight of one of the three solid components is also
known, the proportion of the other two can be estimated from the density of the body
(Behnke, 1961).

We are trying to measure the body composition of malnourished children, and this
paper presents a method for the estimation of total bone mineral and the results
obtained for eight Jamaican children of various nutritional states.

EXPERIMENTAL

Clinical material

The eight children were patients either in the Tropical Metabolism Research Unit
or in the paediatric wards of the University College Hospital. Their ages, weights and
heights are shown in Table 1. Children 1, 5 and 6 suffered from kwashiorkor and died
within 36 h of admission to the ward. Child 2 had been treated for severe malnutrition
for 7 weeks and had been making good progress, but she developed measles and
broncho-pneumonia, and died suddenly. Children 3 and 8 were both outpatients who
had been successfully treated for malnutrition and who had died from gastroenteritis at
home. Child 4 was a nephrotic who died in hospital. Child 7 was brought into hospital
moribund with a severe septicaemia. Thus Children 1, 4, 5 and 6 were severely
malnourished, child 2 moderately so, and children 3, 7 and 8 were clinically well
nourished. In the table they have been arranged in order of increasing bone weight.

The parents of these children gave their bodies to the Anatomy Department of the
University of the West Indies, from which we obtained material for analysis.

Analytical methods

X-ray densitometry of bone. The X-ray opacity of the shaft of the tibia and of the
adjacent soft tissues was estimated by comparing, on the X-ray film, the light trans-
mitted through the image of the bone, of the adjacent soft tissue, and of a standard.

The standard was a block of aluminium in which were cut twelve steps of thickness varying from 0·01 to 1·00 cm. It was placed on the X-ray film and X-rayed at the same time as the leg. The developed film was placed on an X-ray viewing screen, and the transmitted light was measured over a circle 3 mm in diameter by means of a Mullard ORP 60 photoresistor mounted in the tip of a small brass tube. The photoresistor was wired in series with a mirror galvanometer and a 3 V battery across a 0·5 MΩ potentiometer. With this system the galvanometer is set to zero with the photo-resistor applied to the dark background of the X-ray film, and the potentiometer is set to give approximately full-scale deflexion when the photoresistor is applied to the least dense part of the film which is to be measured. It was found that the galvano-meter deflexion was directly proportional to the thickness of the steps in the aluminium standard over the range 0·01–0·6 cm and the readings for bone and soft tissue always fell within this range. Care was taken to place the photoresistor over the centre of the shaft of the tibia so that the light passing through the image of the cortex at the edge of the bone was not measured.

The reading over bone minus that over adjacent soft tissue is expressed in terms of cm of aluminium (D).

Chemical determination of bone mineral. The body was divided sagittally and the right half was taken for analysis. Protein and fat were removed by boiling the bone in 2N-NaOH and the remaining mineral was filtered, washed, dried in an oven at 105° and weighed. To ensure that protein and fat had been completely removed, the bone mineral was then dissolved in dilute hydrochloric acid and the resultant solution was analysed for nitrogen (by Kjeldahl) and for fat by extraction with petrol. In all samples the nitrogen content of the dried mineral was negligible, but a small amount of fat was found, and its weight was subtracted to obtain a true weight of bone mineral for the half skeleton.

<div align="center">RESULTS</div>

The results are summarized in Table 1.

It was assumed that the total bone mineral of a child could be calculated from the three variables: (1) height of the child in cm, H; (2) length of the tibia in cm, L; and (3) the X-ray opacity of the bone in cm of aluminium, D. The formula relating W, the observed weight of bone mineral to these three variables, was assumed to be of the form

$$W = AH^\alpha L^\beta D^\gamma + K,$$

where A, K, α, β and γ are constants. Regression analysis showed the value of K to be zero and

$$W = 10^{0\cdot6573} H^{0\cdot1045} L^{1\cdot7248} D^{0\cdot5360}.$$

From this equation was derived the simplified formula $W = 3\cdot30\ L^2 D^{0\cdot5}$, which was used to calculate the values shown in Table 1. Also shown are the differences of these values from those found by chemical analysis, both in g and also as a percentage of the weight of bone mineral. The maximum difference was 16·3 % and the mean difference 10·5 %.

