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ORIGINAL ARTICLE

Difference in prevalence of diabetes, obesity, metabolic syndrome and associated cardiovascular risk factors in a rural area of Tamil Nadu and an urban area of Delhi

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Abstract This study compared difference in diabetes, obesity, metabolic syndrome (MetS), C-reactive protein (hs-CRP), homocysteine, and other cardiovascular risk factors between rural and urban Asian Indians using similar/standardized field measurements. The design used a cross-sectional and population-based study among rural (Tamil Nadu) and urban (Delhi) Asian Indians aged 18 years and older. 574 rural Indians and 508 urban Indians completed face-to-face interviews, and anthropometric measurements. Fasting venous blood samples were obtained for fasting plasma glucose and serum lipid tests. The mean age was 42.6±11.8 y (urban) and 39.5±13.9 y (rural). Although the prevalence of type 2 diabetes (T2DM) was lower in rural (8.4%) than urban (13.6%) areas, rural Asian Indians had a higher percent of undiagnosed cases (25%), poorer glycemic control, and unawareness of diabetes than their urban peers. Urban Indians had elevated rates of the MetS (as defined by NCEP and IDF criteria), hs-CRP, total cholesterol, LDL, and hypertension than their rural peers. Females in general had significantly higher central obesity and lower HDL-C than males. Homocysteine levels (measured only among urban respondents) was higher among males than females (p=.04). Prevalence of hypertension increased with age (r=.37, p<.001) and correlated with respondents' blood glucose levels (r=.11, p<.001). There was a step-wise worsening of risk factors as individuals progressed from normal to IFG to T2DM. High burden of diabetes and other cardiovascular risk factors in urban and rural Asian Indians provide basis for tailored and cost-effective prevention and intervention programs, in such resource-constrained settings.

Keywords Diabetes · Prevalence · C-reactive protein · Metabolic syndrome · Urban · Rural · India

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Background

The burden of diabetes is more pronounced in India than any other country in the world [1]. An estimated 46.5 million Indians have diabetes (2007) with a projected increase to 80 million by 2030 [1].Type 2 diabetes mellitus (T2DM) occurs a decade earlier than in other ethnic groups and may lead to more complications [2, 3]. Increased urbanization, nutrition and lifestyle transitions are associated with the rapid rise of T2DM in urban as well as rural areas [4–6]. In particular, affluence and automation has resulted in pronounced physical inactivity and consumption of diets rich in fat, sugar and calories [7].

With more than a billion people, India is home to significantly diverse groups of people in terms of ethnicity, caste and religion, socioeconomic status, educational level, and lifestyle and food habits [6]. Approximately 70% of India's population lives in rural areas and in resource-poor settings where the increasing prevalence and chronic nature of T2DM poses considerable health and economic burden [3]. Studies consistently show high rates of T2DM and the Metabolic Syndrome (MetS) and cardiovascular disease (CVD) in the Asian Indian population as compared to Caucasians and other ethnic groups [8–11]. Insulin resistance, a key pathophysiologic factor, is highly prevalent in Asian Indians, despite low rates of obesity [9, 12–14]. Impaired glucose tolerance is more common in Asian Indians at a young age. Most of the studies have been carried out on the prevalence of diabetes in urban areas [15–20] with a few in rural areas [21–23]. The study by Mahadik et al. [9] and Zargar et al. [15] examined both rural and urban populations but the former study assessed only MetS and the later was limited to Kashmir state in North India. The prevalence of diabetes in India study (PODIS) [6] is the only country-wide prevalence study on diabetes that took into account the marked heterogeneity of the Indian population.

The purpose of this population-based study was to determine the prevalence of pre-diabetes, T2DM, MetS and association with hs-CRP, homocysteine, and lipid profile in rural and urban sites in India using similar design and field measures.

