Summary

Serum vitamin C, vitamin A and carotene concentrations were measured in 425, 256 and 256 infants aged between 3 weeks and 12 months. Vitamin C concentrations were in general satisfactory, whereas vitamin A and especially carotene concentrations were unacceptably low in a large number of infants. Concentrations were not correlated with age and sex nor with breast-feeding, but low and very low concentrations were more common after 6 months. Although clinical manifestations of the vitamin deficiencies were not present, the evidence points to an increased health risk for children.

In spite of the recorded low intakes of vitamin C in underprivileged and developing countries, including South Africa, clinical scurvy in infants is rare.1,2

Wheat-eating populations in Africa have less vitamin A deficiency than similar populations in Asia which are largely rice-eating; wheat contains some vitamin A whereas rice has none. South of the Sahara endemic areas of vitamin A deficiency have been reported in Kenya, Tanzania and the Lapula valley in Zambia.3

In southern Africa vitamin A deficiency has been reported from Johannesburg but is uncommon in Durban and Cape Town.4 Konno et al.6 found that Cape Town children who are underweight for age and children with gastro-enteritis have low serum vitamin A levels, while very low levels were recorded in children with kwashiorkor and marasmus.6 The South African Medical Research Council project group on food fortification found very little evidence of clinically significant vitamin A deficiency in the South African population, except in a small proportion of young children with protein-energy malnutrition.2

It is claimed that children aged 1 - 6 years with mild vitamin A deficiency have an increased mortality7 and an increased risk of bacterial colonisation and infection,8 and show evidence of interference with immune competence.8 In southern Africa infant mortality rates are still high and infection in infants is common. The prevalence of subclinical vitamin A deficiency states in infants in various regions of the subcontinent requires definition.

The vitamin A status of infants under the age of 12 months in southern Africa is not well recorded. A study on the vitamin A nutritional status of children at school without evidence of clinical disease has been published.10 A health survey of infants during the dry winter months in the Rehoboth-Gebiet of SWA/Namibia offered the opportunity to study their serum vitamin C, vitamin A and carotene levels.11

Subjects and methods

The Rehoboth-Gebiet is populated predominantly by peoples of Baster and Nama origin, the Basters forming the larger group. The area was traversed by teams consisting of paediatricians, community nurses and guides using four-wheel-drive vehicles. A temporary base camp equipped with a mobile laboratory was established in the vicinity of the examining teams.

A detailed questionnaire was completed for each infant (defined as a child aged 12 months or less), including a full history of its health, growth and development, its age, sex and ethnic group, and feeding and dietary patterns. Each infant underwent a physical examination and the weight, length and skull circumference were recorded. After informed consent had been obtained, venous blood was collected. The time of collection varied between 09h00 and 17h00, most samples being collected between 11h00 and 16h00. The blood was transported to the mobile laboratory in insulated bags containing ice. On arrival the sera were separated, divided into batches, stored and transported at −20°C to Cape Town and maintained in storage at −40°C until analysed. Serum vitamin C and albumin concentrations were measured in 425 infants, of whom 197 were boys and 228 girls. Serum vitamin A and carotene levels were measured in a random selection of 60% of the samples available for vitamin C determination. Serum albumin was determined using Albustrate reagent (General Diagnostics, Morris Plains, NJ, USA). Serum vitamin C, vitamin A and carotene concentrations were determined by Dr J. P. du Plessis in the laboratories of the National Research Institute for Nutritional Diseases of the South African Medical Research Council.12,13 Concentrations were classified as very low, low, acceptable and high according to the criteria14,15 set out in Table 1.

Statistical methods

The infant population sample was divided into four decimal age groups, i.e. 0,042 - 0,250 (3 weeks - 3 months), 0,251 - 0,500 (3 - 6 months), 0,501 - 0,750 (6 - 9 months) and 0,751 - 1,041 (9 - 1 year 2 weeks). As the log values of the vitamin C, vitamin A and carotene levels exhibited a normal or near-normal curve in the groups, statistical significance was evaluated with two sample t-tests and one-way analysis of variance. Differences were accepted as significant at a 5% level. Linear regression curves were plotted to determine the effect of age on the vitamin C, vitamin A and carotene levels.

