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ARTICLE

Can the high prevalence of micronutrient deficiencies, stunting and overweight in children at ages 1 and 3 years in the Central Region of Limpopo province be explained by diet?

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Objective. To assess whether the high prevalence of stunting and overweight accompanied by serum deficiencies of iron, folate and vitamin B_{12} in children at ages 1 and 3 years, can be explained by their diet.

Design. A prospective cohort study.

Setting. Villages in the central region of Limpopo province, which are serviced by Mankweng Hospital.

Subjects. A cohort of children (N = 219) followed from birth were included in the study. Of the original cohort, 156 and 162 could be traced and assessed at ages 1 and 3 years, respectively. Dietary intake of the children was assessed using a quantitative food frequency questionnaire and at 3 years a 24-hour recall questionnaire was also administered.

Results. The children in this cohort consumed an energy-dense diet of poor quality as evidenced by insufficient intakes of iron, zinc, calcium and phosphates as well as folate, riboflavin, vitamin B_6, niacin and vitamin A. Overall, nearly 70% of the energy intake of the diet came from carbohydrates while the contribution from fat was less than 20%. Average protein intake was adequate but comprised mainly protein from vegetable sources which are poor sources of iron and certain essential amino acids. Furthermore, the diet was judged to be high in phytates because of the high intake of cereals and this would have contributed to making iron and zinc less available for absorption. Low fruit and vegetable intake was the cause of the low intake of folate, vitamin A and vitamin C. The prevalence of micronutrient deficiencies was confirmed by the high prevalence of children with iron and folate biochemical deficiencies.

Conclusion. The children's diet was poor in several micronutrients which included iron, calcium, folate and vitamin A. Chronic energy deficiency, especially from animal sources, seems to be the factor contributing to the high levels of stunting observed.

Limpopo province (LP) is among the poorest of the provinces in South Africa, both economically and demographically.[1] A province with 5.3 million residents, it showed the following indicators of poverty in 2001: 49% of adults were unemployed; 33% had no schooling; only 21% had a grade 12 or higher education; 23% had no toilet facilities, and only 14% had refuse removal. Furthermore, 60% still used wood for cooking and 61% had no refrigerator.[2]

The poverty reflected by the above sociodemographic statistics is reflected by the findings of past studies on the nutritional status of children living in the province. In 1994 the South African Vitamin A Consultative Group (SAVACG) study showed that 34.2% of 6 - 71-month-old children in LP were stunted and 12.6% were underweight.[3] In 1999 the National Food Consumption Survey (NFCS) found that 19.9% of 12 - 36-month-old children in LP were stunted and

14% were underweight.[4] Furthermore, the SAVACG study also found that 43.5% of children in LP had a marginal vitamin A deficiency (< 20 µg/dl serum retinol), 11% had iron deficiency (< 12 µg/l ferritin) and 27.7% had anaemia (Hb < 11 g/dl). Clearly dietary intake was deficient in terms of energy and specific micronutrients.

More recently data have been published on the present cohort of children (*N* = 219) in the Central Region of LP who were examined at birth, 12 months and 36 months. It was found that at birth 8.8% of the infants had low birth weight, 9.6% were stunted, 48.9% were underweight and 7.3% were wasted.[5] However at 36 months 48% of these children were stunted, 9% were underweight, 22% were overweight (BMI 25 - 29.9 kg/m^2) and 22% were obese (BMI ≥ 30).[6] Hence the group went from a high prevalence of underweight and a low prevalence of stunting at birth to a low prevalence of underweight and a high prevalence of stunting, plus a high prevalence of overweight, at 36 months of age.

The above nutritional outcomes imply that complex dietary influences are taking place during the 36-month period under consideration. The aim of this study was therefore to evaluate the diet of the children at age 12 months and again at 36 months with a view to explaining these changes in nutritional status.

