Original Article

Sunlight Exposure and Development of Rickets in Indian Toddlers

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ABSTRACT

Objective. To study the role of sunlight exposure in determining the vitamin D status of underprivileged toddlers.

Methods. Height and weight were measured, clinical examination was performed, Food Frequency Questionnaire was administered and history of sunlight exposure was obtained in all (61) toddlers attending daytime crèche (Group B). Ionised calcium (iCa), inorganic Phosphorous (iP), alkaline phosphatase activity (ALP), serum parathyroid hormone (PTH) and 25 Hydroxy vitamin D (25OHD) were measured. Data were compared with results of a survey measuring similar parameters in 51 (of 251 eligible) toddlers from the same slum (Group A).

Results. 111 children (mean age 2.6 yr (0.7), boys 56) were studied. Prevalence of hypovitaminosis D was 77% in group B toddlers (46 of 60) and 16.4% (10 of 61) had rickets, while none of the group A toddlers had 25OHD levels below 30nmol/L. Four children (7.8%) from Group A as against 24 (42.9%) from Group B, had sunshine exposure of < 30 minutes per day.

Conclusion. Underprivileged toddlers who were deprived of sunlight had a much greater incidence of hypovitaminosis D and frank rickets. The study has important public health implications and underscores the necessity for sunlight exposure in young children. **[Indian J Pediatr 2010; 77 (1) : 61-65]** *E-mail: akhadilkar@vsnl.net; vamankhadilkar@gmail.com*

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Vit D is necessary for adequate bone mineralization and its deficiency results in rickets in children and osteomalacia in older adolescents and adults. In humans, the main source of vit D is that formed in the skin by conversion of 7-dehydrocholesterol to cholecalciferol (vit D3) on exposure to the sun's ultraviolet B (UVB) radiation.[1] Vit D deficiency is unexpected in a tropical country such as India, where there is abundant sunlight. Nevertheless, hypovitaminosis D, resulting in severe osteomalacia, has been observed in adolescents in India, in pregnant women and in rural and urban South Indian adults.[2,3,4]

Various studies from developing countries have reported dietary deficiency of calcium in children.[5] In the Indian context, milk being an expensive commodity, consumption of milk and milk products, which are good sources of dietary calcium, is meager in children of the lower socio-economic class.[6] Deficient calcium intake has been shown to be the cause of rickets in a large proportion of Indian children as well as in children from tropical countries.[7,8]

In a recent nutritional survey, carried out in September 2006, in economically deprived toddlers in Pune (latitude 18.34° N), India, known to have low dietary intake of calcium (<400mg/day), it was found that the toddlers had serum concentrations of vit D (25-hydroxyvitamin D; a measure of an individual's Vit D status) of 126.3 ± 62.6 nmol/L, indicating that they had excellent body stores of this vitamin. (Unpublished data) These toddlers, who largely spent their daytime playing outdoors, did not have clinical or radiological evidence of rickets. Within the same urban slum, the authors observed a group of toddlers who belonged to the same socio-economic status and had a diet which was similar to those from the earlier study, but who spent most of their daytime in a crèche indoors with

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little sunshine exposure. Their vit D status and biochemical parameters of bone health were measured during the same season, in the month of October, 2008. Physical examination was carried out to look for clinical signs of rickets. It was hypothesised that the reduced sunshine exposure would lead them to have lower serum 25OHD values, in comparison to the previously studied 'free roaming' group of toddlers.

MATERIAL AND METHODS

Two nutritional surveys were done on apparently healthy toddlers living in urban slums in Pune (India) with an aim to document vit D deficiency in them and to relate it with exposure to sunlight.

First survey was carried out in September 2006, including toddlers who were exposed to sunlight and labelled as group 'A'. Second survey was done in December 2007,including children who were kept in crèche and not being exposed to sunlight from same slum and labelled as group 'B' The studies were approved by the Ethical Committee of the Hirabai Cowasji Jehangir Medical Research Institute and an informed consent was obtained from mothers of children participating in the trial. The study subjects were derived from a low socio-economic group with the approximate average monthly per capita income of 590 (Group A) and 715 (Group B) Indian Rupees. The crèche attended by the toddlers was run by a Non- Government Organization, for children of mothers who were housemaids and had to leave children at home, unattended. None of the subjects were receiving vitamin D or any other dietary supplements.

