Original Article

# Serum vitamin A, D and E concentrations and status in children in Shaanxi Province, Northwest China

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**Background and Objectives:** To investigate the vitamin A, D, E concentrations and status, and analyse the associated risk factors for vitamin A, D, E deficiency in children in Shaanxi Province, Northwest China. **Methods and Study Design:** The study included a total of 25,806 children admitted to hospitals in Shaanxi province from January 2019 to December 2019. Fasting venous blood samples were collected to measure serum vitamin A, D, E concentrations. A logistic regression model was performed to estimate the association between risk factors and vitamin A, D, E deficiency and insufficiency. **Results:** The mean serum vitamin A, D, E concentrations were 0.87±0.33 μmol/L, 63.7±29.7 nmol/L and 20.8±6.98 μmol/L, respectively. The prevalence of vitamin A, D, E deficiency was high in neonates (15.1%, 81.5% and 44.9%, respectively). Children living in rural areas were at higher risk for vitamin A, D, E deficiency and insufficiency. Logistic regression analyses revealed that the risk of vitamin D deficiency and insufficiency in children was 7.68 times (95% CI: 6.97-8.47) higher in winter than in summer. With adjustment for gender, season, and living regions, age correlated positively with serum vitamin A concentration (r=0.110, $p<0.001$), and negatively with vitamin D and E concentrations (r=-0.370 and r=-0.250 both $p<0.001$). **Conclusions:** This study showed that the prevalence of vitamin A, D and E deficiency was extremely high in neonates in Shaanxi province, northwest China. Children living in rural areas and winter had a high risk of vitamin A, D, E deficiency and insufficiency.

**Key Words: vitamin A, vitamin D, vitamin E, children, China**

## INTRODUCTION

Fat-soluble vitamins A, D and E play important roles in the growth of children. Vitamin A and vitamin D deficiency is a public health problem worldwide. In China, the nutritional status of children has greatly improved with the economic and social development, while they are still facing the problem of micronutrient deficiency, such as vitamin A, vitamin D, iron and zinc.

Vitamin A and its major oxidative metabolite retinoic acid participate in cell production, improve immunity and resist infection, which deficiency may cause repeated infections, anaemia, anorexia, slow growth, diarrhoea, and hyperkeratosis.[1] It is recognized as a moderate public health nutrition problem in Chinese children. Vitamin D is important in calcium and phosphorus homeostasis, bone mineralization, bone mass acquisition, autoimmune, metabolic, and chronic diseases during childhood and adolescence.[2,3] 25-hydroxyvitamin D (25(OH)D) is the major circulating metabolite of vitamin D, and its serum concentration is the best indicator of vitamin D status. Vitamin E is significant to the protection of cell membrane components against free radical oxidation. It can regulate cell proliferation and gene expression, enhance immune response, and also important for the maintenance of normal neurological structure and function.[4,5] In conclusion, sufficient fat-soluble vitamin A, D and E concentrations are important for children and adolescents. This study aimed to investigate vitamin A, D, E concentrations and status, and analyse the associated risk factors for vitamin A, D, E deficiency in children in Shaanxi Province, Northwest China.

## METHODS

### *Participants*

This is a cross-sectional study. A total of 25,806 children aged one day to 18 years admitted to 86 hospitals in dif-

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Manuscript received 29 September 2021. Initial review and accepted 14 October 2021.
doi: 10.6133/apjcn.202112_30(4).0015

ferent regions of Shaanxi province from January 2019 to December 2019 were included in the study. Children with epilepsy or other chronic diseases were excluded. This study was executed according to the Helsinki Declaration guidelines and approved by the Medical Ethics Committees of Xi'an Children's Hospital (20210009). All participants were provided informed consent.

***Data collection***

Basic information including age, sex, living region and areas, and season of blood collection was collected by questionnaires or from medical records. The children were divided into seven age groups: neonatal period (1-<28 days), little infant period (28 days-<6 months), infant period (6 months-<1 year), toddle period (1-<3 years), preschool age (3-<6 years), school-age (6-<12 years), and adolescence (12-<18 years). Shaanxi province is located in north-western China (31°42'-39°35' N, 105°29'-111°15' E), within it there are three regions: namely central Shaanxi (between the Loess Plateau and the Qinling Mountains), northern Shaanxi (Loess Plateau) and southern Shaanxi (south of the Qinling Mountains), which have different geographic, climate, cultural and economic. The urban residence is defined as the centre area of the big city, and the rural residence is defined as all the district and county cities. The four seasons were divided into spring (March to May), summer (June to August), autumn (September to November), and winter (December to February).

