Dietary Calcium Intake and Association with Serum Calcium in Healthy Urban North Indian Adults: The Calcium-Chandigarh Urban Bone Epidemiological Study

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Abstract

Introduction: Data on dietary calcium intake (DCI) from healthy North Indian adults are limited. Hence, the present study aims to assess DCI in healthy community-dwelling adults residing in an affluent North Indian city and correlate with serum biochemical parameters. **Methods:** Healthy men and women were recruited from the community by door-to-door surveys. Serum total calcium, phosphate, 25-hydroxyvitamin D, and iPTH were estimated. DCI was assessed by recalling the diet consumed in the previous 7 days. **Results:** A total of 291 participants were included (mean age = 39.4 ± 12.9 years). The mean (± standard deviation) and median (inter-quartile range) DCI were 392.6 ± 169.1 mg/day and 391 (274-518) mg/day, respectively. DCI was higher in men compared with women. Only 21.3% of participants had DCI more than RDA (600 mg/day). Serum calcium was found to be significantly higher across each quartile of DCI. On multiple linear regression analysis, DCI emerged as an independent positive predictor of serum total calcium. **Conclusion:** DCI is low in urban Indians. Promotion of consumption of dairy products and fortification of commonly consumed foods with calcium is needed.

Keywords: Calcium, dietary calcium intake, India, nutrition, vitamin D

Introduction

Dietary calcium intake (DCI) is a major factor affecting the attainment of peak bone mass in children/adolescents and the preservation of skeletal mass in adults. Accordingly, low DCI has been shown to adversely affect accrual and retention of bone mass, manifesting as low bone mineral density and increased risk of osteoporosis.[1,2] Dietary calcium intake varies markedly, being the highest in the North European countries and the lowest in the Asian nations. Data on daily adult calcium intake in the Indian population are limited; a survey conducted in 2011–2012 reported a DCI of 429 mg/day.[1] Subsequently, a few small-scale studies evaluated DCI in the South Indian population; all had shown that calcium intake was by far inadequate amongst Indians.[3,4]

The typical Indian diet is a carbohydrate-rich diet with the consumption of dairy products, the principal source of dietary calcium, being a minimum. Besides, milk and milk products are expensive and are not universally accessible to all. This is supported by the fact that the consumption of milk and milk products by people residing in rural India is lower than that of those living in urban/metropolitan cities.[3]

Although data on DCI in children and adolescents residing in North India are available,[5,6] there is a dearth of similar data in healthy adults. Hence, the present study was undertaken to evaluate DCI in healthy community-dwelling adults residing in an affluent North Indian city and correlate it with serum calcium and other biochemical parameters.

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Materials and Methods

The study was a part of the Chandigarh Urban Bone Epidemiological Study (CUBES). It was an observational cross-sectional study conducted in Chandigarh over 2½ years (December 2016 to June 2019). Chandigarh is a Union Territory in North India and caters to an urban population of more than 11,00,000. In addition, the city ranks fourth in terms of per capita income in India, making it one of the most affluent cities in the country.

A detailed methodology of the CUBES has been published elsewhere.[7-11] In short, community-dwelling healthy adult Indian men and women aged 20 years or above were recruited from four sectors in Chandigarh. The selection of sectors, houses within each sector, and subsequently subjects within each household were randomised. Enrolled subjects with no history of co-morbidities, chronic drug intake (including calcium/vitamin D supplements), or addictions underwent blood sampling following an overnight fast. Investigations included haemoglobin, creatinine, liver function test, serum albumin, total calcium, phosphate, total alkaline phosphatase (ALP), fasting blood glucose, glycated haemoglobin, testosterone, thyroid function test, 25-hydroxyvitamin D, intact parathyroid hormone, and IgA tissue transglutaminase antibody. The serum total calcium was corrected for the corresponding serum albumin (total corrected calcium).