Methods

Study area and subjects

The study took place in villages in the Central Region of LP, which is in the northern part of South Africa. These villages are typical of those found in rural areas of the country. They are characterised by poor infrastructure and very high levels of unemployment, and as such reflect a transition between traditional and modern lifestyles since many of the younger adults work in neighbouring towns and cities and return home for periodic visits.[7]

The study participants were infants born to women who were recruited while attending prenatal clinics at nine randomly selected local clinics during their third trimester. Of the 219 infant participants, 156 and 162 could be traced at 12 and 36 months of age respectively (71% and 74% response rate respectively). The fall in number at follow-up was largely due to migrations both within the studied villages and to outside the study area. The lack of proper addresses, formal streets and roads in these villages impeded the process of tracing the mothers and their infants, especially during the early phases of the study.

Assessment of the children's dietary intake

At both 1 year (2000 - 2001) and 3 years (2002 - 2003) of age (or within 1 month thereof), trained field workers administered a quantitative food frequency questionnaire (QFFQ). The QFFQ used in this study was the same as the one used in the NFCS in 1999.[4] The NFCS questionnaire was an adaptation of the original questionnaire designed and validated by MacIntyre for a survey on African urban and non-urban adults in the North-West province of South Africa.[8-10]

In addition, a 24-hour recall (24-HR) was administered to the caregivers of the children at age 3 years. This was done because the QFFQ is known to overestimate dietary intake while the 24-HR is known to underestimate intake.[11] This pre-coded questionnaire was originally validated in 12-year-old children and their mothers/caregivers/grandmothers in a study done in the Western Cape Province of South Africa among all ethnic groups.[12] Recently the questionnaire was modified for use in the NFCS.[4]

The relative validity of both questionnaires was also tested during the NFCS by means of a comparison with the 3-day weighed records on a sample of mothers/caregivers/children in the Limpopo and Western Cape provinces. For all nutrients the QFFQ gave higher intakes than the 24-HRs. Bland-Altman (B-A) plots for the completed data, after excluding outliers, showed wide limits of agreement.[4] Both Steyn *et al.*[12] and MacIntyre[8] tested the 24-HR questionnaire and the QFFQ for reproducibility during their original development. The adapted versions were also tested in the NFCS, with good correlation coefficients.[4]

Blood analysis

Fasting blood samples were collected from the children at both 1 and 3 years for the determination of haemoglobin concentration (Hb) and red cell indices using a Coulter STKS analyser (Beckman Coulter, Calif., USA). Ferritin, vitamin B_{12} and serum folate levels were determined by the Access ImmunoAssay autoanalyser (Beckman Coulter, Calif.,USA).

Statistical analysis

Dietary data were analysed using Food Finder 3.[13] Percentages of children with intakes < 67% of the dietary reference intake (DRI) were calculated, and these were regarded as having low intake.[14] Energy, macro- and micronutrient intakes were calculated using the age category 1 - 3 years of the DRI[14] in order to allow for comparisons to be made. Further analysis was done using SPSS 11.0 for Windows.[15] The analysis done included descriptive statistics and frequencies to describe both continuous and categorical data.

Ethical approval

Ethical approval and permission to undertake the study were obtained from the University of Limpopo Ethics Committee and the Limpopo Province Department of Health and Welfare's Research Committee. Informed consent for participation of the mothers and their children in the study was obtained before administration of the questionnaires at both 1 and 3 years of age.

Results

Data on daily nutrient intakes at both 1 and 3 years are summarised in Table I as medians and interquartile ranges. The latter were used because the data were not normally distributed. Fourteen per cent and 7% of the children had energy intakes below 67% of the DRI at both 1 and 3 years of age, respectively. None of the children had low protein intakes at 1 or 3 years of age. Overall it is noted that mean nutrient intakes increased between age 1 and 3 years, with the exception of vitamin A and the polyunsaturated to saturated fat (P/S) ratio. Furthermore, mean vitamin A, folate and calcium intakes were below the DRI at both ages.

Another general finding was the disparity in intakes between the two dietary methods used at 3 years of age. Generally the mean intakes measured by the 24-HR were lower than those measured by the QFFQ. At 1 year of age the nutrients that showed most deficiencies were calcium, folate and vitamin A. These percentages had escalated by 3 years of age, with the exception of folate. The mean contributions of the macronutrients to energy intakes were within the World Health Organization (WHO) population reference ranges[16] except for the mono-unsaturated fatty acids (Table II and Fig. 1). The data show that on average the children conformed to the WHO recommendations except for intakes of polyunsaturated fatty acids, which were lower.

