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ORIGINAL ARTICLE

Vitamin D Insufficiency Is Associated with Abdominal Obesity in Urban Asian Indians Without Diabetes in North India

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Abstract

Objective: We evaluated the associations of serum 25-hydroxyvitamin D [25(OH) D] levels with clinical, biochemical, and anthropometric profiles and total abdominal adipose tissue (TAAT), subcutaneous abdominal adipose tissue (SCAT), and intraabdominal adipose tissue (IAAT) depots in Asian Indians without diabetes residing in north India.

Subjects and Methods: In this cross-sectional study ($n = 137$; 74 males and 63 females; 18–60 years of age), anthropometric (body mass index, waist and hip circumferences, and skinfold thickness at four sites) and biochemical (fasting plasma glucose, lipid profile, and fasting insulin levels) assessments were done. Measurement of percentage body fat was done by dual energy x-ray absorptiometry, and areas of TAAT, SCAT and IAAT were measured at the L2–L3 intervertebral level by single-slice magnetic resonance imaging. Levels of 25(OH) D were measured by radioimmunoassay. Correlation analysis was used to assess relationships among clinical, biochemical, and anthropometric profiles, areas of TAAT, SCAT, and IAAT, and 25(OH) D levels.

Results: The mean concentration of 25(OH) D was 40.5 ± 8.6 ng/mL. Overall, 6.6% had vitamin D deficiency (< 10 ng/mL), 87.6% had insufficiency (<30 ng/mL), and 5.8% had a sufficient level (>30 ng/mL). Levels of 25(OH) D did not correlate with demographic, biochemical, and anthropometric profiles or with abdominal fat depots (TAAT, SCAT, and IAAT). In the correlation regression model, 25(OH) D was associated with TAAT in obese subjects.

Conclusions: In obese urban Asian Indians without diabetes, higher values of total abdominal fat at the L2–L3 intervertebral level were associated with low 25(OH) D levels.

Introduction

Nearly 1 billion people suffer from vitamin D insufficiency globally.[1] Several studies have demonstrated low serum 25-hydroxyvitamin D [25(OH) D] levels in people living in various regions of across India.[2,3] In North India, 94.3% of adults,[2] 96% of neonates,[4] 91% of healthy schoolgirls,[5] 78% of healthy hospital staff,[6] and 84% of pregnant women[4] were found to have low vitamin D levels.

Obesity is associated with low levels of serum 25(OH) D. In healthy subjects, serum 25(OH) D concentration inversely correlates to both fat mass and body mass index (BMI) in the Austrian population.[7,8] Arunabh et al.[7] concluded that percentage body fat was inversely related to the serum 25(OH) D levels in healthy women in North America. Ramel et al.[8] reported that BMI was negatively associated with serum 25(OH) D in the Icelandic population.

Many studies have shown the relationships between 25(OH) D levels and insulin secretion and sensitivity.[9,10] Forouhi et al.[11] observed the baseline levels of 25(OH) D to be inversely associated with fasting glucose, fasting insulin, and homeostasis model of assessment for insulin resistance (HOMA-IR) in a 10-year prospective study in whites. Pittas et al.[12] have reported that vitamin D deficiency influences insulin secretion and sensitivity via its effects on intracellular calcium in type 2 diabetes mellitus (T2DM).

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Abdominal obesity is widely prevalent in Asian Indians and believed to be an important cause of insulin resistance and T2DM.[13] However, published data are not available regarding any relationship between abdominal obesity and 25(OH) D in Asian Indians. We hypothesized that generalized or abdominal adiposity is linked with low levels of 25(OH) D in Asian Indians. In the current study, we examined the association of 25(OH) D to adiposity in Asian Indians residing in a metropolitan city of North India.

Subjects and Methods

Study subjects

This cross-sectional population-based study involved 137 adults without diabetes (74 males, 63 females) and was conducted at the All India Institute of Medical Sciences and the Fortis Hospital, New Delhi, India, from April 2006 to April 2011. The institutional ethics committee approved the study, and informed consent was obtained. Subjects were randomly selected to have approximate representation from each income group (high-income group, approximately 10%; middle-income group, approximately 65–70%; and low-income group, approximately 15–20%) according to the proportion living in a metropolitan city. Subjects with diabetes, any severe acute or chronic illness, known human immunodeficiency virus seropositivity, and pregnant and lactating women were excluded from the study.