The reference range for calcium was 8.8–10.2 mg/dL with the intra-assay coefficient of variation (CV) being 1.34%. The reference range for albumin was 3.5–5.7 g/dL with the intra-assay CV being 1.5%. The reference range for phosphorus was 2.7–4.5 g/dL with an intra-assay CV of 1.5%. The reference range for total ALP was 34–104 U/L with an intra-assay CV of 1.5%. Plasma iPTH and 25(OH)D were measured by electrochemiluminescence using an Elecsys 2010 Analyzer (Roche Diagnostics, Mannheim, Germany). Vitamin D deficiency was defined as plasma 25(OH)D levels <20 ng/mL.

Subjects with abnormal laboratory investigations were excluded, although serum 25-hydroxyvitamin D level was not a part of the exclusion criteria. Thereafter, every fourth participant underwent a detailed evaluation of daily DCI by recalling the diet consumed in the previous 7 days. A single investigator (AK) recorded the dietary history. The validity and repeatability of the documentation were confirmed at random by another senior investigator (SKB). From the raw weights of foods, the DCI was calculated using the standard food composition table detailing the nutritive value of Indian foods.[12]

Statistical analysis was carried out using the Statistical Package for Social Sciences 23.0 software program (SPSS Inc., Chicago, IL, USA). The normality of data was checked using Kolmogorov–Smirnov test. Normally distributed data were expressed as mean ± standard deviation (SD), while non-parametric data were expressed as median (inter-quartile range, IQR). Between-group comparisons in DCI were made using the Mann–Whitney U test. Correlations between dietary calcium with age and biochemical parameters were made using the Spearman rank-order correlation test. Lastly, with serum total calcium as the dependent variable, multiple linear regression analysis was used to find out the significant predictors of the same. A P value of < 0.05 was considered as statistically significant.

Ethical aspects

The study was approved by the Institute Ethics Committee (approval number INT/IEC/2017/285 dated 23 March 2017). The study has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All participants gave their written informed consent before their inclusion in the study.

Results

Following exclusion, 291 subjects with complete dietary history were included. The group included 114 men (39.1%); among 177 women, 34 were post-menopausal. The mean age of the participants was 39.4 ± 12.9 years (range 20–85 years). The decade-wise age distribution of the population was as follows: 20–29 years (n = 76, 26.1%), 30–39 years (n = 85, 29.3%), 40–49 years (n = 63, 21.6%), 50–59 years (n = 42, 14.4%), 60–69 years (n = 20, 6.9%), and >70 years (n = 5, 1.7%). The demographic characteristics and the biochemical parameters are summarized in Table 1. Hypovitaminosis D (defined as serum 25-hydroxyvitamin D <20 ng/ml) was common, seen in 229 subjects (78.6%).

The mean ± SD and median (IQR) DCI of the participants were 392.6 ± 169.1 mg/day and 391 (274–518) mg/day, respectively. Dietary calcium intake was higher in men [432.0 (343.7–566.0) mg/day] compared with women [350.0 (240.0–470.5) mg/day)] (P value < 0.001). There was no difference in DCI between pre- and post-menopausal women (P value = 0.513). There was no correlation between participant's age and dietary calcium intake (r_s = -0.009,

Table 1: Demographic characteristics and biochemical parameters of the study participants (*n*=291)

Characteristic	Result
Male (%)	39%
Female (%)	61%
Age (years) Mean±SD	39.4±12.9
Serum corrected calcium (mg/dl) Mean±SD	9.26±0.32
Serum phosphate (mg/dl) Mean±SD	3.55±0.44
Serum total alkaline phosphatase (IU/l) Median (IQR)	105.0 (88.0 – 123.0)
Plasma iPTH (pg/ml) Median (IQR)	50.80 (38.50 – 68.50)
Plasma 25-hydroxyvitamin D (ng/ml) Median (IQR)	10.50 (7.29 – 18.30)

P value = 0.885). There was no statistically significant difference in DCI between subjects aged >60 years (n = 22) and those ≤60 years (453.9 ± 141.5 mg/day vs 387.6 ± 170.5 mg/day, *P* value = 0.077).