Table 1. *Results of the estimation, by X-ray densitometry, of total bone mineral in eight children after death, and their comparison with those obtained by chemical analysis*

Subject no....	1	2	3	4	5	6	7	8
Age (months)	6	14	10	11	16	14	9	13
Body-weight (kg)	4·10	4·17	4·69	7·60	6·70	5·67	7·50	7·70
Height (*H*) (cm)	55	58	57	70	65	67	65	71
Length of tibia (*L*) (cm)	8·3	9·1	8·9	10·1	11·0	10·3	10·1	11·5
Opacity of tibia (*D*) (cm aluminium)	0·088	0·090	0·083	0·115	0·122	0·118	0·175	0·140
Total bone mineral by chemical analysis (*A*) (g)	74	76	90	109	126	134	148	190
Bone mineral as % body-weight	1·80	1·82	1·92	1·44	1·88	2·37	1·97	2·47
Total bone mineral by calculation from formula* (*W*) (g)	67·5	82·0	75·3	117·6	139·4	152·0	140·6	163·0
Difference between estimates (*A−W*) (g)	+6·5	−6·0	+14·7	−8·6	−13·4	−18·0	+7·4	+27·0
Difference as % of *A*	+8·8	−7·9	+16·3	−7·9	−10·6	−13·4	+5	+14·2

$$* \quad W = 3 \cdot 30\ L^3 D^{0 \cdot 5}.$$

Table 2. (*A*) *Body composition of a hypothetical child weighing 6 kg with a density of 1·041, body water of 3·9 l. and 120 g of bone mineral and (B) effect on estimates of contents of protein and fat if the content of bone mineral in this child is overestimated by 20%*

		A		B	
Component	Density (g/ml)	Weight (g)	Volume (ml)	Weight (g)	Volume (ml)
Water	0·993	3900	3927	3900	3927
Mineral: bone	3·000	120	40	144	48
soluble	2·000	39	19	39	19
Protein	1·340	1038	770	985	735
Fat	0·900	903	1008	932	1035
Whole body	1·041	6000	5764	6000	5764

DISCUSSION

We have found that bone mineral accounts for about 2% of the body-weight of a child between the ages of 6 and 14 months. The remaining mineral is in solution in body water, and is about 1% of the weight of body water. The effect of a 20% error in the estimation of bone mineral on the estimation of total body composition is shown by considering the following hypothetical example:

A child who weighs 6000 g is found to have a total body water of 3900 g and a density of 1·041. His bone mineral is estimated to be 120 g. The total body composition is therefore shown in Table 2 *A*.

If the bone mineral had been overestimated by 20% the calculated composition would be as in Table 2 *B*. Thus an error of 20% in the estimate of bone mineral produces an error of about 5% in the estimate of protein, and a smaller error in the

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estimate of fat. This error is of a similar size to that which arises from a 3 % error in the estimation of body water or an error of 0·3 % in the estimation of body volume and hence density.

SUMMARY

1. It was found by chemical analysis of bodies of eight children between 6 and 14 months old that bone mineral accounted for an average of 2·0% of total body-weight (range 1·4–2·5 %).

2. A simple method is described for measuring the X-ray opacity of the shaft of the tibia. It was found that from this value, and the length of the tibia, a value for the weight of total bone mineral of the child could be calculated, which did not differ by more than 17% from the weight of bone mineral as found by chemical analysis.

3. This degree of accuracy was adequate for the determination of total body protein and fat in these children from their density.

REFERENCE

Behnke, A. R. (1961). *Ann. N.Y. Acad. Sci.* **110**, 118.