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FULL LENGTH ARTICLE

High prevalence of vitamin D insufficiency in Chinese children with upper limb fractures

Tianjing Liu, Enbo Wang, Qiwei Li, Lianyong Li*

Department of Pediatric Orthopedics, Shengjing Hospital of China Medical University, China

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Abstract This study aimed at investigating the vitamin D status of pediatric patients with upper limb fractures and finding out the influences of age, gender, season and fracture sites. 695 patients were admitted for upper limb fractures between November 1st 2014 and October 31st 2015. 224 healthy children were included during the same period. Serum 25(OH)D was measured at the time of visit and their demographic data were recorded. Generally fracture patients had significant lower vitamin D level than the healthy children. The average serum 25(OH)D of the patients was 24.5 ng/ml, compared to 28.1 ng/ml in healthy children. Vitamin D status worsened with the increase of age and adolescents had a deficiency rate of as high as 68.6%. Gender and fracture sites had no influence on vitamin D level. This study revealed high prevalence of vitamin D deficiency and insufficiency in pediatric patients with upper limb fractures. Adolescents had such high rate of vitamin D deficiency that called for vast attention.

Introduction

In the last decade, the biological function of vitamin D had been extensively studied. Apart from the well-known rickets, vitamin D deficiency had been associated with hip and knee osteoarthritis,[1,2] distal radius fracture[3] and joint symptoms.[4] Their findings called on more attention to the relationship between vitamin D status and orthopedic diseases.

Since vitamin D has long been acknowledged as closely related to skeletal health, its relationship with fractures has attracted considerable attention. However, most previous researches focused on the role of vitamin D status on fractures in elderly people.[3,5] Only few studies focused on the association of hypovitaminosis D with pediatric fractures.[6–8] In this case, the influence of vitamin D deficiency/insufficiency on the pediatric population remained inadequately explored.

Since upper limb fractures were largely caused by low-energy injury, the role of suboptimal bone health might be

* Corresponding author. No. 36 Sanhao Street, Shenyang, China.
E-mail address: 13889382889@163.com (L. Li).
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more discernible than those caused by high-energy injury. This study aimed at investigating the vitamin D status of pediatric patients with upper limb fractures and comparing it with healthy children. The influences of age, gender, season and fracture sites were evaluated to find out factors that might be associated with vitamin D status and the incidence of fractures.

Material and methods

This study was carried out in Shenyang, a northeast Chinese city on 41°N latitude. Data were collected from all the patients that were admitted for simple upper-limb fractures between November 1st 2014 and October 31st 2015. The diagnosis of fractures were made based on X-ray and/or three-dimensional computed tomography. Their age, gender, fracture site were recorded at the time of admittance. Cases with the following circumstance were excluded: 1. pathological fracture or fracture in a site with pre-existing lesion; 2. recurrent fractures that were indicative of osteogenesis imperfecta; 3. pre-existing systematic diseases; 4. during treatments of other diseases and 5. multiple fractures. The control data were obtained from healthy children who visited our hospital for regular health check. They had neither any known diseases nor recent trauma. All the subjects were grouped according to time of visit and age.

Seasons were recorded according to the time of visit. March, April and May was classified as spring, June to August as summer, September to November as autumn and December to February as winter. Subjects were grouped according to their age: those younger than three years were grouped as toddlers, when they were generally under family care. Those between three and five years were grouped as preschool, as most of them had joined a kindergarten. Children six to eleven years were grouped as school age when they were in the primary school. Those older were grouped as adolescents, most of who had participated in a middle school.

Serum 25(OH)D was measured at the time of visit, using liquid chromatography with mass spectrometry detection. The measurement was done in the Laboratory Center of Shengjing Hospital. >30 ng/ml was regarded as vitamin D sufficient. 20–30 ng/ml was vitamin D insufficient and <20 ng/ml was vitamin D deficient.

Data were collected and analyzed using Statistical Package for Social Science 22.0(SPSS Inc, Chicago, IL.). Independent sample *t* test was used to analyze the difference between genders and groups. R × C X^2 test was used to investigate difference in distribution among groups. Multivariant correlation was used to analyze the relationship between vitamin D status, time of year and age. $P < 0.05$ was regarded as statistical significant.