***Measurements***

Fasting venous blood samples were collected from children in the morning. Serum samples were extracted from blood samples after centrifugation, then stored in a refrigerator, and followed the principles of cold chain sent to Xi'an Hehe Medical Laboratory (Xi'an, China) for vitamin A, D, E testing.

Serum vitamin A and E concentrations were measured by high-performance liquid chromatography (HPLC; LC-20A, Shimadzu, Japan) and vitamin D by liquid chromatography-mass spectra (LC-MS; MS8030, Shimadzu, Japan). Liquid-liquid extraction was used and quantification by the internal standard. Thawed serum samples (200 µL), 10 µL of internal standard and 400 µL of ethyl acetate were placed into a centrifuge tube, adequately mixed for 5 minutes. Subsequently, the mixture was centrifuged at 15,000 rpm for 10 minutes. Accurately absorb 390 µL of supernatant and place it in a centrifuge tube, blow dry with nitrogen, then add 200 µL of methanol, mix for 1 minute. The supernatant of 100 µL was accurately absorbed and injected into the HPLC system for detection.

***Standards***

Vitamin A sufficiency was defined as serum vitamin A concentration of ≥1.05 µmol/L (≥0.70 µmol/L for children less than six years of age), marginal vitamin A deficiency was defined as serum vitamin A concentration between 0.7 µmol/L-<1.05 µmol/L (0.35 µmol/L and <0.7 µmol/L for children less than six years of age), vitamin A deficiency as serum vitamin A concentration <0.70 µmol/L (<0.35 µmol/L for children less than six years of age).[6,7]

Vitamin D deficiency was defined as serum 25(OH)D concentration of <30 nmol/L, vitamin D insufficiency was defined as serum 25(OH)D concentration between 30 nmol/L and 50 nmol/L, and vitamin D sufficiency was defined as serum 25(OH)D concentration of >50 nmol/L.[8]

Vitamin E deficiency was defined as serum vitamin E concentration of <12 µmol/L, vitamin E insufficiency was defined as serum vitamin E concentration between 12 µmol/L and <16.8 µmol/L, and vitamin E sufficiency was defined as serum vitamin E concentration of ≥16.8 µmol/L.[9,10]

***Statistical analysis***

Statistical analyses were performed using SPSS Statistics 18.0. Results are expressed as number and percentage, mean±standard deviation (SD) for normally distributed data. Logistic regression models with corresponding odds ratios (ORs) and 95% confidence intervals (CIs) were used to determine the risk factors of vitamin A, D, E deficiency and insufficiency. Correlations were assessed using Pearson partial correlations to allow adjustment for age and other covariates. A two-tailed $p<0.05$ was considered statistically significant.

## RESULTS

***Concentrations and status of vitamin A, D, E***

The vitamin A, D, E concentrations of participants were 0.87±0.33 µmol/L, 63.7±29.7 nmol/L and 20.8±6.98 µmol/L, respectively. Boys had higher vitamin D and lower vitamin E concentrations than girls. The prevalence of vitamin A, D, E deficiency was extremely high in neonates (15.1%, 81.5% and 44.9%, respectively). Meanwhile, the prevalence of vitamin A and vitamin D deficiency was also high in school-age children and adolescents (Table 1-3). As shown in Figure 1-3, there were significant differences in serum vitamin A, D, E concentrations among children of different age groups and different regions of Shaanxi province. The children aged 1 to 18 years living in north Shaanxi were in lower vitamin A concentrations, compared with the children in south and central Shaanxi. The neonates and children aged 3 to 18 years had significantly lower vitamin D concentrations whenever they live in central or north Shaanxi. Changes in vitamin A, D, E concentrations among children in different areas and seasons are shown in Figure 4. There were no significant differences in vitamin A, D, E concentrations between urban and rural children in the four seasons. In addition, children living in north Shaanxi had significantly lower vitamin A, D, E concentrations.

