PAPERS AND ORIGINALS

Rickets, Growth, and Alkaline Phosphatase in Urban Adolescents

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Summary

Calciferol therapy for 12 months in white, Asian, and West Indian schoolchildren resulted in a highly significant increase in height and weight when compared with schoolchildren not so treated. The rate of fall of serum alkaline phosphatase was similar in both the treated and untreated schoolchildren and in other children treated in hospital for rickets. Dietary studies on 9% of the total survey by weighed inventory methods showed a low average intake of vitamin D, while random estimates of 25-hydroxycalciferol levels on 6% of the children were less than 3·8 ng/ml in 40% of those studied (principally Asian). It was concluded that there was a significant problem of vitamin D deficiency among Asian and West Indian teenagers and that white children were also affected to a less degree.

Introduction

Swan *et al.* (1971) reported their observations on rickets and osteomalacia in Birmingham immigrants, and Cooke *et al.* (1973) in a survey of city schoolchildren noted a high prevalence of raised levels of serum alkaline phosphatase and a significant incidence of rickets (A.P.) irrespective of race. This paper reports further observations on the children in the school survey and on a group of children referred to hospital who had the diagnosis of rickets confirmed by bone biopsy or radiologial examination or both. Particular record has been made of the effects of calciferol therapy on the levels of A.P. and on the growth rate.

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Methods and Materials

To facilitate identification and interpretation the schoolchildren and patients have been classified into groups and subgroups in the text and in the tables.

Of the original 569 children studied by Cooke *et al.* (1973) 121 with levels of A.P. of 30 K.A. units or more were re-examined and subjected to *x*-ray examination. Tablets of calciferol were given to each child with instructions to take 1·25 mg daily, and the children were seen regularly for blood checks and measurements of height and weight. Initially they were seen at monthly intervals, and after the first few times every two months. Of the 121 children 29 failed to keep up their attendances for the full 12 months and were excluded from the study, most being treated for six to nine months, but 81 boys (group 1) and 11 girls (group 4) attended for at least 12 months. Seventeen of the schoolboys had radiographic rickets (group 1a).

Fifty-one children—31 boys (group 7) and 20 girls (group 8)—who were referred to the hospital with symptoms—had rickets. Forty-seven showed radiological evidence and the remaining four had marked genu valgum and bone biopsy specimens showing excess osteoid tissue. In the boys A.P. levels varied from 34-258 K.A. units. Fifteen underwent bone biopsy and five jejunal biopsy. All except two of the boys ate a mixed type of diet. There were two West Indians, one white boy, and the rest were Asian. Among the girls three had had bone biopsies and two had had jejunal biopsies, and their A.P. levels varied from 31-330 K.A. units. Three were white girls and the rest Asians. Apart from the three white girls four took a mixed diet and the rest were vegetarians. These 51 children were also treated with calciferol 1·25 mg daily and the results of therapy were monitored with regular blood checks. All bone biopsy specimens showed excess osteoid tissue and the jejunal specimens were all normal.

Twenty female patients (aged 23-44) with osteomalacia (group 9) confirmed by the radiological presence of pseudo-

fractures or positive results of bone biopsies or both were also studied to provide evidence for the effect of calciferol 1·25 mg daily upon A.P. levels, free from the influence of the physiological growth spurt.

Two further control groups of schoolchildren from the original 569 schoolchildren were restudied. In one group permission was obtained from the parents of the pupils of two schools to recheck the height and weight and biochemical findings. As a result, 69 boys (group 2) and 10 girls (group 5) were examined 10 months after their initial examination. A further 90 boys (group 3) and 22 girls (group 6) were only weighed and measured, without blood examinations, 12 months after their initial examination and provided control evidence on the rate of growth in the absence of calciferol therapy.

25-Hydroxycholecalciferol levels were estimated by the competitive protein binding assay of Preece *et al.* (1973) on random samples taken during the initial survey of the schoolchildren and in some of the control children (2 and 5) as well as in many of the children referred to hospital with symptoms and with evidence of rickets (7 and 8). The mean value for the method cited (± S.D.) is 12·0 ng ± 5·4 (range 3·8 — 32·4 ng/ml). Other laboratory methods, including bone biopsy, have been detailed previously (Swan *et al.*, 1971; Cooke *et al.*, 1973).

