Original Article

Serum vitamin A concentrations and growth in children and adolescents in Gansu Province, China

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The association between serum vitamin A concentration and growth was assessed in a random sample of 650 children aged 0–14 years and 143 adolescents aged 15–19 years from the four prefectures of Jiayuguan, Linxia, Lanzhou and Tianshui in Gansu Province, China. Serum vitamin A concentrations were measured using a high performance liquid chromatograph. Height and weight were measured with standard methods. The results show that serum vitamin A concentration appeared to be the lowest in the age group 5–9 years which was only 0.28 mg/mL (95% confidence interval [CI]: 0.27–0.30) in males and 0.30 mg/mL (95% CI: 0.28–0.32) in females; and then it gradually increased with age. There was no statistically significant difference between males and females in any of the age groups. There were statistically significant correlations between vitamin A and weight ($r = 0.37$; $P < 0.001$) and body mass index ($r = 0.26$; $P < 0.001$). This study suggests that serum vitamin A concentrations in children and adolescents may affect child growth. Concerted efforts to improve vitamin A status from a very early age become increasingly important if vitamin A has a genuine impact on child growth.

Key words: body mass index, Gansu Province (China), height, nutrition and growth, vitamin A, weight.

Introduction

Malnutrition is a significant child health problem in many developing countries.[1] Nutrient deficiencies have been linked to reduced linear growth.[2] Growth retardation has been associated with adverse health consequences, such as increased risk of morbidity and mortality, impaired intellectual performance and later outcomes, such as reduced work capacity and poor reproductive performance.[3,4] Supplementary feeding programs aimed at increasing energy and protein intakes have generally produced small improvements in physical growth, implying that poverty as well as deficits in the intake of a variety of nutrients, including vitamin A, may limit growth.[5]

Vitamin A is an essential nutrient for mammalian growth and health.[6] Clinical vitamin A deficiency has long been linked to poor child growth, including symptoms of eye damage, stunting and wasting.[7,8] Children who develop mild xerophthalmia (night blindness or Bitot's spot) also show less weight gain and poorer growth than their non-cerophthalmic peers. Conversely, improved weight gain can accompany spontaneous recovery from xerophthalmia.[9] However, randomised trials of vitamin A supplementation have produced mixed results, ranging from improved ponderal or linear growth to little or no discernible effects.[10–12]

Few data are available on the relationship between mild deficiency of vitamin A and growth. In this paper, we examine the difference in serum vitamin A concentration and to explore the associations between height, weight and serum vitamin A concentrations among a random sample of children and adolescents in Gansu Province, China.

Subjects and methods

Study sample

A sample of 650 children aged 0–14 years and 143 adolescents aged 15–19 years were randomly selected from four prefectures (Jiayuguan, Linxia, Lanzhou and Tianshui) which represent the eastern, western and central areas in Gansu Province, China. These subjects who participated in this study were primarily young children in kindergartens and students attending schools.

Data collection

Interviewers collected data on participants' sociodemographic factors with a questionnaire to mothers or adolescents. Weight was measured using electronic scales which were regularly checked for their precision. Height was measured using a calibrated scale consisting of a wooden platform with a scale and sliding head piece. Children aged 2 years or younger were measured lying down; older children or adults were measured standing. All interviewers were trained and the protocol was standardised for anthropometric measurement.

Blood samples (2 mL) were taken by antecubital venipuncture, stored in cool boxes for less than 3 h and then centrifuged at room temperature for 10 min. The analyses were

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conducted using a high performance liquid chromatography (HPLC), according to the method described by Bieri *et al.*[13] Serum samples were treated with an equal volume of ethanol and then extracted three times with an equal volume of hexane. The hexane extracts were pooled and dried under nitrogen. The HPLC analysis at 295 nm was used to confirm the absorption quantification. This study was conducted in accordance with the internationally agreed ethical principles for the conduct of medical research.