Result

695 patients were finally recruited during this one-year period. There were 448 boys and 247 girls. The average age was 7.1 years (1–15 years). 224 healthy controls were collected during this period. There were 113 boys and 111 girls. The average age was 7.8 years (1–15 years). All of the fractures were caused by mild or moderate trauma, according to Clark.[9] Their fracture sites were listed in Table 1. Supracondylar fracture of the humerus accounts for 36.5% of all the upper limb fractures, followed by lateral humeral condylar fracture. The distribution of fracture sites was not influenced by season ($P = 0.186$). Adolescents had more forearm fractures, while in other age groups distal humeral fractures were dominant ($P < 0.001$).

The average serum 25(OH)D of the patients was 24.5 ng/ml (3.0–70.0 ng/ml), compared to 28.1 ng/ml in healthy children (5.9–70.0 ng/ml) ($P < 0.001$). The vitamin D level of the fracture patients was significantly lower than that of the healthy controls in most age groups and seasons (Table 2). Gender difference was observed in neither the patients ($P = 0.738$) nor the controls ($P = 0.336$). The prevalence of vitamin D deficiency, insufficiency and sufficiency was compared between the fracture patients and the healthy controls in all the seasons and age groups (Table 3, Figs. 1 and 2).

In the patients, the vitamin D level was the lowest in spring, averaging 18.9 ng/ml (4.1–58.4 ng/ml) and highest

Table 1 Details of the fractures.

Sites	Cases	Frequency (%)
Proximal humerus	18	2.6
Humeral shaft	9	1.3
Distal humerus	378	54.4
Supracondyle	254	36.5
Lateral condyle	91	13.1
Epiphysis	19	2.7
Others	14	2.0
Proximal Radius	30	4.3
Proximal Ulnar	50	7.2
Monteggia fracture	40	5.8
Olecroanon	10	1.4
Forearm Shaft	144	20.7
Radius	6	0.9
Ulnar	7	1.0
Both	131	18.8
Distal Radius	61	8.8
Distal Ulnar	5	0.7

Table 2 Variations of 25(OH)D levels in the healthy controls and fracture patients.

	Fractures		Controls		P value
	25(OH)D (ng/ml)	N. of Cases	25(OH)D (ng/ml)	N. of Cases	
Spring	18.9 ± 9.8	169	28.0 ± 12.3	49	0.000
Summer	25.9 ± 10.9	263	31.5 ± 13.2	78	0.000
Autumn	28.3 ± 12.0	208	36.0 ± 16.9	34	0.001
Winter	20.5 ± 12.6	55	19.9 ± 10.4	63	0.795
Toddler	39.4 ± 13.7	69	41.9 ± 14.1	12	0.563
Preschool	25.9 ± 11.4	190	36.2 ± 13.0	65	0.000
School	22.7 ± 9.6	351	26.3 ± 12.5	104	0.002
Adolescent	17.3 ± 7.4	86	16.6 ± 6.8	43	0.616
Total	24.5 ± 11.7	695	28.1 ± 14.0	224	0.000

Table 3 Comparisons of vitamin D levels between the fracture patients and healthy controls in different seasons and age groups.

	Fractures			Controls			P value
	Suffi	Insuffi	Defici	Suffi	Insuffi	Defici	
Spring	11.2% (19/169)	21.3% (36/169)	67.5% (114/169)	34.7% (17/49)	34.7% (17/49)	30.6% (15/49)	0.000
Summer	28.5% (75/263)	42.2% (111/263)	29.3% (77/263)	51.3% (40/78)	26.9% (21/78)	21.8% (17/78)	0.001
Autumn	36.5% (76/208)	39.4% (82/208)	24.0% (50/208)	58.8% (20/34)	26.5% (9/34)	14.7% (5/34)	0.048
Winter	18.2% (10/55)	14.5% (8/55)	67.3% (37/55)	14.3% (9/63)	20.6% (13/63)	65.1% (41/63)	0.634
Toddler	76.5% (52/68)	14.7% (10/68)	8.8% (6/68)	75.0% (9/12)	25.0% (3/12)	0.0% (0/12)	0.422
Preschool	32.1% (61/190)	33.7% (64/190)	34.2% (65/190)	66.2% (43/65)	21.5% (14/65)	12.3% (8/65)	0.000
School	17.9% (63/351)	39.9% (140/351)	42.2% (148/351)	30.8% (32/104)	31.7% (33/104)	37.5% (39/104)	0.017
Adolescent	4.7% (4/86)	26.7% (23/86)	68.6% (59/86)	4.7% (2/43)	23.3% (10/43)	72.1% (31/43)	0.911
Total	25.9% (180/695)	34.1% (237/695)	40.0% (278/695)	38.4% (88/224)	26.8% (60/224)	34.8% (78/224)	0.001

in autumn, averaging 28.3 ng/ml (7.1—69.56 ng/ml) (Table 4). 25(OH)D level was significantly correlated with time of year ($P < 0.001$). The differences were statistically significant between spring and summer ($P < 0.001$), summer and autumn ($P = 0.022$), autumn and winter ($P < 0.001$), but insignificant between winter and spring ($P = 0.334$). No gender difference was found in any season.