Only 62 participants (21.3%) had DCI more than the recommended dietary allowance (RDA) of 600 mg/day as proposed by the Indian Council of Medical Research (ICMR) in 2010. Compared to women, men were more likely to have DCI than the RDA (Pearson Chi-square, *P* value = 0.013). As per the revised Indian Council of Medical Research-National Institute of Nutrition (ICMR-NIN) proposed in 2020,[13] only one participant had an RDA of 1000 mg/day.

Regarding biochemical parameters, DCI was found to significantly correlate with serum total corrected calcium (r_s = 0.890, *P* value < 0.001, Figure 1) and with total ALP (r_s = -0.180, *P* value = 0.002) but not with serum phosphate (r_s = -0.028, *P* value = 0.640), iPTH (r_s = -0.340, *P* value = 0.564) or 25-hydroxyvitamin D (r_s = -0.011, *P* value = 0.852).

We classified the DCI into four quartiles: first quartile (Q1) (≤274 mg/day), second quartile (Q2) (275–391 mg/day), third quartile (Q3) (392–518 mg/day), and fourth quartile (Q4) (>518 mg/day). Table 2 depicts the biochemical parameters for every quartile of DCI. Serum calcium was significantly higher across each quartile of DCI [Figure 2]. Amongst other biochemical parameters, only serum total ALP was found to be significantly higher in Q1 than in Q4 [Supplementary Figure 1].

On further univariate analysis, serum total corrected calcium was found to negatively correlate with total ALP (r_s = -0.163, *P* value = 0.005); however, there was no significant correlation with 25-hydroxyvitamin D (r_s = 0.035, *P* value = 0.551) or iPTH (r_s = -0.058, *P* value = 0.327).

Table 3 depicts the DCI and biochemical parameters between participants having normal and raised iPTH (>65 pg/ml). Participants with raised iPTH had significantly lower serum phosphate and 25(OH)D and higher total ALP levels.

On multiple linear regression analysis with serum calcium as the dependent variable and DCI and ALP as the independent variables, only DCI was found to positively predict serum calcium (R^2 = 0.768, β = 0.002, *P* value < 0.001).

Discussion

In this well-designed cross-sectional study conducted amongst healthy community-dwelling men and women residing in one of the most affluent cities of India, we found that DCI was low with 79% of the study participants having DCI well below the RDA. In addition, DCI was found to be an independent predictor of serum total calcium, necessitating the importance of maintaining good calcium content in the diet.

The principal source of calcium in the diet is milk and milk products. However, dairy products are expensive; in a developing country like India with an overall poor socio-economic status, every household cannot afford an adequate amount of milk or milk products. Accordingly, the per-capita milk consumption in India is only 106.06 kg/year compared with 254.87 kg/year in the United States of America and more than 200.00 kg/day in most of European nations.[14] As a result, DCI in India is low.[1,3,4] The present study also found a low DCI in urban North Indian adults even in a city like Chandigarh, which happens to be one of the wealthiest cities in the country. Seventy-nine percent of the subjects did not meet the daily RDA of calcium. Besides, as has been shown in previous studies,[1] women had a lower DCI compared with men. This might be attributable to gender bias where side dishes that contain a higher proportion of micronutrients (like dairy products) are preferentially allocated to male members of the family.[15] With nearly 46 million post-menopausal