Individual seven-day inventory records of weighed food intake (Marr, 1971) were kept by 53 children (group 10; 46 boys and 7 girls). The method of survey was similar to that given by Evans (1972). These children were drawn from groups 2, 3, 5, and 6 of two schools and had not been under regular surveillance. All had had an initial measurement of A.P., height, and weight, and all had a further measurement of height and weight but not all a second estimation of A.P. Forty-seven children (22 Asians 14 whites, and 11 West Indians) completed their food inventory satisfactorily (Ruck, 1973).

Results

The serum A.P. levels at the initial examination and at differing periods over 12 months while under treatment with vitamin D are given in table I and fig. 1. There was a significant difference between the mean initial levels found in the hospital boys with rickets (7) and those in the schoolboys (1; P <0·001) but not between the schoolboys (1) and the schoolboys with rickets (1a)

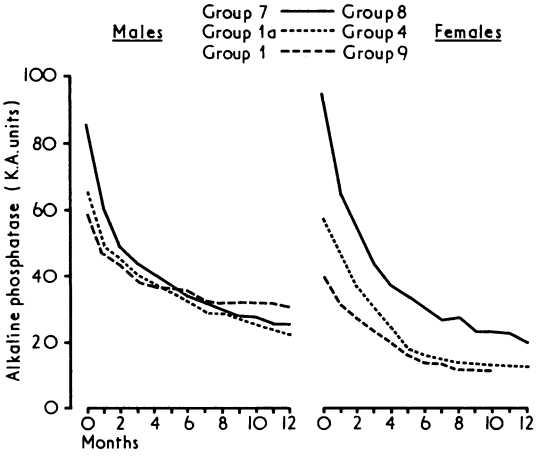

FIG. 1—Effect of vitamin D treatment on mean levels of alakaline phosphatase in males and females.

nor between these boys with rickets (1a) and the hospital boys with rickets (7). At 12 months the difference between the mean levels of all groups was slight. When subgroups of the treated (1a) and untreated control schoolboys (2a) were compared in comparable initial ranges of A.P. (30-49 K.A. units) there was no significant difference between these schoolboys in regard to rate of fall or the final levels of A.P. It will be seen (table 1) that in hospital boys (7) and girls (8) with rickets, and in schoolboys, both treated (1) and untreated (2), the upper limit of A.P. at 10 months was 40, 80, 60, and 54 K.A. units respectively. Such high levels did not correlate with a high initial level.

The increase of growth of schoolboys (1) treated with vitamin D and of some of those not so treated (3) are compared in tables II, III, and IV. The untreated schoolchildren (3) showed no significant differences from the treated (1) with regard to mean age or mean initial height and weight, but there was a highly significant difference in the rate of increase of height and weight (see table IV). The results have been broken down into groups according to the children's initial A.P. levels and when compared in ranges of A.P. above 30 K.A. units the children in treated groups still showed a significant increase in both height and

TABLE I—*Groups Studied with their Ages and Serum Alkaline Phosphatase Levels at Beginning of Study, after 10 Months, and after 12 Months*

Composition of Groups	Group	No. in Group	Age			Alkaline Phosphatase (K.A. units)								
						Initial Levels			10-Month Levels			12-Month Levels		
			Mean	S.E.	Range	Mean	S.E.	Range	Mean	S.E.	Range	Mean	S.E.	Range
Treated schoolboys	1	81	15·16	0·10	14-17	58·61	2·33	30-135	31·40	1·55	10-60	29·78	1·44	11·65
With rickets	1a	17	14·87	0·19	14-17	65·7	6·70	30-135	25·75	2·59	12-45	21·73	1·98	11-36
Comparable with 2a and 3a	1b	31	15·25	0·10	14-17	40·77	0·98	30-49	25·0	1·80	10-56	25·32	2·08	11-49
Control schoolboys	2	69	15·15	0·11	14-17	37·80	2·19	8-115	22·3	1·19	8-54	—	—	—
Comparable with 1b and 3a	2a	37	14·93	0·37	14-17	38·2	0·49	30-49	24·4	0·75	13-52	—	—	—
Growth control schoolboys	3	90	15·49	0·09	14-17	27·63	1·60	8-95	—	—	—	—	—	—
Comparable with 1b and 2a	3a	37	14·88	0·08	14-17	37·97	0·83	30-49	—	—	—	—	—	—
Treated schoolgirls	4	11	15·39	0·22	14-17	58·5	10·53	32-150	13·90	1·07	10-20	13·36	0·94	10-20
Control schoolgirls	5	10	15·59	0·25	14-17	19·1	3·39	9-38	13·4	2·03	7-24	—	—	—
Growth control schoolgirls	6	22	15·9	0·18	14-17	17·0	3·24	9-82	—	—	—	—	—	—
Hospital boys	7	31	15·19	0·45	7-18	86·12	9·86	26-258	28·0	1·88	13-40	25·1	2·04	13-38
Hospital girls	8	20	13·60	0·81	5-19	94·8	17·18	40-330	22·3	5·23	10-80	19·2	4·69	8-75
Osteomalacic women	9	20	31·2	1·55	23-44	39·6	5·14	20-110	13·6	0·97	5-26	—	—	—