Most fractures happened to school-age children, accounting for 50.5% of the total cases. 25(OH)D level seemed to decrease with age ($P < 0.001$). Adolescents had the lowest 25(OH)D while toddlers had the highest (Table 5). There were statistical differences between toddlers and preschool children ($P < 0.001$), preschool and school children ($P = 0.001$) as well as school children and adolescents ($P < 0.001$). No gender difference was found in any age group.

Proximal and medial humeral fracture had the lowest serum 25(OH)D level of 22.1 ng/ml, followed by forearm fractures with 23.2 ng/ml. Distal humeral fractures had the highest 25(OH)D level of 25.7 ng/ml, with significant difference compared to forearm fractures ($P = 0.005$). No significant difference was found between distal and proximal/medial humeral fractures ($P = 0.147$) as well as between forearm and proximal/distal humeral fractures ($P = 0.635$) (Fig. 3).

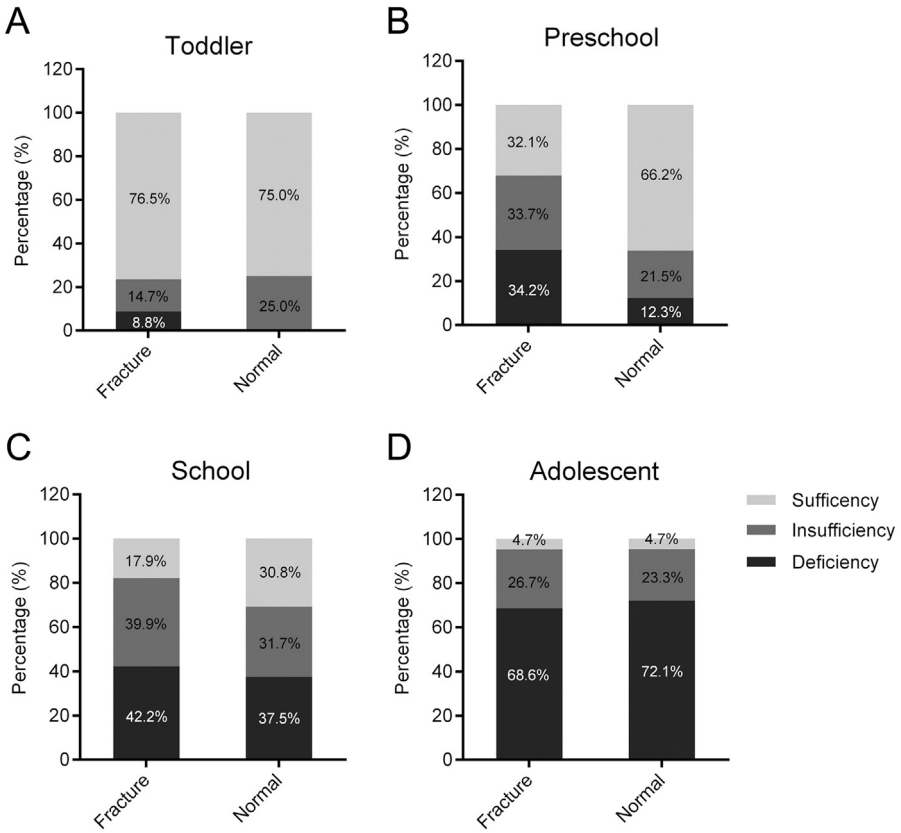

Figure 1 Vitamin D status in different age groups. A-D represents toddlers, preschool, school age and adolescent respectively.