Clinical and anthropometric measurements

Height, weight, waist circumference (WC), hip circumference, and skinfold thickness at four sites (triceps, biceps, suprailiac, and subscapular) were measured according to standard protocols.[14] BMI and waist–hip ratio were calculated. Total skinfold thickness was calculated as the sum of the four skinfold thicknesses.

Biochemical assays

Venous blood samples were obtained after an overnight fast for estimation of plasma glucose, total cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL-C) as mentioned previously.[14] The low-density lipoprotein cholesterol value was calculated using the equation of Friedewald et al.[15] Fasting insulin levels were measured using commercially available radioimmunoassay insulin kits (Immunotech, Marseille, France) as described previously.[16] The intra- and interassay variations for all assays were less than 5%.

Percentage body fat, bone mineral density, and abdominal fat depots

Body fat and bone mineral density were estimated by whole-body dual-energy x-ray absorptiometry (DEXA) scan (Lunar Prodigy™ advanced whole body DEXA system; GE Medical Systems, Madison, WI). Measurement of abdominal adipose tissue was done by single-slice magnetic resonance imaging (1.5 T; Signa high-definition MR; GE Medical Systems) at the L2–L3 intervertebral level. Magnetic resonance imaging was done with the patient in the supine position with arms by the side. The abdominal region was scanned using axial 8-mm-thick slices during the breath-holding spell. We used a T_1-weighted spin echo sequence (TR/TE/NEX-300 ms/15 ms/1). Adipose tissue areas were easily identified on the images because fat has short T_1 and long T_2 proton relaxation times compared with other tissues. Specifically, the short T_1 time of fat is characteristic, resulting in high signal intensity (increased brightness) on T_1-weighted images. Areas (in mm^2) of intraabdominal adipose tissue (IAAT) and subcutaneous adipose tissue (SCAT) were measured on the computer screen using a trackball. The area of total abdominal adipose tissue (TAAT) was calculated as the sum of IAAT and SCAT.

Vitamin D assay

Serum 25(OH) D levels were measured by radioimmunoassay (25-OH D assay; DiaSorin, Stillwater, MN). The intra-assay coefficient of variation was 1.61%, and the inter-assay coefficient was 2.19%.

Definitions

Overweight and obesity were defined as BMI of ≥ 23–$24.9\ kg/m^2$ and BMI $\geq 25\ kg/m^2$, respectively.[17] WC cutoffs of ≥ 90 cm for males and ≥ 80 cm for females were considered an indicator of abdominal obesity.[17] Values for fasting blood glucose of ≥ 100 mg/dL, serum triglycerides of ≥ 150 mg/dL (or on lipid-lowering drugs), blood pressure $\geq 130/85$ mm Hg (or on antihypertensive therapy), and HDL-C in males of < 40 mg/dL and in females of < 50 mg/dL[17] were defined as abnormal. Insulin resistance was measured by HOMA-IR. The value of HOMA denoting insulin resistance was termed HOMA-IR and was calculated as (fasting insulin [in μU/mL] $\times$ fasting glucose [in mmol/L]/22.5).[18,19] Cutoffs for percentage body fat (25.5% for males and 38% for females[20]), TAAT ($\geq 245.6\ cm^2$ for males and $\geq 75.73\ cm^2$ for females), SCAT ($\geq 135.3\ cm^2$ for males and $\geq 134.02\ cm^2$ for females), and IAAT ($> 203.46\ cm^2$ for males and $> 110.74\ cm^2$ for females) were used from previous studies on Asian Indians.[20,21] Vitamin D status was defined as deficient (≤ 10 ng/mL), insufficient (10.1–30 ng/mL), or sufficient (30.1–100 ng/mL).[22]

Statistical analysis

Data were recorded on an Excel® worksheet (Microsoft Corp., Redmond, WA). Statistical analysis was performed using STATA software (version 9; StataCorp, College Station, TX). After the normality aspect of quantitative variables was confirmed, descriptive statistics were computed using mean $\pm$ SD, median (minimum–maximum), and Student's *t* test. An independent-sample *t* test was used to examine significant changes in clinical, anthropometry, and body composition profiles and in vitamin D levels between males and females. Correlations of vitamin D with demographic, biochemical, anthropometry, and body fat parameters were performed. Regression analyses were carried out to evaluate the independent association of 25(OH) D with body fat variables. A P value of < 0.05 was considered as statistically significant.

