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RESEARCH

Association of micronutrients and child growth in children aged 7-15 years from Qwa-Qwa, South Africa

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Objectives: This study investigated the possible associations between micronutrient deficiencies and child growth in the rural community of Qwa-Qwa in the Free State province of South Africa (SA).
Design: Cross-sectional observational baseline survey.
Setting: Rural Qwa-Qwa, Free State, SA.
Subjects: Children 7- 15 years of age ($n = 73$; randomly selected).
Outcome Measures: Nutritional status in terms of height and weight measurements, and serum haemoglobin, vitamins A and E and zinc.
Results and conclusions: The results of this study showed that there was no significant difference between the mean age of the two genders ($p = 0.94$). The prevalence of micronutrient deficiencies were 47.3% vitamin E, 25.0% zinc, 3.9% haemoglobin and 1.4% vitamin A. The prevalence of wasting, stunting and underweight was 19.2, 13.7 and 11.4%, respectively. Linear regression analysis showed statistically significant positive correlations between weight-for-age (WAZ) and haemoglobin ($r = 0.38$, $p = 0.049$), zinc ($r = 0.71$, $p = 0.008$) and vitamin E ($r = 0.43$, $p = 0.029$) levels, while there were no significant correlations between vitamin A with WAZ, height-for-age (HAZ) and body mass index-(BMI)-for-age (BAZ). This study shows that there are some associations between child growth and certain micronutrient deficiencies that affects the growth and well-being. Therefore, regular and continued monitoring is recommended for the benefit of, specifically South African children, but also the general population, researchers and the government.

Keywords: Children, child growth, growth monitoring, micronutrient

Background

Periodic anthropometric and micronutrient status measurements are important public health indicators for monitoring child growth, health and wellbeing.[1] Globally, the impact of these two indicators are more pronounced in resource-limited communities where dietary intakes are in adequate and malabsorption problems are often aggravated by the presence of infections and diseases.[2] In turn, infections and diseases can also be complicated by malabsorption problems. The association between child growth and micronutrient status is well established. The latter is difficult to detect and, hence, is called 'hidden hunger'.[3] Persistence of hidden hunger over time leads to susceptibility to diseases in later life.[4,5]

According to the South African National Health and Nutrition Examination Survey (SANHANES) of 2013, undernutrition in children is a major public health issue despite several interventions in the recent past.[6] A persistently high prevalence of micronutrient deficiencies (vitamin A, iron and zinc), as well as anaemia (deficiency in vitamin B12, iron and folate) have been reported among almost a third of women and children. Also of public health concern is the high national prevalence of undernutrition, specifically stunting, with the highest levels (21.1%) of undernutrition arising from the rural areas of South Africa (SA). Moreover, for children under five, the national prevalence of vitamin A deficiency (VAD) was 43.6% and the overall prevalence of anaemia was 10.7% (SANHANES-1).[6]

We conducted a study to investigate the associations between micronutrient deficiencies and child growth in the rural community of Qwa-Qwa in the Free State province of SA.

Methods

Study design

This study was part of a cross-sectional, observational baseline survey study undertaken during May of 2008 and June of 2013.

The study area and participants' characteristics

The study community resides in the mountainous areas of the Qwa-Qwa region in the Free State province of SA. Qwa-Qwa is a severely impoverished area with 73% of its population living below the poverty line for South Africa.[7] Research in the same community found that 60.4% of the households are classified as very poor with the household members living on less than US$ 1 per day, which results in poor dietary intake despite 91.3% of households having a vegetable garden.[8]

Sampling method

This study formed part of a study undertaken to determine the prevalence of food security and malnutrition, in three rural communities that were purposively selected by the local community leaders in the Qwa-Qwa region. Data were obtained from the baseline survey for which a power calculation was used to determine a statistically representative sample size of 271 households.[8] However, this part of the study covers a subsample of children aged 7–15 years old from those households with children; therefore, 162 households were selected ($n = 162$).