Table III shows the 30 most frequently consumed foods at both ages. Overall the lists are very similar at both ages and using both dietary methods. The most commonly eaten foods at 1 year are potatoes, bread, maize meal, milk and bananas and sugar. At 3 years of age sweets and crisps are the 3rd and 4th most commonly consumed items. Since added sugar intake more than doubled between 1 and 3 years, the results are consistent with these findings. At 1 year milk falls within the top 5 frequently consumed items, while at 3 years it is outside the 20 most consumed items. The finding that milk is not at the top of the list is supported by the low calcium intakes found in these children. Sadly, tea is more commonly consumed than milk, but even though it is a source of tannins, which inhibit iron absorption, tea drinking could be turned into a useful method for giving purified water to children if teas low in tannins are given. The low fat intake can be explained by the finding that margarine comes far down the frequency list.

A large proportion of the children were found to have biochemical iron (33%) and folate (20%) deficiency (Table IV), and in addition many were stunted (48%), and stunted and overweight (19%) at 3 years of age.[6] The researchers evaluated the contribution of dietary intake towards the observed serum micronutrient deficiencies and the anthropometric outcomes (Table V). In essence there was an attempt to explain the nutritional status outcomes in terms of dietary intake (see 'Discussion')

Discussion

The overall nutrient intakes of the children in this study were low, a finding consistently found in black South African preschool children over the years.[4,17,18] Furthermore, the children's diet was of poor quality, comprising mainly carbohydrate-rich foods with a low intake of dairy products and fruit and vegetables. This is consistent with previous studies undertaken in this province.[4,17,19]

A large percentage of children were stunted at both 1 and 3 years (35% and 48% respectively). This could have been due to chronic energy deficiency, which is evidenced by the high percentage of children with low total energy intake (59.3%) and low percentage of energy received from proteins (87%). Furthermore, at 3 years a higher percentage (94%) of the stunted children received inadequate energy from proteins. The large prevalence of overweight at 3 years implies that many of the stunted children were then exposed to a higher than required energy intake from carbohydrates, or even possibly a normal intake. In most respects mean energy intakes were similar to what has been reported in South African children less than 5 years old.[18,20,21] Protein deficiency does not appear to be a problem; however we do question the quality and absorbability of the protein, since the diet had low animal sources. This is a finding consistent with previous results from blacks in rural areas, both children and adults.[17,18,22,23] Low or normal dietary energy intake accompanied by a lack of animal proteins could result in the observed phenomenon of children being both stunted and overweight at 3 years of age.[6] This is supported by the apparently high number of stunted children who received inadequate energy from proteins at both 1 and 3 years.

The high prevalence of iron deficiency at both 1 and 3 years is clearly indicated by the large proportion of children with low ferritin, Hb and mean cell volume (MVC) (Table IV). These data are supported by the results shown in Table V, which illustrates the link between diet and nutritional status outcomes.. According to the QFFQ, at 1 year 55.6% and 50% of the children with low dietary intake had anaemia and low serum ferritin levels respectively. By 3 years the figures were 18.3% and 37.5% respectively. The iron sources in the diet were mainly chicken and beef. However, we know from an earlier study that the amounts of these are generally very low because they are infrequently consumed.[24] In the case of 1 - 5-year-old children in LP[24] per capita intake of meat and chicken was

Table I. Dietary intakes of selected nutrients in 1-year-old infants as determined by the QFFQ (median (interquartile range)) and percentages below 67% DRI[14]