TABLE II—*Rate of Growth in 81 Schoolchildren (Group 1) with Initial Alkaline Phosphatase Levels of 30 K.A. Units or more who were Treated with Vitamin D*

Alkaline Phosphatase (K.A. units)			No. of Children	Age (Years)		Height (cm)					Weight (kg)				
						Initial		Increase			Initial		Increase		
Range	Mean	S.E.		Mean	S.E.	Mean	S.E.	Mean	S.E.	Range	Mean	S.E.	Mean	S.E.	Range
30-39	35·1	0·90	12	15·4	0·18	163·5	3·32	8·0	1·92	2·4-18	49·6	2·75	8·1	1·68	3-24
40-49	44·4	0·61	19	15·1	0·14	161·3	2·04	7·7	0·66	3·0-14	51·6	2·67	7·3	0·69	3-14·3
50-59	53·8	0·66	17	15·1	0·15	165·8	2·80	6·8	0·79	2·0-11	52·8	2·37	6·4	0·83	0-12·5
60-69	62·4	0·80	15	14·9	0·15	162·6	1·51	7·0	0·61	4·1-10	48·5	2·37	7·9	0·66	3-12·8
70-135	86·0	3·94	18	15·3	0·25	162·1	2·29	6·6	0·75	1-12	47·9	2·24	7·3	0·77	2·1-15
30-135	58·6	2·33	81	15·2	0·09	162·9	1·05	7·16	0·41	2·4-14	50·4	1·10	7·38	0·39	0-15

TABLE III—*Rate of Growth over 12 Months in 90 Schoolchildren (Group 3) who were not given Vitamin D*

Alkaline Phosphatase (K.A. units)			No. of Children	Age (Years)		Height (cm)					Weight (kg)				
						Initial		Increase			Initial		Increase		
Range	Mean	S.E.		Mean	S.E.	Mean	S.E.	Mean	S.E.	Range	Mean	S.E.	Mean	S.E.	Range
8-19	13·2	0·78	23	16·3	0·18	164·4	1·81	1·5	0·40	0-7·7	58·9	2·04	1·6	0·38	1-10
20-29	24·2	0·54	26	15·8	0·13	163·3	1·30	2·1	0·36	0-6·3	53·0	1·81	3·8	0·37	0-20
30-39	34·8	0·68	22	15·0	0·11	161·1	1·29	4·9	0·52	0-9·0	52·9	1·66	4·1	0·52	0-9·1
40-49	42·9	0·61	15	14·7	0·12	163·8	1·53	3·4	0·58	0-7·8	53·1	1·80	4·8	0·61	0-9·6
50-95	82·0	6·75	4	14·9		161·0		5·9		3·3-7·8	57·2		1·7		0-5·4
8-95	27·6	1·6	90	15·5	0·09	162·9	0·75	2·9	0·27	0-90	54·59	0·98	3·5	0·38	0-20

TABLE IV—*Statistical Comparison of Rate of Increase in Height and Weight for Children from Groups 1 and 3 according to Levels of Alkaline Phosphatase*