***Risk factors for vitamin A, D, E deficiency***

Logistic regression models were used to study the risk factors for vitamin A, D, E deficiency and insufficiency, and the results are shown in Table 4. Girls had a higher risk of vitamin D deficiency and a lower risk of vitamin E deficiency than boys. Compared with infants aged 28 days to three years, neonates had an extremely higher risk of vitamin A, D, E deficiency and insufficiency. Meanwhile, school-age children and adolescents also had a higher risk of vitamin A, D, E deficiency. There was a high risk of vitamin D deficiency and insufficiency in children in winter and spring. Children living in rural areas were at

**Table 1.** Vitamin A concentrations and status of children in Shaanxi province

| Variables | Cases | Vitamin A concentration (μmol/L) | *p*-value | Status of vitamin A, n (%) | | | *p*-value |
|---|---|---|---|---|---|---|---|
| | | | | VAD | MVAD | Sufficiency | |
| Total | 25806 | 0.87±0.33 | | 1445 (5.6) | 8060 (31.2) | 16301 (63.2) | |
| Sex | | | 0.165 | | | | 0.593 |
| Boys | 14798 | 0.88±0.33 | | 810 (5.5) | 4631 (31.3) | 9357 (63.2) | |
| Girls | 11008 | 0.87±0.33 | | 635 (5.8) | 3429 (31.1) | 6944 (63.1) | |
| Age | | | | | | | |
| 1~<28d | 1229 | 0.53±0.20 | <0.001 | 186 (15.1) | 795 (64.7) | 248 (20.2) | <0.001 |
| 28d~<6m | 2106 | 0.74±0.28 | | 93 (4.4) | 891 (42.3) | 1122 (53.3) | |
| 6m~<12m | 2857 | 0.94±0.32 | | 16 (0.6) | 629 (22.0) | 2212 (77.4) | |
| 1~<3y | 7330 | 0.93±0.33 | | 68 (0.9) | 1732 (23.6) | 5530 (75.5) | |
| 3~<6y | 7220 | 0.86±0.31 | | 94 (1.3) | 2219 (30.7) | 4907 (68.0) | |
| 6~<12y | 4620 | 0.89±0.32 | | 939 (20.3) | 1661 (36.0) | 2020 (43.7) | |
| 12~<18y | 444 | 1.13±0.38 | | 49 (11.0) | 133 (30.0) | 262 (59.0) | |
| Seasons | | | <0.001 | | | | <0.001 |
| Spring | 8564 | 0.87±0.32 | | 416 (4.9) | 2690 (31.4) | 5458 (63.7) | |
| Summer | 6474 | 0.91±0.34 | | 296 (4.6) | 1889 (29.1) | 4289 (66.3) | |
| Autumn | 4823 | 0.87±0.34 | | 348 (7.2) | 1483 (30.8) | 2992 (62.0) | |
| Winter | 5945 | 0.85±0.32 | | 385 (6.5) | 1998 (33.6) | 3562 (59.9) | |
| Areas | | | 0.860 | | | | <0.001 |
| Urban | 14759 | 0.87±0.34 | | 923 (6.3) | 4579 (31.0) | 9257 (62.7) | |
| Rural | 11047 | 0.87±0.31 | | 522 (4.7) | 3481 (31.5) | 7044 (63.8) | |
| Regions | | | <0.001 | | | | <0.001 |
| Central Shaanxi | 10661 | 0.87±0.34 | | 688 (6.4) | 3333 (31.3) | 6640 (62.3) | |
| Northern Shaanxi | 5323 | 0.79±0.29 | | 374 (7.0) | 2064 (38.8) | 2885 (54.2) | |
| Southern Shaanxi | 9822 | 0.92±0.32 | | 383 (3.9) | 2663 (27.1) | 6776 (69.0) | |

†VAD: vitamin A deficiency, MVAD: marginal vitamin A deficiency.