Results

The clinical, anthropometric, biochemical, and body composition profiles are summarized in Table 1. The mean $\pm$ SD

Table 1. Demographic, Biochemical, Anthropometric, and Body Composition Profiles

Parameter	*Total* (n = *137*)	*Males* (n = *74*)	*Females* (n = *63*)	P *value*
Age (years)	40.2 ± 7.9	40.8 ± 8.8	39.4 ± 6.9	0.3
BMI (kg/m^2)	24.8 ± 5.5	24.4 ± 7.6	25.2 ± 4.5	0.1
FBG (mmol/L)	5.3 ± 1.1	5.3 ± 1.05	5.23 ± 1.22	0.7
25(OH) D (ng/mL)	18.9 ± 6.7	18.5 ± 5.7	19.4 ± 6.3	0.4
Lipid profile (mmol/L)				
S. TG	1.8 ± 0.56	2.13 ± 0.51	1.41 ± 0.48	0.02[a]
Total cholesterol	4.99 ± 1.24	5.11 ± 1.33	4.86 ± 1.11	0.2
HDL-C	1.07 ± 0.25	1.02 ± 0.23	1.13 ± 0.19	0.008[a]
LDL-C	3.1 ± 1.07	3.26 ± 1.10	3.06 ± 1.03	0.2
VLDL	0.86 ± 0.28	1.03 ± 0.19	1.01 ± 0.14	0.1
Fasting insulin (μU/L)	8.2 ± 2.3	7.9 ± 3.2	8.5 ± 3.4	0.6
HOMA-IR	1.8 ± 0.9	1.9 ± 0.8	1.6 ± 0.6	0.3
Circumference (cm)				
Waist	87.8 ± 10.6	90.5 ± 9.5	85.3 ± 10.6	0.01[a]
Hip	97.5 ± 11.7	95.5 ± 12.5	101.0 ± 11.5	0.0005[a]
Waist–hip ratio	0.90 ± 0.09	0.95 ± 0.76	0.84 ± 0.92	0.001[a]
Skinfold (mm)				
Biceps	16.9 ± 5.7	15.3 ± 4.2	18.4 ± 6.9	0.05[a]
Triceps	24.4 ± 8.7	21.8 ± 7.7	27.5 ± 8.8	0.001[a]
Subscapular	30.2 ± 8.7	29.1 ± 7.8	34.5 ± 8.8	0.05[a]
Suprailiac	32.8 ± 9.8	30.2 ± 7.3	35.7 ± 7.9	0.05[a]
TSF	104.3 ± 32.8	95.6 ± 26	115.9 ± 28.5	0.0004[a]
Area of adipose tissue (cm^2)[b]				
TAAT	391.48 ± 130.5	321.07 ± 119.03	461.9 ± 141.99	0.0001[a]
SCAT	256.35 ± 76.08	189.05 ± 53.40	323.65 ± 98.76	0.0001[a]
IAAT	135.13 ± 54.43	132.02 ± 65.63	138.25 ± 43.23	0.1
Body composition by DEXA scan				
Body fat (%)	36.0 ± 10	29.5 ± 7.4	43.4 ± 7.3	0.0001[a]
BMD (g/cm^2)				
Arms	29.2 ± 10.1	19.4 ± 7.6	40.3 ± 13.2	0.001[a]
Legs	33.8 ± 12.6	24.9 ± 8.4	44.1 ± 7.8	0.0001[a]
Trunk	39.7 ± 10.8	34.3 ± 10.1	45.9 ± 8.2	0.0001[a]

Data are mean ± SD values. An independent-sample *t* test was used to examine significant changes in clinical, anthropometric, and body composition profiles and vitamin D levels between males and females.

[a]*P* value of < 0.05 was considered statistically significant.

[b]At the L2–L3 intervertebral level by single-slice magnetic resonance imaging.