Methods

Subjects

A cross-sectional and population-based study design was used among rural and urban Indians ≥18 years. The period of study was 2005 to 2007. Urban sample was selected based on multi-stage cluster sampling technique, according to the modified World Health Organization Expanded Program of Immunization Sampling Plan [24]. First, a list of residential colonies within 10 km of the All India Institute of Medical Sciences was prepared. Colonies were randomly selected from this list for inclusion. The number of houses in each colony was determined and the Resident Welfare Associations of these colonies were approached to conduct the study in their locality. The households were selected randomly and one member from each was invited to participate in the study. 900 urban respondents from a wide range of socioeconomic strata were contacted for participation and 610 completed the face-to-face interviews (response rate 67.7%) and 508 (56.4%) completed anthropometric measurements, and provided venous blood sample after an overnight fast of at least 8 h for blood tests. The questionnaire (in both Hindi and English) used for the study was initially pretested in a smaller population (n=10 in each site) and validated. Most of the subjects who refused to participate in Delhi did not want to spare time for the survey and blood work since they had to report to work early in morning.

In the rural site, sample was randomly selected from eight hamlets (out of 30) classified as 'rural' by the Indian government land records. 850 individuals were contacted through door-to-door visitations, 599 rural Indians participated in the face-to-face interviews by trained interviewers and 574 completed the anthropometric measurements and fasting blood work (response rate 67.5%) at the Gandhigram Rural Institute. Most of the respondents who refused to participate in the rural areas were migrant workers. The All India Institute of Medical Sciences (AIIMS), Delhi was used for urban Indians and also served as the core laboratory for biochemical analysis. The study was approved by the Institutional Review Board of Texas A & M University and AIIMS.

Data collection

Information was collected on demographic profile, anthropometrics, T2DM and CVD risk factors e.g., blood pressure, smoking, generalized and abdominal obesity, fasting blood glucose values, serum lipids, fasting plasma insulin, and high-sensitivity C-reactive protein (hs-CRP) levels. The primary endpoint of the study was the prevalence of diabetes, MetS, and CVD risk. Prior to beginning the study, a workshop was held to train the field staff about the anthropometric measurements. The measurements were taken by one observer each for males and females and the intra- and inter-observer variation was less than 10%. Study protocol and data collection procedures were standardized, calibrated equipments used at both sites, and all research assistants were trained at AIIMs and monitored during the study period.

Demographic profile Comprised of age, gender, marital status, education, employment status, income, and personal and family history of diabetes and chronic diseases.

Anthropometrics profile Height, weight, waist and hip circumference.

Fasting blood glucose and serum insulin test Venous blood sample was obtained after an overnight fast of at least 8 h for fasting plasma glucose (FPG). Subjects were diagnosed to have diabetes if FPG was >=126 mg%. Plasma insulin was measured using the Radio Immunoassay procedure (RIA; Linco Research, Inc., St. Louis, MO), and glycosylated hemoglobin (HbA1c) was measured using the Thiobarbituric acid method.

Serum lipids Serum levels of total cholesterol, triglycerides and HDL-c were estimated using commercially available reagent kits (Randox Laboratory, San Francisco, CA, USA) on a semi-automated analyzer (das srl, palombara, Sabina, Italy). Value of LDL-c was calculated using the Friedewald's equation.

Definitions Overweight and obesity was defined as BMI ≥23 kg/m^2 and ≥25 kg/m^2 respectively [25]. Abdominal obesity was defined using the cut-off points of waist circumference (WC) as defined by NCEP, ATP III and also according to the Asian Indians and WHO Asian Pacific Guidelines specific cut-off points [26]. High waist-to-hip circumference ratio (W-HR) was defined as >0.90 in males and >0.80 in females [27]. Diabetes was labelled if FPG was >=126 mg% and/or a self-reported admission to the question "Have you ever been told by a doctor or health professional that you have diabetes or are on treatment for diabetes". Hypertension was defined as blood pressure >140/90 mmHg and/or self-reported admission for the question "Have you ever been told by a doctor or health professional that you have hypertension or high blood pressure?" Subjects were classified as the MetS according to the National Cholesterol Education Program, Adult Treatment Panel III (NCEP, ATP III criteria): (1) WC, men >102 cm, women >88 cm; (2) triglyceride level ≥150 mg/dL; (3) HDL cholesterol (HDL-C), men, <40 mg/dL, women, 50 mg/dL; (4) blood pressure ≥130/85 mmHg or known treatment for hypertension; and (5) fasting glucose level of ≥100 mg/dL or known treatment for diabetes. For each criterion, subjects received a score of 1 if present or 0 if absent, therefore allowing a range of 0–5. A score of ≥3 indicated MetS. International Diabetes Federation (IDF) criteria: central obesity for South Asians (WC, men >90 cm, women >80 cm), plus any two of the following four criteria: (1) triglyceride level ≥150 mg/dL; (2) HDL-C, men <40 mg/dL, women <50 mg/dL ; (3) blood pressure ≥130/85 mmHg or known treatment for hypertension; and (4) fasting glucose level of ≥100 mg/dL or known treatment for diabetes. For each criterion, subjects received a score of 1 if present or 0 if absent, therefore allowing a range of 0–5.