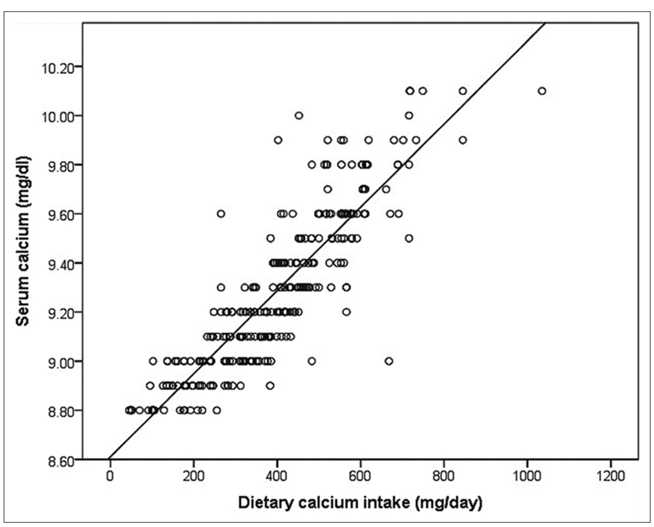

Figure 1: Scatter diagram showing correlation between dietary calcium intake and serum total corrected calcium (r_s = 0.890, *P* value < 0.001)

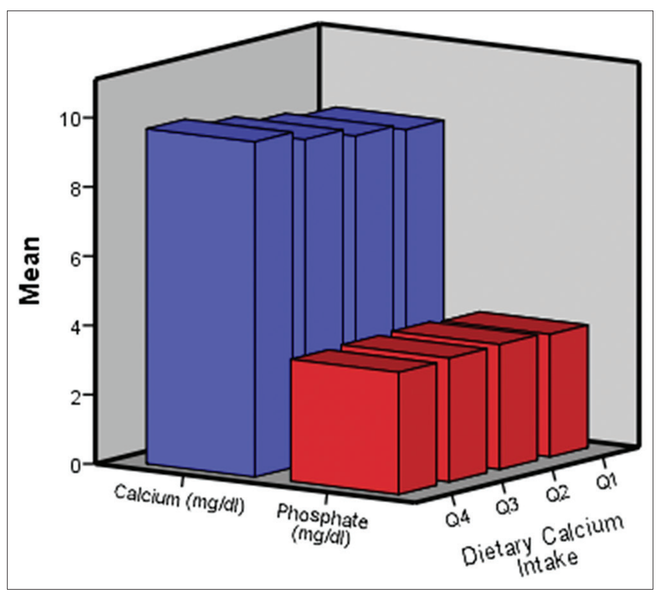

Figure 2: Three-dimensional bar diagram showing distribution of serum calcium and phosphate across quartiles of dietary calcium intake

Table 2: Various biochemical parameters across percentiles of dietary calcium intake

Parameter	Q1	Q2	Q3	Q4	*P*
Serum corrected calcium (mg/dl) Mean±SD	8.94±0.14	9.12±0.12	9.38±0.19	9.67±0.23	<0.001
Serum phosphate (mg/dl) Mean±SD	3.53±0.44	3.61±0.44	3.57±0.48	3.52±0.42	0.676
Serum total alkaline phosphatase (IU/l) Median (IQR)	112.0 (96.0-123.5)	107.0 (91.0-123.8)	101.0 (81.5-125.5)	98.0 (79.7-119.7)	0.007*
Plasma iPTH (pg/ml) Median (IQR)	50.85 (37.09-68.90)	50.80 (39.50-69.00)	54.20 (38.79-67.50)	47.67 (36.39-69.27)	0.747
Plasma 25-hydroxyvitamin D (ng/ml) Median (IQR)	10.30 (6.64-18.34)	12.95 (9.50-21.46)	9.70 (5.72-15.00)	11.38 (7.81-18.55)	0.046^

*Q1 vs Q4: *P*=0.006 (after Bonferroni correction). ^No significance after Bonferroni correction

Table 3: Dietary calcium intake and biochemical parameters between study participants having normal and raised intact parathyroid hormone

Parameter	Normal iPTH	Raised iPTH (>65 pg/ml)	*P*
Dietary calcium intake (mg/day) Median (IQR)	390.0 (274.0-517.0)	395.0 (271.5-520.2)	0.897
Serum corrected calcium (mg/dl) Mean±SD	9.28±0.32	9.25±0.34	0.472
Serum phosphate (mg/dl) Mean±SD	3.59±0.42	3.45±0.48	0.014
Serum total alkaline phosphatase (IU/l) Median (IQR)	101.0 (85.0-120.0)	112.0 (98.7-137.0)	<0.001
Plasma 25-hydroxyvitamin D (ng/ml) Median (IQR)	12.80 (8.70-20.60)	7.34 (4.89-11.28)	<0.001