Standing height was measured to the nearest millimeter using a portable stadiometer (Leicester Height Meter, Child Growth Foundation, UK) and weight was measured using a digital scale to the accuracy of 100 g. A clinical examination was performed (NH) to look for clinical features of rickets (delayed closure of fontanel, frontal bossing, dental enamel hypoplasia, rickety rosary, swelling of wrists, knees and ankles, knock knees and bow legs). Food Frequency Questionnaire (FFQ) and Gopalan *et al's* tables of nutrient value of Indian foods were used to estimate daily dietary intake of calcium, phosphorous, protein and calories.[9] The contribution of animal (Cow or Buffalo) milk to the overall calcium intake was also estimated. The percentage of body surface area exposed to sunlight, when wearing their most commonly worn daytime clothes was estimated using the "rule of nines" used in clinical practice to estimate the burnt area of skin.[10] The toddler's mothers also completed a questionnaire that was used to determine the daily sunlight exposure.

Hematological & Biochemical analysis (reference range given in parenthesis): Hemoglobin (90-140gm/L) was measured using the Beckman Coulter (Coulter Corporation, Miami, USA). Serum Ferritin (15.29 – 31.46 pmol/L) concentration was measured using a Monobind Elisa kit (CA, USA). Ionised calcium (iCa; 1.12-1.23 mmol/L) was measured using ion selective auto analyser. Serum concentrations of inorganic phosphorus (Pi;1.25 – 2.10 mmol/L) and alkaline phosphatase activity (ALP; 145 – 200 U/L) were measured using a semi auto analyser (Biotech, USA). Serum intact parathyroid hormone (PTH) was measured using the enzyme immunoassay technique (BioSource Europe S.A). The in-house reference range for the PTH assay was 1.1-6.4 pmol/L, which was established in one hundred 15 to 45 yr old healthy volunteers from Pune. The sensitivity was 0.22 pmol/L and interassay variation was 10%. Serum concentration of 25-hydroxyvitamin D (25OHD) was measured using radioimmunoassay (DiaSorin, Stillwater, Minnesota, USA). The sensitivity of the assay was 3.75 nmol/L and the interassay variation was <5%.

Statistical Methods: All the analyses were carried out using SPSS version 11.0 (Chicago, USA, 2001). Associations between categorical variables such as sunlight exposure, recurrent infections, signs of rickets and place of residence were tested using Chi square test. Comparison of numerical variables *e.g.*, hemoglobin, serum calcium, phosphorus, dietary nutrient intakes, *etc.* amongst two groups was done by Student's t test. To test the difference between anthropometric, dietary and blood parameters in children having vit D deficiency and/or rickets *vs* normal toddlers, one way Analysis of Variance was performed. Generalized linear model was used to assess relative significance of vitamin D3, PTH, calcium, and phosphorous in repeated infections after adjusting for effect of hemoglobin.

RESULTS

A total of 111 children (mean age 2.6 yr (0.7), boys 56) were studied. Table 1 shows baseline characteristics of Group A (consisting of toddlers from the slum, outdoors) and Group B (consisting of toddlers looked after in the crèche, indoors). The height and weight standard deviation scores estimated from the contemporary World Health Organization (WHO) growth data showed that as a group the toddlers were short (Height Z score -1.8(1.3)) and light (Weight Z score -1.4(0.1)) in relation to the age and gender matched WHO norms.[11] Boys in Group B were significantly older, taller and heavier than the Group A boys. The median total energy intake of the Group A toddlers was around 70% while for Group B it was adequate as per the recommendations for Indian toddlers.[9] The protein intake was adequate for both