Statistical analysis

Body mass index (BMI) was calculated as BMI = weight (kg)/height (m)^2. Student t- and F-tests were used to compare two and more group means, respectively. Scatter-plots and correlation analyses were performed to describe the relationships between vitamin A and height, weight or BMI. A 95% individual prediction interval was used to reflect the area where 95% of actual individual values were located. Multiple linear regression analysis was performed to examine the independent impact of vitamin A on height, weight and BMI after adjustment for sex and age. Statistical analysis was performed using the Statistical Package for the Social Sciences.[14]

Results

Table 1 shows the mean and standard deviation of vitamin A in serum, height, weight and BMI by sex and age in Gansu, China. The results show that the mean concentration of vitamin A was same for both male (0.34 μ/mL (95% confidence interval [CI]: 0.32–0.35)) and female (0.34 μg/mL (95% CI: 0.32–0.35)). The average height (130.97 cm) and weight (32.42 kg) in males were significantly greater than those in females (height: 129.13 cm; weight: 30.86 kg). There were also significant differences in height and weight between males and females for the age groups 5–9 years and 15–19 years. No significant difference was observed in BMI for any of the age groups.

Figure 1 shows the mean concentration and 95% CI of serum vitamin A by sex and age. Serum vitamin A concentration appeared to be the lowest in the age group 5–9 years which was only 0.28 μg/mL (95% CI: 0.27–0.30) in males and 0.30 μg/mL (95% CI: 0.28–0.32) in females; and then it gradually increased with age. There was no statistically significant difference between males and females in any of the age groups.

Figures 2 and 3 show the scatter-plots and bivariate relationships between serum vitamin A and weight/BMI. There was a significant correlation between vitamin A and weight ($r = 0.37$; $P < 0.001$) and between vitamin A and BMI ($r = 0.26$; $P < 0.001$). However, there was no significant relationship between vitamin A and height.

Table 2 shows the independent impacts of vitamin A, sex and age on height, weight and BMI. The results show that serum vitamin A concentration appeared to be positively associated with weight ($P < 0.001$) and BMI ($P < 0.001$), even after adjustment for the effects of age and sex. The results suggest that, for every unit change in serum vitamin A, there was a 10.39 kg change in weight and 4.32 kg/m^2

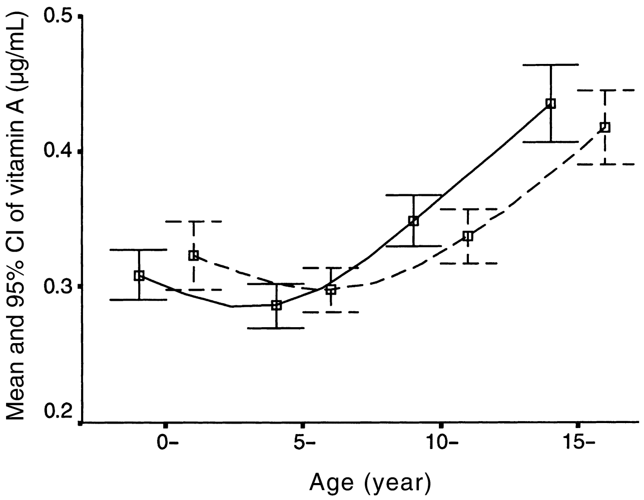

Figure 1. Mean concentrations and 95% confidence interval of serum vitamin A by sex and age. (–□–), male; (--□--), female.

Table 1. Mean and SD of vitamin A, height, weight and BMI by age and sex in Gansu, China

