or heart disease. About 50 cases (5%) were considered under these headings and epidural anaesthesia was given on 13 occasions.

Dilatation of the cervix is the measure of progress in labour and a simple graph on which cervical dilatation is plotted every hour is of much help in routine practice (Philpott and Castle, 1972 b). Rectal examination has a decided advantage over vaginal examination in assessing progress because it can be performed at regular intervals with much less formality, which is an important practical consideration in a busy unit. There is a growing belief that labour cannot be conducted efficiently without mechanical aids, though the opposite is frequently the case when undue emphasis is laid on one aspect of labour to the detriment of total patient care. Automated pumps are not used in this hospital because precise rates of flow offer no advantage and a machine can be a poor substitute for personal attention. A personal nurse is the basis of good intranatal care.

Though doubts have been expressed about the practical problems arising from the supervision of numerous infusions (British Medical Journal, 1972), it is only when the duration of labour is restricted that it is possible to provide every patient with personal attention. There were 7,250 births in this hospital during 1972 and every patient had a personal nurse because for each nurse employed the number of babies born was three times greater than in similar hospitals in the United Kingdom (O’Driscoll, 1972). The unproductive use of nursing time is related to the number of inductions but of the 267 cases in the present series in which labour was induced only 63 required the use of oxytocin (6-3%). Nurses were therefore free to concentrate on patients in labour.

The conclusion is that once labour has started it is possible to regulate the duration with almost complete success. This requires a systematic approach with formal diagnosis, regular assessment, and decisive action in every case admitted to a delivery unit. A realization that the important decisions are made in the first two hours is essential. Greatly improved efficiency leads to the ideal situation in which every woman has a personal nurse. There is an urgent need for radical reappraisal of labour along these lines because, in spite of a growing awareness of the principle of planned action, conventional attitudes, both lay and medical, are still based on the assumption that labour remains open-ended and not subject to genuine control. Neither is it generally recognized that almost all the complications of labour are secondary phenomena, themselves products of passive management. The problem of pain is a noteworthy example. Active management has been standard practice in this hospital for more than five years, when more than 30,000 babies were born, and it has been presented to students of medicine, nursing, and physiotherapy as the normal approach to labour. The educational process has now been extended to patients, particularly primigravidae on whom the mere prospect of prolonged labour may have a prejudicial effect.

We are grateful to the nursing sisters in the delivery unit at the National Maternity Hospital to whom the credit for the management of these patients is due, to Dr. Francis Geoghegan who performed the necropsies, and to Dr. Niall O’Brien who assisted the infants for brain damage. We wish to acknowledge the encouragement and constructive criticism of the Master, Dr. Declan Meagher.

References

British Medical Journal, 1972, 2, 126.

Plasma Calcium, Magnesium, Phosphorus, and Alkaline Phosphatase Levels in Normal British Schoolchildren

JOAN M. ROUND

British Medical Journal, 1973, 3, 137–140

Summary

In a cross-sectional survey 624 schoolchildren were screened for plasma calcium, inorganic phosphate, and alkaline phosphatase levels. Plasma magnesium and alkaline phosphatase isoenzymes were also estimated in some cases.

No significant difference was found between adult and childhood values for calcium and magnesium. Levels of alkaline phosphatase and inorganic phosphorus varied with both age and sex. The magnitude of these variations in normal ranges is of clear importance in assessing data from individual paediatric or adolescent patients.

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Introduction

While biochemical values in apparently healthy adults have been well documented similar data from children and adolescents are scanty, and this makes the interpretation of biochemical tests from young patients difficult. Particular difficulties exist with regard to the investigation of hereditary and acquired disorders of bone growth and development. It was therefore important to estimate plasma calcium, alkaline phosphatase, and inorganic phosphate in a sample population of apparently healthy schoolchildren between the ages of 7 and 17 years, thus covering almost completely any changes which might be associated with normal puberty. Magnesium, another cation closely related to calcium, was also determined.

