High Prevalence of Diabetes and Cardiovascular Risk Factors Associated With Urbanization in India

AMBADY RAMACHANDRAN, MD
SIMON MARY, BSC
ANNASAMI YAMUNA, PHD
NARAYANASAMY MURUGESAN, PHD
CHAMUKUTTAN SNEHALATHA, DSC

OBJECTIVE — To compare prevalence of diabetes, impaired glucose tolerance (IGT), impaired fasting glucose (IFG), and cardiovascular risk factors between a city, a town, and periurban villages (PUVs) in southern India and to look for temporal changes in the city and PUVs.

RESEARCH DESIGN AND METHODS — Subjects aged ≥20 years were studied in Tamilnadu, India, in Chennai (city, $n = 2{,}192$; 1,053 men and 1,138 women), Kanchipuram (town, $n = 2{,}290$; 988 men and 1,302 women), and Panruti (PUVs, $n = 2{,}584$; 1,280 men and 1,304 women) in 2006. Demographic, socioeconomic, and anthropometric details; blood pressure; physical activity; diet habits; and lipids were studied. Risk associations with diabetes were analyzed using multiple logistic regression analyses. Present and previous data in the city and the PUVs were compared.

RESULTS — Mean BMI, waist circumference, and family history of diabetes were significantly lower in the PUVs. The PUVs had a lower prevalence of diabetes (9.2 [95% CI 8.0–10.5], $P < 0.0001$) than the city (18.6 [16.6–20.5]) and town (16.4 [14.1–18.6]). Approximately 40% of subjects were newly diagnosed. Prevalence of impaired glucose tolerance (IGT) was higher ($P < 0.0001$) in the city (7.4 [6.2–8.5]) than in the town (4.3 [3.3–5.3]) and the PUVs (5.5 [4.6–6.5]). Prevalence of IFG was generally low. Age, family history, and waist circumference were significantly associated with diabetes, while physical activity was not. Overweight, elevated waist circumference, hypertension, and dyslipidemia were more prevalent in the city.

CONCLUSIONS — In the city, diabetes increased from 13.9 to 18.6% in 6 years and IGT decreased significantly. The town and city had similar prevalences; the PUVs had lower diabetes prevalence, but prevalence had increased compared with that in a previous survey. Cardiometabolic abnormalities were more prevalent in urban populations.

Diabetes Care 31:893–898, 2008

The rising prevalence of diabetes in India (1–8) and other developing countries (9–11) is chiefly attributed to urbanization. India will continue to have the largest number of diabetic subjects as a result of the rapid urbanization and economic development (2). In Chennai city, the prevalence had increased from 5.2% in 1984 to 13.9% in 2000 (12,13). In 2003, a further increase to 14.3% was reported (4). Prevalence of impaired glucose tolerance (IGT) was also high (13).

The epidemic of diabetes is seen even in rural areas undergoing socioeconomic development and urbanization (1,14). Diabetes shows an association with economic status (13,15).

Previous studies in Chennai (13) and in periurban areas (1,16) showed an IGT-to-diabetes ratio of >1, indicating a large pool of pre-diabetic subjects. Prevalence of IGT and its proportion to prevalence of diabetes will depend on the stage of the epidemic, the rapidity of conversion to diabetes, and the maximum attainable prevalence of diabetes in the population.

This study was done in three locations: a metropolitan city (Chennai), a town (Kanchipuram), and periurban villages (PUVs) (Panruti) in Tamilnadu. The primary aims were to see whether the prevalence of diabetes differed significantly between the town and city and whether the prevalence had increased since the last surveys in the city and villages. Second, the changes in diabetes and IGT prevalence and a comparative analysis of the risk associations with diabetes were studied. Prevalence rates of cardiovascular risk factors were also assessed.

RESEARCH DESIGN AND METHODS

— The survey was conducted from February to June 2006. By census definition, the selected PUVs are rural areas; however, due to proximity to town, the poplation has accessibility to urban facilities. Chennai city was chosen because data from previous surveys were available (3,12,13,16) and the temporal changes could be assessed. Kanchipuram is a typical town in India, 80 km away from Chennai. Panruti was selected because of its periurban characteristics.