Nutrient	QFFQ at 1 year	QFFQ at 3 years	Median difference between 1 and 3 years	24-HR at 3 years	DRIs (1 - 3 years)	N (%) QFFQ deficient 1 year	N (%) QFFQ deficient 3 years	N (%) 24-HR deficient
Energy (kJ)	4 653.07 (2 285.68)	5 779.44 (2 570.25)	1 319.06 (3 371.93)	3 303.26 (1 455.20)	4 393* 6 237†	21 (13.5)	12 (7.4)	108 (66.7)
Total protein (g)	35.96 (20.09)	43.04 (16.18)	4.87 (25.84)	26.27 (10.65)	13	0 (0)	0 (0)	0 (0)
Plant protein (g)	23.43 (11.09)	26.44 (12.35)	3.73 (17.85)	15.16 (6.57)				
Animal protein (g)	12.47 (9.26)	13.51 (8.53)	1.97 (11.09)	9.78 (9.09)				
Total fat (g)	24.79 (19.86)	34.06 (17.44)	6.85 (21.61)	17.24 (11.87)				
SFA (g)	6.66 (4.92)	8.45 (5.49)	2.42 (6.19)	4.65 (4.23)				
MUFA (g)	6.63 (7.01)	9.95 (6.19)	2.60 (6.59)	5.41 (4.40)				
PUFA (g)	8.71 (6.70)	11.18 (6.89)	2.47 (7.11)	4.49 (5.02)				
Cholesterol (mg)	111.60 (106.78)	141.77 (120.92)	39.99 (157.79)	41.34 (159.10)				
P/S ratio	1.27 (0.76)	1.32 (0.47)	-0.77 (0.83)	1.12 (0.83)				
Carbohydrate (g)	162.74 (89.50)	206.93 (84.91)	48.55 (127.55)	126.63 (47.17)	130	11 (7.2)	1 (0.6)	16 (9.9)
Total sugars (g)	20.52 (17.38)	24.01 (19.51)	1.13 (26.78)	15.6 (17.13)				
Added sugar (g)	12.75 (13.42)	27.85 (16.37)	14.14 (19.30)	11.53 (9.10)				
Total dietary fibre (g)	12.29 (8.27)	16.56 (7.11)	4.42 (11.96)	9.95 (5.49)	19	86 (55.1)	31 (19.1)	123 (75.9)
Calcium (mg)	243.98 (201.61)	257.47 (155.19)	40.18 (257.82)	122.64 (130.27)	500	105 (67.3)	118 (72.8)	152 (93.8)
Fe (mg)	7.34 (4.43)	7.67 (3.85)	0.17 (6.03)	4.07 (1.99)	7	25 (16.0)	13 (8.0)	113 (69.7)
Magnesium (mg)	207.83 (112.67)	244.47 (104.52)	28.79 (157.78)	144.95 (57.85)	80	0 (0)	1 (0.6)	4 (2.5)
Phosphorus (mg)	665.53 (331.69)	726.06 (331.79)	57.67 (494.17)	413.59 (169.02)	460	9 (5.8)	1 (0.6)	30 (18.5)
Zinc (mg)	4.67 (2.64)	5.08 (2.26)	0.46 (3.55)	3.11 (1.44)	3	8 (5.1)	1 (0.6)	29 (17.9)
Vitamin A (µg)	255.64 (379.36)	206.74 (237.14)	-31.11 (439.53)	99.50 (140.66)	300	62 (39.7)	80 (49.4)	129 (79.6)
Thiamin (mg)	0.76 (0.48)	0.79 (0.32)	0.02 (0.56)	0.51 (0.21)	0.5	4 (2.6)	1 (0.6)	17 (10.5)
Riboflavin (mg)	0.61 (0.43)	0.91 (0.52)	0.24 (0.71)	0.41 (0.54)	0.5	26 (16.7)	8 (4.9)	72 (44.4)
Niacin (mg)	8.38 (5.84)	9.58 (5.18)	1.15 (6.68)	4.96 (5.48)	6	11 (7.2)	2 (1.2)	55 (33.9)
Vitamin B_6 (mg)	0.68 (0.44)	0.69 (0.31)	0.00 (0.40)	0.38 (0.28)	0.5	12 (7.7)	4 (2.5)	63 (38.9)
Folate (µg)	106.34 (84.22)	130.85 (76.87)	22.27 (106.96)	82.61 (55.98)	150	73 (46.8)	40 (24.7)	103 (63.6)
Vitamin B_{12} (µg)	2.25 (2.74)	2.39 (2.50)	0.59 (3.67)	0.63 (1.16)	0.9	30 (19.2)	13 (8.0)	77 (47.5)
Vitamin C (mg)	49.07 (63.59)	44.37 (31.34)	-3.92 (54.68)	22.42 (52.19)	15	4 (2.5)	0 (0)	39 (24.1)
Vitamin D (µg)	3.11 (3.26)	3.66 (3.15)	0.76 (4.12)	0.56 (2.26)	5.0	80 (51.3)	73 (45.1)	127 (78.4)