**Table 2.** Vitamin D concentrations and status of children in Shaanxi province

| Variables | Cases | Vitamin D concentration (μmol/L) | *p*-value | Status of vitamin D, n (%) | | | *p*-value |
|---|---|---|---|---|---|---|---|
| | | | | Deficiency | Insufficiency | Sufficiency | |
| Total | 25806 | 63.7±29.7 | | 3440 (13.3) | 5573 (21.6) | 16793 (65.1) | |
| Sex | | | 0.001 | | | | 0.001 |
| Boys | 14798 | 64.2±29.6 | | 1915 (12.9) | 3113 (21.1) | 9770 (66.0) | |
| Girls | 11008 | 63.0±30.0 | | 1525 (13.9) | 2460 (22.3) | 7023 (63.8) | |
| Age | | | | | | | |
| 1~<28d | 1229 | 20.7±10.7 | <0.001 | 1002 (81.5) | 202 (16.5) | 25 (2.0) | <0.001 |
| 28d~<6m | 2106 | 74.0±35.5 | | 287 (13.6) | 222 (10.6) | 1597 (75.8) | |
| 6m~<12m | 2857 | 92.2±28.9 | | 88 (3.1) | 113 (3.9) | 2656 (93.0) | |
| 1~<3y | 7330 | 77.4±25.8 | | 222 (3.0) | 789 (10.8) | 6319 (86.2) | |
| 3~<6y | 7220 | 55.8±19.1 | | 709 (9.8) | 2177 (30.2) | 4334 (60.0) | |
| 6~<12y | 4620 | 45.9±18.1 | | 963 (20.8) | 1887 (40.9) | 1770 (38.3) | |
| 12~<18y | 444 | 38.3±16.5 | | 169 (38.1) | 183 (41.2) | 92 (20.7) | |
| Seasons | | | <0.001 | | | | <0.001 |
| Spring | 8564 | 63.3±29.2 | | 1185 (13.8) | 1925 (22.5) | 5454 (63.7) | |
| Summer | 6474 | 73.9±28.4 | | 310 (4.8) | 902 (13.9) | 5262 (81.3) | |
| Autumn | 4823 | 64.3±28.9 | | 525 (10.9) | 1161 (24.1) | 3137 (65.0) | |
| Winter | 5945 | 52.7±28.5 | | 1420 (23.9) | 1585 (26.7) | 2940 (49.4) | |
| Areas | | | 0.304 | | | | <0.001 |
| Urban | 14759 | 63.5±30.3 | | 2103 (14.3) | 3107 (21.0) | 9549 (64.7) | |
| Rural | 11047 | 63.9±28.8 | | 1337 (12.1) | 2466 (22.3) | 7244 (65.6) | |
| Regions | | | <0.001 | | | | <0.001 |
| Central Shaanxi | 10661 | 62.7±27.7 | | 1309 (12.3) | 2391 (22.4) | 6961 (65.3) | |
| Northern Shaanxi | 5323 | 55.0±29.0 | | 1209 (22.7) | 1288 (24.2) | 2826 (53.1) | |
| Southern Shaanxi | 9822 | 69.4±30.9 | | 922 (9.4) | 1894 (19.3) | 7006 (71.3) | |

**Table 3.** Vitamin E concentrations and status of children in Shaanxi province

| Variables | Cases | Vitamin E concentration (μmol/L) | *p*-value | Status of vitamin E, n (%) | | | *p*-value |
|---|---|---|---|---|---|---|---|
| | | | | VAD | MVAD | Sufficiency | |
| Total | 25806 | 20.8±6.98 | | 1318 (5.1) | 5754 (22.3) | 18734 (72.6) | |
| Sex | | | <0.001 | | | | <0.001 |
| Boys | 14798 | 20.5±6.82 | | 802 (5.4) | 3417 (23.1) | 10579 (71.5) | |
| Girls | 11008 | 21.2±7.17 | | 516 (4.7) | 2337 (21.2) | 8155 (74.1) | |
| Age | | | | | | | |
| 1~<28d | 1229 | 15.5±10.2 | <0.001 | 552 (44.9) | 230 (18.7) | 447 (36.4) | <0.001 |
| 28d~<6m | 2106 | 24.8±9.58 | | 146 (6.9) | 235 (11.2) | 1725 (81.9) | |
| 6m~<12m | 2857 | 25.3±8.16 | | 79 (2.8) | 277 (9.7) | 2501 (87.5) | |
| 1~<3y | 7330 | 22.5±6.38 | | 151 (2.1) | 1085 (14.8) | 6094 (83.1) | |
| 3~<6y | 7220 | 18.9±4.52 | | 211 (2.9) | 2187 (30.3) | 4822 (66.8) | |
| 6~<12y | 4620 | 18.3±4.36 | | 155 (3.4) | 1583 (34.2) | 2882 (62.4) | |
| 12~<18y | 444 | 18.0±4.14 | | 24 (5.4) | 157 (35.4) | 263 (59.2) | |
| Seasons | | | <0.001 | | | | <0.001 |
| Spring | 8564 | 20.5±7.00 | | 467 (5.4) | 2190 (25.6) | 5907 (69.0) | |
| Summer | 6474 | 21.3±6.89 | | 265 (4.1) | 1240 (19.1) | 4969 (76.8) | |
| Autumn | 4823 | 21.2±7.25 | | 251 (5.2) | 924 (19.2) | 3648 (75.6) | |
| Winter | 5945 | 20.6±6.77 | | 335 (5.6) | 1400 (23.6) | 4210 (70.8) | |
| Areas | | | <0.001 | | | | <0.001 |
| Urban | 14759 | 21.2±7.42 | | 905 (6.1) | 2903 (19.7) | 10951 (74.2) | |
| Rural | 11047 | 20.3±6.31 | | 413 (3.7) | 2851 (25.8) | 7783 (70.5) | |
| Regions | | | <0.001 | | | | <0.001 |
| Central Shaanxi | 10661 | 21.5±7.15 | | 419 (3.9) | 2108 (19.8) | 8134 (76.3) | |
| Northern Shaanxi | 5323 | 18.8±6.63 | | 576 (10.8) | 1503 (28.2) | 3244 (61.0) | |
| Southern Shaanxi | 9822 | 21.3±6.77 | | 323 (3.3) | 2143 (21.8) | 7356 (74.9) | |