For Chennai, the required sample was 1,712 individuals at 80% power with an α error of 5% and an assumed increase in prevalence from 13.5 to 17%. The required number in Kanchipuram was 1,422 individuals with an assumed change from 7 to 10%, and for Panruti the requirement was 1,275 individuals and an increase from 6.0 to 9.0%. In each area, samples larger than the calculated numbers were studied.

In all areas, a multistage, random selection of streets was made to get a fair representation of all socioeconomic strata, and all eligible members were studied. In the city, from the five corporation zones, areas were randomly selected. In the town, selection was based on the municipal wards, and in the villages census wards were used.

Subjects aged ≥20 years were invited

From the India Diabetes Research Foundation & Dr. A. Ramachandran's Diabetes Hospitals, Egmore, Chennai, India.

Corresponding author: Prof. A. Ramachandran, MD, PhD, India Diabetes Research Foundation, Chairman and Managing Director, Dr. A. Ramachandran's Diabetes Hospitals, 28 Marshall's Road, Egmore, Chennai 600008, India. E-mail: ramachandran@vsnl.com.

Received for publication 25 June 2007 and accepted in revised form 13 February 2008.

Published ahead of print at http://care.diabetesjournals.org on 12 March 2008. DOI: 10.2337/dc07-1207.

Abbreviations: FPG, fasting plasma glucose; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; PUV, periurban village.

Table 1—*Characteristics of the study population and prevalence of cardiovascular risk factors*

Variables	City	Town	PUVs	χ^{2*}	F*
n	2,192	2,290	2,584		
Education					
Illiterate	8.2	10.9	22.8	174.8	
School	68.0	77	71.7	—	
College	17.8	12.1	5.4	144.3	
Occupation					
Laborers	24.6	33.5	43.0	102.9	
Homemaker/business	48.0	51.4	48.0	—	
Executive/professional/clerical/student/retired/unemployed	27.5	18.8	9.1	192.1	
Physical activity					
Sedentary	29.9	17.9	10.3		201
Light	38.1	46.3	40.5		13.5
Moderate	14.0	12.4	19.0		33.5
Heavy	18.0	23.4	30.1		59.8
Diet					
Total calorie consumption (kcal)	2022 ± 354	1960 ± 332	1897 ± 304		62.3
Carbohydrates (%)	65.4 ± 5.0	66.8 ± 4.2	69.9 ± 3.2		752.9
Protein (%)	11.1 ± 1.2	10.4 ± 1.1	9.8 ± 0.9		956.4
Fat (%)	22.8 ± 5.0	21.3 ± 4.6	18.6 ± 2.9		627.9
Age (years)	38.2 ± 12.8	36.8 ± 11.6	38.0 ± 11.9		18.7
BMI (kg/m^2)	24.2 ± 4.7	23.7 ± 4.7	21.5 ± 4.2		249.3
Total cholesterol (mg/dl)	170.9 ± 50.1	159.9 ± 44.2	148.5 ± 44.6		139.5
Triglycerides (mg/dl)	134.1 ± 94.1	129.8 ± 81.7	119.7 ± 85.2		17.7
Systolic blood pressure (mmHg)	121.6 ± 13.2	119.6 ± 12.9	118.1 ± 11.9		47.6
Diastolic blood pressure (mmHg)	76.9 ± 9.4	77.0 ± 8.3	75.3 ± 8.4		31.2
Prevalence of cardiovascular risk factors					
BMI (≥25 kg/m^2)	895 (40.8)	818 (35.7)	504 (19.5)	151	
BMI (≥23 kg/m^2)	1289 (58.8)	1232 (53.8)	810 (31.3)	157	
Waist circumference (≥90 [men] and ≥85 cm [women])	799 (36.5)	736 (32.1)	499 (19.3)	107	
Hypertension ≥130/85mmHg	459 (20.9)	361 (15.8)	272 (10.5)	72	
Cholesterol ≥200 mg/dl	545 (24.9)	354 (15.4)	250 (9.7)	144	
Triglycerides ≥150 mg/dl	660 (30.1)	644 (28.1)	561 (21.7)	28	
HDL cholesterol <40 mg/dl	714 (27.4)	822 (31.5)	1070 (41.1)	28	

