Serum Calcium, Magnesium, Phosphorus, Alkaline Phosphatase and 25-Hydroxyvitamin D Concentrations in Children

J. M. PETTIFOR, F. P. ROSS, G. MOODLEY, J. WANG, G. MARGO, C. SKJOLDE

SUMMARY

Serum calcium, magnesium, phosphorus, alkaline phosphatase and 25-hydroxyvitamin D concentrations for Coloured children between the ages of 1 and 17 years are reported. No evidence of vitamin D deficiency was found. The problem of the interpretation of 'normal' alkaline phosphatase concentrations is highlighted.


Normal values for serum calcium, phosphorus, magnesium, alkaline phosphatase and 25-hydroxyvitamin D in a population are of importance if abnormalities of calcium metabolism are to be detected. Although rickets due to vitamin D deficiency is still seen in infants in Southern Africa, no information is available on the concentration of vitamin D and other substances related to mineral metabolism in children over the age of 1 year. For these reasons, and to assess the nutrition of Coloured (mixed-race) children in Johannesburg, chemical variables related to calcium metabolism were measured.

SUBJECTS AND METHODS

Two hundred and fifty-five Coloured children between the ages of 1 and 17 years, living in Western Township (part of the Coloured residential area of Johannesburg), were studied. The techniques employed in sampling the population have previously been described. The study was conducted during the winter months of 1974. Blood samples were obtained by venepuncture in the majority of children without proximal occlusion of the vein. The sera were separated and stored at −20°C until biochemical analyses were performed in batches. Informed consent was obtained from a parent in all cases.

Serum calcium coefficient of variation (CV 2.4%) and magnesium (CV 7.4%) were measured on a Varian 1200 atomic absorption spectrophotometer. Serum phosphorus was assayed by standard techniques (CV 4.6%) and alkaline phosphatase by the method of Morgenstern et al. (CV 14.1%), with a Technicon AutoAnalyzer II. Measurement of 25-hydroxyvitamin D was by a competitive protein binding technique utilizing vitamin D-deficient rat serum as the binding protein (interassay variation 14%).

RESULTS

The general nutritional status of the children has been reported previously. Only 4 children had serum albumin concentrations below 35 g/l. Of these, 1 was diagnosed as having kwashiorkor and 3 as suffering from marasmus. Of the sample, 36.5% and 16.1% were below the 3rd percentile for weight and height respectively.

Calcium concentrations: The mean serum calcium concentration for the sample was 9.71 ± 0.59 mg/dl (2.43 ± 0.15 mmol/l, mean ± 2 SD) (Table I). No differences were noted between the sexes, nor was there any correlation with age (Fig. 1). A positive correlation was shown between serum albumin and calcium concentrations (r = 0.268; p = 0.001). Two children had serum calcium values below 9.0 mg/dl (2.25 mmol/l), an incidence of 0.72%.

Magnesium: The mean serum magnesium concentration for the sample was 2.08 ± 0.29 mg/dl (0.85 ± 0.12 mmol/l, mean ± 2 SD) (Fig. 2). There were no sex differences. A
TABLE I. SERUM CALCIUM AND MAGNESIUM VALUES IN COLOURED CHILDREN AGED 1 - 16 YEARS (RESULTS FOR BOYS AND GIRLS HAVE BEEN COMBINED)

<table>
<thead>
<tr>
<th>Age group (yrs)</th>
<th>Whole group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16</td>
</tr>
<tr>
<td>(mean ± 2 SD)</td>
<td>0.66 0.38 0.61 0.65 0.55 0.48 0.49 0.54 0.52 0.66 0.45 0.65 0.56 0.59 0.66 0.59</td>
</tr>
<tr>
<td>Number in group</td>
<td>25 21 20 21 18 11 13 16 17 20 18 21 12 18 14 11 276</td>
</tr>
<tr>
<td>Magnesium (mg/100 ml)</td>
<td>2.14 2.13 2.07 2.12 2.08 2.14 2.03 2.07 2.07 2.06 2.01 2.05 2.15 2.04 2.09 2.05 2.08</td>
</tr>
<tr>
<td>(mean ± 2 SD)</td>
<td>0.36 0.36 0.30 0.31 0.25 0.21 0.18 0.30 0.27 0.28 0.23 0.27 0.29 0.14 0.31 0.29 0.29</td>
</tr>
<tr>
<td>Number in group</td>
<td>26 21 20 21 18 11 13 16 17 20 18 21 12 18 14 10 276</td>
</tr>
</tbody>
</table>

slight negative correlation between magnesium concentration and age was found ($r = 0.151; P = 0.006$).

**Phosphorus:** Serum phosphorus values showed both sex and age differences (Table II, Fig. 3). For both sexes the means dropped progressively from the age of 1 year and plateaued around 6 years of age; however only in the 1-3-year age group was the mean significantly different from that of the group aged up to 14 years (Scheffé test, $P < 0.05$). The mean phosphorus concentration for both sexes fell again from 14 years of age, dropping more sharply in the girls. The means for the 14-16-year age group of both sexes were significantly different from the means for children aged 4-14 years ($P < 0.05$).

**Alkaline phosphatase:** The serum alkaline phosphatase values are depicted in Table II and Fig. 4. Mean concentrations were obtained after logarithmic transformation of the data. Values for boys and girls were similar until the age of 10 years, when the values for the girls rose, peaked around 12 years of age and then fell rapidly, approaching adult levels by 16 years of age. This pattern was not evident in the values for the boys; from the age of 13 years, the scatter of concentrations became much greater, but no distinct rise and subsequent fall were seen. The fall to adult values was not seen in the male group, presumably because the age range was not extended far enough. Both boys and girls showed a slight peak, which is unexplained, around the age of 8 years.
DISCUSSION

Data for biochemical variables of mineral metabolism in children are scanty. Studies which have been reported are from developed countries such as Britain and the USA. Values for the children in the various ethnic groups of South Africa are not available.