25(OH) D, 25-hydroxyvitamin D; BMD, bone mineral density; BMI, body mass index; DEXA, dual-energy X-ray absorptiometry; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homoeostasis model of assessment for insulin resistance; IAAT, intraabdominal adipose tissue; LDL-C, low-density lipoprotein cholesterol; S. TG, serum triglycerides; SCAT, subcutaneous abdominal adipose tissue; TAAT, total abdominal adipose tissue; TSF, total skinfolds; VLDL, very low-density lipoprotein.

for age was 40.2 ± 7.9 years. Males had significantly higher values of serum triglycerides ($P = 0.02$), WC ($P = 0.01$), and waist–hip ratio ($P = 0.001$) compared with females. Mean values of HDL-C ($P = 0.008$), hip circumference ($P = 0.0005$), skinfolds (biceps [$P = 0.05$], triceps [$P = 0.001$], subscapular [$P = 0.05$], and suprailiac [$P = 0.05$]), and total skinfold ($P = 0.0004$) were significantly higher in females compared with males. The values of TAAT ($P = 0.0001$), SCAT ($P = 0.0001$), percentage body fat ($P = 0.0001$), and bone mineral density (arm [$P = 0.001$], leg [$P = 0.0001$], and trunk [$P = 0.0001$]) were significantly higher in females. IAAT was not significantly different between males and females.

The mean concentration of 25(OH) D was 40.5 ± 8.6 ng/mL. Overall, 6.6% had vitamin D deficiency, 87.6% had insufficiency, and 5.8% had sufficient levels. No significant correlation was observed between levels of 25(OH) D with demographic, biochemical, and anthropometric variables, bone mineral density and body fat parameters (SCAT, IAAT, and TAAT) (Table 2). In correlation regression analysis, levels of 25(OH) D were negatively associated with TAAT in obese subjects (Table 3).

Discussion

In this cross-sectional study, we observed an association of higher TAAT values with low 25(OH) D levels and no association of 25(OH) D with SCAT and IAAT. Although some previously published studies[7–9] have shown that serum 25(OH) D levels were inversely correlated with body fat, in almost all of them serum 25(OH) D levels were studied in either morbidly obese or nonobese subjects. Similar to our study, some data suggest that abdominal obesity is significantly associated with vitamin D deficiency.[23–25] Furthermore, Moy and Bulgiba[23] have reported that vitamin D insufficiency was independently associated with greater abdominal obesity in Malaysian subjects. Cheng et al.[24] reported that lower 25(OH) D levels were strongly associated with greater regional adiposity in the Framingham Heart

Table 2. Correlations of Mean ± SD 25-Hydroxyvitamin D Levels with Demographic, Biochemical, Anthropometric, and Body Fat Parameters

Parameter	*Correlation coefficient*	P *value*[a]
Body mass index (kg/m^2)	−0.064	0.51
Fasting blood glucose (mg/dL)	0.021	0.23
Lipid profile (mg/dL)		
Serum triglycerides	−0.003	0.39
Total cholesterol	−0.087	0.30
HDL-C	0.02	0.79
LDL-C	−0.085	0.32
VLDL	−0.06	0.4
Fasting insulin (μU/L)	0.093	0.34
HOMA-IR	−0.040	0.67
Circumference (cm)		
Waist	0.001	0.92
Hip	0.045	0.65
Waist–hip ratio	−0.059	0.5
Skinfold (mm)		
Biceps	0.043	0.67
Triceps	0.059	0.56
Subscapular	−0.084	0.40
Suprailiac	−0.0006	0.91
TSF	0.016	0.87
Area of adipose tissue (cm^2)[b]		
TAAT	0.070	0.47
SCAT	0.087	0.37
IAAT	0.053	0.60
Body composition by DEXA scan		
Body fat (%)	0.017	0.83
BMD (g/cm^2)		
Arms	−0.036	0.69
Legs	−0.007	0.93
Trunk	−0.002	0.90

[a]A *P* value of < 0.05 was considered statistically significant.
[b]At the L2–L3 intervertebral level by single-slice magnetic resonance imaging.
BMD, bone mineral density; DEXA, dual-energy X-ray absorptiometry; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homoeostasis model of assessment for insulin resistance; IAAT, intraabdominal adipose tissue; LDL-C, low-density lipoprotein cholesterol; SCAT, subcutaneous abdominal adipose tissue; TAAT, total abdominal adipose tissue; TSF, total skinfolds; VLDL, very low-density lipoprotein.

Table 3. Correlation of Serum 25-Hydroxyvitamin D Levels with Total Body Fat and Adipose Tissue Depots According to Body Mass Index Categories (Obese and Nonobese)

Variable	*Obese (BMI ≥ 25 kg/m^2)*	*Nonobese (BMI < 25 kg/m^2)*
Body fat (%)	0.014	0.26
TAAT (cm^2)	−0.44[a]	−0.006
SCAT (cm^2)	0.069	−0.002
IAAT (cm^2)	0.014	−0.24

Correlation regression analyses was carried out to evaluate the independent association of 25-hydroxyvitamin D with body fat variables. Coefficients represent the change in 25-hydroxyvitamin D level (ng/mL) for an increase in the value of the predictor variables.
[a]$P < 0.05$.
IAAT, intraabdominal adipose tissue; SCAT, subcutaneous abdominal adipose tissue; TAAT, total abdominal adipose tissue.