Subjects and Methods

Boys and girls from four London and two Hertfordshire schools participated in the survey. The schools in London were selected in order to try to cover a cross-section of socioeconomic backgrounds, and the Hertfordshire schools were also visited to
include some children who were living in a more rural area. The children were invited to volunteer for the project. The parents of every child who wished to donate a blood specimen were approached and their consent in writing was requested. A very high response was obtained with more than 95% of the parents assenting to the investigation.

The volunteers included children of European, Asian, and African origin. However, in view of current uncertainties concerning the effects of such factors as diet, skin pigmentation, and genetic variation on normal biochemical values only results from children of European origin have been included. Values in other ethnic groups will be the subject of a later report.

The children were divided into yearly age groups from 7 years to 17 years 11 months. About 25 boys and 25 girls were included in each group. Before venesection each child was weighed and measured for standing height without shoes. Blood specimens were collected on school premises with the permission of the local education authorities and by arrangement with head teachers and other school staff. Collections were made just before lunch, so that each child had been fasting for about three hours. A 10-ml sample of blood was obtained from each child and the plasma was separated within 90 minutes of collection.

Plasma calcium was measured by flame emission spectrophotometry and each result was corrected for plasma specific gravity. This correction is necessary because various factors— for example, postural changes or venous occlusion during venesection—may give rise to variations in plasma protein level. These variations, while not significantly affecting ionized calcium cause changes in the protein-bound calcium fraction resulting in artificially raised or lowered total plasma calcium. In order to correct for these errors a value of 0.25 mg/100 ml is added to the total calcium for each 0.001 specific gravity point below 1.027 (the mean normal plasma protein as reflected by specific gravity). Similarly 0.25 mg/100 ml is subtracted for each specific gravity point above this value. In this way errors in total calcium measurement due to temporary variations in the protein-bound fraction are minimized (Dent, 1962). This specific gravity correction depends for its validity on the presence of normal plasma proteins and a normal albumin/globulin ratio. Total protein, albumin, and globulin were estimated in 50 boys and 50 girls, including children from each age group. In all cases the levels fell within the normal ranges—total protein 5.8-7.8 g/100 ml, albumin 3.6-5.2 g/100 ml, globulin 1.6-3.2 g/100 ml. A normal electrophoretic distribution of protein fractions was therefore assumed for all the children tested.

Plasma inorganic phosphorus was measured by the method of Fiske and Subba Row (1925) modified for use with an autoanalyser, using metol as a reducing agent.

Magnesium was estimated using the Perkin Elmer atomic absorption spectrophotometer. The precision of calcium and magnesium estimations in this laboratory is ±1% and of phosphorus estimations ±2%.

Plasma alkaline phosphatase was estimated by the method of Kind and King (1954). The precision of phosphatase estimation in this laboratory is ±0.25 K.A. units/100 ml. Electrophoresis on polyacrylamide gel was carried out on specimens from five boys and five girls in each age group in order to separate tissue-specific alkaline phosphatase fractions (Rowe and Canapa-Anson, 1970).

Results

Plasma Calcium.—Levels of plasma calcium are shown in the form of a histogram (fig. 1). Results from both sexes and all age groups showed no significant deviation from the previously reported normal adult levels for this laboratory (Davies et al., 1971). A probability plot of cumulative frequencies showed a normal distribution. The mean calcium was 9.6 mg/100 ml and the range (mean ± 2 S.D.) was 9.0-10.2 mg/100 ml.

Plasma Magnesium.—Results showed no significant difference from the normal adult levels for this laboratory. The mean was 2.09 mg/100 ml with a range (mean ± 2 S.D.) of 1.77-2.41 mg/100 ml.

Plasma Phosphorus.—The results are shown in fig. 2. In each sex a steady fall occurred from the high childhood levels seen at 7 years to the normal adult levels which were reached in girls ~ the age of 15 and in boys by the age of 17. An analysis of variance showed that the lower phosphorus level in girls between the ages of 8-16 was significant at the 5% level (F1,4,5) up to the age of 14 and at the 1% level at ages 15 and 16. The mean and 95% confidence limits (range) for each sex and age group are given in table I. Normal adult values for this laboratory have a mean of 3.6 mg/100 ml with a range (mean ± 2 S.D.) of 2.6-4.6 mg/100 ml.