Age Group	Sex	*n*	Vitamin A (μg/mL) Mean	SD	Height (cm) Mean	SD	Weight (kg) Mean	SD	BMI (kg/m^2) Mean	SD
0–	Male	104	0.31	0.10	94.24	14.25	15.26	4.01	17.31	3.79
	Female	83	0.34	0.12	94.63	13.04	15.31	4.60	17.06	3.28
	Total	187	0.32	0.11	94.41	13.69	15.28	4.27	17.20	3.56
5–	Male	117	0.28	0.09	122.64*	9.77	25.03**	5.48	16.50	2.08
	Female	111	0.30	0.09	119.39	12.20	22.99	5.14	16.15	2.88
	Total	228	0.29	0.09	121.06	11.11	24.03	5.41	16.33	2.50
10–	Male	118	0.35	0.10	147.77	10.63	38.51	7.93	17.50	2.15
	Female	117	0.34	0.11	145.47	10.71	37.16	8.34	17.38	2.73
	Total	235	0.34	0.11	146.62	10.71	37.84	8.15	17.44	2.45
15–	Male	75	0.43	0.12	168.46**	8.12	58.16**	7.92	20.53	2.59
	Female	68	0.42	0.12	159.02	4.87	51.89	5.39	20.52	1.86
	Total	143	0.42	0.12	163.97	8.24	55.18	7.50	20.52	2.26
Total	Male	414	0.34	0.11	130.97	28.57	32.42	16.19	17.72	3.04
	Female	379	0.34	0.12	129.13	25.54	30.86	14.21	17.51	3.14
	Total	793	0.33	0.12	130.09	27.16	31.68	15.29	17.62	3.09

$^*P < 0.05$, $^{**}P < 0.01$. BMI, body mass index; SD, standard deviation.

change in BMI. As observed in the correlation analysis, vitamin A was not significantly associated with height in the multiple linear regression model.

Discussion

This study systematically assessed the relationships between serum vitamin A and anthropometric measures, such as height, weight and BMI, in a random sample of 650 children aged 0–14 years and 143 adolescents aged 15–19 years in Gansu, China. The results show that serum vitamin A concentration appears to be the lowest in the age group 5–9 years (0.28 μg/mL for male and 0.30 μg/mL for female). It gradually increased with age and then reached 0.43 μg/mL for males and 0.42 μg/mL for females in the group aged 15–19 years. Younger children appeared to have systematically lower serum vitamin A concentrations than others. A significant association between vitamin A and weight or BMI was observed in this particular population.

Our findings agree with the results of several other studies. In the Sudan Vitamin A Study, dietary vitamin A intake was associated with attained weight and height after controlling for confounding factors. Higher dietary vitamin A intake was also associated with reduced risk of stunting and wasting.[15] In a recent study conducted by Donnen *et al.* in Zaire, vitamin A supplementation appeared to improve growth.[16] Weight increments were significantly higher in the vitamin A-supplemented group than in the control group during the 6 months of follow-up.[16] A controlled field trial which was carried out in Java, Indonesia, showed that children who consumed small, frequent amounts of vitamin A in fortified monosodium glutamate experienced greater weight gain than control children.[11] Another intervention study conducted in Aceh, Senegal, indicated that large doses of vitamin A given every 6 months were associated with increments in weight, but had little effect on height, although this was limited to boys who were 4–5-years-old.[17]

A few studies, however, reported that vitamin A supplements did not have an appreciable effect on growth.[18,19] There are two explanations for the inconsistency observed in these studies. First, the characteristics of the study populations may differ. For example, some study populations may have been suffering from deficits in other growth-limiting nutrients, including fat, protein and zinc that are vital for the absorption and metabolism of vitamin A. Therefore, vitamin A supplementation alone had no effect.[20] Second, the magnitude of vitamin A deficiency, supplement doses and timing may have important impacts on the intervention outcomes. However, these issues have not been investigated thoroughly.

Vitamin A is known to play a role in cell differentiation and organ growth.[21] In animals, reduced weight gain is one of the earliest manifestations of vitamin A deficiency.[22] The results of this research and other studies (but not all) suggest that deceleration of weight gain may also be one of the earliest signs of vitamin A deficiency in human beings.[23,24]