Study. These authors further showed that the association of 25(OH) D and visceral fat was stronger than that of 25(OH) D and subcutaneous abdominal fat.

Association of obesity with low levels of serum 25(OH) D[7] may be attributed to decreased exposure to sunlight because of limited mobility of obese people and negative feedback from elevated 1,25-dihydroxyvitamin D and parathyroid hormone levels on hepatic synthesis of 25(OH) D.[25] Liel et al.[26] have suggested that the serum 25(OH) D level increases appropriately in response to ultraviolet radiation in obese subjects, implying that low 25(OH) D levels do not result from impaired dermal production and delivery. The association between 25(OH) D and adipose tissue was unchanged by adjustment for physical activity and was present even in analyses restricted to lean individuals.[27] Furthermore, experimental studies indicate that differences in sunlight exposure are not enough to account for the differences in 25(OH) D concentrations seen between obese and nonobese volunteers.[28] Thus, confounding by differences in sunlight exposure is unlikely to be an explanation for poorer vitamin D status with greater adiposity. Skin synthesis of vitamin D accounts for the majority of vitamin D in the human body; thus, it is possible that body fat has a lower impact in blacks because there is less vitamin D formed in the skin to sequester. In this context it is important to note that a systematic review by Renzaho et al.,[29] which focused on the association between 25(OH) D status and obesity, cardiovascular disease, the metabolic syndrome, and T2DM in ethnic minorities (immigrants from low- to high-income countries), showed that this subgroup of people had significantly higher rates of vitamin D insufficiency (<50 nmol/L) than their white counterparts (for children, 43.6–48.7% vs. 10%; for adults, 30.3–53% vs. 13.7–26%) respectively. However, the strength of this association varies across ethnic groups depending on the index used to measure adiposity, T2DM, and cardiovascular disease. It was suggested in the review that further research specific to migrant populations using randomized controlled trials is required to establish whether causal links between 25(OH) D and obesity-related chronic diseases exist. Finally, the authors also raised research question whether vitamin D supplementation could be useful in the prevention or treatment of obesity-related diseases.

Obesity, abdominal obesity, and associated metabolic consequences are a burgeoning problem in Asian Indians. We have previously shown that Asian Indians have relatively higher truncal and abdominal fat mass compared with white and black populations[30] and that high subcutaneous adiposity is an independent risk factor for metabolic syndrome.[31] Increasing abdominal adiposity, at a younger age, is significantly contributing to the burden of T2DM and cardiovascular disease in Asian Indians. It is important to note that in preliminary publications, we have shown higher prevalence of severe vitamin D deficiency in patients of T2DM[33] and nonalcoholic fatty liver disease[34] in north India. Overall observations of low vitamin D levels with abdominal obesity are important for Asian Indians

because both contribute to resistance to action of insulin and may also increase CVD risk.

Vitamin D is emerging as an important correlate of obesity. Other important factors include gut hormones like ghrelin and glucagon-like peptide-1, which have been shown to be important in energy balance and weight loss, and their dysregulation may be important in obesity. Decreased plasma levels of active ghrelin are significantly associated with abdominal adiposity, hyperinsulinemia, and insulin resistance in T2DM subjects.[35,36] It would be interesting to research the effects of various gut hormones (ghrelin, glucagon-like peptide-1, etc.) and vitamin D in regulation of adipose tissue mass in humans.

The limitations of the study include small sample size as well as the cross-sectional nature of the study. More subjects in all age groups in both genders in urban and rural areas in different parts of the country should be studied in the future. Other potential protective factors, such as exposure to sunlight and nutritional status, were not assessed. Data regarding exposure to sunlight would have been helpful. Furthermore, no cause–effect relationship inferences can be drawn from the present study as it is a cross-sectional study. Longitudinal studies are warranted to study the interplay between vitamin D deficiency, obesity, insulin resistance, and T2DM in Asian Indians.