High-sensitivity C-reactive protein Elevated level of hs-CRP was defined as >1.0 mg/dL [28].

Statistical analysis

The first stage of analysis was to assess normal distribution of variables, descriptive statistics and differences by rural and urban Indians and data expressed as mean (SD) and proportions of the sample. The prevalence and mean (SD) of obesity, abdominal obesity, T2DM and the MetS was determined for rural and urban subjects. Analysis of Covariance (ANCOVA) (adjusted for age since there was difference in age distribution between the two groups) was used to compute all indicators. All analyses were done with the SPSS system (version 17.0). The sample size was based on power calculations for an unadjusted pair wise comparison of MetS and T2DM between rural and urban Indians. The power was set to 80% with a goal to detect differences in mean for our primary outcomes (type 1 error rate of 0.05, two-tailed significance tests). Calculations indicated that 956 participants would provide over 80% power to detect important rural urban differences in MetS, T2DM and CVD risk factors.

Results

Demographic & socioeconomic characteristics

The mean age was 39.5±13.9 y, 18–88 y (rural) and 42.6±11.8 y 18–77 y (urban). The majority of respondents (>75%) were married. Level of education varied between sites with 84.7% of rural Indians and 53.5% of urban Indians reporting a high school diploma or below. The modal income was ≥$200/ month for urban Indians and <$25/month for rural Indians. However, 86% of rural Indians and 9% of urban Indians had income below Rs 3,500/month (approximately $70.00). The majority of urban and rural Indians were employed or self-employed (56% and 53% respectively); 37% and 33% of urban and rural respondents were homemakers. Twenty four percent of urban respondents and 19% of rural respondents reported a family history of diabetes (includes siblings and parents). Thirty percent of rural Indians and 28% of urban Indians used some form of tobacco (sometimes or always; cigarettes, *beedi*, *gudka, snuff*, and tobacco with *Betel leaves*). Significantly more rural women (20%) used tobacco than urban women (5.2%).

Prevalence of pre-diabetes and diabetes

Urban Indians had significantly higher rate of diabetes and pre-diabetes (p=.002 and .008 respectively). Among the urban Indians, 22% of the respondents had pre-diabetes (Table 1) and 13.6% had T2DM (11.2% with known diabetes and 2.4% with undiagnosed diabetes). Approximately one-fifth (17.4%) of the T2DM patients did not know they had the disease; 50% and 16.6% of the undiagnosed cases had HbA1c greater than 7.0 and 8.0%, respectively. The prevalence of pre-diabetes and diabetes in the rural sample was 12.5% and 8.4% (6.3% with known