Data are *n* (%), means ± SD, or percent. $P < 0.0001$.

to participate; the response rate was 86% (7,066 of 8,216, of whom 3,321 were male and 3,745 female). The number of subjects was as follows: city, 2,192 (1,053 male and 1,139 female); town, 2,290 (988 male and 1,302 female); and PUVs, 2,584 (1,280 male and 1,304 female). Response rates were 82, 88, and 87%, respectively. Demographic and socioeconomic characteristics were similar between the responders and nonresponders. Participants gave informed consent, and study protocol was approved by the institution's ethics committee. Details on demography, anthropometry, medical history, education, monthly income, occupation, physical activity, and diet habits (24-h recall method) were filled in a computerized proforma by personal interview. Height was measured to the nearest centimeter using a tape stuck to the wall with the subject standing erect. Weight was measured to the nearest 0.1 kg using a digital bathroom scale. BMI was calculated as kilograms divided by the square of height in meters. Waist circumference, the smallest girth between the coastal margin and the iliac crest, was measured. The average of two blood pressure readings taken at a 5-min interval in sitting position was noted. Physical activity at work, during leisure time, and in household activities was recorded as minutes of activity per week and was divided into quartiles. Categories of income (INR/month) were as follows: low, <5,000; middle, 5,000–10,000; and high, >10,000. Total calorie consumption and percentage of proximate principles were calculated by a dietitian.

For known diabetic cases, fasting blood glucose (FPG) and 2-h postprandial blood glucose were measured. Others underwent a standard oral glucose tolerance test (17). Blood samples were kept in ice until plasma or serum was separated. Plasma for glucose collected in fluoride oxalate was separated within 2 h and assayed by glucose-oxidase peroxidase method using Hitachi autoanalyzer 912 (Roche Diagnostics, Germany). The coefficient of variation was <2%. Diabetes was diagnosed if FPG value was ≥126 mg/dl and/or 2-h postglucose was ≥200 mg/dl, impaired fasting glucose (IFG) if FPG was between 110–125 mg/dl, and IGT if the 2-h values were ≥140 mg/dl and <200 mg/dl with fasting values <110 mg/dl (17). Fasting serum lipid profile was estimated by standard enzymatic procedures (Roche Diagnostics). HDL cholesterol was estimated by the direct assay method.

BMIs ≥23 kg/m^2 and ≥25 kg/m^2 were considered to indicate overweight

Table 2—*Comparison of characteristics and prevalence of diabetes and IGT between surveys in the city and PUVs*

	City			PUVs		
	2000	2006	*P*	2003	2006	*P*
n	1,668	2,192		1,213	2,584	
Men/women	708/960	1,053/1,139		497/716	1,280/1,304	
Age (years)	44 ± 15	38.2 ± 12.8	<0.0001	41 ± 6	38.0 ± 11.9	<0.0001
BMI (kg/m^2)						
Men	22.6 ± 4.1	23.1 ± 4.1	0.012	20.7 ± 3.9	21.5 ± 3.9	<0.0001
Women	23.8 ± 4.8	25.3 ± 5.0	<0.0001	21.5 ± 4.2	21.5 ± 4.5	NS
Waist circumference (cm)						
Men	82.5 ± 10.0	83.8 ± 10.8	0.011	79.9 ± 10.7	79.1 ± 10.0	NS
Women	81.9 ± 12.3	83.7 ± 11.4	<0.0001	76.4 ± 10.6	76.8 ± 10.2	NS
BMI ≥25 kg/m^2						
Total	29.8	40.8	<0.0001	17.1	19.5	NS
Men	22.3	30.9	<0.0001	14.3	18.6	0.038
Women	35.4	50.0	<0.0001	19.1	20.4	NS
Prevalence (%)						
Diabetes	13.9	18.6	<0.0001	6.4	9.2	0.004
IGT	16.7	7.4	<0.0001	7.2	5.5	0.048

Data are means ± SD or percent unless otherwise indicated. NS, not significant.

and obesity, respectively. The normal cutoff values for waist circumference for men and women were ≥90 and ≥85 cm, respectively. Hypertension was diagnosed if blood pressure values were ≥130 and or ≥85 mmHg or if antihypertensives were being used. Cutoff values were as follows: cholesterol ≥200 mg/dl, triglycerides ≥150 mg/dl, and HDL cholesterol <40 mg/dl.