Conclusions

This study suggests that higher value of total abdominal fat at the L2–L3 level was associated with low 25(OH) D levels in obese urban Asian Indians without diabetes.

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Author Disclosure Statement

No competing financial interests exist.

References

1. Holick MF: Vitamin D deficiency. N Engl J Med 2007; 357:266–281.
2. Vupputuri MR, Goswami R, Gupta N, Ray D, Tandon N, Kumar N: Prevalence and functional significance of 25-hydroxyvitamin D deficiency and vitamin D receptor gene polymorphisms in Asian Indians. Am J Clin Nutr 2006; 83:1411–1419.
3. Zargar AH, Ahmad S, Masoodi SR, Wani AI, Bashir MI, Laway BA, Shah ZA: Vitamin D status in apparently healthy adults in Kashmir Valley of Indian subcontinent. Postgrad Med J 2007;83:713–716.
4. Sachan A, Gupta R, Das V, Agarwal A, Awasthi PK, Bhatia V: High prevalence of vitamin D deficiency among pregnant women and their newborns in northern India. Am J Clin Nutr 2005;81:1060–1064.
5. Puri S, Marwaha RK, Agarwal N, Tandon N, Agarwal R, Greqal K, Reddy DH, Singh S: Vitamin D status of apparently healthy schoolgirls from two different socioeconomic strata in Delhi: relation to nutrition and lifestyle. Br J Nutr 2008;99:876–882.
6. Arya V, Bhambri R, Godbole MM, Mithal A: Vitamin D status and its relationship with bone mineral density in healthy Asian Indians. Osteoporos Int 2004;15:56–61.
7. Arunabh S, Pollack S, Yeh J, Aloia JF: Body fat content and 25-hydroxyvitamin D levels in healthy women. J Clin Endocrinol Metab 2003;88:157–161.
8. Ramel A, Jonsson PV, Bjornsson S, Thorsdottir I: Vitamin D deficiency and nutritional status in elderly hospitalized subjects in Iceland. Public Health Nutr 2009;12:1001–1005.
9. Scragg R, Sowers M, Bell C: Serum 25-hydroxyvitamin D, diabetes, and ethnicity in the Third National Health and Nutrition Examination Survey. Diabetes Care 2004;27: 2813–2818.
10. McGill AT, Stewart JM, Lithander FE, Strik CM, Poppitt SD: Relationships of low serum vitamin D3 with anthropometry and markers of the metabolic syndrome and diabetes in overweight and obesity. Nutr J 2008;7:4.
11. Forouhi NG, Luan J, Cooper A, Boucher BJ, Wareham NJ: Baseline serum 25-hydroxy vitamin-D is predictive of future glycemic status and insulin resistance: the Medical Research Council Prospective Study 1990–2000. Diabetes 2008;57:2619–2625.
12. Pittas AG, Lau J, Hu FB, Dawson-Hughes B: The role of vitamin D and calcium in type 2 diabetes. A systematic review and meta-analysis. J Clin Endocrinol Metab 2007; 92:2017–2029.
13. Misra A, Khurana L: Obesity and the metabolic syndrome in developing countries. J Clin Endocrinol Metab 2008; 93(11 Suppl 1):S9–S30.
14. Misra A, Pandey RM, Devi JR, Sharma R, Vikram NK, Khanna N: High prevalence of diabetes, obesity and dyslipidaemia in urban slum population in Northern India. Int J Obes Relat Metab Disord 2001;25:1722–1729.
15. Freidewald WT, Levy RT, Frederikson DS: Estimation of the concentration of low-density lipoprotein cholesterol in plasma without use of the preparative ultracentrifugation. Clin Chem 1972;18:499–502.
16. Vikram NK, Misra A, Pandey RM, Dwivedi M, Luthra K, Dhingra V, Talwar KK: Association between subclinical inflammation & fasting insulin in urban young adult North Indian males. Indian J Med Res 2006;124:677–682.
17. Misra A, Chowbey P, Makkar BM, Vikram NK, Wasir JS, Chadha D, Joshi Sr, Sadikot S, Gupta R, Gulati S, Munjal YP: Consensus Group: Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. J Assoc Physicians India 2009;57:163–170.
18. Lambert M, Paradis G, O'Loughlin J, Delvin EE, Hanley JA, Levy E: Insulin resistance syndrome in a representative sample of children and adolescents from Quebec, Canada. Int J Obes Relat Metab Disord 2004;28:833–841.
19. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC: Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412–419.
20. Joseph L, Wasir JS, Misra A, Vikram NK, Goel K, Pandey RM, Chandra M, Poddar P, Kondal D: Appropriate values of adiposity and lean body mass indices to detect cardiovascular risk factors in Asian Indians. Diabetes Technol Ther 2011;13:899–906.