Table 1 Prevalence of diabetes and pre-diabetes in rural and urban Indians

Group	Urban Indians in New Delhi		Rural Indians in Tamil Nadu		Urban rural difference
	(*n*=508) Prevalence (% frequency)	(*n*=508) Blood glucose Mean (SD)	(*n*=574) Prevalence (% frequency)	(*n*=574) Blood glucose Mean (SD)	χ^2value (*p*-value)
Normoglycemia	64.6 (328)	84.6 (9.3)	79.1 (450)	82.7 (10.1)	2.56 (.011)
Prevalence. of pre-diabetes	21.9 (111)	108.2 (8.2)	12.5 (71)	105.3 (5.0)	2.67 (.008)
Gender					
Males	25.9 (66)	107.6 (6.9)	13.6 (24)	105.3 (5.76)	11.40 (.001)
Females	17.8 (45)	108.9 (9.7)	12.0(47)	105.2 (4.6)	
Age groups					
18–29 years	13.5 (15)	107.6 (3.3)	17.1 (12)	103.2 (2.3)	0.73 (.692)
30–39 years	27.9 (31)	109.5 (7.2)	24.3 (17)	105.1 (3.9)	
40–49 years	31.5 (35)	107.5 (7.5)	31.4 (22)	105.9 (6.4)	
50–59 years	18.0 (20)	108.5 (4.5)	14.3 (10)	105.6 (5.1)	
≥60 years	9.0 (10)	109.6 (7.6)	12.9 (9)	107.1 (5.5)	
Prevalence. of diabetes	13.6 (69)	144.2 (46.3)	8.4 (48)	180.7 (76.7)	3.19 (.002)
Known diabetes	11.3 (57)	142.6 (47.1)	6.3 (36)	182 (78.9)	
Undiagnosed diabetes	2.4 (12)	152.2 (43.5)	2.1 (12)	174.4 (72.3)	
Gender					
Males	13.3 (34)	141.0 (46.8)	10.4 (18)	199.4 (94.2)	1.59 (.207)
Females	13.8 (35)	147.3 (46.3)	7.6 (30)	169.4 (63.1)	
Age groups					
18–29 years	1.4 (1)	157.0 (0)	4.2 (2)	103.5 (31.8)	1.17 (.882)
30–39 years	14.5 (10)	124.5 (55.2)	14.6 (7)	111.4 (46.2)	
40–49 years	30.4 (21)	132.6 (26.9)	25.0 (12)	159.5 (59.4)	
50–59 years	29.0 (20)	155.8 (62.2)	29.3 (14)	185.5 (52.1)	
≥60 years	24.6 (17)	144.3(46.3)	27.1 (13)	206.3 (84.3)	

diabetes and 2.1% with undiagnosed diabetes) respectively. One-fourth (25.0%) of the T2DM individuals were unaware they had the disease; 91.7% and 49.8% of the undiagnosed cases had HbA1c greater than 7.0 and 8.0% respectively.

Mean HbA1c was significantly higher among rural Indians with T2DM than urban Indians ($p<.001$). Although no gender differences were noted in rural areas, urban males (7.27±1.24) had poor glycemic control ($p=0.90$) as compared to their female peers (6.80±0.99). The prevalence of diabetes in different age groups showed an increase with age while the prevalence of IFG did not change ($p<.001$).

Obesity, hypertension, and the metabolic syndrome

The mean BMI (kg/m^2) was 24.7±4.8 and 21.3±4.0 for urban and rural respondents respectively. According to the Asian criteria, 16% of urban Indians and 14% of the rural Indians were overweight and 50% of urban Indians and 18% of rural Indians were obese. The mean WC was 89.6±13.0 and 74.8±11.3 for urban and rural Indians respectively (Table 2). Using WC criterion, 66% of urban respondents and 24% of rural respondents had central obesity, significantly higher among females (76%, 27%) than males (57%, 17%) in both urban and rural areas. The mean WHR was 0.94±.09 and 0.84±.08 for urban and rural respondents respectively; WHR was elevated in 40% of urban & 16% of rural males and 43% of urban & 36% of rural females. Men and women living in urban areas had higher BMI, WC and W-HR, and were more likely to be overweight or obese than rural subjects (Table 3).

Prevalence of pre-hypertension (Urban, 38% systolic & 44% diastolic; Rural, 30% systolic & 20% diastolic) and hypertension (Urban, 20% systolic and 24% diastolic; Rural 9% systolic and 7% diastolic) was significantly higher ($p=.001$) among urban Indians than rural Indians, and increased with age ($p=.001$). There was a linear (significant) increase in systolic and diastolic blood pressure with the increase in fasting blood glucose levels. Approximately one-third (30.3%, males, 34.5%, females, 25.8%; $p=0.03$) of urban and 12.0% (males, 10.2%, females, 12.8%) of rural subjects were hypertensive. The

Table 2 Metabolic syndrome among rural and urban Indians by ATP/ NCEP III and IDF criteria