This survey and a similar one done in 2000 in the city were compared (12,13). Results for PUVs were compared with data in similar areas in 2003 (1). Age-specific prevalence of diabetes and IGT and anthropometric characteristics in the city in 2000 and 2006 and in the villages in 2003 and 2006 were compared. The comparisons were valid because the methodology was similar in all surveys.

In the national survey done in 2000 (13), Chennai was one of the six cities included. Subjects aged ≥20 years (n = 1,668, 708 of whom were male and 960 female; mean age 44 ± 15 years) were tested. Capillary whole blood glucose tested and quality check done in every 10th sample with 2-h plasma glucose (glucose oxidase–peroxidase method) showed good correlation between the two methods ($r = 0.91$, $P < 0.0001$). Glucose tolerance was categorized using the same criteria (17). In 2003, a group of villages 40 miles away from the city was studied (n = 1,213 [497 male and 716 female]; mean age 41 ± 6 years) (1). The screening methodology, anthropometric and biochemical measurements, and assessment of physical activity were performed with the methods used in the present survey.

Statistical analysis

Prevalence estimates were age standardized by direct standardization method using the census data (2001) for respective populations of ≥20 years in Tamil Nadu and were compared using Z statistics. Odds ratios (95% CIs) are reported. Means ± SD are reported for normally distributed variables. Group comparisons were done using Student's t test or ANOVA. Multiple logistic regression analyses (forward stepwise addition) were performed to identify the variables significantly associated with diabetes in the total group and in each area. Analysis was also done in the full dataset taking the areas into consideration. Two areas were compared by creating a dummy variable, which was PUVs because they were likely to have the lowest prevalence of diabetes. The dependent variable was diabetes versus normal glucose tolerance. Independent variables included in all models were age (units of 10), sex, family history of diabetes, BMI (units of 5), waist circumference (units of 5), monthly income (three categories), physical activity (four categories), education (three categories), and occupation (three categories). BMI showed significance only in the total group. Interactions of BMI and physical activity with age were not included.

A P value of <0.05 was considered as significant. SPSS for Windows (version 10.0; SPSS, Chicago, IL) was used.

RESULTS — Prevalence of diabetes in the city, town, and PUVs, respectively, was 18.6 ([95% CI 16.6–20.5]), 16.4 ([14.1–18.6]), and 9.2 ([8.0–10.5]). The PUVs had significantly lower prevalence vs. that in the city and town ($P < 0.0001$). Men had higher prevalence than women: city, men 20.9 (95% CI 17.9–23.9) and women 16.7 (14.2–19.3) (P = 0.014); town, men 17.1 (13.9–20.2) and women 15.9 (12.6–19.3); and PUVs, men 10.4 (8.6–12.3) and women 8.0 (6.2–9.7) (P = 0.041). Prevalence of IGT was as follows: city, 7.4 (6.2–8.5); town, 4.3 (3.3–5.3); and PUVs, 5.5 (4.6–6.5) (city vs. town $P < 0.0001$; city vs. PUVs P = 0.009). In the city, men had higher prevalence of IGT (men 9.4 [95% CI 7.6–11.3] vs. women 7.0 [5.4–8.6], P = 0.048). Prevalence of IFG was generally low in all areas (city, 3.5 [2.7–4.3]; town, 0.8 [0.4–1.3]; and PUVs, 1.9 [1.4–2.5]) (PUVs vs. city $P < 0.0001$; PUVs vs. town P = 0.002).

The proportion of illiterate subjects was the highest (22.8%) and college education was the lowest (5.4%) in the PUVs (Table 1). The majority in the PUVs were laborers or homemakers and were physically active. A lower percentage reported positive family history of diabetes in the PUVs (7.9 vs. 34.2% in the city and 30.2% in the town; $P < 0.0001$). Subjects in the PUVs had significantly lower anthropometric values, blood pressure, cholesterol, triglycerides, and HDL cholesterol than subjects in the city and the town (Table 1). Components of diet were