* DRI at 1 year.
† DRI at 3 years.
SFA = saturated fatty acids; MUFA = mono-unsaturated fatty acids; PUFA = polyunsaturated fatty acids; CHO = carbohydrates; P/S ratio = polyunsaturated fat to saturated fat ratio.

Table II. Mean percentage energy contribution of macronutrients of the children at 1 and 3 years of age

Macronutrient	Reference ranges	QFFQ, 1 year	QFFQ, 3 years	24-HR
Protein	10 - 15%	12.94 ± 2.61	12.18 ±1.67	13.25 ± 3.37
Fat	15 - 30%	21.77 ± 6.79	22.07 ± 5.68	19.70 ± 7.01
SFA	< 10%	5.82 ± 2.35	5.77 ± 1.89	5.36 ± 2.45
MUFA	> 10%	6.38 ± 2.62	6.59 ± 2.16	6.29 ± 2.73
PUFA	6 - 10%	7.08 ± 2.89	7.34 ± 2.20	6.0 ± 3.17
CHO	55 - 75%	65.06 ± 7.91	65.74 ± 5.98	67.03 ± 8.27

SFA = saturated fatty acids; MUFA = mono-unsaturated fatty acids; PUFA = polyunsaturated fatty acids; CHO = carbohydrates.

Table III. The 30 major food items most frequently consumed by the children at 1 and 3 years

QFFQ at 1 year	QFFQ at 3 years	24-HRQ at 3 years
Potatoes	Sugar	Maize meal
Bread	Maize meal	Sugar
Maize meal	Sweets	Tea
Milk	Crisps	Bread
Banana	Potatoes	Chicken
Sugar	Bread	Milk
Eggs	Cabbage	Cabbage
Tea	Fish	Tomato and onion
Chicken	Tea	Banana
Oranges	Banana	Oranges
Tomato and onion	Oranges	Crisps
Cabbage	Rice	Eggs
Crisps	Tomato and onion	Soups
Mabella	Cookies	Beef
Spinach	Apple	Potatoes
Sweets	Eggs	Mabella
Fish	Spinach	Bread, white
Pumpkin	Atchaar	Rice
Cookies	Chicken	Spinach
Rice	Cold drink	Margarine
Yoghurt	Samp	Sweets
Soups	Beef	Fish
Apple	Milk	Apple
Cold drink	Vetkoek	Pumpkin
Beef	Margarine	Beetroot
Margarine	Squash	Vetkoek
Macaroni	Macaroni	Squash
Fruit juice	Soya	Avocado
Soya	Soups	Cookies
Vetkoek	Yoghurt	Peanut butter

only 40.5 g/day. The per capita intake of green leafy vegetables was 48.8 g/day. However, the latter would have contributed mainly non-haem iron, which is not very bioavailable. The type of diet consumed, which is predominantly cereal- and vegetable-based, contains absorption inhibitors such as phytates, dietary fibre, oxalates, tannins and phenols.[25,26] Tatala *et al*.[27] reported that even though iron might be available in the cereal-based diets its bioavailability is low when measured by *in vitro* methods.

With respect to the dietary intake of other minerals at both 1 and 3 years, a large proportion of children had inadequate intakes of calcium. Calcium and phosphorus are known to be important for growth in

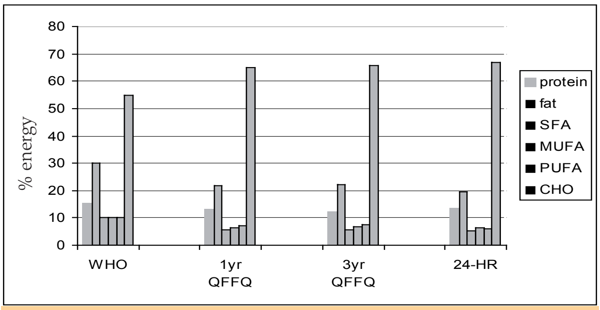

Fig. 1. Energy distribution of macronutrients as assessed by both QFFQ and 24-HR at 1 and 3 years of age (SFA = saturated fatty acids; MUFA = mono-unsaturated fatty acids; PUFA = polyunsaturated fatty acids; CHO = carbohydrates).