Metabolic syndrome	Indicator components	Total sample (n=508)		Male	Female	Gender difference[a]	Rural–urban difference[a]
		Mean (SD)	% at risk	(n=255)	(n=253)	T-value (p-value)	T-value (p-value)
Urban Indians				Male	Female	Urban Indians	
Blood pressure[b]	≥130/85 mmHg	123/82	42.9%	45.1%	40.6%	9.98 (0.327)	14.40 (<.001)
HDL[c]	≤40 mg/dl in M	46.93 (5.7)	40.0%	4.7%	68.0%	19.67 (<.001)	15.56 (<.001)
HDL[c]	≤50 mg/dl in W						
FBG[d]	≥100 mg/dl	97.82 (28.1)	35.6%	39.2%	31.9%	1.72 (0.085)	1.82 (.068)
Serum triglyceride[e]	≥150 mg/dl	146.50 (65.3)	40.0%	43.1%	36.8%	1.46 (0.143)	6.37 (<.001)
Waist circumference[f]	≥102 cm in M	89.61 (13.1)	38.6%	18.4%	58.9%	10.27 (<.001)	15.52 (<.001)
Waist circumference[f]	≥88 cm in W						
Waist circumference[g]	≥90 cm in M	74.75 (11.4)	66.3%	56.5%	76.3%	4.82 (<.001)	20.00 (<.001)
Waist circumference[g]	≥80 cm in W						
NCEP[b,c,d,e,f]	Met S%	30.8%		17.6%	44.2%	7.53 (<.001)	87.48 (<.001)
IDF[b,c,d,f,g]		39.2%		30.6%	47.8%	4.03 (<.001)	122.09 (<.001)
Rural Indians				Male (n=177)	Female (n=397)		
Blood pressure[b]	≥130/85 mmHg	115/73	18.6%	16.4%	19.6%	0.92 (0.355)	
HDL[c]	<40 mg/dl in M	52.04 (5.0)	27.9%	0%	40.5%	10.95 (<.001)	
HDL[c]	<50 mg/dl in W						
FBG[d]	≥100 mg/dl	95.42 (47.6)	21.2%	24.3%	19.8%	1.21 (0.225)	
Serum triglyceride[e]	≥150 mg/dl	121.17 (64.9)	22.8%	25.4%	21.6%	1.01 (0.311)	
Waist circumference[f]	≥102 cm in M	74.75 (11.4)	7.7%	3.4%	9.6%	2.58 (0.010)	
Waist circumference[f]	≥88 cm in W						
Waist circumference[g]	≥90 cm in M	74.75 (11.4)	23.9%	16.9%	27.0%	2.77 (0.006)	
Waist circumference[g]	≥80 cm in W						
NCEP[b,c,d,e,f]	Met S%	8.6%		4.6%	10.4%	4.48 (<0.001)	
IDF[b,c,d,f,g]		10.5%		6.2%	12.3%	2.49 (0.013)	

NCEP Criteria: metabolic syndrome is present if any three indicators [b,c,d,e,f] meet the criterion

IDF Criteria: Metabolic syndrome is present if central obesity and any two indicators[b,c,d,f,g] meet the criterion

[a] Significant difference between groups based on Student t-test

[b–g] Presents indicators of Metabolic Syndrome as defined by NCEP and IDF

[b] Blood Pressure ≥130/85 mmHg

[c] HDL <40 mg/dl in Men and <50 mg/dl in Women

[d] FBG ≥100 mg/dl

[e] Serum triglyceride ≥150 mg/dl

[f] Waist Circumference ≥88 cm in Women and ≥102 cm in Men

[g] Waist Circumference ≥80 cm in Women and ≥90 cm in Men

prevalence of the MetS was 30.8% and 8.6% among the urban and rural respondents respectively using the NCEP, ATP III definition, and 39.2% and 10.5% using the IDF definition (Table 2). The prevalence of the MetS is significantly higher among urban females (44.2% and 47.8% using NCEP, ATP III and IDF criteria, respectively) than males (39.2% and 47.8%, respectively); a similar pattern was noted among rural males and females (Table 2). In urban Asian Indians, the prevalence rates were higher for blood pressure (42.9%), serum triglyceride (40%), and low levels of HDL-C (40%; higher among females than males), and abdominal obesity (66.3%). The rates were lower in the rural Indians in all the individual MetS criteria, with the highest abnormalities noted in low levels of HDL-C (27.9%; higher among females than males), triglyceride (22.8%), and abdominal obesity (23.9%). These results show the prevalence of the MetS is significantly higher among urban Indians than rural Indians with significant gender differences in two of the five criteria (cholesterol and abdominal obesity). Both

Table 3 Average values of CVD risk by urban-rural habitat, gender, and blood glucose category

