The Metabolism of Nitrogen, Calcium and Phosphorus in Undernourished Children

1. Adaptation to Low Intake of Calories, Protein, Calcium and Phosphorus

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Diet surveys carried out by various workers in different parts of India (Aykroyd, 1939; Wilson & Widdowson, 1942; Mitra, 1953; Indian Council of Medical Research, 1951) have shown that the diets consumed by a vast majority of the people belonging to the low-income groups are based mainly on cereals and millets and contain only small quantities of pulses, vegetables, oils and fats, and negligible amounts of milk and other animal foods. The diets in general have been found to be deficient in vitamin A, riboflavin, calcium and proteins of high biological value (Aykroyd & Krishnan, 1937). Further, a fair proportion of the poor people do not get enough food to eat, their mean daily intake being less than 1500 Cal. per consumption unit (Mitra, 1953). The rate of growth of children on poor diets is found to be very much lower than that observed in better-fed children of the upper classes and far below that of English children (Wilson & Widdowson, 1942).

Very few metabolic studies have so far been reported on undernourished children whose daily diet is deficient both in quantity and quality. Nitrogen-balance studies have been carried out in China on children aged 4–5 years (Kung & Fang, 1935) and on adolescent boys aged 14–21 years (Kung & Yeh, 1938). Nicholls & Nimalasuriya (1939) studied the metabolism of calcium in Sinhalese children. More recently, Bray (1953) has reported the results of nitrogen-metabolism studies on African boys aged 7–9 years.

The present paper deals with studies on the metabolism of nitrogen, calcium and phosphorus in young children who have been subsisting for long periods on an ill-balanced and insufficient vegetarian diet based on rice.

EXPERIMENTAL

Subjects. The subjects were five girls aged between 7 and 9 years who were residents of an orphanage in Mysore city. They had been in the orphanage during the previous 2 years. They were examined clinically and were found to be free from any disease likely to interfere with the metabolic experiment. Their previous record showed that they had not suffered from any debilitating disease. The subjects were de-wormed by administering santonin 3 months before the metabolic experiment was begun. Information about the weight and height, and the haemoglobin content and

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red blood cell count of the blood was obtained at the beginning and end of a period of 6 months. Haemoglobin was determined by the acid-haematin method using a Sahli-Hellige haemometer (Hepler, 1950), and the red blood cell count was made by standard methods using Neubauer's haemocytometer. The results are given in Table 1.

Table 1. *Height, weight, haemoglobin level and red blood cell count in blood of children at the beginning and end of the observation period of* 6 *months*

		Weight (lb.)			Height (in.)			Haemoglobin (g/100 ml. blood)			Red blood cell count ($10^6/mm^3$)		
Child no.	Age (years)	Initial	Final	Difference	Initial	Final	Difference	Initial	Final	Difference	Initial	Final	Difference
1	7	31·0	31·75	0·75	41·5	42·25	0·75	12·2	11·6	−0·6	3·62	3·48	−0·14
2	9	40·0	39·75	−0·25	45·0	45·75	0·75	11·2	11·6	0·4	3·75	3·91	0·16
3	8	29·0	29·4	0·4	41·5	42·0	0·50	11·0	11·2	0·2	4·20	4·30	0·10
4	9	39·0	39·5	0·5	46·0	46·75	0·75	10·6	10·2	−0·4	4·30	4·20	−0·10
5	7	33·0	33·0	0	42·75	43·0	0·25	10·9	11·2	0·3	4·65	4·86	0·21

Pattern and nutritive value of the diets consumed in the orphanage. The pattern and nutritive value of the diets consumed by the children in the orphanage have already been reported (Reddy, Doraiswamy, Sankaran, Swaminathan & Subrahmanyan, 1954). The diet survey was repeated once every 2 months, and the pattern and composition of the diet was found to be more or less constant throughout the observation period.

Plan of the experiment. The subjects were fed during the experimental period on their usual orphanage diet. The experimental period was of 10 days' duration, the first 5 days of which were treated as a preliminary period to allow the subjects to become accustomed to the experimental discipline and to the use of equipment kept for the collection of urine and faeces. The collection of excreta for the metabolic study was therefore confined to the last 5 days of the experimental period.