the early stages of human life, where they are involved in linear growth.[28-31] During infancy calcium supplied in the mother's milk is primarily derived from maternal bone stores, which are quickly replenished during and after weaning. Early childhood is a time of relatively slow bone growth, with a rapid increase occurring during puberty.[32] Since approximately 70% of the bone weight is accounted for by calcium phosphate crystals, the importance of adequate dietary calcium for optimal bone growth is unquestionable. Very low calcium intake in children induces rickets, osteomalacia and growth retardation.[33] This study suggests that with deficiencies in calcium, and to a lesser degree in phosphorus, the children may be experiencing metabolic shortages affecting the basic structure of their bones, which may manifest as growth failure as evidenced by high stunting levels.[31,32]

Another mineral that appeared to be acutely deficient was zinc. It has been shown that during childhood zinc deficiency contributes to stunting and impaired cognitive development and is associated with an increased prevalence of infectious diarrhoea, pneumonia and malaria.[34,35] Furthermore it has been shown that diets rich in plant-based foods result in poor bioavailability of zinc,[36] owing to their high levels of phytates which are known to form complexes with zinc that render it un-absorbable.[37-39] In this study, where inadequate zinc intake was observed at 1 year, the high phytate levels in the diet may be contributing to the high prevalences of stunting. On the other hand, Manary *et al.*[40] observed in healthy Tanzanian children that reducing phytates does not necessarily improve zinc absorption. This in itself shows the multi-linkages in nutrients during absorption. As such it is reasonable to speculate that with insufficient intakes of several essential minerals the children's metabolism may adapt by transporting the small amounts consumed to other crucial organs at the expense of linear growth.

At 1 year, 3 (14.3%) of the children with low dietary vitamin B_{12} intake had deficient serum levels, while at 3 years the finding that there was no biochemical deficiency is supported by the results on dietary

Table IV. Children (number and percentage) below the reference ranges of haematological and biochemical measurements at 1 and 3 years of age

Serum variables	Reference ranges	1 year (*N* = 127)	3 years (*N* = 143)	
Haemoglobin (g/dl)	< 11	66 (52.0%)	31 (21.7%)	
HCT (%)	< 33	52 (40.9%)	34 (24.0%)	
MCV (fl)	< 72	47 (37.0%)	21 (14.7%)	
MCH (pg)	< 24	63 (49.6%)	17 (12.0%)	
Ferritin (µg/ml)	< 121	50 (39.4%)	47 (32.9%)	
Serum folate (ng/ml)	< 5	29 (22.8%)	28 (19.6%)	
Vitamin B_{12} (pg/ml)	< 145	13 (10.2%)	0 (0%)	
			3 years (*N* = 162)	
Dietary variables		**1 year (N = 156)**	**QFFQ**	**24-HR**
Iron	< 67% DRI	25 (16%)	64 (39.5%)	113 (69.8%)
Vitamin C	< 67% DRI	4 (2.56%)	0 (0%)	39 (24.1%)
Dietary fibre	> 133% DRI	8 (5.1%)	20 (12.3%)	3 (1.8%)
Vitamin B_{12}	< 67% DRI	30 (19.2%)	13 (8%)	77 (47.5%)
Folate	< 67% DRI	72 (46.2%)	1 (0.4%)	103 (63.6%)
Energy intake	< 67% DRI	84 (53.8%)	12 (7.4%)	108 (66.7%)
	>133% DRI	39 (25%)	21 (12.9%)	0 (0%)
Protein	< 67% DRI	0 (0%)	0 (0%)	0 (0%)
Protein	15 - 20% E	128 (82.1%)	152 (93.8%)	122 (75.3%)
CHO	> 70% E	44 (28.2%)	44 (27.1%)	61 (37.6%)
Fat	> 30% E	17 (10.9%)	14 (8.6 %)	12 (7.4%)

HCT = haematocrit; MCV = mean cell volume; MCH = mean cell haemoglobin; CHO = carbohydrates; % E = % of energy from.