Plasma Alkaline Phosphatase.—Alkaline phosphatase showed a log normal distribution with the upward skew being more apparent in the higher age groups. Statistical analysis was therefore carried out on log transformed values. After analysis the figures were reconverted to the absolute values shown in fig. 3. Mean and 95% confidence limits (range) for either sex and each age group are shown in table II. In girls a significant (0.005 > P > 0.001) rise was seen between the ages of 8-12.
years and in boys a significant (P < 0.0005) rise occurred between 10-14 years. Tissue-specific phosphatase fractions were calculated as absolute figures from the mean value for either sex and each age group and the percentage bone and liver enzyme seen in each fractionation gel. Liver phosphatase remained relatively constant, while the high bone phosphatase seen during growth fell gradually to adult levels. This fall is not complete in boys by the end of the 18th year (fig. 4).

**Mean Height.**—Mean height for each sex and age group is shown in fig. 3. When plotted on percentile charts for standard height in British schoolchildren (Tanner and Whitehouse, 1959) the mean heights for girls fell on the 50th percentile and those for boys on the 75th percentile.

**Discussion**

While normal laboratory values in infancy and in adult life are reasonably well established, clinical investigation and treatment has been hampered by the scarcity of such data in later childhood and adolescence. Tanner (1962) drew attention to the “meagre data” available and few additional reports have since appeared (Dunnigan and Gardner, 1965; de Wijn, 1966; Cooke et al., 1973). Data from these have been conflicting. The purpose of the present study was to resolve some of these problems with respect to some aspects of mineral metabolism.

Normal adult calcium values have been previously established in this laboratory (Davies et al., 1971) and the present study has shown that in children over 7 years old these values are unchanged. Two children, one boy and one girl both aged 15, had calcium levels of 6.6 mg/100 ml, and possible abnormalities are being investigated.

Plasma specific gravity did not vary significantly with either age or sex and all values fell within the range 1.024–1.030. Persistence of the high phosphorus levels which are found in

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**TABLE I—Plasma Inorganic Phosphate (Normal Ranges in mg/100 ml)**

<table>
<thead>
<tr>
<th>Age in Years</th>
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<th>17</th>
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</thead>
<tbody>
<tr>
<td>Range (95% confidence limits)</td>
<td>3.95–5.5</td>
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**TABLE II—Plasma Alkaline Phosphatase (Normal Ranges in K. A. Units/100 ml)**

<table>
<thead>
<tr>
<th>Age in Years</th>
<th>7</th>
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<th>10</th>
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<tbody>
<tr>
<td>Boys Mean</td>
<td>18.1</td>
<td>15.5</td>
<td>17.0</td>
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<tr>
<td>Girls Mean</td>
<td>18.1</td>
<td>15.5</td>
<td>17.0</td>
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<td>17.5</td>
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<tr>
<td>Range (95% confidence limits)</td>
<td>15.4–20.8</td>
<td>15.4–20.8</td>
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<td>No. in each group</td>
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Our normal adult range = Men 4-12 K.A. units/100 ml, women 3-10 K.A. units/100 ml.
infancy was seen, but to a lesser degree, in both sexes at 7 years. Significantly lower levels are subsequently seen in girls until the age of 16 years. Plasma phosphorus did not rise in either sex during the adolescent growth spurt. This finding suggests that an increase in growth hormone at this time is unlikely, since it has been shown that the level of inorganic phosphate in plasma is raised by the administration of growth hormone over a 10-month period (Raben, 1958). The later maturation in boys is, however, indicated by a two-year lag in the fall to adult levels. A survey of plasma inorganic phosphate levels by Greenberg et al. (1960), which included both children and adults resident in various parts of the United States of America, also showed changes related to age and sex. Their upper limit for children under 14 was 5·9 mg/100 ml, rather higher than the value of 5·2 mg/100 ml found in the present series; their lower limit in adolescence was 3·4 mg/100 ml, which is in agreement with the results reported here. Early work on whole blood phosphorus (Harvard and Reay, 1925) showed a seasonal variation in inorganic phosphate levels in adults where low spring time levels rose slowly to a maximum in August; however, more recently changes in plasma phosphorus were reported in Dutch children where higher levels were found in the spring than in the autumn (de Wijn, 1966). Statistical analysis of phosphorus results in the present series did not show any significant seasonal variation in phosphate levels, nor was there any within-group variation in values between children from urban or semirural homes.