The composition of the experimental diet and the feeding of the children. The mean composition of the diet consumed daily by the subjects during the experimental period is shown in Table 2. The intake of ragi, fat and jaggery was less than the corresponding means for the orphanage diet reported earlier (Reddy *et al.* 1954); however, the general pattern of the breakfast, lunch and dinner was the same. During the preliminary experimental period the quantities of food consumed by the subjects were weighed in order to obtain an idea of their usual food intake. During the collection period, weighed quantities of food equal to the average daily individual consumption observed in the preliminary period were given to each subject. Samples of the cooked food preparations equivalent to the mean quantities consumed by the subjects were collected daily. These were dried in an air oven at 70–80°, weighed, powdered and analysed for nitrogen, calcium and phosphorus. Samples of rice, ragi, pulses and vegetables used in the experiments were also analysed separately for the above constituents.

Collection and preservation of urine and faeces. The procedure adopted for the

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collection and preservation of urine and faeces was that described by Murthy, Swaminathan & Subrahmanyan (1954). Carmine was used as a marker for the collection of faeces. A check on the proper collection of urine was maintained by determining the daily excretion of creatinine in urine.

Analytical methods. The methods used for the determination of nitrogen, calcium and phosphorus in foods, urine and faeces were those described by Murthy *et al.* (1954).

Table 2. *Mean daily food consumption of subjects*

Constituent	Mean daily intake/child (g)
Rice, raw milled	227·0
Ragi (*Eleusine coracana*)	14·2
Red gram dhal (*Cajanus indicus*)	5·0
Horse gram (*Dolichos biflorus*)	12·0
Radish	5·0
Radish tops	13·0
Amaranth leaves (*Amaranthus gangeticus*)	4·0
Groundnut oil	2·8
Jaggery (crude cane-sugar)	5·7
Common salt (crude sea-salt)	7·1
Condiments (tamarind fruit pulp, onions, chillies)	5·7

RESULTS AND DISCUSSION

The results obtained for nitrogen metabolism are given in Table 3, for calcium metabolism in Table 4 and for phosphorus metabolism in Table 5.

Table 3. *Mean daily intake, excretion and balance of nitrogen of children on a poor vegetarian diet containing rice*

				Nitrogen excretion			
Child no.	Body-weight (lb.)	Calorie intake (Cal.)	Nitrogen intake (mg)	Faecal (mg)	Urinary (mg)	Total (mg)	Nitrogen balance (mg)
1	31	960	2787	1146	1512	2658	129
2	40	980	2889	1134	1704	2838	51
3	29	1020	2974	1225	1483	2708	266
4	39	1050	3100	1091	1545	2636	464
5	33	1040	3027	1132	1392	2524	503
Mean	34·4	1010	2955 ± 54·3	1146 ± 21·9	1527 ± 51·0	2673	282 ± 89·2

Table 4. *Mean daily intake, excretion and balance of calcium of children on a poor vegetarian diet containing rice*

				Calcium excretion			
Child no.	Body-weight (lb.)	Calorie intake (Cal.)	Calcium intake (mg)	Faecal (mg)	Urinary (mg)	Total (mg)	Calcium balance (mg)
1	31	960	195·2	160·0	22·5	182·5	12·7
2	40	980	197·4	170·1	34·5	204·6	−7·2
3	29	1020	192·6	109·3	31·5	140·8	51·8
4	39	1050	205·8	165·1	28·5	193·6	12·2
5	33	1040	208·0	103·5	60·0	163·5	44·5
Mean	34·4	1010	199·8 ± 3·0	141·6 ± 6·5	35·4 ± 14·5	177·0	22·8 ± 11·1