Indian women with osteoporosis, low DCI might be one of the underlying contributory factors.[16]

We found a strong positive correlation between DCI and serum total calcium, an association that has been inconsistently reported in the literature.[17,18] Besides, only DCI was found to be a positive predictor of serum calcium. Although hypovitaminosis D was rampant, the positive association between DCI and serum calcium perhaps points towards an efficient vitamin D-independent calcium absorption mechanism in the gut.[19,20] Notably, the loss of vitamin D receptor (VDR) from the distal intestine and kidney in mice leads to a compensatory increase in VDR-independent duodenal calcium absorption.[21] Similarly, VDR knockout mice can maintain normal plasma calcium when fed with a 2% calcium rescue diet due to VDR-independent regulation of intestinal calcium absorption.[22] In a country like India where hypovitaminosis D is so rampant, it is likely that vitamin D-independent mechanisms of intestinal calcium absorption are operational and play a major role in maintaining normal serum calcium levels. It underscores the importance of having a calcium-rich diet irrespective of the presence or absence of concurrent vitamin D deficiency. Nevertheless, studies are needed in humans to prove that higher dietary calcium overcomes the need for vitamin D for calcium absorption as demonstrated in animals.

We do respect the inherent limitations of the study. First, the sample size was relatively small with the study being conducted in only one city. A pan-India study assessing DCI in both urban and rural populations is the need of the hour. Second, dietary phytate intake was not estimated. Phytate binds with dietary calcium and inhibits intestinal absorption. Notably, the Indian diet, being a predominantly vegetarian diet, is rich in phytates.[23] Third, the correlation between DCI and bone mineral density was not assessed. Lastly, urinary calcium was not measured as a part of the study.

Conclusions

Dietary calcium intake is inadequate even in the affluent part of India resulting from a limited intake of milk and milk products. Together with hypovitaminosis D, inadequate DCI can adversely affect bone health. Promotion of consumption of dairy products and the fortification of commonly consumed food items like cereals, bread, margarine, and beverages with calcium is the need of the hour.

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Authors' contribution

RP is the primary author. SKB is the guarantor and edited the manuscript. AA and AK helped in data collection. The manuscript has been read and approved by both the authors, that the requirements for authorship have been met, and that each author believes that the manuscript represents honest work.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Data availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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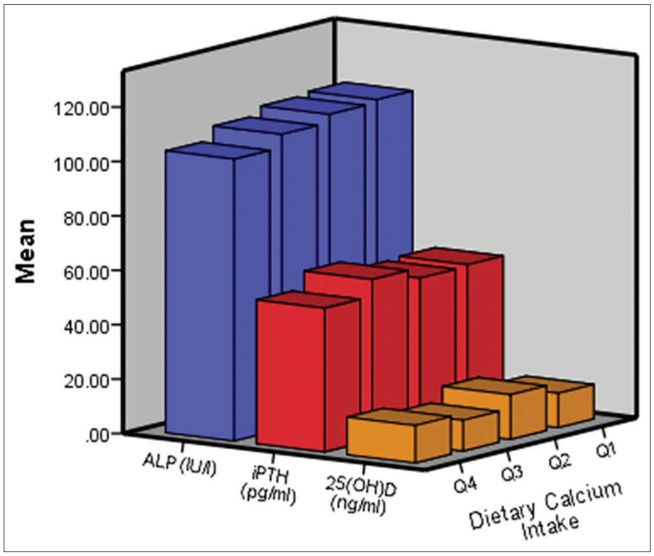

Supplementary Figure 1: Three-dimensional bar diagram showing distribution of serum total alkaline phosphatase, plasma intact parathyroid hormone, and 25-hydroxyvitamin D across quartiles of dietary calcium intake