Table V. Dietary variables and their impact on anthropometric and biochemical outcomes at 3 years

	1 year QFFQ			3 years QFFQ			3 years 24-HR		
	Dietary iron	Dietary folate	Dietary vitamin B_{12}	Dietary iron	Dietary folate	Dietary vitamin B_{12}	Dietary iron	Dietary folate	Dietary vitamin B_{12}
Anaemic	10 (55.6%)	33 (58.9%)	16 (76.2%)	11 (18.3%)	1 (100%)	2 (16.7%)	19 (17.9%)	21 (22.3%)	15 (48.4%)
Serum ferritin	9 (50%)	-	-	21 (37.5%)	-	-	33 (34%)	-	-
Serum folate	-	10 (17.9%)	-	-	1 (100%)	-	-	17 (19.5%)	-
Serum vitamin B_{12}	-	-	3 (14.3%)	-	-	0 (0%)	-	-	0 (0%)

intake (Table V). Clearly the dietary sources were available in sufficient amounts to ensure adequacy. However, a large number of children had serum folate deficiency at both 1 year and 3 years of age. This is not supported by the QFFQ at either time, probably because serum folate reflects recent intake. The main source of folate in the diet was green leafy vegetables, but the availability thereof varies between 25% and 50%.[24] Furthermore, deficiencies of iron and vitamin C in the host can impair folate absorption.[41]

The only other vitamin found to be deficient was vitamin A, which is the most studied with respect to its association with growth.[41] It has been shown that both plasma and dietary deficiencies affect linear growth.[42] However, intervention studies with vitamin A supplementation have yielded small effects on linear growth,[43-45] suggesting that there are other factors involved, possibly including deficiencies in other vitamins and minerals, that were not covered by the supplementation studies. This is supported by observational studies which revealed that increased vitamin A intake from the diet yields more effective results than supplementation, suggesting that other nutrients in the diet are also responsible for the improved linear growth.[42,46]

It is known that the human body utilises dietary energy inefficiently in the presence of specific deficiencies of many vitamins and micronutrients.[47] The importance of nutrient-nutrient interactions in determining energy needs for maintenance and growth has been stressed by previous researchers.[48,49] In general, the body will use energy with maximal efficiency if all other necessary nutrients are present in adequate amounts. A rate-limiting deficiency in any one micronutrient or amino acid will decrease the efficiency of energy utilisation. These (micronutrients and amino acids) deficiencies are common in developing countries[26,47,50] and were found in the present study. It is therefore possible to speculate that the energy requirements of these (deficient) children are elevated for physiological processes taking place in their bodies, including growth, a view supported by Allen[51] in her review of single-nutrient supplementation in developing countries.

If the macronutrient intake of the current diet is examined in terms of contribution to energy intake it is clear that these children are following a very prudent diet. Very few children had a fat intake greater than 30% and the mean saturated fat intake was very low. Fibre intake, however, was not very high and protein intake was lower than desired. The very low fat intake may have some implications regarding adequacy of essential fatty acids in the diet.

In conclusion, therefore, it was found that at 1 and 3 years of age the children had a diet that was energy-dense but low in micronutrients, particularly iron and folate. This was supported by the finding of serum deficiencies of both micronutrients. The low intake of meat and dairy foods was cause for concern, particularly with regard to the high prevalence of calcium, riboflavin, iron and zinc deficiencies. Vitamin A intake was also not optimal and raised concerns regarding resistance to infections. From the results it can therefore be speculated that the high prevalences of stunting in these children were due to chronic energy deficiency from protein sources, especially those of animal origin. This in itself could result in the observed overweight/obesity, as the extra calories consumed from carbohydrates are metabolised and stored as fat because essential micronutrients (amino acids, vitamins and minerals) required for linear growth are deficient. From a chronic diseases perspective the diet was low in total fats and saturated fat; however the issue of essential fatty acids would need to be considered in children with such a low fat intake.

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