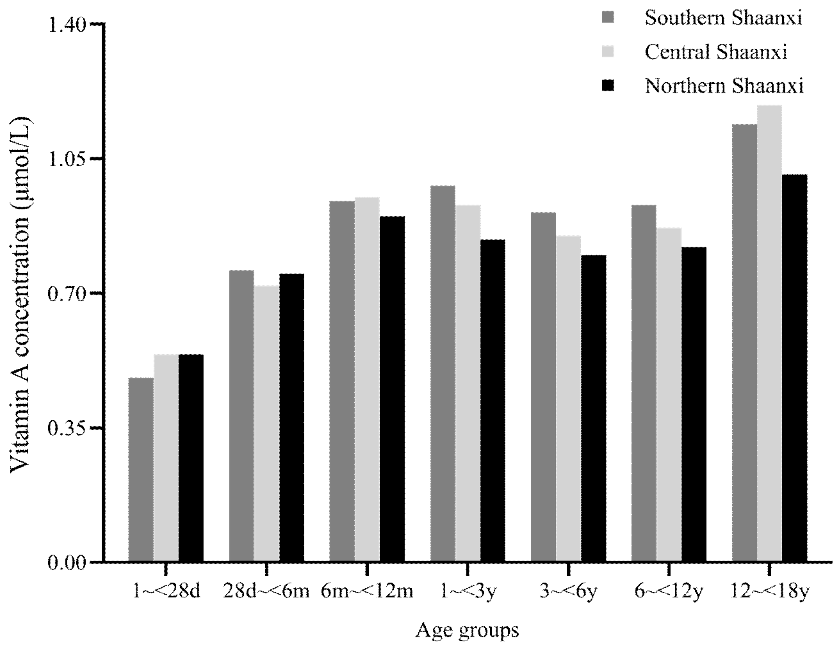


**Figure 1.** Serum vitamin A concentration in children with different age groups and regions in Shaanxi province.

high risk of vitamin A, D, E deficiency and insufficiency. Among the different regions of Shaanxi province, there was no significant risk of vitamin A and D deficiency for children living in northern Shaanxi, while those living in southern Shaanxi were less likely to suffer from vitamin A and D deficiency.

***Correlation analysis of vitamin A, D, E***

Vitamin A concentration was positively correlated with age (r=0.110, $p$<0.001), while vitamin D and vitamin E concentrations were negatively correlated with age (r=-0.370 and r=-0.250 both $p$<0.001), after adjustment for gender, season, and living regions. Moreover, vitamin A concentration was positively correlated with vitamin D (r=0.106, $p$<0.001) and vitamin E concentration (r=0.432, $p$<0.001), and vitamin D concentration was positively correlated with vitamin E concentration (r=0.239, $p$<0.001), after further adjustment for age.

## DISCUSSION

In this study, we investigated the vitamin A, D, E concentrations and status of 25,806 children aged one day to 18 years in Shaanxi province, northwest China. The results show that the prevalence of vitamin A, D, E