Group	Alkaline Phosphatase Range (K.A. units)	No. in Group	Age (Years)		Height (cm)					Weight				
					Initial		Increase			Increase		Initial		
			Mean	S.E.	Mean	S.E.	Mean	S.E.	P	Mean	S E.	Mean	S.E.	P
1	30-39	12	15·4	0·18	163·5	3·32	8·0	1·92	0·066	49·6	2·75	8·1	1·68	<0·01
3	30-39	22	15·0	0·11	161·1	1·29	4·9	0·52		52·4	1·66	4·1	0·52	
1	40-49	19	15·1	0·14	161·3	2·04	7·7	0·66	<0·0001	51·6	2·67	7·3	0·69	<0·02
3	40-49	15	14·7	0·12	163·8	1·53	3·4	0·58		51·3	1·80	4·8	0·61	
1	30-135	81	15·2	0·09	162·9	1·05	7·2	0·41	<0·0001	50·4	1·10	7·4	0·39	<0·0001
3	8-95	90	15·5	0·09	162·9	0·75	2·9	0·27		54·6	0·98	3·5	0·38	
1	30-135	81	15·2	0·09	162·9	1·05	7·2	0·41	<0·0001	50·4	1·10	7·4	0·39	<0·0001
3	30-95	41	14·9	0·08	162·0	0·97	4·56	0·38		53·2	1·31	4·1	0·42	
1b	30-49	31	15·3	0·10	162·3	1·77	7·8	0·79	<0·001	50·0	1·99	7·4	0·75	<0·001
3a	30-49	37	14·9	0·08	162·2	1·00	4·4	0·40		52·1	1·32	4·4	0·44	

TABLE V—*Age, Serum Alkaline Phosphatase, and Rate of Growth (Increase after 12 Months) in White, Asian, and West Indian Children according to Vitamin D Treatment. P values hold between Groups given Vitamin D and those not given Vitamin D*

	Alkaline Phosphatase Range (K.A. units)	No. in Range	Mean Age (± S.E.)	Alkaline Phosphatase Levels (K.A. units)		Height (cm)			Weight (kg)		
				Initial	At 12 Months	Initial	Increase		Initial	Increase	
				(Mean ± S.E.)	(Mean ± S.E.)	(Mean ± S.E.)	(Mean ± S.E.)	P	(Mean ± S.E.)	(Mean ± S.E.)	P
White:											
No Vitamin D	10-47	27	15·4 ±0·14	29·4 ±1·88	—	164·6 ±1·20	3·5 ±0·54	<0·0001	57·2 ±1·5	4·1 ±0·58	<0·01
	30-47	13	14·9 ±1·45	37·6 ±1·45	—	161·4 ±1·65	5·0 ±0·68	0·021	54·2 ±2·24	5·1 ±0·72	0·08
Vitamin D	30-72	23	15·3 ±0·13	47·9 ±2·3	27·0 ±2·01	164·5 ±2·04	7·3 ±0·60		55·2 ±2·33	6·9 ±0·68	
Asian:											
No Vitamin D	7-95	44	15·8 ±0·13	26·1 ±2·95	—	161·9 ±1·00	2·8 ±0·37	<0·0001	53·7 ±1·46	2·8 ±0·43	<0·0001
	30-95	11	15·6 ±0·20	50·9 ±7·49	—	162·6 ±0·95	3·9 ±0·53	0·015	55·1 ±2·59	2·5 ±0·73	<0·001
Vitamin D	30-102	31	15·0 ±0·15	62·1 ±4·01	25 ±2·47	160·24 ±1·72	7·6 ±0·83		45·4 ±1·62	7·5 ±0·80	
West Indian:											
No Vitamina D	15-63	19	14·9 ±0·18	38·0 ±2·18	—	163·1 ±1·87	3·9 ±0·71	<0·01	52·2 ±2·11	3·9 ±0·64	<0·001
	30-63	18	14·9 ±0·19	38·8 ±2·18	—	162·4 ±1·83	4·1 ±0·70	0·011	51·6 ±2·32	4·2 ±0·66	<0·002
Vitamin D	30-135	27	15·0 ±0·10	62·0 ±3·91	38·6 ±2·49	165·4 ±1·76	6·8 ±0·67		52·4 ±1·54	7·1 ±0·54	

TABLE VI—*Mean (± S.E.) Nutrient Intakes of 53 Children (Group 10) by the Weighed Inventory Method. Figures in Parentheses are Percentages of British Recommended Allowance for appropriate Age and Sex*

	Whole Group	Boys	Girls	Asians	West Indians	Whites
Calories	2,170 ± 610	2,270 ± 590 (81)	1,441 ± 330 (62)	2,140 ± 700	2,030 ± 510	2,300 ± 620
Vitamin D (μg)	1·70 ± 1·20	1·70 ± 0·60	1·10 ± 0·60	1·50 ± 1·20	1·80 ± 1·30	1·60 ± 1·00
Calcium (mg)	780 ± 310	790 ± 310	510 ± 130	850 ± 330	540 ± 240	780 ± 260
Phytate (mg)	160 ± 130	170 ± 130	90 ± 30	230 ± 140	80 ± 30	90 ± 40

weight. This was particularly so in children in the most comparable ranges of 30-49 K.A. units (Groups 1b and 3a). This significant difference was also shown when untreated white, Asian, and West Indian schoolchildren (3) were compared with treated white, Asian, and West Indian schoolchildren (1) respectively (table V).