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It will be observed from the results given in Tables 3–5 that the intake of calories, protein, calcium and phosphorus fell short of the recommended allowances suggested by the Indian Council of Medical Research: Nutrition Advisory Committee (1944). It will also be noted that the intakes of calories, protein, calcium and phosphorus differ in some respects from those reported earlier (Reddy *et al.* 1954). The difference was due to the following reasons: (1) the intakes of ragi, oil and jaggery by the five experimental subjects were lower than the corresponding mean intakes reported earlier for all the children (ninety-six children aged 5–17 years) residing in the orphanage, and (2) the protein, calcium and phosphorus contents of the diet consumed by the subjects in the present study were determined by actual analysis, whereas the values reported earlier were obtained by calculation using figures given

Table 5. *Mean daily intake, excretion and balance of phosphorus of children on a poor vegetarian diet containing rice*

Child no.	Body-weight (lb.)	Calorie intake (Cal.)	Phosphorus intake (mg)	Phosphorus excretion: Faecal (mg)	Phosphorus excretion: Urinary (mg)	Phosphorus excretion: Total (mg)	Phosphorus balance (mg)
1	31	960	521·4	382·9	131·6	514·5	6·9
2	40	980	540·0	391·6	208·9	600·5	−60·5
3	29	1020	555·6	388·3	133·3	521·6	34·0
4	39	1050	587·4	396·8	120·5	517·3	70·1
5	33	1040	628·9	227·9	140·2	368·1	260·8
Mean	34·4	1010	566·7 ± 19·0	357·5 ± 15·8	146·9 ± 32·5	504·4	62·3 ± 54·0

by Aykroyd, Patwardhan & Ranganathan (1951) for the nutritive value of Indian foods. For example, the mean daily intake of calcium found in the present experiment (200 mg) was very much lower than the value of 310 mg reported before (Reddy *et al.* 1954). This lower value was due to (1) lower intake of ragi (14·2 g as against 40 g) and (2) to the lower calcium content (216 mg/100 g) of the sample of ragi consumed during the metabolism experiment as compared with the figure of 333 mg/100 g used in the earlier calculation. The mean daily intake of phosphorus (568 mg) by the five subjects was higher than the value (460 mg) reported earlier for the orphanage diet. This difference was due to the higher phosphorus content (168 mg/100 g) of the sample of rice consumed in the present experiment as compared with the value of 110 mg/100 g used in the earlier calculations.

Calorie intake. The mean daily intake of calories of the subjects was only 1010 Cal. This intake is quite inadequate as compared with the recommended allowance of 1700 Cal. (Aykroyd *et al.* 1951). Since the basal metabolism of individuals serves to some extent as a guide for finding out whether the intake of calories is insufficient to meet the requirements, the basal metabolism was calculated from body surface area using the standards suggested by Lewis, Kinsman & Iliff (1937). The body surface area was calculated according to the formula of Dubois & Dubois (1916). A reduction of 15% was made in the values obtained, as the basal metabolic rate of Indians has been found to be lower to that extent than the American standard (Patwardhan, 1944). The mean basal metabolism (for 24 h) of the children was found

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to be 718 Cal. (Table 6), as compared with the mean daily calorie intake of 1010 Cal. It will be observed that the mean calorie intake was about 40% more than the basal metabolism. Yudkin (1951) reported that the mean daily intake of calories by college students was greater than the calculated basal metabolism by about 50%, and the subjects were apparently maintaining good health. Macy (1942) found that the mean calorie intake of healthy children was greater than their basal metabolism by 90–100%. It is evident, therefore, that further work needs to be carried out on the basal metabolism and calorie requirements of undernourished children.

Table 6. *Comparison between the calculated 24 h basal metabolism and the mean daily calorie intake of children on a poor vegetarian diet containing rice*

Child no.	Body surface area* (m^2)	Calculated basal metabolism (*a*)	Calculated basal metabolism (*b*)	Mean daily calorie intake	Difference between the calorie intake and the basal metabolism: Cal.	Difference between the calorie intake and the basal metabolism: As percentage of basal metabolism
1	0·65	787	679	960	281	41
2	0·76	881	749	980	231	31
3	0·64	780	663	1020	357	54
4	0·76	881	749	1050	301	38
5	0·69	823	700	1040	340	49

* Calculated according to the formula of Dubois & Dubois (1916).