Results

Vitamin C

There were 80, 116, 91 and 138 infants in the four decimal groups and the mean (± SD) and range of vitamin C values for

Department of Paediatrics and Child Health, Institute of Child Health, Red Cross War Memorial Children's Hospital, Cape Town

H. DE V. HEESE, B.SC., M.D., F.R.C.P., D.C.H.

Accepted 3 July 1987.
TABLE I. REFERENCE VALUES FOR SERUM VITAMIN C, VITAMIN A AND CAROTENE

<table>
<thead>
<tr>
<th>Vitamin C (mg/dl)</th>
<th>Vitamin A (µg/dl)</th>
<th>Carotene (µg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All ages</td>
<td>0-5 mo.</td>
<td>0-12 mo.</td>
</tr>
<tr>
<td>Very low</td>
<td>0.0 - 19</td>
<td>0.0 - 20-39</td>
</tr>
<tr>
<td>Low</td>
<td>20 - 59</td>
<td>20-50</td>
</tr>
<tr>
<td>Acceptable</td>
<td>60 - 100</td>
<td>100 - 400</td>
</tr>
<tr>
<td>High</td>
<td>&gt; 100</td>
<td>&gt; 300</td>
</tr>
<tr>
<td>Reference</td>
<td>No. 14</td>
<td>No. 14</td>
</tr>
</tbody>
</table>

TABLE II. SERUM VITAMIN C, VITAMIN A, CAROTENE AND ALBUMIN CONCENTRATIONS ACCORDING TO DECIMAL AGE

<table>
<thead>
<tr>
<th>Decimal age</th>
<th>Vitamin C (mg/dl)</th>
<th>Vitamin A (µg/dl)</th>
<th>Carotene (µg/dl)</th>
<th>Albumin (g/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.042-0.250</td>
<td>80</td>
<td>111 ± 51</td>
<td>19-215</td>
<td>141 ± 51</td>
</tr>
<tr>
<td>0.251-0.500</td>
<td>116</td>
<td>98 ± 52</td>
<td>14-218</td>
<td>116 ± 52</td>
</tr>
<tr>
<td>0.501-0.750</td>
<td>91</td>
<td>89 ± 56</td>
<td>19-270</td>
<td>91 ± 56</td>
</tr>
<tr>
<td>0.751-1.041</td>
<td>138</td>
<td>84 ± 58</td>
<td>10-253</td>
<td>138 ± 58</td>
</tr>
</tbody>
</table>

Vitamin A and carotene

Serum vitamin A and carotene concentrations were analysed in 51, 70, 58 and 77 infants respectively in the four decimal age groups. There were 123 male and 133 female infants. The means (± SD) and ranges of the values obtained for each age group are set out in Table II.

Vitamin A concentrations were classified according to the reference values (Table I) as low for age in 5.9% of cases, acceptable in 83.2% and high in 10.9%. Forty-four infants (33.6%) aged between 0.501 and 1.041 years had less than satisfactory vitamin A levels when the reference values of O'Neal et al. were used.

One 11-month-old infant had a value of < 10 µg/dl, a level strongly suggestive of deficiency and below which xerophthalmia is likely or imminent. Hypervitaminosis A is probably present when values are in excess of 100 µg/dl, and a fasting serum value in excess of 250 µg/dl is regarded as diagnostic of chronic vitamin A poisoning. The highest values recorded in this study were 124 µg/dl in an infant aged 2 months, and 130 µg/dl in another aged 9 months.

Serum carotene concentrations were classified as very low, low, acceptable and high in 41.8%, 40.6%, 16.8% and 0.8% of the infants respectively when reference values were employed (Table I). The highest values recorded in this study were 124 µg/dl in an infant aged 2 months, and 130 µg/dl in another aged 9 months.

Serum albumin

Serum albumin levels above 2.8 g/dl and 3.5 g/dl in infants under and over the age of 3 months respectively were regarded as acceptable. Levels were acceptable in all infants under the age of 3 months, but 26 (7.5%) of those aged over 3 months had levels lower than 3.5 g/dl; in 19 cases levels were between 3.0 and 3.49 g/dl.

Discussion

The Rehoboth-Gebiet is a sparsely populated area of approximately 14 000 km² and 1300 m above sea level. The area includes the town of Rehoboth and a few smaller villages, but at the time of the study more than 66% of the population was rural and lived on stock farms. We studied 486 infants, estimated to be 75% of the total number in the area.

Methaemoglobinemia is encountered in some parts where the population is dependent on well-water with a high nitrate content for domestic use. The main thrust of the survey was to determine the prevalence of subclinical methaemoglobinemia. Sera were also randomly selected from the 486 samples for measurement of IGE, IgA, IgG and IgM values.

Under the field conditions it was not possible to measure the leucocyte vitamin C level. Serum vitamin C levels reflect recent intake of the vitamin, whereas leucocyte vitamin C levels reflect intake over a longer period. The serum vitamin C values in 80% of the infants surveyed were acceptable or high. Of those aged over 4 months 20 received daily vitamin C supplementation and a further 50% received vitamin C less frequently. Breast-milk is a good source of vitamin C and milk of well-nourished mothers contains on average 4 mg/dl of ascorbic acid. The nutrition of the Rehoboth mothers appeared to be good and infants therefore presumably received ascorbic acid from this source, since breast-feeding is common.