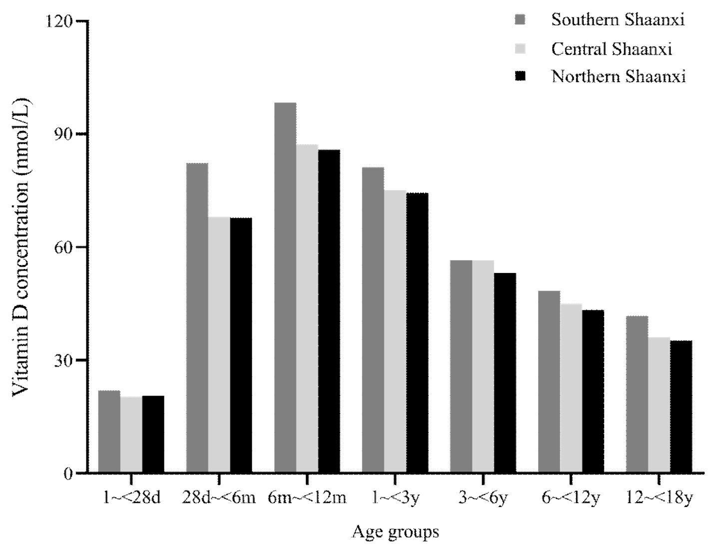


**Figure 2.** Serum vitamin D concentrations in children with different age groups and regions in Shaanxi province

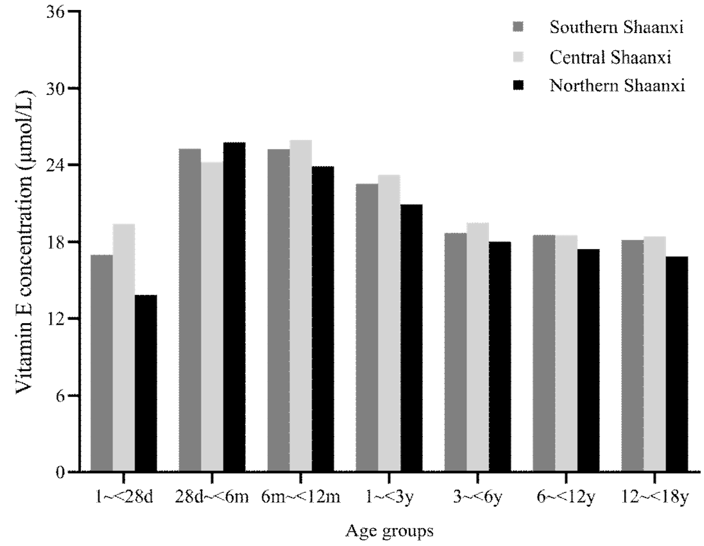


**Figure 3.** Serum vitamin E concentrations in children with different age groups and regions in Shaanxi province

deficiency was 5.6%, 13.3% and 5.1% in children aged one day to 18 years in Shaanxi province. However, the concentration and status of vitamin A, D, E were significantly different among the different age groups. The prevalence of vitamin A, D, E deficiency was much higher in neonates than in other age groups. Since the maternal-foetal transfer is the main source of vitamin A, D, E for neonates, inadequate intake during pregnancy or premature birth could further vitamin A, D, E deficiency.[11,12] After birth, the vitamin A, D, E concentrations of infants gradually increase with the intake of colostrum or formula milk.[13,14] Meanwhile, vitamin A and vitamin D supplementation is a key alternative source since breast milk cannot provide sufficient vitamin A and D to infants. The Chinese Preventive Medicine Association recommends 1 500-2000 U/d of vitamin A supplementation and 400-800 U/d of vitamin D supplementation for infants until three years of age.[15] This may be one of the causes of the finding in the present study that the prevalence of vitamin A and D deficiency of the children aged one month to three years was much lower than that of infants.

In addition, a higher prevalence of vitamin A and D deficiency was observed in school-age children and adolescents of the present study. In a recent study, the prevalence of vitamin A and D deficiency among children and adolescents aged 6-17 years of age in Zhejiang Province was 4.5% and 1.8%, respectively.[16] There was a large gap between the two regions. Additionally, one large population-based multicentre study among children from 18 provinces of China revealed that Shaanxi province was one of the severe regions of vitamin D deficiency.[17] To our knowledge, inadequate dietary intake of vitamin A-rich foods, poor nutrition and chronic diseases are the major cause of vitamin A deficiency.[18] In addition to low vitamin D dietary intake, poor nutrition and chronic diseases, factors affecting vitamin D status include population, latitude, season, sun exposure, skin pigmentation and obesity.[19,20] Liu Y et al investigated the prevalence of vitamin D deficiency of Chinese children aged 7-12 years, they found that 86.1% of children did not get their daily