	Total (n=508) Mean (SD)	Male (n=254) Mean (SD)	Female (n=253) Mean (SD)	Gender difference p-value[a]	Normal FBG (n=328) Mean (SD)	IFG (n=111) Mean (SD)	Diabetes (n=69) Mean (SD)	DM category difference p-value[a]	Rural urban difference p-value[a]
Urban Indians									
Waist circumference (cm)	89.6 (13.0)	90.1 (13.0)	89.1 (13.2)	.412	87.6 (12.8)	90.9 (13.4)	97.3 (10.2)	<.001	<.001
Hip circumference (cm)	95.2 (9.0)	93.2 (8.1)	97.2 (9.4)	<.001	94.9 (9.05)	95.1 (9.6)	96.5 (7.60)	.427	<.001
WHR	0.9 (0.08)	1.0 (0.08)	0.9 (0.09)	<.001	0.9 (.08)	1.0 (.08)	1.0 (.07)	<.001	<.001
BMI	24.8 (4.8)	24.1 (4.4)	25.4 (5.1)	.003	24.2 (4.7)	25.1 (5.2)	26.9 (4.0)	<.001	<.001
Systolic BP (mm/Hg)	123.2 (19.2)	123.1 (18.3)	123.3 (20.1)	.922	121.0 (18.0)	121.6 (18.1)	136.3 (21.1)	<.001	<.001
Diastolic BP (mm/Hg)	81.7 (10.5)	82.7 (10.2)	80.7 (10.6)	.038	80.9 (10.4)	81.3 (10.3)	85.9 (10.1)	.001	<.001
Fasting Blood Glucose (mg/dl)	97.8 (28.0)	98.4 (26.9)	97.2 (29.3)	.634	84.6 (9.3)	108.2 (8.2)	144.2 (46.3)	<.001	.048
HbA1c[b]	7.0 (1.1)	7.3 (1.2)	6.8 (0.99)	.090	5.5 (0.47)	5.7 (0.54)	7.03 (1.14)	<.001	<.001
Total Cholesterol (mg/dl)	174.6 (40.8)	176.4 (44.9)	172.8 (36.1)	.311	173.0 (38.9)	172.4 (41.5)	185.3 (46.9)	.065	<.001
HDL-Cholesterol (mg/dl)	46.9 (5.8)	47.1 (6.0)	46.8 (5.5)	.527	46.8 (5.4)	47.6 (6.2)	46.2 (6.2)	.228	<.001
LDL Cholesterol (mg/dl)	98.6 (38.5)	99.0 (41.2)	98.2 (98.2)	.827	97.9 (38.4)	97.8 (40.1)	103.2 (36.7)	.580	<.001
Triglycerides (mg/dl)	146.5 (146.5)	152.6 (66.7)	140.4 (63.2)	.035	142.6 (61.6)	144.0 (61.1)	168.8 (82.7)	.009	<.001
C-Reactive protein	4.06 (4.0)	3.78 (4.2)	4.35 (3.8)	.112	3.6 (3.6)	4.7 (4.7)	5.4 (4.6)	.001	.002
Homocystein (Umol/L)[c]	19.72 (8.8)	21.81 (8.8)	17.5 (8.3)	0.042	19.7 (8.7)	20.7 (9.5)	19.0 (8.1)	.871	[c]
Lp a (mg/dl)[d]	7.44 (7.3)	6.92 (6.8)	7.98 (7.9)	.432	7.5 (7.6)	6.0 (5.8)	8.7 (7.3)	.472	[d]
Rural Indians									
Waist Circumference (cm)	74.8 (11.3)	78.8 (11.7)	72.9 (10.8)	<.001	73.0 (10.8)	80.2 (11.2)	83.8 (10.0)	<.001	
Hip Circumference(cm)	88.5 (8.7)	87.3 (7.7)	89.0 (9.1)	.022	87.6 (8.6)	92.6 (8.7)	91.3 (8.0)	<.001	
WHR	0.8 (0.08)	0.9 (0.07)	0.8 (0.07)	<.001	0.8 (.07)	0.9 (.07)	0.9 (.08)	<.001	
BMI	21.3 (21.0)	20.4 (3.5)	21.7 (4.1)	<.001	20.8 (3.8)	23.1 (4.3)	23.3 (3.7)	<.001	
Systolic BP (mm/Hg)	114.8(18.1)	114.8(17.1)	114.8(18.6)	.998	112.7 (17.7)	120.7 (18.3)	125.0 (15.8)	<.001	
Diastolic BP (mm/Hg)	72.6 (10.3)	73.5 (10.6)	72.2 (10.2)	.179	71.3 (10.2)	76.9 (9.7)	77.5 (8.9)	<.001	
Blood Glucose (mg/dl)	94.1 (36.3)	98.3 (48.1)	92.3 (30.4)	.072	82.7 (10.1)	105.3 (5.0)	180.7 (76.7)	<.001	
HbA1c[b]	7.9 (0.97)	7.9 (1.0)	7.9 (0.94)	.883	6.0 (.46)	6.3 (.56)	7.9 (.97)	<.001	
Total Cholesterol (mg/dl)	155.7 (30.1)	150.2 (28.7)	157.7 (30.4)	.006	151.9 (28.9)	168.8 (28.8)	167.9 (34.6)	<.001	
HDL-Cholesterol (mg/dl)	52.0 (5.0)	52.6 (4.9)	51.8 (5.2)	.072	52.3 (5.0)	51.5 (5.1)	50.7 (4.6)	.076	
LDL Cholesterol (mg/dl)	79.7 (31.6)	73.7 (27.7)	82.5 (32.8)	.002	77.4 (30.6)	90.4 (30.4)	85.8 (38.5)	.002	
Triglycerides (mg/dl)	121.2 (64.9)	122.8 (68.3)	120.4 (63.5)	.685	114.6 (53.9)	145.0 (95.6)	147.7 (87.8)	<.001	
C-Reactive protein[e]	2.5 (3.4)	9.6 (2.3)	3.0 (3.8)	.04	2.3 (3.4)	4.4 (3.9)	3.1 (1.3)	.221	

