The impact of atmospheric pollution on vitamin D status of infants and toddlers in Delhi, India

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Aims: To compare the vitamin D status of 34 children, 9–24 months old, living in an area of Delhi renowned for high levels of atmospheric pollution (Mori Gate), with a comparable age matched group of children from a less polluted (Gurgaon) area of the city.

Methods: Serum concentrations of calcium, alkaline phosphatase (ALP), parathyroid hormone (PTH), 25-hydroxyvitamin D (25(OH)D), and 1,25-dihydroxyvitamin D (1,25(OH)2D) were measured. Haze scores, regarded as a surrogate marker of solar UVB radiation reaching ground level, were measured in both areas.

Results: Mean 25(OH)D in children in the Mori Gate area was 12.4 (7) ng/ml, compared with 27.1 (7) ng/ml in children living in the Gurgaon area (p < 0.001). The median ALP (p < 0.05) and mean PTH (p < 0.001) concentrations were higher in children living in the Mori Gate area than in the Gurgaon area. The mean haze score in the Mori Gate area (2.1 (0.5)) was significantly lower (p < 0.05) than in the Gurgaon area (2.7 (0.4)), indicating less solar UVB reaching the ground in Mori Gate.

Conclusion: We suggest that children living in areas of high atmospheric pollution are at risk of developing vitamin D deficiency rickets and should be offered vitamin D supplements.

Delhi (latitude 28.35°N) is one of the most polluted cities in the world; the vehicle population, a major contributor to the atmospheric pollution burden, has grown by over 12% annually for the past two decades. In this cross sectional study we assessed the vitamin D status of infants and toddlers living in a downtown area of Delhi, renowned for high levels of atmospheric pollution, with a comparable group of children from a relatively less polluted area on the outskirts of the city. We hypothesised that serum total 25-hydroxycholecalciferol (25(OH)D), a reliable measure of an individual's vitamin D status, of children living in the area with high levels of atmospheric pollution would be lower than in those living in the less polluted area of the city.

METHODS

All eligible children aged 9–24 months from a downtown area of Delhi with high levels of visible atmospheric pollution (Mori Gate) took part in this cross sectional study. Thirty four infants and toddlers were recruited from this area. A similar number of age matched subjects were recruited from the Gurgaon area, a less polluted area on the outskirts of the metropolitan boundary of the city. Families in both study areas received community healthcare from the Community Outreach Department of St Stephen's Hospital, Delhi. The study was approved by St Stephen's Hospital research ethics committee. Witnessed, verbal consent was obtained, as the majority of the parents were illiterate. Housing and the socioeconomic status of families in the two areas were similar. The infants in both areas spent most of the time indoors while the older toddlers played outside their dwellings. The families in both areas lived in single storey, one room houses with a small open space/communal footprint at the front of the house. The lack of designated safe play areas and the age of the subjects meant that they mainly spent most of the time indoors. The approximate average monthly income of families in both the areas was 1500–2000 Indian Rupees ($35–40). All the families studied were Hindu vegetarians. Children in both areas were breast fed and the rest of their diet consisted of boiled cereals, vegetables, and fresh cow or buffalo milk. None of the children was receiving vitamin or dietary supplements.

Haze scores at ground level were measured in both areas between 12 and 26 February 2000, at 0900, 1200, and 1600 hours, using a haze sensor, which had been modified by placing a filter that only allowed UVB radiation (285–310 nm) to be detected by the sensor’s light detecting diode. An average daily haze score was used as a surrogate measure of solar UVB light reaching the ground level. Four ml of blood was collected from each child between 29 March 2000 and 10 April 2000. Blood in vacutainers, containing a clot activator (Greiner Labotechnic, Kemn Munster, Austria), was centrifuged for 10 minutes at 3000 rpm and the serum separated and stored at −24°C, pending biochemical analysis. Sufficient blood for biochemical tests was obtained from 26 children in the Mori Gate area and 31 children in the Gurgaon area. Serum calcium (Ca) concentration and alkaline phosphatase (ALP) activity were analysed using an autoanalyser (BPE Electra, Italy).

Vitamin D metabolites were measured by in-house assays as described in detail previously. Briefly, samples were extracted using acetonitrile and applied to C18 Silica Sep-paks. Separation of metabolites was by straight phase HPLC (Waters Associates, Milford, MA) using a Hewlett-Packard Zorbax-Sil
and 4.2% respectively.

and intra- and inter-assay coefficient of variation (CV) 3.0%.