The parameters used in study were based on children aged between 7–15 years of age whose anthropometric and serum micronutrient data can be obtained. Thus, the children's sample size for this study was calculated by using a sample size calculator

based on 50% of 162 households as recommended by The Survey System (which uses the more conservative approach of reaching 50% of the sample population).[9] Consequently, a 95% confidence level (0.5 margin of error) and confidence interval of 8.65 were employed using the following formula:

$$SS = \frac{Z^{2*}(p)^{*}(1-p)}{c^2}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)

p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)

c = confidence interval, expressed as a decimal (8.65)[10]

A total of 69 children were needed for significantly representative results; however, eight more children were included to account for possible data losses due to capturing errors and dropouts. Thus, the required final sample size totalled 77 children. Sixty households were randomly selected from the 162 households with a total of 148 children, and all the children aged 7–15 years in the selected households were included in the study until a sample size of 77 was obtained.

Data collection

Data collected included anthropometric, haematological and biochemical measurements and included: height and weight, serum haemoglobin (Hb), vitamins A and E, and zinc measurements.

Anthropometric measurements

The World Health Organization (WHO) protocol for anthropometric measurements (weight and height) was followed for all children.[10] A registered dietician (from SA) and public health nutritionist (from US) were responsible for measuring weight and height of all the respondents. Following the procedures described by Gibson,[11] weight was measured using a calibrated Philips electronic scale, model HF350 (135 kg/100 g) (Lifemax, Johannesburg, SA) with a two-point decimal precision. The scale was placed on an even uncarpeted area, with a zero indication (0.0). All participants were weighed in light clothes without shoes. Two measurements were taken, which were not to vary by more than 0.1 kilogram (kg), and the average of the two measurements was used.[12]

Height was measured using a Scale 2000 (Durban, SA) stadiometer with vertical scale in centimetres (cm) and a sliding headpiece, to the nearest 0.1 cm. The respondents were requested to stand straight with the head in the Frankfurt plane, feet together and knees straight. The heels, buttocks and shoulder blades had to be in contact with the vertical surface of the stadiometer, and arms had to hang loosely at the sides with shoulders relaxed. The movable headboard was gently lowered to press the hair flat and touch the crown of the head.[11] Height was recorded in centimetres. Two measurements were taken, which were not to vary by more than 0.1 cm, and the average of the two measurements was used.[11]

Blood collection and analysis

Fasting (8–10 h) venous blood samples were drawn by two nursing sisters and a haematologist with a Vacutainer needle and minimal use of tourniquets. Blood samples included 5 ml (whole blood) in EDTA for the measurement of haemoglobin, 5 ml in silicone-coated tubes for the analysis of vitamin A and E, and 5 ml drawn into trace element-free evacuated tubes with anticoagulant, using silicone stoppers. To prevent light affecting the vitamin A content, the 5 ml blood samples were covered in foil until analysis. The blood was placed on ice until separation which was done within 2 h of blood collection. Thereafter, serum was harvested by low-speed centrifugation at 48 °C and aliquoted into individual tubes. The serum Hb was harvested using cyanomethaemoglobin colorimetric method (Sysmex, Randburg, South Africa). Serum vitamins A and E were analysed using high-performance liquid chromatography (HPLC; Series 200, PerkinElmer, US). Zinc analysis was done using the AAS Atomic Absorption Analyzer 1000 (Torontech Group International, US).

Statistical analyses

A complete dataset of 77 children was obtained for the blood values and 73 for the anthropometric analyses reported in this paper. The weight and height of the children were captured on an Excel spreadsheet and analysed according to the WHO growth standards for nutritional status (2007) on AnthroPlus, version 1.0.4 to determine height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ), and body-mass-index (BMI)-for-age Z scores (BAZ). The cut-off points used were < -3SD for severely underweight (WAZ), severely thin (BAZ) and severely stunted (HAZ), with ≥ -3SD < -2SD as underweight (BAZ), thinness (BAZ) and stunted (HAZ). WAZ is only available for ages 10 and younger,[12] of which there were a total of 14 children

The serum parameters were captured in Statistical Package for Social Sciences (SPSS version 24). The normality check of micronutrient variables was conducted using Kolmogorov-Smirnov test. Means and standard deviations were calculated and compared to the respective cut-off points to reflect a deficiency. One-way Anova was used to test the mean difference between micronutrients in different nutritional status groups. Independent *t*-test was used to elucidate mean differences between the two gender groups in terms of deficiency and prevalence of nutritional status and age. Finally, correlations between z-scores and micronutrients were carried out using both Pearson and regression correlation coefficients. Significance levels were set at *alpha* < 0.05 and all analyses were performed using SPSS V 24.