Table 1. Anthropometric and Biochemical Characteristics of Study Subjects

Parameters	Group A (Outdoor Children)		Group B (Indoor Children)	
	Male (n=25)	Female (n=25)	Male (n=31)	Female (n=29)
Age (yr)	2.26±0.8	2.53±0.8	2.94±0.6**	2.70±0.6[ns]
Height z score	-2.2±1.6	-1.9±1.1	-1.5±1.2**	-1.6±1.4 [ns]
Weight z score	-1.2±1.5	-1.7±0.8	-1.4±0.73*	-1.4±1.0 [ns]
Hemoglobin (mmol/L)	6.14±1.1	6.6±0.8	6.4±0.1[ns]	6.0±1.0*
ALP U/L	492±105	570±138	1039±460**	1094±445**
25OHD [a] (nmol/L)	95.86(91.6)	130.2(67.7)	14.0 (32.0)**	5.2 (21.1)**
PTH[a] (pmol/L)	46.0 (44.0)	62.0 (80.2)	91.2 (84.3)**	95.6 (119.9)[ns]
Serum Phosphorus (mmol/L)	1.8±0.2	2.0±0.2	1.7±0.2*	1.7±0.3*
Serum ionic calcium (mmol/l)	1.0±0.02	1.0±0.05	0.9±0.17*	0.9±0.2*
Energy (kcal)	905±422	766±383	1513±464**	1382±458**
Protein (g)	26.8±16.3	22.2±17.9	35.2±11.2**	31.3±11.1**
Calcium (mg)	216±222	288±196	292±124[ns]	251±101 [ns]
Phosphorus (mg)	581±364	523±357	620±219 [ns]	555±203 [ns]

a. Values are median and inter-quartile range.
* p<0.05, ** p<0.01, ns- not statistically significant.

groups while the calcium intake was between 55-75% as per Indian recommendations. There was no difference in the mean calcium intake in the two groups. However, the median contribution of milk to overall calcium intake was only around 55% in both groups. Dietary parameters could not be assessed in 8 children, history of infections could not be obtained in 6, while history of sunlight exposure could not be obtained in 4 children as a result of difficulty in meeting the mothers who were all employed.

Biochemistry: All 110 toddlers from both groups had serum ionized calcium below the reference range, while serum iP levels were within the reference range for 94% of the toddlers (Group A 95% and Group B 92%). Intact serum PTH levels were above the reference range in 58% of the total subjects with values above the cut-off being observed in 47% from group A and 67% from Group B (Fig 1).

The prevalence of Vit D deficiency (≤30nmol/LmL) was 77% in group B toddlers (46 of 60 participants, mean 25OHD 9.6 (26.6) nmol/L), while none of the group A toddlers (mean 25 OHD 113.1(79.7) nmol/L) had levels below 30nmol/L.[12] Serum vit 25OHD, serum inorganic phosphorus and serum ionic calcium were significantly lower in group B toddlers, while intact serum PTH was significantly higher in group B boys and serum ALP was significantly higher in all the Group B toddlers. Mean hemoglobin levels were below the WHO suggested cut-off of 11gm% (6.8mmol/L) in all groups, but they were significantly lower in Group B girls.

There were 10 children in Group B with clinical signs of rickets which were later confirmed by radiographs, while none of the children from Group A had clinical or radiological signs of rickets. There was a significant association between rickets and indoor status (Pearson R= 0.29, p=0.048). There were 36 children from Group B who had hypovitaminosis D but showed no clinical signs of rickets. When these children were compared with the children having rickets, the vit D and serum inorganic phosphorus were significantly lower in the children with rickets (p= 0.001 and 0.005 resp). There was no significant difference in the calcium, protein or total energy intake between the two groups.

A total of 4 children (7.8%) from Group A had sunshine exposure of < 30 minute per day, while 47 children (92.2%) had over 30 minutes of sunshine exposure daily (Table 2). However in Group B, 24 (42.9%) had sunshine exposure of < 30 minutes per day, while 32(57.1%) children had over 30 minutes of sunshine per day. There was a significant association between indoor status and sunlight exposure among children (Pearson's R = 0.432, p<0.001.). Since the toddlers were so young, there was no difference in the skin exposed in girls and boys with girls wearing frocks with half sleeves and boys wearing half pants and shirts. There was no significant difference in the body surface area exposed to sunlight when wearing their most commonly worn daytime clothes in the two groups. Around 40% of body surface area was exposed in both boys and girls in both groups.

Table 2. Sunlight Exposure

Groups	Sunlight exposure /day			
	< 15 min	15-30 min	30-60 min	> 60 min
Group A (Outdoor Children)	1	3	11	36
Group B (Indoor Children)	9	15	14	18

DISCUSSION

We describe the comparison of two cross sectional studies on hypocalcemic underprivileged toddlers from an urban slum in Pune, India, where one set of toddlers had normal 25OHD levels while the in the other 77% had vitamin D deficiency (≤30 nmol/L). Baseline characteristics of the two groups were similar with no difference in the dietary calcium intake in the two groups. The cohort of toddlers deprived of sunlight had significantly lower iCa, 25 OHD and iP levels with significantly high levels of intact PTH and 10 toddlers from this group showed clinical and radiological signs of rickets.