1.8–3.2 ng/ml). In contrast, none of the children in the limit of vitamin D adequacy.

12 ng/ml, a level that is conventionally regarded as the lower

ated with rickets, and another nine had concentrations below

Gate area (table 1). Three children from the Mori Gate had

ALP and PTH were higher in the children living in the Mori

Gurgaon area. In contrast, the mean serum concentrations of

total serum 25(OH)D concentration of children in the Mori

is, 25(OH)D2 + 25(OH)D3) is 5–30 ng/ml, sensitivity 2 ng/ml,

for recovery. The adult reference range for total 25(OH)D (that

(98:2), quantified by UV absorbance at 265 nm and corrected

ment relies on conversion of UVB light into a voltage by the

level, in the two areas. This inexpensive, but validated instru-

reducing solar radiation in the UVB range reaching ground

importance of cutaneous synthesis as the main source of

concentrations in infants show a seasonal variation, reflecting

skin after exposure to UVB sunlight. Serum 25(OH)D3

biochemical features of vitamin D deficiency rickets, with very

low but detectable serum concentrations of 25(OH)D (range

10–60 pg/ml, sensitivity 1 pg/ml, intra- and inter-assay CV 3%.

Serum intact parathyroid hormone (PTH) was measured

using an immunoradiometric assay (Nichols Institute Diag-

nics, San Juan, Capistrano, USA); adult reference range

10–60 pg/ml, sensitivity 1 pg/ml, intra- and inter-assay CV 3%.

SPSS, version 9 for Microsoft Windows was used for statisti-

cal analysis. The normally distributed data are presented as

mean (1 SD); for the non-normally distributed variables, the

data are presented as median and range. The normally

distributed data between the two groups were analysed using

the unpaired Student’s t test; those not normally distributed

were analysed using the Mann–Whitney test. All tests were

two tailed, and p values less than 0.05 were considered statisti-

cally significant.

RESULTS

As table 1 shows, mean age of children in the Mori Gate and

Gurgaon areas was not different. In both areas 15 subjects

were boys. In both areas 10 subjects were 9–12 months old, 15

were 13–18 months old, and nine were 19–24 months old.

Table 1 shows the results of serum Ca, ALP 25(OH)D, 25(OH)D,

total 25(OH)D, 1,25(OH)2D, and PTH. The mean total serum

25(OH)D concentration of children in the Mori Gate area was significantly lower than of those living in the

Gurgaon area. In contrast, the mean serum concentrations of

ALP and PTH were higher in the children living in the Mori

Gate area (table 1). Three children from the Mori Gate had

serum total 25(OH)D concentrations <5 ng/ml, a level associated

with rickets, and another nine had concentrations below

12 ng/ml, a level that is conventionally regarded as the lower

limit of vitamin D adequacy. None of the children in the

Gurgaon area had detectable serum concentrations of 25(OH)D.

(range 1.8–3.2 ng/ml). In contrast, none of the children in the

Gurgaon (low pollution area) had detectable serum concentra-

tions of 25(OH)D. One infant from the Mori Gate area had

markedly raised serum ALP of 3739 IU/l, raised PTH of 284

pg/ml, and very low serum 25(OH)D of 3.2 ng/ml. The mean

haze score in the Mori Gate area (2.1 (0.5)) was significantly

lower (p < 0.05) than in the Gurgaon area (2.7 (0.4)), indicat-

ing less solar UVB reaching the ground in Mori Gate. There

were significant inverse relations between 25(OH)D and PTH

(−0.49, p < 0.05), and 25(OH)D and ALP (−0.46, p < 0.05)

among subjects in the Mori Gate area. No such relations were

observed in subjects from the Gurgaon area.

DISCUSSION

We assessed the vitamin D status of infants and toddlers who

lived in similar types of housing in two areas of the city with
different levels of atmospheric pollution. We found that

subjects living in the Mori Gate, an area with high levels of

atmospheric pollution, had significantly lower mean serum

total 25(OH)D concentrations compared to those living in the

less polluted area (Gurgaon). Twelve children living in the

Mori Gate were vitamin D deficient (total 25(OH)D <12

mg/ml) and three had severe vitamin D deficiency (total

25(OH)D < 5 ng/ml). As expected, the mean PTH and the

median ALP levels were significantly higher in subjects from

the Mori Gate than in those from Gurgaon. One infant had

biochemical features of vitamin D deficiency rickets, with very

low serum total 25(OH)D and high PTH and ALP concentra-

tions. In contrast, none of the children in the Gurgaon were

vitamin D deficient.