Ethics

The study protocol followed the guidelines laid down in the Declaration of Helsinki and the SA Medical Research Council. All the procedures were approved by the University of the Witwatersrand's Human Research Ethics Committee (Medical) (M080931). Written informed consent was obtained from the women and assent from the children aged ≥ 7 years after an explanation of the objectives and study procedures. Written consent was obtained from the mothers of the children < 7 years old.

Results

The sample consisted of 49.4% boys (n = 38) and 50.6% girls (n = 39) aged 7 to 15 years. The mean ± SD age of the sample was 11 ± 2.11 years and no significant difference was observed for age between the two genders (p = 0.94).

In Table 1, the mean ± SD z-scores of weight-for-age (WAZ), height-for-age (HAZ) and BMI-for-age (BAZ) were –0.69 ± 1.06, –0.75 ± 1.34 and -0.82 ± 1.24, respectively, indicating normal

Table 1: Nutritional status of the children.

Nutritional status	Boys (*n* = 35)		Girls (*n* = 38)		Total (*n* = 73)	
	Mean ± SD	Z-score <-2SD *N* (%)	Mean ± SD	Z-score <-2SD *N* (%)	Mean ± SD	Z-score <-2SD *N* (%)
WAZ	−0.84±1.13	2(13.3)	−0.55±1.04	2(10.0)	−0.69±1.06	4(11.4)
HAZ	−0.87±1.10	7(20.0)	−0.63±1.54	3(7.9)	−0.75±1.34	10(13.7)
BAZ	−0.89±1.28	7(20.0)	−0.76±1.22	7(18.4)	−0.82±1.24	14(19.2)

There is no significant difference between the means of the two gender groups ($p > 0.05$).

values. However, 19.2%, 13.7% and 11.4% of the children were wasted (10 years and younger, $n = 14$), stunted and underweight, respectively. Thus, a prevalence of both chronic and acute undernutrition existed. The prevalence in girls for wasting, stunting and underweight was lower than for boys, but this was not statistically significant ($p > 0.05$).

In Table 2, the results of the mean serum blood levels of Hb, vitamins A and E, and zinc were within the normal range for boys and girls, and the total group. No significant differences between the means of the measured serum micronutrients between the two genders were observed ($p > 0.05$). However, 3.9% of the children had anaemia in terms of low serum Hb (< 11 g/dl)[13] and 1.4% had vitamin A deficiency (< 200 µg/l).[14] The prevalence of zinc deficiency (< 65 µg/dl)[15] was 25.5%. Although vitamin E serum levels were deficient (< 3 mg/l)[16] in 47.3% of the children, serum vitamin E levels are not a reliable measure of vitamin E deficiency.[11] A further analysis of all four parameters (Table 3) indicated that there are no statistically significant differences in the measured serum parameters between normal weight and underweight, normal weight and stunting, normal weight and thinness. However, in stunted children ($n = 10$, 13.7%), the prevalence of vitamin E deficiency was 50%, zinc deficiency 28.6%, anaemia 10% and VAD 0% (no children). In the wasted children ($n = 14$, 19.2%), the prevalence of vitamin E deficiency was 50.0%, followed by 33.3%, 14.3% and 7.1% for zinc deficiency, anaemia and VAD, respectively. In the underweight group of children ten years and younger ($n = 4$, 11.4%), 50% of the children ($n = 2$) had a zinc deficiency, 25% vitamin E deficiency, 25% ($n = 1$) anaemia and 0% (no children) with VAD deficiency.

In Table 4, the linear regression analysis showed that Hb ($r = 0.38$, $p = 0.049$), zinc ($r = 0.71$, $p = 0.008$) and vitamin E ($r = 0.43$, $p = 0.029$) levels showed a statistically significant positive correlation with the WAZ score. However, only the younger group of children were reported on here since WAZ measures are used only in children under 10 years of age. There were no significant correlations between serum micronutrient levels and growth indicators of HAZ and BAZ scores found in this study.