The majority of infants with low (< 20 mg/dl) values were in the latter half of infancy.
Although symptoms of scurvy such as fretfulness, pallor, loss of appetite and localising signs including tenderness and swelling of the legs usually appear at this time, none of the infants studied showed such manifestations.

The reference ranges for serum vitamin A and carotene do not appear wholly satisfactory.

A significant number of infants had low vitamin A levels and a large percentage had low carotene levels after the age of 6 months. The significance of a low vitamin A value appears uncertain. Children with manifestations of severe malnutrition such as kwashiorkor and marasmus and with low serum vitamin A values can have adequate vitamin A stores in the liver. None of the infants with low vitamin A values showed clinical signs of deficiency such as xerosis of the conjunctiva, keratomalacia, Bitor's spots or dry scaly skin with hyperkeratosis. Information on the prevalence of night blindness in the area is not available.

In their study of preschool-age rural Indonesian children Sommer et al. found that increased mortality was associated with mild xerophthalmia manifested by night blindness, Bitor's spots and the two combined. They also suspected that mortality among children with subclinical vitamin A deficiency was excessive, and have recently presented evidence of the favourable impact of vitamin A supplementation on childhood mortality.

In the present survey, it was noted that deaths of previous infants had been more common in high-nitrate areas than in other areas. It was not possible to establish a similar relationship for infants with low vitamin A and carotene values. Adequate vitamin A values during the first 6 months of infancy and to a larger extent during the second 6 months are evidence of adequate ingestion of the vitamin. Human and animal milk, although they are not rich sources of vitamin A or of its precursors, are usually adequate for infants. However, in undernourished communities the vitamin A content of human milk is low. Breast-feeding is commonly practised in the areas studied. At the time of this investigation 50% of infants aged 1 - 2 months were breast-fed only, while 20% were fed on breast-milk and artificial milk. Of the infants aged 11 - 12 months 30% received breast-milk only and 21% breast-milk and artificial milk. Between 60% and 70% of infants received meat regularly and from an early age. Only 10% of the infants received vitamin supplements regularly and then only during early infancy.

Possible causes for the less than acceptable carotene values in 70 - 80% of the infants studied were considered.

Storage

Serum for carotene estimation must be stored at −20°C, because carotene is more unstable than vitamin A. It is also affected by light and haemolysis. These factors may affect values obtained in field studies, so the venous blood samples were immediately placed in a coolbag and taken to the mobile laboratory where the sera were separated, labelled and stored at −20°C until transported to Cape Town. Exposure to light was minimised and haemolysed samples were discarded.

Ingested water nitrates

The conversion and absorption of carotenoids (pro-vitamin A) may possibly be interfered with by ingested water nitrates or methaemoglobin. Beta-carotene is converted to vitamin A in the intestinal mucosa by cleavage and action of reductase enzymes. Man also absorbs intact carotenoids which are then converted to vitamin A in the liver by a cleavage enzyme.

The effect of nitrates has been indirectly analysed in that no correlation was demonstrated between blood methaemoglobin and serum carotene, but methaemoglobin values in excess of 4-5 mg/dl were associated with low carotene levels (P < 0.05).

Nutritional status

The nutritional status of over 90% of the infants assessed according to National Center for Health Statistics standards for weight, length and skull circumference and serum albumin levels was satisfactory. Failure to thrive from birth was noted in 4.7% of the infants surveyed and undernutrition of short duration in 4%.

Inadequate ingestion of carotenoids

This appears the most likely cause of less than acceptable carotene values. The investigation was carried out during the dry winter. Few infants received green vegetables. Only 33% of the infants had received carrots and 30% tomatoes, and only 20% were given peas, 18% beans and 5% spinach at some time. None of the vegetables had been offered on a regular basis.

A significant percentage of infants over 6 months of age had subclinical low vitamin A and still lower carotene values. This finding in a region of SWA/Namibia where rainfall and farming conditions had been good both at the time of the survey and for a number of years before suggests an increased health risk for children under adverse climatic and economic conditions.

This study was supported by grants from the McCaul Bell Bequest and the South African Medical Research Council. The assistance of Dr J. M. E. du Plessis, Dr M. Super, Mr W. S. Dempster and the late Professor D. McKenzie, the support of the SWA/Namibia Departments of Health and Water Affairs, and the help of Mrs P. Betts with the preparation of the article are recorded with appreciation. The study would not have been possible without their help.

REFERENCES