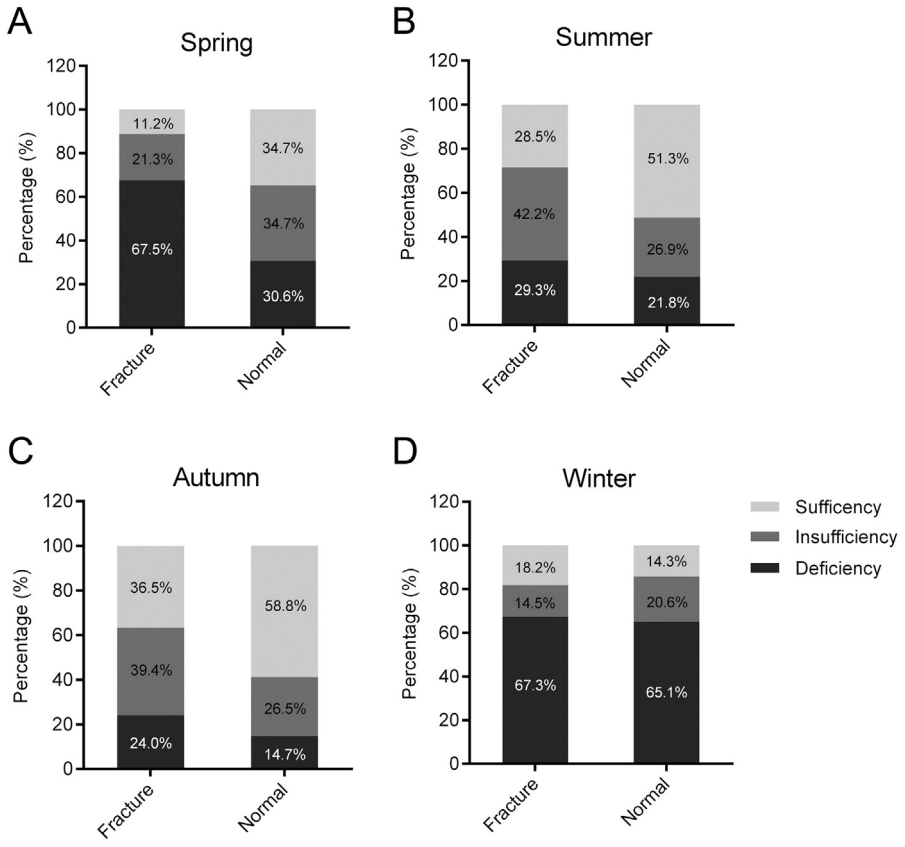

Figure 2 Vitamin D status in different seasons.

Table 4 Seasonal variation of 25(OH)D levels in male and female fracture patients.

Season	Boys		Girls		P value
	25(OH)D (ng/ml)	N. of Cases	25(OH)D (ng/ml)	N. of Cases	
Spring	18.0 ± 8.2	104	20.3 ± 11.7	65	0.146
Summer	26.2 ± 10.7	171	25.4 ± 11.3	92	0.565
Autumn	28.2 ± 12.2	138	28.6 ± 11.5	70	0.845
Winter	19.4 ± 12.3	35	22.4 ± 13.1	20	0.390
Total	24.4 ± 11.6	448	24.7 ± 12.0	247	0.738

P value refers to the difference between genders.

Table 5 Age variation of 25(OH)D levels in male and female fracture patients.

Age group	Boys		Girls		P value
	25(OH)D (ng/ml)	N. of Cases	25(OH)D (ng/ml)	N. of Cases	
Toddler	41.4 ± 14.2	36	37.2 ± 13.1	32	0.216
Preschool	26.5 ± 11.4	98	25.2 ± 11.4	92	0.426
School	23.3 ± 9.5	234	21.4 ± 9.7	117	0.091
Adolescent	17.5 ± 7.5	80	14.7 ± 5.0	6	0.370

P value refers to the difference between genders.

Discussion

This study demonstrates that although vitamin D insufficiency is prevalent in children in Shenyang, pediatric patients with upper limb fractures are more vitamin D deficient than the healthy controls. This case gets more severe with the increase of age.

The overall vitamin D level of the healthy population is insufficient in this study, with the average serum 25(OH)D 28.1 ng/ml. In summer and autumn the vitamin D level reaches sufficiency while in winter it drops to deficiency.

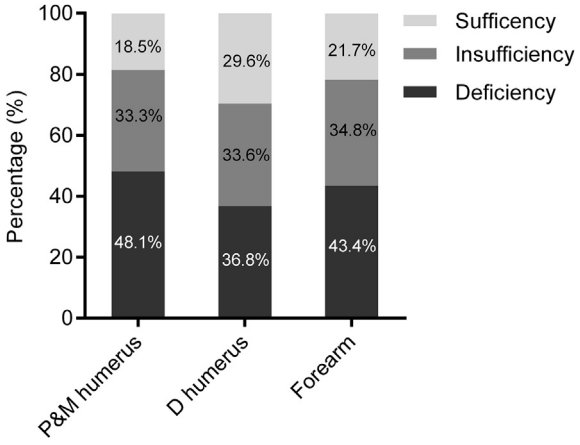

Figure 3 Vitamin D status in different fracture sites.