Discussion

The SANHANES-1 survey of 2012 clearly indicated persistent child malnutrition especially in under nutrition in SA. For instance, the national prevalence of child stunting remained high as it increased from 19% as measured by the National Food Consumption Survey (NFCS) of SA in 1999[17] to 21% reported by SANHANES-1 in 2012.[6] The national overall prevalence of child IDA is 10.7% (moderate 8.6% + mild 2.1%); however, there was no severe IDA reported at all.[6] The findings of this smaller study support the SANHANES-1 results as a low anaemia prevalence with no public health concerns (Hb < 11 g/dl in less than 4.9%) was found compared to SANHANES-1 who reported a mild public health problem (5.0% – 19.9% prevalence). The results of this study indicated that there is an association between Hb and the WAZ growth indicator.

SANHANES-1 reported a high national prevalence of VAD (43.6%), which was inconsistent with the findings of this smaller study where a low prevalence (1.4%) was found. These contrasting findings show that there are areas where there is virtually no vitamin A deficiency. This fact might help health care professionals and nutritionists when planning interventions in certain areas to counteract possible subclinical deficiency and toxicity of vitamin A that could cause severe adverse health effects on pregnant and lactating women and growing children alike.[12] This study found a significant association between serum vitamin A and the WAZ growth indicator.

At the time of writing this manuscript, literature about vitamin E deficiency in SA children was scanty whereby the only available source from the web-based search was the NFCS in 1999, published in 2007.[17] However, the prevalence of vitamin E deficiency in the children in this study was 47.3% compared to 33% reported by the NFCS .[17] Although serum vitamin E is not a reliable indicator of vitamin E deficiency, the high prevalence rates reported in this study and the NFCS indicate a possible public health problem in SA children. Both vitamins A and E have important functions in human health.[18,19] Vitamin E deficiency may lead to reversible motor and sensory neuropathies in

Table 2: Serum biochemical micronutrient status of the children.

Nutritional status	Boys (*n* = 35)		Girls (*n* = 37)		Total (*n* = 72)	
	Mean ± SD	Deficiency *N* (%)	Mean ± SD	Deficiency *N* (%)	Mean ± SD	Deficiency *N* (%)
Haemoglobin (g/dl)	13.3±1.45	1(2.6)	13.1±1.20	2(5.1)	13.2±1.33	3(3.9)
Vitamin A (µg/l)	350.2±84.3	1(2.8)	352.6±83.7	0(0.0)	351.4±84.0	1(1.4)
Vitamin E (mg/l)	6.48±1.63	16(44.4)	6.30±1.75	19(50.0)	6.39±1.69	35(47.3)
Zinc (µg/dl)	80.79±24.1	10(30.3)	85.20±24.1	7(20.0)	83.0±1.24	17(25.0)

There is no significant difference between the means of the two gender groups ($p > 0.05$).
Cut-off points: Haemoglobin < 11 g/dl, Vitamin A < 200 µg/l, Vitamin E < 36 mg/l & Zinc < 65 µg/dl.

Table 3: Serum micronutrients and stratified nutritional status.

	N (%)	Haemoglobin (g/dl)	Vitamin A (µg/l)	Vitamin E (mg/l)	Zinc (µg/dl)
*WAZ (Underweight)**					
Moderate	4(11.4)	13.050±2.28(11.4%)	361.95±108.9(12.5%)	6.36±1.27(12.5%)	68.82±17.34(13.79%)
Normal	31(88.6)	13.345±0.95(88.6%)	358.40±85.49(87.5%)	6.05±1.80(87.5%)	82.43±29.02(86.21%)
*HAZ (Stunting)**					
Severe	4(5.5)	12.625±0.71(5.5%)	358.04±76.74(5.7%)	6.83±1.29(5.7%)	80.19±6.85(4.7%)
Moderate	10(13.7)	12.670±1.76(13.7%)	345.30±76.20(14.29%)	6.64±1.32(14.3%)	76.74±16.32(10.9%)
Normal	59(80.7)	13.338±1.07(80.7%)	347.04±83.41(80.01%)	6.28±1.67(80.01%)	81.83±27.90(84.4%)
*BAZ (Thinness)**					
Severe	4(5.5)	13.275±1.06(5.5%)	282.76±69.56(5.7%)	6.481±1.21(5.7%)	71.65±15.13(4.7%)
Moderate	14(19.2)	12.579±1.39(19.2%)	329.71±82.39(20.0%)	6.68±1.41(20.0%)	73.02±28.05(18.8%)
Normal	56(76.7)	13.405±11.10(75.3%)	351.07±81.07(74.3%)	6.32±1.61(74.3%)	82.25±27.69(76.50%)

**p*-values one-way ANOVA < 0.05 (There were no significant differences of individual micronutrients in the 3 anthropometric classes).