The correlation between the initial A.P. levels and the rate of increase of height of each child in the subsequent 12 months was significant both in the treated (1; r = 0·44; P <0·005) and untreated groups (C3; r = 0·39; P <0·001; fig. 2). Also, the mean increase in height for the individual ranges of A.P. was plotted against the mean serum level for that range. Though there were only four and five points respectively the correlation coefficient for increase in height with initial alkaline phosphatase in the untreated children (3) was 0·85 (0·05 < P <0·10) and −0·87 for the treated schoolboys (1) (P <0·05). The correlation of initial A.P. with weight increase was not significant in either the treated or untreated children. In fig. 3 the results of estimation of 25-hydroxycholecalciferol in 33 randomly chosen schoolchildren are plotted against A.P. (r = −0·34; P = 0·05). Low values (less than 3·8 ng/ml) were noted in four Asian girls with A.P. levels between 7 and 13; no *x*-ray pictures were taken.

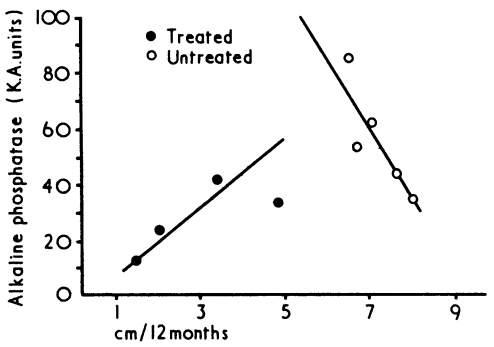

FIG. 2—Correlation between individual alkaline phosphatase levels and subsequent increase in height for 90 untreated schoolboys (group 3; r = 0·39; P <0·001) and 81 schoolboys (group 1) treated with calciferol (r = 0·44; P <0·0001). Superimposed points show relation between mean values of ranges of alkaline phosphatase (10-19, 20, 29, 30-39, etc.) and mean increase in height (cm/year) for these ranges.

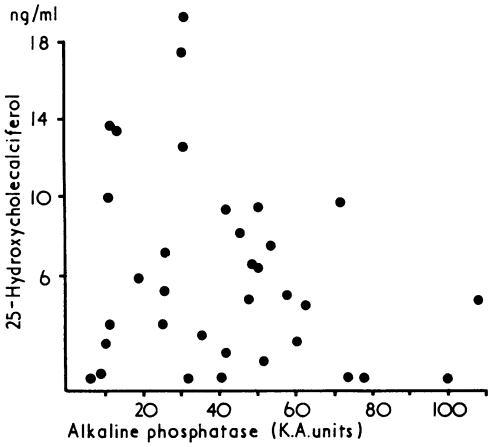

FIG. 3—Serum levels of 25-hydroxycholecalciferol and alkaline phosphatase in 33 schoolchildren.

There were also 10 children with A.P. levels greater than 30 K.A. units in whom 25-hydroxycholecalciferol values were within the normal range for the laboratory. The mean 25-hydroxycholecalciferol levels in nine white children was 10·3 ng/ml (range 3·6-19·4), in 13 Asian children 2·3 ng/ml (range 0·8-9·4), and in 11 West Indians 6·9 ng/ml (range 1·6-12·6). Of the nine hospital patients with rickets with available estimations the mean value was 1·6 ng/ml (range 0·8-4·7). Of these nine the child with the most florid radiological appearances of rickets had serum values of 2·6 ng/ml and 4·7 ng/ml taken two months apart before treatment began.