Serum calcium and magnesium concentrations in our subjects were very similar to those reported by Round6 for the ages 7 - 17 years (mean 9,6 mg/100 ml and 2,09 mg/100 ml) respectively. Unlike the results obtained by Arnaud et al., who showed a gradual fall in mean calcium values until 6 - 8 years of age, no age-related changes were noted. These authors also noted that girls aged 8 - 16 years had higher calcium values than the boys; this finding has not been confirmed in our patients, and is supported by the data of Round.6 The Coloured children in the present study tended to fall below the 50th percentile of the Boston standards for height, % being below the third percentile. Although this appears to indicate poor nutrition, it had little effect on the serum calcium values, as the means were very similar to those reported in an earlier study6 in which the majority of children were above the 50th percentile.

Serum inorganic phosphorus concentrations have previously been shown to change during childhood, the values being highest in the immediate postnatal period, after which they fall to a plateau which is maintained until adolescence, when the concentrations rapidly fall to adult levels.7-8 The present study showed a similar trend, although the actual values lie between those of Arnaud et al.7 and Round.6 Factors such as the time of the day when the sample was taken, when the subject had last eaten, the age at which the child enters puberty and the differences in methodology may account for the differences.

As has been previously reported,5,6,9-10 serum alkaline phosphatase concentrations are mildly affected by puberty. Values in prepubertal children are generally considered to be 2 - 3 times higher than in adults; during puberty the values rise and then fall rapidly to adult values, as the children become sexually mature.20 The wide scatter of

---

**TABLE I. SERUM PHOSPHORUS, ALKALINE PHOSPHATASE AND 25-HYDROXYVITAMIN D CONCENTRATION IN AGE GROUPS OF 2 YEARS.**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Inorganic phosphorus (mg/100 ml)</th>
<th>Alkaline phosphatase (U/l)</th>
<th>25-hydroxyvitamin D (ng/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 2 yr</td>
<td>5.77 - 6.40</td>
<td>4.31 - 5.10</td>
<td>11.2 - 15.6</td>
</tr>
<tr>
<td>3 - 4 yr</td>
<td>5.31 - 5.97</td>
<td>4.08 - 5.10</td>
<td>10.7 - 17.6</td>
</tr>
<tr>
<td>5 - 6 yr</td>
<td>5.02 - 5.74</td>
<td>3.96 - 5.00</td>
<td>11.0 - 15.4</td>
</tr>
<tr>
<td>7 - 8 yr</td>
<td>4.74 - 5.51</td>
<td>3.88 - 4.83</td>
<td>10.4 - 17.2</td>
</tr>
<tr>
<td>9 - 10 yr</td>
<td>4.52 - 4.58</td>
<td>3.74 - 4.70</td>
<td>10.1 - 16.9</td>
</tr>
<tr>
<td>11 - 12 yr</td>
<td>4.36 - 4.50</td>
<td>3.66 - 4.60</td>
<td>9.9 - 16.6</td>
</tr>
<tr>
<td>13 - 14 yr</td>
<td>4.19 - 4.39</td>
<td>3.56 - 4.50</td>
<td>9.7 - 16.4</td>
</tr>
<tr>
<td>15 - 16 yr</td>
<td>4.18 - 4.36</td>
<td>3.54 - 4.40</td>
<td>9.5 - 16.2</td>
</tr>
</tbody>
</table>

---

**Fig. 5. Serum 25-hydroxyvitamin D concentrations. Results for boys and girls have been combined.**

---

**25-hydroxyvitamin D:** Mean values were relatively constant until around the age of 9 years, when they fell slowly to a mean of 22.7 ng/ml in children over the age of 15 years (Fig. 5, Table II). There was no difference in the concentrations between the boys and girls. No children had values less than 10 ng/ml.
normal values during puberty makes the use of alkaline phosphatase concentration for the diagnosis of pathological conditions such as rickets very unsatisfactory without evidence of changes in calcium and phosphorus concentrations. The numerous different units and methods used to measure alkaline phosphatase values also make comparison of results with those of other authors very difficult.

The major circulating form of vitamin D is 25-hydroxyvitamin D. Its serum concentration is considered to be an indication of the vitamin D status of the individual. Although not the physiologically active metabolite, serum 25-0H-D values reflect the vitamin D intake or the conversion of 7-dehydrocholesterol to vitamin D in the skin by ultraviolet light. The mean values obtained in this study were higher than those reported from Britain, but were similar to those reported in the USA. The progressive fall in values seen in the Coloured children from the age of about 8 years may relate to a decrease in sunlight exposure, as the children generally start school around the age of 7 years.

In conclusion, concentrations of serum calcium, phosphorus and magnesium in a random sample of Coloured children were similar to those reported for other children. Alkaline phosphatase values change with both age and sex, but comparison with other populations is difficult because of the different methods used by other authors. No evidence of vitamin D deficiency was demonstrated in children over the age of 1 year. Circulating levels of 25-OH-D fall with age, and this may be related to decreased exposure to sunlight as the children grow older.

The financial support of the South African Medical Research Council and the Atomic Energy Board is gratefully acknowledged. The continued encouragement of Professor J. D. L. Hansen is appreciated.

REFERENCES