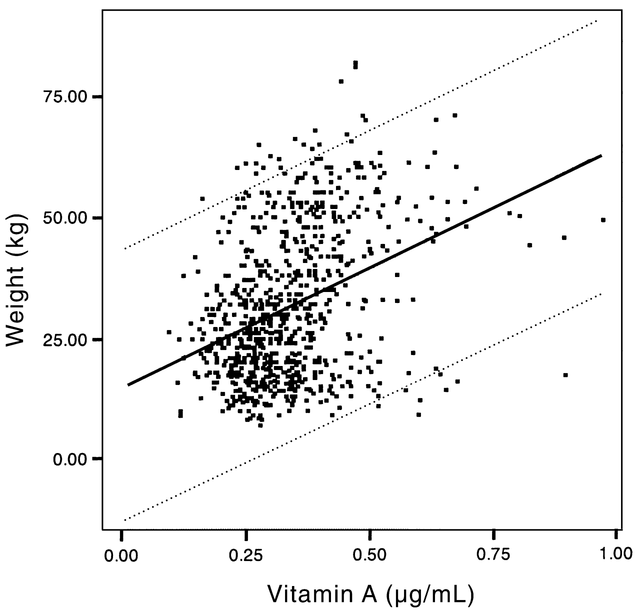

Figure 2. The relationship between vitamin A and weight. (….), 95% individual prediction interval; (—), regression line.

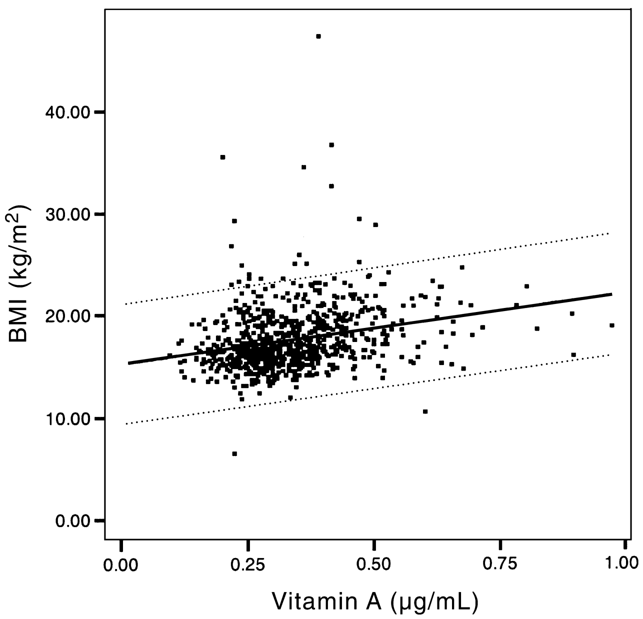

Figure 3. The relationship between vitamin A and body mass index (BMI). (….), 95% individual prediction interval; (—), regression line.

Table 2. Regression parameter estimates of height, weight and BMI with vitamin A, sex and age

	Height			Weight			BMI		
Variable	B	SE	*P*	B	SE	*P*	B	SE	*P*
Intercept	87.70	1.40	0.000	5.78	0.86	0.000	14.88	0.44	0.000
Age	5.10	0.07	0.000	2.74	0.04	0.000	0.18	0.02	0.000
Sex	–2.00	0.70	0.002	–1.72	0.41	0.000	–2.34	0.20	0.248
Vitamin A	–3.40	3.00	0.263	10.39	1.85	0.000	4.32	0.93	0.000

BMI, body mass index; SE, standard error.

One strength of the present study is in its use of a population-based random sampling procedure in the deprived areas in China. Such methodology is essential for reflecting the current situation in the rural population. Another strength of this study is that a wide range of ages was covered and the pattern of vitamin A deficiency in both children and adolescents was assessed.

Several limitations in this study must also be noted. First, about 2% of children in Gansu do not attend school because of their financial inability. Therefore, the results of this study are likely to underestimate the magnitude of vitamin A deficiency in this population. Second, data on several putative confounding factors (for example, socioeconomic status and morbidity) were not available. The possibility that unmeasured confounders and residual confounding explain at least part of the association between vitamin A and weight cannot be excluded.

Evidence from this study suggests that there may be a need for the development of an appropriate guideline to describe vitamin A status among different age groups. There appear to be some differences in serum vitamin A concentrations as a result of normal physiological processes among children.[18] An important consideration is whether lower serum vitamin A concentrations in younger children are because of normal biological events or from suboptimal health conditions; for example, infection and/or other micronutrients deficiency. Research on this issue is clearly warranted.

These findings of this study reinforce the importance of assessing a role of vitamin A in promoting growth in children without clinical signs of vitamin A deficiency. If vitamin A has a genuine impact on child growth, efforts to improve vitamin A status from a very early age become increasingly important.

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