The values for calorie, vitamin D, calcium, and phytate intakes for the 47 children (10) are given in table VI). There was no overall relation between A.P. levels and either vitamin D or phytate intake or between vitamin D intake and growth though intakes below 50% of recommended allowances of 2·5 μg/day were negatively correlated with A.P. (r = 0·6; P <0·005). Those who ate margarine had significantly higher intakes (mean 2·35 μg) than the others (P <0·005). The range of intakes was from 0·30 to 4·90 μg. Five Asian boys with initial A.P. values above 80 K.A. units had a mean intake of 0·6 μg. Three of these and one white child who had A.P. above 30 units at time of dietary survey—that is, 10-12 months after initial observations—had a mean intake of 0·9 μg. In a group of seven children whose vitamin D intakes were low before and during the survey four had stopped growing and three had growth rates less than 0·15 cm per month. The influence of the size of family is shown in table VII. The largest intake of vitamin D was seen in those with the largest families. This was due to the number of West Indians in this group and the large amount of margarine consumed by them.

TABLE VII—*Mean Calcium and Vitamin D Intake according to size of Family*

No. of children per family:	1 or 2	3 or 4	5 or 6	7–10
No. of families ..	9	13	13	10
Calories (boys only) ..	2,600	2,250	2,190	1,960
Vitamin D (μg) ..	1·40	1·50	1·60	2·20

Discussion

The time taken for the mean levels of A.P. to return to normal levels in osteomalacic women treated with calciferol was 10-12 months. The time in the children was similar in girls but much longer in boys. There was virtually no difference in the rate of fall between the children with rickets, children who were treated with vitamin D, or the control children, who had no therapy. The fact that levels of A.P. in the untreated children (2) after 10 months were of the same order as those in the treated schoolboys (1) or the boys with rickets (1a and 7) lends support to the contention that the raised A.P. levels reflect no more than the effect of the physiological growth spurt. If A.P. is raised in adult osteomalacics (9), however, and returns to normal levels with therapy, presumably there is a similar factor playing a part in producing the raised levels seen in the school survey, particularly in those boys and girls with radiological evidence of rickets, which must be associated with vitamin D deficiency.

It is evident from this study that the level of A.P. bears a significant relation to the rate of growth experienced by the child over the next 12 months. This is quite clear in relation to increase in height but not with regard to weight. Nevertheless, when the increases in weight and height of the group of schoolchildren (1) receiving vitamin D and those not so treated (3) were compared there was a highly significant difference. In view of the definite relation between rate of growth and A.P. levels, however, the two groups are not entirely comparable. Those treated with calciferol were treated because their levels were 30 K.A. units or greater, while in those not treated the levels ranged from 7 to 95 K.A. units. Even so, comparisons of the rate of growth in those whose initial levels were between 30 and 49 units did show significant differences. In addition, the inverse correlation of the rate of increase in height with A.P. levels in those treated with calciferol, in contrast with direct correlation in the untreated schoolchildren, does suggest that there were real differences between the two groups. Consequently, the marked increase in height and weight was probably related to the effects of calciferol therapy and, by inference, lack of adequate amounts of cholecalciferol in the serum of the untreated children.

Breakdown of treated and untreated schoolchildren into their racial groups showed that the significant differences in increases in height and weight persisted in whites, Asians, and West Indians. Despite some differences in their initial heights and weights there was no real difference in regard to the increase in height and weight, whether in the treated groups or in untreated groups. It is worth noting that the mean height of the white children in these subgroups and of the white schoolboys of this age discussed in our previous report (Cooke *et al.*, 1973) fell between the 10th and 25th percentile. They were 8-10 cm shorter in Birmingham than those in the London area, who fell on the 75th percentile (Round, 1973). Indeed, though the height of the 14-year-old white children in our school survey showed no significant difference from those in Round's report, the differences in the 15-year-olds (P <0·0001) and 16-year-olds (P <0·006) were highly significant, suggesting that the London and Birmingham surveys may not be strictly comparable as regards their nutritional status. Whether the amount of sunlight experienced by the children in the two areas plays any part

in the differences must remain conjectural. It is worth comment that there are fewer hours of sunlight in Birmingham than those found nationally or in London; indeed, during the summer months, the sunshine is also less than that seen in Glasgow.

If the increase in height and weight in our treated children was related to vitamin D intake why was there so little difference between the rates of fall of A.P. in those treated and those not treated? During the growth spurt, the factors for which are by no means clear, there is an increased demand for vitamin D. Relevant to this point, radiological evidence of healing rickets was seen in some of the children. The children must therefore be getting small quantities of cholecalciferol. Indeed, from the evidence of weighed meals, a child with severe rickets diagnosed radiologically in our hospital series was taking an estimated 0·6 μg vitamin D daily, while the average vitamin D intake calculated for 53 of the schoolchildren (10) was 1·90 μg.