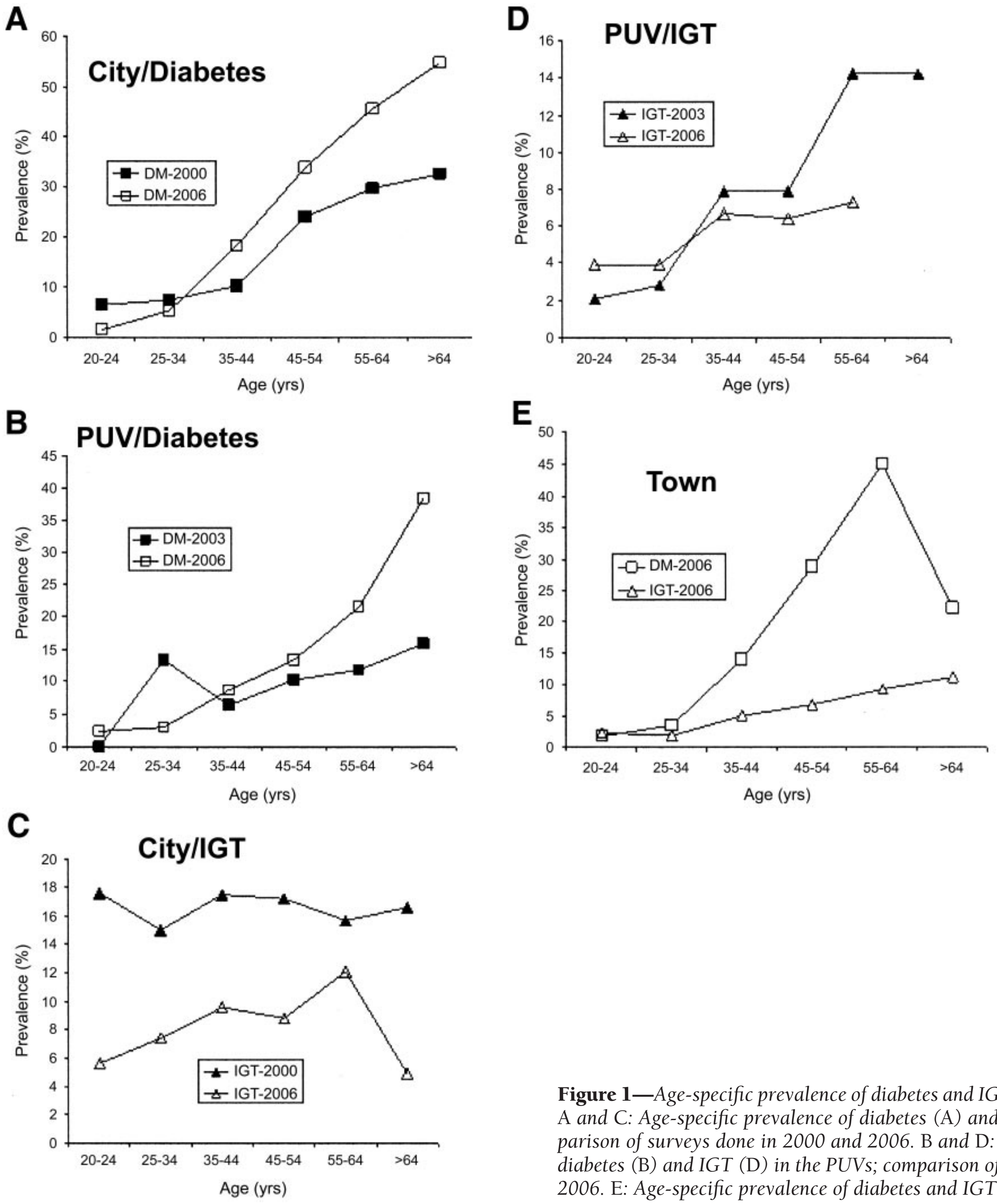

Figure 1—*Age-specific prevalence of diabetes and IGT in the three populations.* A *and* C*: Age-specific prevalence of diabetes* (A) *and IGT* (C) *in the city; comparison of surveys done in 2000 and 2006.* B *and* D*: Age-specific prevalence of diabetes* (B) *and IGT* (D) *in the PUVs; comparison of surveys done in 2003 and 2006.* E*: Age-specific prevalence of diabetes and IGT in the town in 2006.*

similar in all areas; rice was the staple food. Fat consumption was significantly lower ($P < 0.001$) in the PUVs than in other areas (Table 1).