The amount of UVB exposure available for the synthesis of vit D depends on several factors such as time spent outdoors, clothing, the amount of skin exposed, skin pigmentation, body mass, degree of latitude, season, cloud cover, and the extent of air pollution. Puliyel *et al* have reported higher incidence of vit D deficiency rickets in infants and toddlers living in areas of high atmospheric

pollution in Delhi.[13] Women who are house bound and live in crowded localities and dark alleys, with covered-up style of clothing and veil (*purdah)*, are at higher risk of developing vit D deficiency.[14] Bhatia *et al* have reported high prevalence of physiologically significant hypovitaminosis D among pregnant women and their newborns from northern India.[3] Teotia et al have suggested that women and children residing in the northern parts of India are more likely to be vit D deficient due to North-South gradient of the solar ultraviolet radiations (UVR-B 219- 315 nm) and the striking angle of UVR on the skin, which is believed to be narrow and of shorter duration.[15] Thus, residing in a geographical area with abundant sunlight is not a guarantee against the development of nutritional rickets, but adequate sunshine exposure is necessary for the formation of vit D.

Several factors affect vit D synthesis by the skin and so it is difficult to determine what is the adequate sunshine exposure for any given child. Teotia *et al* recommend that for adequate production of vit D a minimum of 30 minutes of sunshine exposure is essential.[15] Full-body exposure during summer months for 10 to 15 minutes, in an adult with lighter pigmentation, is said to generate between 10 000 and 20 000 IU of vit D3 within 24 hours; individuals with darker pigmentation would require 5 to 10 times more exposure to generate similar amounts of vit D3.[16] However, when advising sunshine exposure, risks of various skin cancers should be kept in mind, especially in light skinned children.

The natural dietary sources of vit D are limited and in India very few foods are fortified with vit D. There is neither a recommendation for dietary intake of vit D in toddlers nor a monitored food fortification program, for the intake of calcium or vit D, in India. The American Academy of Pediatrics recommends daily intake of 200 IU vit D to prevent vit D deficiency in normal infants and children.[16]

In recent times it has been suggested that dietary deficiency of calcium may play a pivotal role in development of rickets among older children in developing countries.[17]

As is seen in the present study, major part of dietary calcium is derived from cereals and green leafy vegetables, which are poor sources of bioavailable calcium. Consistent with the findings of Balasubramanim *et al*, the present study subjects from the slum (Group A) showed hypocalcemia, but none of the children showed signs of rickets.[7] However 59% of the Group B study toddlers who were also deprived of sunlight alongwith calcium showed hypovitaminosis D and 16% showed clinical and radiological signs of rickets. The final common pathway in the pathogenesis of rickets, is an ability to meet the calcium needs of the growing skeleton. Thus we speculate that the addition of vit D deficiency to a very low calcium intake may have played a synergistic role in the development of rickets in the present set of toddlers who spent most of their daytime indoors.

Apart from it's importance in calcium metabolism and bone health, epidemiologic studies in recent years suggest that vit D deficiency places adults at risk for developing several disorders including cancer (breast, colon and prostate).[18] Studies have also reported the association between vit D deficiency and respiratory infections.[19]

The present study has several shortcomings including the fact that the sample size is small and the two surveys were undertaken during different years, though they were performed in a similar season. Routine radiographs were done for all toddlers in Group A but in only those with clinical signs of rickets in Group B. Though all results have been tested statistically, the number of children with vit D deficiency rickets was very small. This imposes restriction on generalizing these results and calls for a larger study to confirm these preliminary findings.

CONCLUSION

The results of the present study in underprivileged toddlers suggest that lack of sunlight exposure in toddlers resulted in hypovitaminosis D and a higher percentage of frank rickets. This study has important public health implications and underscores the necessity for sunlight exposure and vit D supplementation/ fortification of food in young children. The importance of sunlight exposure thus needs to be emphasized to mothers, caregivers of young children and the community in general.

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