The most important source of vitamin is that produced in

the skin after exposure to UVB sunlight. Serum 25(OH)D, 25(OH)D

distributions in infants show a seasonal variation, reflecting

the importance of cutaneous synthesis as the main source of

this vitamin, even at this age.11 In this study, the vitamin D

status was measured in late March and early April, and there-

fore reflects the vitamin D status of the subjects at the end of

the winter season. We used the modified haze sensor10 to

measure indirectly the effect of atmospheric pollution on

reducing solar radiation in the UVB range reaching ground

level, in the two areas. This inexpensive, but validated instru-

ment relies on conversion of UVB light into a voltage by the

light emitting diode. The higher the amount of atmospheric

pollution, the lower the amount of UVB light reaching ground

level and thus the lower the haze score. We found that the haze

score was significantly lower in the more polluted Mori Gate

area than in the less polluted Gurgaon area.

Dietary sources of vitamin D are limited mainly to oily fish,

eggs, and fortified foods, which were not consumed by the

Table 1 Age, gender, haze score, and biochemical parameters of subjects from the Mori Gate and Gurgaon areas

<table>
<thead>
<tr>
<th></th>
<th>Mori Gate (High pollution area)</th>
<th>Gurgaon (Low pollution area)</th>
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<tbody>
<tr>
<td>Age (months)</td>
<td>16 (4.1)</td>
<td>15.9 (3.8)</td>
</tr>
<tr>
<td>Haze score</td>
<td>2.1 (0.5)</td>
<td>2.7 (0.4)*</td>
</tr>
<tr>
<td>Gender</td>
<td>15 males, 11 females</td>
<td>15 males, 16 females</td>
</tr>
<tr>
<td>Ca (mg %)</td>
<td>9.7 (0.9)</td>
<td>9.6 (0.8)</td>
</tr>
<tr>
<td>ALP (IU/l, median (range))</td>
<td>498 (116–3739)</td>
<td>398* (196–780)</td>
</tr>
<tr>
<td>25(OH)D1 (ng/ml)</td>
<td>11.7 (7)</td>
<td>27.1 (7)**</td>
</tr>
<tr>
<td>25(OH)D2 (ng/ml)</td>
<td>2.4 (0.6) (n=5)</td>
<td>0</td>
</tr>
<tr>
<td>Total 25(OH)D (ng/ml)</td>
<td>12.4 (7)</td>
<td>27.1 (7)**</td>
</tr>
<tr>
<td>1,25(OH)2D (pg/ml)</td>
<td>73.7 (30)</td>
<td>65 [19]</td>
</tr>
<tr>
<td>PTH (pg/ml, median (range))</td>
<td>25 (5–284)</td>
<td>13.1* (1.6–37)</td>
</tr>
</tbody>
</table>

* p<0.05, ** p< 0.01, ***p<0.001.

Except for ALP and PTH, all data are presented as mean (1 SD). Serum 25(OH)D1 was only detected in five children from the Mori Gate area and none from the Gurgaon area; it is presented as range only for the subjects from the Mori Gate area.

Thirty-four subjects aged 9–24 months were recruited from each of the study areas; however, data are not provided for eight subjects from the Mori Gate area and three subjects from the Gurgaon area due to failed venepunctures.
From the results of this study, we conclude that children living in areas of high atmospheric pollution are at risk of developing vitamin D deficiency rickets. The findings of Palm in 1890 are still relevant today.

There are several limitations to our study, which include its cross sectional design and lack of clinical and radiological assessment for features of rickets in the subjects. Dietary intake of vitamin D was not formally assessed but this would have only contributed a very small proportion to the body pool. We did not collect data on the duration of time spent outdoors by the subjects, and ideally we should have measured the UVB exposure of the individual child during the study period. The modified haze scores should have been measured during the summer months, a period of maximal cutaneous vitamin D synthesis; however, we believe that measurements in February reflect the trends in solar UVB reaching the ground level in the two areas of the city during summer months. Nevertheless, our data clearly indicate that infants and toddlers living in a more polluted area of Delhi had lower serum levels of vitamin D than those living in a less polluted area of the city.

From our study, we conclude that children living in areas of high atmospheric pollution are at risk of developing vitamin D deficiency rickets. The findings of Palm in 1890 are still relevant today.

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REFERENCES
1. Palm TA. The geographical distribution and aetiology of rickets. Practitioner 1890;45:270–9; 321–42.