High alkaline phosphatase levels as compared with adults are seen at 7 years in both sexes. In boys the significant rise between the ages of 10 and 14 years parallels the adolescent growth spurt. This phosphatase “flare” was less noticeable in girls, but a significant rise occurring between 8 and 12 years. These age differences match the earlier adolescent growth spurt in girls as indicated by the attainment of peak height velocity (Tanner, 1969, 1970). It may be that an analysis of phosphatase levels in girls based on sexual maturity rather than age would accentuate the “flare” during the growth spurt. These results confirm the rather scanty data of Harrison et al. (1948) though they conflict with those of Clark and Beck (1950) who were unable to show a pubertal rise in phosphatase in girls. The latter workers, however, grouped their results in two-yearly steps, which would tend to blur small changes.

While the rapid fall to normal adult levels is complete in girls by the end of the 15th year, in boys, where the fall begins two years later, the normal adult range has not been reached by the end of the 18th year. In both sexes this fall is due to a reduction in bone phosphate levels. Our method of gel fractionation also detects intestinal phosphatase, but such bands were found in only two children among those investigated in this way (one boy and one girl both aged 17) in whom it represented 15% of the total phosphatase.

No girl showed a total alkaline phosphatase level above 30 K.A. units/100 ml, while of the boys two had values above 32 K.A. units/100 ml—one aged 14 and one 15 years. Rickets was not suspected in either of these children and their calcium and phosphorus levels were normal.

Statistical analysis of alkaline phosphatase data showed no significant differences within groups between children from urban and semirural homes. These findings conflict with the conclusions of Dunnigan and Gardner (1965) who found higher mean alkaline phosphatase levels in urban children than in another group from a semirural area. Their data, however, were not paired for age and sex and included an appreciably larger number of urban boys who were in the puberty growth spurt (12-14 years) and would therefore be expected to have higher alkaline phosphatase levels for this reason alone.

Recent work in the Midlands on children aged 14-17 years of both sexes (Cooke et al., 1973) has suggested that “biochemical rickets” indicated by a raised alkaline phosphatase level is becoming more common. The present study has shown that the interpretation of alkaline phosphatase levels should not be based on a normal gaussian distribution as was assumed by these workers. It is also clearly important when using alkaline phosphatase as a diagnostic aid to take into account the increase seen normally during the adolescent growth spurt, especially in boys, and the rapid fall which subsequently takes place in the 14-17 age groups. The present survey indicates that “biochemical rickets” measured by phosphatase alone is not a problem among European schoolchildren in London or South Hertfordshire, and these findings must cast some doubt on the validity of the conclusions of Cooke et al. (1973).

The scanty data available on alkaline phosphatase levels in adolescents has led to the production of inadequate reference tables in many standard textbooks, where it is common practice to include children of both sexes and all ages in a single group (Coodley, 1970; Eastham, 1971). Even when rises at puberty are mentioned (King, 1965; Tietz, 1970), the differences between boys and girls with regard to the extent and timing of the pubertal changes are not documented. The present report has now clarified this situation and should help to reduce the incidence of diagnostic confusion.

I thank the following: Professor C. E. Dent for permission to report on the study; the Medical Officers of Health and Education Authorities for the London Boroughs of Croydon, Enfield, Shore-ditch, the Inner London Education Authority, and the County of Hertfordshire for their co-operation; and in particular all the children who donated blood specimens; Mr. R. Burns for magnesium estimations, Mr. D. J. F. Rowe for phosphatase fractionations, and Miss B. Chandhok and Miss J. Trott for expert technical help.

References