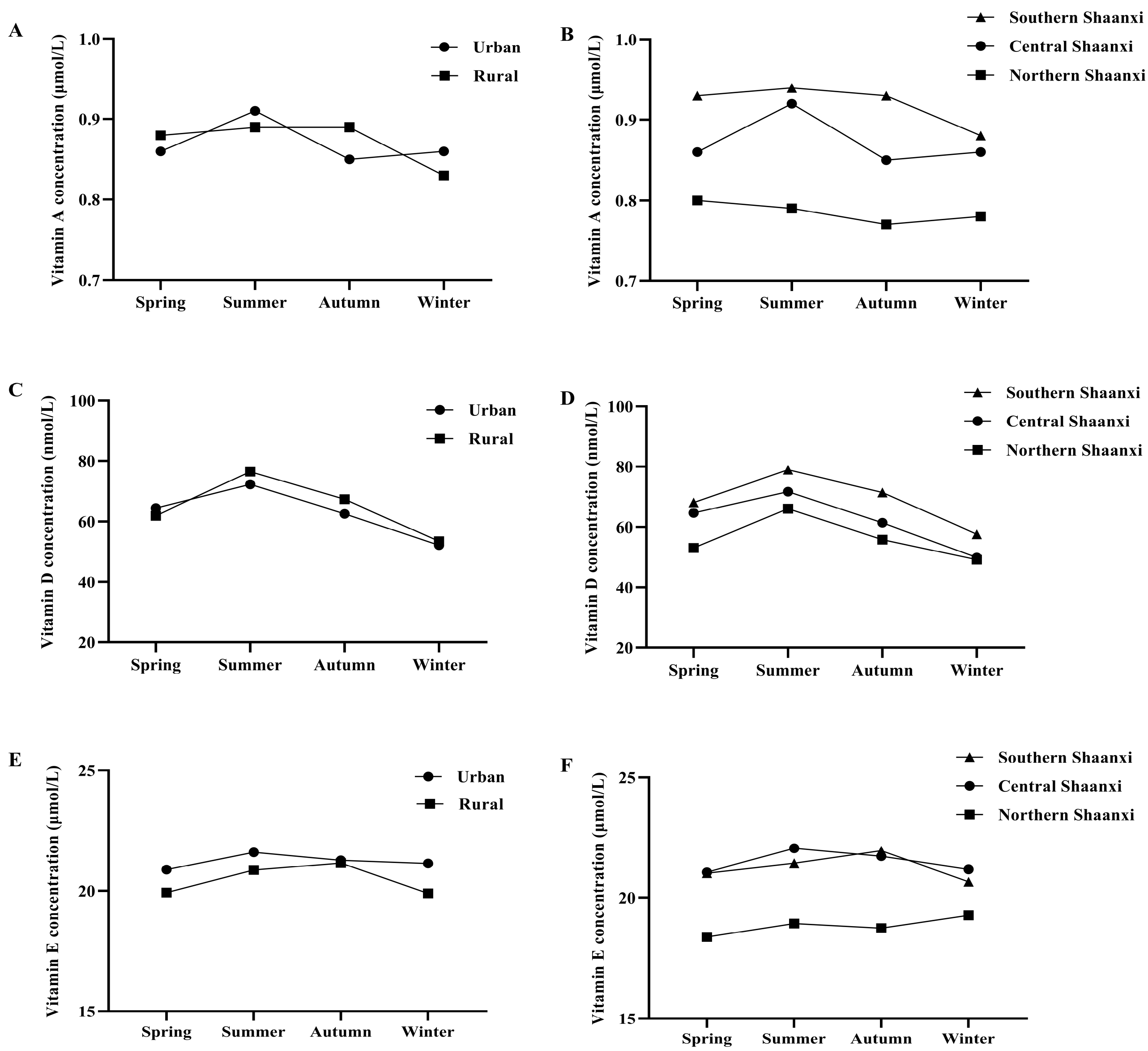


**Figure 4.** Trends of vitamin A, D, E concentrations among children in different areas and regions in the four seasons

reference nutrient intake of vitamin D (10 μg/d), and the median vitamin D intake was 1.1 (0.5, 2,2) μg/d. Besides, they also found that high vitamin D intake was inversely associated with the risk of vitamin D deficiency.[21] Animal liver and eggs are rich food sources of vitamin A, while carotenoids are primarily from orange-yellow vegetables and fruits. Vitamin E-rich foods included vegetable oils, nuts, and green leafy vegetables.[22] Children with a low frequency of these foods' consumption were more likely to have vitamin A and E deficiency.[23] China is a vast country with unbalanced economic development. Furthermore, Animal foods are relatively expensive in China. Shaanxi province in northwest China has a lower per capita income, especially in the rural areas of northern and southern Shaanxi.[24] This situation may partially explain our findings. A previous study showed that pregnant women in rural areas and northern Shaanxi had a lower intake of vitamin E.[11] There are several limitations in the present study. Further studies are needed to confirm the relationship between dietary intake and vitamin A, E concentrations of children in rural areas of Shaanxi province. Unlike vitamin A and vitamin E, vitamin D is rarely found naturally in foods. The main sources of vitamin D are produced in the skin through sunlight exposure and vitamin D supplements.[25] Children in northern latitudes are at high risk of vitamin D deficiency during the winter months.[5] In addition, children are more susceptible to vitamin D deficiency as they often stay indoors and difficult to receive sunlight due to the cold weather in winter and spring.[17] In the present study, we found that the risk of vitamin D deficiency and insufficiency in children was 7.68 times higher in winter than in summer.