Table 4: Nutritional status correlation coefficients (***r***) with serum micronutrients.

	Haemoglobin *r* (*p*)	Vitamin A *r* (*p*)	Vitamin E *r* (*p*)	Zinc *r* (*p*)
WAZ	0.38(0.049)*	–0.39(0.11)	0.43(0.029)*	0.71(0.008)*
HAZ	0.16(0.12)	0.03(0.86)	–0.41(0.64)	0.19(0.23)
BAZ	0.21(0.096)	0.21(0.17)	0.70(0.59)	–0.005(0.98)

*p < 0.05 = significantly correlated
Note: There is no significant difference between the means of the two gender groups (*p* > 0.05).

children. Furthermore, vitamin E is an antioxidant that provides protection for vitamin A and possible risk of coronary atherosclerosis and thrombosis in the body.[16] There was a higher prevalence of vitamin E deficiency for children participating in this study compared to VAD. There is little literature on the actual relationship between vitamins E and A. The closest relevant literature reported that plasma tocopherol (Vit E) was remarkably decreased by high dosages of vitamin A supplementation, indicating an inverse relationship.[20] This might explain the observed higher prevalence of vitamin E deficiency and quasi-adequate vitamin A levels found in this study. On the other hand, this is contradictory to the national studies in the country where vitamin A deficiency is more prevalent.[6,17] This study, however, found that vitamin E deficiency was significantly associated with WAZ. At the time of writing this manuscript, no other studies were found highlighting associations between the investigated micronutrients (Hb, vitamin E and zinc) and WAZ. This study could, thus, possibly be one of the first to report a correlation between vitamin E, zinc and Hb with WAZ.

The most commonly used tests for diagnosing zinc deficiency is through plasma or serum zinc levels. Although cell zinc content can also be used, it is technically more difficult to perform and the superiority over serum-based tests has not been clearly demonstrated. Zinc levels in hair has also been used, but the analysis is unclear[21] and thus, for this study, serum zinc was used to determine zinc deficiency. Zinc is known to be of particular importance in children for optimum growth and development of cognitive functions.[22] However, in SA, the prevalence of zinc deficiency in children has always been high – 50–73% reported in the NFCS.[17] In this study, the prevalence of zinc deficiency among the children was 25%, which is lower than another region-specific study in Kimberley where a prevalence of 47% was found.[21] This finding warrants the need for constant nutritional status monitoring of the children as body zinc requirements fluctuate subject to both growth and dietary intake.[23,24] In this study, zinc was significantly associated with underweight, contrary to the well-known fact that a zinc deficiency is associated with stunting.[25]

The article by Reynaldo Martorell entitled 'The nature of child malnutrition and its long-term implications' summarises that all nutrient deficiencies are interrelated, and studies focusing on only one nutrient may mask the effect of these deficiencies within the human body and more specifically on child growth and well-being[19] This was also reported in three national SA nutrition surveys (The 1995 South African Vitamin A Consultative Group (SAVACG) survey,[26] The National Food Consumption Survey 2005[17] and SANHANES-1[6]). The results of this study partially support the inter-relationship between child growth standards and micronutrient malnutrition

Conclusions

In this study, multiple micronutrient deficiencies were prevalent among this group of children. Furthermore, no overweight and obesity were found, but stunting, wasting and underweight were observed. Acute and chronic undernutrition is thus the main challenge to address in the study community. Although both macronutrient and micronutrient malnutrition were prevalent in these children, associations between the WHO growth standards and micronutrient deficiencies could not be established, with the exception of haemoglobin, zinc and vitamin E with WAZ. This indicates that younger children that are malnourished are more susceptible to micronutrient deficiencies than the older children. Although much progress has been made to address both macronutrient and micronutrient malnutrition in SA, continued and regular national surveys in these areas are of paramount importance to address the various forms of malnutrition, especially screening during the crucial early years of growth.

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