21. Misra A, Wasir JS, Vikram NK, Pandey RM, Kumar P: Cutoffs of abdominal adipose tissue compartments as measured by magnetic resonance imaging for detection of cardiovascular risk factors in apparently healthy adult Asian Indians in North India. Metab Syndr Relat Disord 2010;8:243–247.
22. Lee JH, O'Keefe JH, Bell D, Hensrud DD, Holick MF: Vitamin D deficiency: an important, common, and easily treatable cardiovascular risk factor? J Am Coll Cardiol 2008;52:1949–1956.
23. Moy FM, Bulgiba A: High prevalence of vitamin D insufficiency and its association with obesity and metabolic syndrome among Malay adults in Kuala Lumpur, Malaysia. BMC Public Health 2011;11:735.
24. Cheng S, Massaro JM, Fox CS, Larson MG, Keyes MJ, McCabe EL, Robins SJ, O'Donnell CJ, Hoffman U, Jacques PF, Booth SL, Vasan RS, Wolf M, Wang TJ: Adiposity, cardiometabolic risk, and vitamin D status: the Framingham Heart Study. Diabetes 2010;59:242–248.
25. Bell NH, Shaw S, Turner RT: Evidence that 1,25-dihydroxyvitamin D3 inhibits the hepatic production of 25-hydroxyvitamin D in man. J Clin Invest 1984;74:1540–1544.
26. Liel Y, Ulmer E, Shary J, Hollis BW, Bell NH: Low circulating vitamin D in obesity. Calcif Tissue Int 1988; 43:199–201.
27. Fox CS, Massaro JM, Hoffman U, Pou KM, Maurovich-Horvat P, Liu CY, Vasan RS, Muraboti JM, Meigs JB, Cupples LA, D'Agostino RB Sr, O'Donnell CJ: Abdominal visceral and subcutaneous adipose tissue compartments: associations with metabolic risk factors in the Framingham Heart Study. Circulation 2007;116:39–48.
28. Worstman J, Matsuoka LY, Chen TC, Lu Z, Holick MF: Decreased bioavailability of vitamin D in obesity. Am J Clin Nutr 2000;72:690–693.
29. Renzaho AM, Halliday JA, Nowson C: Vitamin D, obesity, and obesity-related chronic disease among ethnic minorities: a systematic review. Nutrition 2011;27:868–879.
30. Misra A, Vikram NK: Insulin resistance syndrome (metabolic syndrome) and obesity in Asian Indians: evidence and implications. Nutrition 2004;20:482–491.
31. Goel K, Misra A, Vikram NK, Poddar P, Gupta N: Subcutaneous abdominal adipose tissue is associated with the metabolic syndrome in Asian Indians independent of intra-abdominal and total body fat. Heart 2010;96:579–583.
32. Gupta R, Misra A, Vikram NK, Kondal D, Gupta SS, Agarwal A, Pandey RM: Younger age of escalation of cardiovascular risk factors in Asian Indian subjects. BMC Cardiovasc Disord 2009;5:28.
33. Subramanian A, Nigam P, Misra A, Pandey RM, Mathur M, Gupta R, Madhusudan S: Severe vitamin D deficiency in patients with type 2 diabetes mellitus in north India. Diabetes Management 2011;1:477–483.
34. Bhatt SP, Nigam P, Misra A, Guleria R, Qadar Pasha MA: Independent associations of low 25 hydroxy vitamin D and high parathyroid hormonal levels with nonalcoholic fatty liver disease in Asian Indians residing in north India. Atherosclerosis 2013;230:157–163.
35. Katsuki A, Urakawa H, Gabazza EC, Murashima S, Nakatani K, Togashi K, Yano Y, Adachi Y, Sumida Y: Circulating levels of active ghrelin is associated with abdominal adiposity, hyperinsulinemia and insulin resistance in patients with type 2 diabetes mellitus. Eur J Endocrinol 2004;151:573–577.
36. Chen CY, Tsai CY: Ghrelin and motilin in the gastrointestinal system. Curr Pharm Des 2012;18:4755–4765.

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