Number indicate mean values

FBG fasting blood glucose; *IFG* impaired fasting glucose

[a] Significant difference between groups based on Student t-test

[b] T2DM respondents (Rural = 48, Males = 18, Females = 30; Urban = 69, Males = 34, Females = 35)

[c] Analysis in a sub-sample of urban respondents (Total = 68; Males = 35, Females = 33)

[d] Analysis based on a sub-sample of urban respondents (Total = 117; Males = 59, Females = 59)

[e] Analysis in a sub-sample of rural respondents (Total = 78; Males = 27, Females = 51)

urban and rural females had significantly higher risk for abdominal obesity and low levels of HDL-C than their male peers.

C-reactive protein, other cardiovascular disease risk factors and relationship to glycemia

There was a high prevalence of total cholesterol (24.8%), high LDL-C (20.3%, >130 mg/dl), and hs-CRP (77%) in the urban respondents. Abnormal levels were lower among rural Indians: 9.5% total cholesterol, 7.8% high LDL, and 50% high hs-CRP. Urban males had significantly higher triglyceride levels than urban females while rural females had higher cholesterol and LDL cholesterol than rural males. Clinical and bioclinical parameters were significantly different among normoglycemic, IFG, and T2DM individuals in both rural and urban areas (Table 3). The rates of general and abdominal obesity, elevated hs-CRP, increased systolic and diastolic blood pressure and low HDL-C were higher among T2DM respondents compared to normoglycemic and IFG urban and rural Indians. Homocysteine levels (measured only among urban respondents) was higher among males than females (p=.04). There was a step-wise worsening of all metabolic parameters progressing from normal to IFG to T2DM, suggesting that Indians progress through the stages of dyglycemia to overt diabetes in a similar manner in both rural and urban India.

Discussion

This is the first comprehensive study to investigate T2DM, obesity, the MetS, hs-CRP and other CVD risk factors in a large population of urban and rural Indians using similar and standardized field measurements. The prevalence of T2DM (13.6%) and IFG (21.9%) and the MetS was high in urban areas, similar to other reports from other regions of India [5, 6, 10, 18, 29, 30]. The dysmetabolic phenotype of urban inhabitants is due to rapid nutrition transition, physical inactivity, and stress. The changing dietary profile over the last decade includes increased consumption of non-traditional 'westernized' foods and 'energy-dense' Asian Indian foods, more so in urban areas.