We found that the rickets or vitamin D deficiency seems likely to be cured with the ending of the physiological growth spurt. This occurs, however, at the expense of 3-4 cms less height and 3-4 kg less weight in the untreated children compared with those who had adequate vitamin D. There is little data in the literature as to the effects of vitamin D on the rate of fall of serum A.P. levels. Though no comment was made, there was no difference in the changes in A.P. in Asians as reported by Holmes *et al.* (1973), whether treated or not treated. Morgan *et al.* (1965) showed considerable variations in the post-treatment levels of A.P. in his postgastrectomy patients with osteomalacia and also commented that no change was effected in 12 months in one patient.

As had been indicated many children and patients continued to show persistently raised levels of A.P., despite evident relief of symptoms in those with rickets or osteomalacia and increased growth rate in the schoolchildren. In some instances this was due to failure to take tablets but often keen parental interest made this possibility improbable, while raised 25-hydroxycholecalciferol levels in others showed that therapy must have been taken. For example, G.S.—a West Indian boy aged 15 with an initial S.A.P. of 135, minimal evidence of radiological rickets, and a serum 25-HCC of 2·3 ng/ml—after an initial fall in S.A.P. to 70 K.A. units, showed a persistently raised S.A.P., varying between 55 and 74, over the next 12 months. His 25-HCC level was 111·8 ng/ml at 8 months. Hence, the failure to take therapy is not the only explanation. A sufficient number of examples were found among our patients with rickets in whom therapy had undoubtedly been accepted to prompt us to seek additional explanations—such as vitamin D "resistance" for which there may be many causes. To cover such possibilities a daily dose of 1·25 mg calciferol was used. This was the same dosage customarily given to our patients with osteomalacia secondary to intestinal disorders or in old age. In more than 1,000 blood examinations carried out in this study no subjective symptoms of vitamin D intoxication nor instances of hypercalcaemia were found.

Serum levels of 25-hydroxycholecalciferol are thought to represent the best way of assessing rickets though the evidence on which to base this is as yet inconclusive. The presumed active metabolite—1·25-dihydrocholecalciferol—exists in extremely low concentrations. According to Arnaud (1973) it will probably be necessary to measure this compound in the plasma to achieve meaningful investigations in disorders of vitamin D metabolism. Even so, low serum values of 25-hydroxycholecalciferol must have some clinical significance. In this survey the sampling was started late in the study and the individual studied was determined by the ease of withdrawal of blood. There was no evidence to suggest that any of these 33 children were clinically different from others in the survey. The values for 25-hydroxycholecalciferol in these children showed that 40% had values less than 3·8 ng/ml.

Only one of the 24 children with obvious radiological rickets reported previously (Cooke *et al.*, 1973) was included in the group, the radiological changes of which were otherwise minimal. The incidence of low serum levels of 25-hydroxycholecalciferol was biased by the large number of Asians with low values. Thus, values of less than 3·8 ng/ml were found in 10 out of 13 Asians, one out of nine white children, and three out of 11 West Indians. Allowing for this bias, deductions from this small sample and the height and weight changes associated with vitamin D administration suggest that the incidence of low serum values of 25-hydroxycholecalciferol in the schoolchildren in this survey may be unacceptably high.

The dietetic survey was subject to error of measurement as well as to variations in the weekly intake. Allowing for such errors the findings were in keeping with the other results in this study and supported our suggestion that there is a fairly widespread deficiency in dietary sources of vitamin D. The sample examined represented 9·4% of the 569 survey children and was selected on the basis of availability and ability to co-operate in carrying out the study. The higher daily intake of vitamin D in the West Indians in this small sample underlines the possible value of fortified dietary fats and further study in this area may well prove rewarding.

In summary we can only conclude that many schoolchildren in Birmingham have evidence of vitamin D deficiency and that whites, Asians, and West Indians are affected. We have been impressed by the improvement in muscle tone and activity in those children on treatment and by the fact that even the children with the worst cases of rickets shown radiographically are otherwise well nourished. Also, we think that vitamin D deficiency cannot be determined merely by looking at and talking to the children. It is evident that there is a serious problem among the immigrant population of school age, which warrants more definitive action. While the problem is not of the same degree of severity, vitamin D deficiency also affects the white population of school age and, until more complete and adequate investigations are carried out in other cities, we find it difficult to accept the assurance that the problem amongst teenage children is a minor one (Department of Health and Social Security, 1973).

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