(*a*) Calculated from the body surface area using the standards of Lewis *et al.* (1937).
(*b*) Calculated basal metabolism after allowing 15% for the lower B.M.R. of Indians (Patwardhan, 1944). For details of calculation see p. 206.

Nitrogen metabolism. The mean daily intake of nitrogen of the children was 3·0 g and the mean daily retention was only 0·28 g. In spite of a low nitrogen intake of 191 mg/kg body-weight all the children were in positive balance. Macy, Hunscher, Hummel, Bates & Poole (1936) and Porter (1939) working with healthy, well-nourished children found large variations in the nitrogen retention of individual children in each age and weight group on identical intakes of nitrogen. They concluded that a mean daily consumption of 473 mg/kg body-weight is adequate for children of the age group 4–12 years. As might be expected, nitrogen retention of the growing child is likely to be affected by dietary factors other than the quantity and quality of the protein component, especially the calorie intake. Wang, Hawks & Kaucher (1928) reported that the mean nitrogen retention of seven undernourished children was greater than that of seven normal children of similar age (4–12 years) on a low protein intake. It is also of interest to note that Bartlett (1926) and Parsons (1930), working on diabetic children aged 4–14 years, found that a positive nitrogen balance could be attained on a low nitrogen intake of 160 mg/kg body-weight. A comparison of some of the available information on nitrogen intake and retention in children is presented in Table 7.

Calcium metabolism. The mean daily intake of calcium by the subjects was 200 mg. Four subjects were in positive balance and one was in negative balance. The mean

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calcium retention was only 23 mg. It is generally agreed that children require more calcium per unit body-weight than adults, to allow for bone formation during the periods of rapid growth. Age, height and weight must therefore be taken into account in determining a child's minimum calcium requirement. Further, calcium requirements have been reported to be affected by the previous nutritional history and the rate of growth of the individual (Wang, Kaucher & Franck, 1928; Nicholls & Nimalasuriya, 1939). Nicholls & Nimalasuriya (1939) presented evidence that poor classes of Sinhalese children frequently got no more than 0·2–0·4 g calcium daily, and yet their bone was normal in structure and composition. The children, however, were small in stature. These authors put forward the view that a process of adaptation to low levels of intake had taken place. The results obtained in the present study are in conformity with those reported by them.

Table 7. *Nitrogen intake and retention in children: a comparison of available data*

Reference	No. of subjects	Age (years)	Mean body-weight (kg)	Mean nitrogen intake (mg/kg body-weight)	Mean nitrogen retention (mg/kg body-weight)
Present work	5	7–9	15·5	191	18
Macy (1942)	6	6	21·8	466	20
	6	8	26·2	442	24
	2	9	28·4	457	37
Wang, Hawks & Kaucher	7	8·9	25·8	537	76
(1928)	7	8·9	24·9	269	1

Phosphorus metabolism. Phosphorus metabolism is linked with that of calcium as both minerals are essential for bone formation. In the present experiment the mean daily phosphorus intake was 567 mg. The mean retention was 64 mg, corresponding to 11 % of the intake. A large variation in the individual retention of phosphorus was observed. Of the five subjects, one was in negative balance and four maintained positive balance. Macy (1942) carried out phosphorus- and calcium-balance studies on well-nourished children fed on diets that were considered adequate. She found that on an average 14 % of an intake of 1·25 g phosphorus/day was retained.

SUMMARY

1. The metabolism of nitrogen, calcium and phosphorus was studied in five undernourished girls (aged 7–9 years) subsisting on a poor vegetarian diet based on rice. The mean daily calorie intake was 1010 Cal.

2. The mean daily nitrogen intake and retention were 3·0 and 0·28 g respectively. All the subjects maintained a positive balance.

3. The mean daily intake and retention of calcium were 200 and 23 mg respectively. One of the five subjects maintained a negative balance.

4. Four subjects maintained positive phosphorus balance, and one was in negative balance. The mean daily phosphorus intake was 567 mg and the average retention was 62 mg.

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