In consequence, a more balanced diet and individualised vitamin A, D supplementation is needed for children in Shaanxi province especially in the rural areas to reduce the prevalence of vitamin A and D deficiency. Previous studies reported that vitamin D supplements of 400 U/d may be ineffective in maintaining 25(OH)D concentrations at optimal concentrations (>75 nmol/L).[26] Moreover, children with obesity should take at least two to three times the conventional supplemental dose of vitamin D due to vitamin D sequestration out of plasma into adipose tissue.[27,28] In addition, parents should be educated to encourage children to increase safe sunlight exposure by

**Table 4.** Risk factors of vitamin A, D, E deficiency and insufficiency among children in Shaanxi province

| Variables | Vitamin A deficiency | | Vitamin D deficiency | | Vitamin E deficiency | |
|---|---|---|---|---|---|---|
| | OR (95% CI) | *p*-value | OR (95% CI) | *p*-value | OR (95% CI) | *p*-value |
| Sex | | | | | | |
| Boys | - | - | 1.00 (Ref.) | | 1.00 (Ref.) | |
| Girls | | | 1.09 (1.02-1.15) | 0.010 | 0.85 (0.80-0.90) | <0.001 |
| Age† | | | | | | |
| Infants | 1.00 (Ref.) | | 1.00 (Ref.) | | 1.00 (Ref.) | |
| Neonates | 9.94 (8.55-11.55) | <0.001 | 431.19 (287.01-647.80) | <0.001 | 8.38 (7.34-9.57) | <0.001 |
| School-age | 1.80 (1.71-1.90) | <0.001 | 6.91 (6.46-7.39) | <0.001 | 2.80 (2.64-2.98) | <0.001 |
| Adolescents | 1.79 (1.47-2.17) | <0.001 | 38.36 (29.86-49.27) | <0.001 | 3.59 (2.95-4.38) | <0.001 |
| Seasons | | | | | | |
| Summer | 1.00 (Ref.) | | 1.00 (Ref.) | | 1.00 (Ref.) | |
| Spring | 1.07 (1.00-1.15) | 0.049 | 3.29 (3.00-3.60) | <0.001 | 1.48 (1.37-1.60) | <0.001 |
| Autumn | 1.14 (1.05-1.23) | 0.002 | 2.77 (2.50-3.07) | <0.001 | 1.00 (0.91-1.10) | 0.978 |
| Winter | 1.30 (1.20-1.40) | <0.001 | 7.68 (6.97-8.47) | <0.001 | 1.37 (1.26-1.49) | <0.001 |
| Areas | | | | | | |
| Urban | 1.00 (Ref.) | | 1.00 (Ref.) | | 1.00 (Ref.) | |
| Rural | 1.23 (1.15-1.32) | <0.001 | 1.16 (1.06-1.25) | 0.001 | 1.15 (1.06-1.24) | 0.001 |
| Regions | | | | | | |
| Central Shaanxi | 1.00 (Ref.) | | 1.00 (Ref.) | | 1.00 (Ref.) | |
| Northern Shaanxi | 0.96 (0.88-1.04) | 0.326 | 0.92 (0.84-1.02) | 0.105 | 1.53 (1.40-1.67) | <0.001 |
| Southern Shaanxi | 0.66 (0.61-0.71) | <0.001 | 0.70 (0.64-0.77) | <0.001 | 1.06 (0.97-1.15) | 0.195 |

OR: odds ratio; CI: confidence interval.

† Neonates: 1 day to 28 days of age; infants: 28 days to 3 years of age; school-age children: 3 to 12 years of age; adolescents: 12 to 18 years of age.

more outdoor activities.

### *Conclusion*

The prevalence of vitamin A, D and E deficiency was extremely high in neonates in Shaanxi province, northwest China. Children living in rural areas and winter had a high risk of vitamin A, D, E deficiency and insufficiency. Therefore, it is important to enhance dietary balance and fat-soluble vitamin A, D, E supplementation for children in Shaanxi province, especially in rural areas.

## ACKNOWLEDGEMENTS

We thank all staff at the hospitals and children for participating in this study. We also thank the Xi'an Hehe Medical Laboratory (Xi'an, China) for technical assistance.

## AUTHOR DISCLOSURES

The authors declare no conflict of interest. This work was funded by the Medical and Health Science and Technology Development Research Centre, National Health Commission (W2016EWQT33), Shaanxi Municipal Science and Technology Program (2020SF-002), Xi'an Municipal Science and Technology Program (201805098YX6SF32-6). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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