Interestingly, our study shows one of the highest prevalence of diabetes among all rural surveys in India [3, 21, 31]. Chow et al. [22] showed higher prevalence of T2DM in villages of south east India (13.2%). However, the authors used capillary blood glucose test and sample population consisted of people >30 y age (as opposed to >18 y in the current study). A high prevalence of diabetes (9.2%: [95% CI 8–10.5]) was shown in peri-urban villages in South India [32], however, self-reported diabetes (~3%) [33] and mean levels of fasting blood glucose and lipids [34] were similar in rural and peri-urban areas of north India. High and increasing prevalence of diabetes and other CVD risk factors in rural and urban residents is due to decreased consumption of traditional frugal diets, less labor-intensive work due to mechanization and commuting, and increased obesity [35, 36].

Worldwide studies have shown that Asian Indians develop diabetes a decade earlier than other ethnic groups [37]. Clustering of risk factors and diabetes are clearly evident even at a young age in the present study; 29% and 13.4% of the sample showing glucose intolerance (diabetes or pre-diabetes) in urban and rural areas, respectively in 18–39 y age group. Here again, the prime reason is that change from traditional diets to energy-dense, high saturated fat diets is occurring more rapidly and relentlessly in children and young adults. Importantly, the prevalence of pre-diabetes is highest in young urban and rural dwellers in this age group, providing opportunity for early application of preventive strategies. Further, as can be clearly seen from Table 3, most of these people with pre-diabetes are converting to diabetes, thus increasing prevalence of diabetes in later decades, with simultaneous decrease in the prevalence of pre-diabetes.

A notable feature was higher prevalence of the MetS in women as compared to men in both urban and rural areas, an observation reported from other regions of India [38]. This is primarily due to high prevalence of abdominal obesity and low levels of HDL-C in women. Two factors contribute to such a phenotype; first, largely sedentary lifestyle of females in India [39] and second, the inability to shed weight gained post-pregnancy contributed by inactivity and imbalanced diets during perinatal and postnatal periods. In rural western India, women who gained more weight during and after pregnancy were sedentary and had thicker skinfolds and showed more tendency for hyperglycemia after pregnancy [40]. Interestingly, in the current study, despite higher prevalence of the MetS in women, the prevalence of diabetes was almost similar to men. It is likely that if women with the MetS continue with the current imbalanced lifestyle, conversion to diabetes may occur rapidly, and thus prevalence of diabetes may also rise later.

High prevalence of generalized and abdominal obesity is clearly a precursor for development of cluster of risk factors comprising the MetS, and also increase subclinical inflammation. Typical Asian Indian phenotype of obesity consists of high body fat for comparatively low BMI, high subcutaneous and intra-abdominal fat, and ectopic fat deposition in liver [4]. Such high adipose tissue mass seen early in life, contribute importantly to the dysregulation of glucose-insulin-lipid metabolism.

Another interesting observation was elevated hs-CRP in urban and rural Indians. Among urban Indians, the average levels fall in the high cardiovascular risk category (>1) and is a concern given it mediates the relationship between body fat, other inflammatory markers, and coronary artery disease [41, 42]. Moreover, hs-CRP levels were higher in females, in both urban and rural areas. High levels of hs-CRP in Asian Indians may be due to the following two factors; excess adiposity, and second, possibly induced by subclinical infections. Whether these high levels of hs-CRP relate to excess cardiovascular risk in Asian Indians remains to be demonstrated.

High prevalence of pre-diabetes in urban and rural areas provides us opportunity to pursue lifestyle-based primary prevention strategies. Poor glycemic control due to late diagnosis and poor medical care among rural subjects who were mostly illiterates and unaware of diabetes and its consequences suggest that health education, early diagnosis and effective management are especially needed in rural areas of India. We have recently reported successful reduction of key risk factors (WC and blood pressure) and fasting blood glucose levels among pre-diabetic youth by 17%, pre-diabetic adults by 11%, and adults with T2DM by 25% in a 7 month community-based intervention in rural South India [11]. Intervention improved intake of fiber and protein besides lowering obesity in youth and adults.

In conclusion, there was a high prevalence of diabetes, MetS, obesity and low HDL in urban communities as compared to rural areas along with elevated levels of hs-CRP and homocysteine. There was a progressive worsening of all metabolic parameters from normoglycemic to IFG to T2DM among respondents that provide a firm basis for tailored prevention and intervention programs, an economically beneficial feature in such resource-constrained settings.

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