This is mildly lower than reported in Hangzhou and Nanjing, two southern Chinese cities.[10,11] Compared to these two cities, Shenyang was located in higher latitude with longer and colder winters. The overall vitamin D level was higher than reported in Yuci, another northern Chinese city,[12] although Yuci was in lower latitude and had milder climate compared to Shenyang. However, due to lack of direct comparison between the demographic information of the studies, we were unable to draw exact conclusion as to the reason of the differences.

Serum 25(OH)D level was <20 ng/ml in 40% of the fracture patients, while only 25.9% had their serum 25(OH)D levels >30 ng/ml. This revealed serious vitamin D deficiency in pediatric patients with upper limb fractures. A recent study found a vitamin D deficiency rate of 34% in pediatric patients with upper or lower extremity fractures,[13] while another found a lower rate of 24% in patients with upper extremity fractures only.[8] This status was even worse in winter and spring, with as many as 67% of the patients had serum 25(OH)D levels <20 ng/ml and less than one in five had sufficient vitamin D. Long and cold winters, followed by chilly and windy springs, significantly reduced outdoor time and increased clothing, which might be part of the explanation. Although seasonal variation had been established in adult population,[14] some reports on pediatric patients found it irrelevant to vitamin D status.[8,15] Those reports, however, were based on limited sample size in which the underlying seasonal difference was not reached by statistical analysis.

Vitamin D deficiency had been associated with the incidence, severity and recovery of fractures.[3,16,17] When below 40 ng/ml, vitamin D status had a dose-dependent effect on the incidence of distal radius fracture in elderly people.[3] A large-scale study found a 38% increase in hip fracture risk in the lowest percentile of vitamin D status.[18] Recently, the pediatric orthopedic society started to address attention on the role of vitamin D. However, a 2019 review came to conflicting results as to the association of vitamin D deficiency and fracture risk.[19] A pediatric report similar to this one found vitamin D deficiency in 24% and insufficiency in 35% of the pediatric fracture patients.[8] Another study disclosed that children with forearm fractures were more likely to be vitamin D deficient.[14] However, one study found no relevance between hypovitaminosis D and fracture risks.[20] This opinion contradicted with subsequent findings,[6,7] including ours. Patients with upper limb fractures had significantly lower serum vitamin D than the healthy controls in most of the time and most of the age groups. One theory might be able to explain this was that lower vitamin D level might be indicative of more severe fractures.[21] Those "severe fractures" included open or displaced fractures that made up of the patient cohort in this study.

Age was strongly correlated with serum 25(OH)D level in the patients as well as the healthy children. Vitamin D status in children younger than three years was the most optimal, with vitamin D sufficiency in 76.5% of the toddlers. However in adolescent patients the sufficiency rate was as low as 4.7%. This was even much lower than reported in adolescents with other fractures.[22] In China it had been suggested that at least 400IU/d should be taken in throughout till age eighteen,[23] but this dosage was not enough to meed their needs, as later guidelines suggested 600—1000IU/d for children aged 1—18 years.[24,25] With the increase of age, especially when the local heathcare agencies stopped to provide free regular health consults by the age of 6, vitamin D fortified food and supplements withdrew from the menu of most children and the parents' attention on vitamin D status gradually faded. To make things worse, in middles schools, increasing school work limited outdoor time to minimal. This severely deficient vitamin D status made them prone to low-energy fractures such as those affecting the upper limbs. Urgent attention on the vitamin D status of the adolescent population in our country is needed.

The limitations of this study were as follows. Patients admitted for fractures generally had severe fractures that needed intensive treatment, so that this study did not include those milder fractures that did not require hospitalization. Besides, other influencing data, such as sunlight exposure and diet intake were not included because the heterogeneity of the data. Sophisticatedly designed large-scale studies were needed to find out other factors contributing to the 25(OH)D status and fractures.

In conclusion, this study revealed high prevalence of vitamin D deficiency and insufficiency in pediatric patients with upper limb fractures. With the increase of age, vitamin D status worsens and the adolescent population had such low serum vitamin D status that required vast attention.

Conflict of interest

None of the authors had any conflict of interest.

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