Prevalence of overweight (≥23 kg/m^2) and obesity (BMI ≥25 kg/m^2) and prevalence of abdominal obesity were similar in the city and town and were significantly lower in the PUVs (Table 1). Obesity was more prevalent in women (city, men 30.9% vs. women 50%; town, 28.8 vs.40.9%; and PUVs, 18.6 vs. 20.4%; $P < 0.001$ in all). Hypertension, hypercholesterolemia, and hypertriglyceridemia were more prevalent in city dwellers, and low HDL cholesterol was more common in PUVs. More than 25% of the adults had some form of dyslipidemia in any area.

Table 2 shows a comparative analysis of the characteristics of study subjects in the same city (2000 and 2006) and in different PUVs of similar characteristics (2003 and 2006). In the city, BMI and waist circumference had increased in both sexes. In the PUVs, an increase in BMI and obesity occurred only in men. Prevalence of diabetes increased in both areas by 34% in the city and 43.8% in the PUVs (Table 2 and Fig. 1), while prevalence of IGT decreased (Fig. 1).

Prevalence of diabetes and IGT increased with age in all areas (Fig. 1). In the city, diabetes showed an increasing trend with age (Fig. 1). In subjects aged <35 years, the prevalence decreased in 2006. In all ages, IGT decreased in 2006—most markedly in those aged >64 years (Fig. 1). IGT showed an age-specific increase in

Table 3—*Risk variables for diabetes: results of multiple logistic regression analyses*

Variables	β	SE of β	*P*	OR (95% CI)
Total study population				
Age	0.90	0.04	<0.00001	2.46 (2.27–2.66)
BMI	0.12	0.06	0.0449	1.12 (1.00–1.27)
Positive family history	0.75	0.09	<0.00001	2.12 (1.77–2.53)
Waist circumference	0.34	0.05	<0.00001	1.40 (1.27–1.55)
Higher education	0.29	0.13	0.0238	1.34 (1.04–1.72)
City vs. PUV	0.61	0.10	<0.00001	1.84 (1.51–2.24)
Town vs. PUV	0.32	0.10	0.0020	1.38 (1.13–1.67)
City				
Age	0.97	0.06	<0.00001	2.64 (2.12–2.97)
Family history	0.79	0.14	<0.00001	2.20 (1.67–2.90)
Waist circumference	0.33	0.08	<0.0001	1.39 (1.19–1.63)
BMI	0.14	0.10	0.150	1.15 (0.95–1.40)
High income	0.31	0.15	0.0378	1.36 (1.11–1.83)
School education	−0.45	0.15	0.0025	0.64 (0.48–0.85)
Town				
Age	0.98	0.06	<0.00001	2.67 (2.14–3.00)
Family history	0.55	0.14	<0.0001	1.73 (1.13–2.28)
Waist circumference	0.34	0.09	<0.00001	1.40 (1.18–1.68)
BMI	0.05	0.10	0.624	1.05 (0.86–1.28)
PUVs				
Age	0.70	0.07	<0.00001	2.01 (1.76–2.31)
Family history	1.28	0.20	<0.00001	3.61 (2.43–5.32)
Waist circumference	0.31	0.10	0.001	1.36 (1.12–1.66)
BMI	0.20	0.11	0.072	1.22 (0.98–1.52)

The dependent variable was diabetes vs. normal glucose tolerance. Independent variables in all models were age, sex, family history, BMI, waist circumference, income, physical activity, occupation, and education.

both periods in the city and the PUVs. In the town, a significant fall in diabetes was seen in those aged >64 years (Fig. 1).

Mean age of diabetic subjects decreased significantly in the present survey (city, 49.6 ± 15.7 to 45.2 ± 11.3 years [$t = 4.12$, $P < 0.0001$]; PUVs, 53.2 ± 12.3 to 47.5 ± 10.8 years [$t = 3.9$, $P < 0.0001$]). In the city, the proportion of young diabetic subjects (aged ≤44 years) increased from 25 to 35.7% ($Z = 2.95$, $P = 0.003$), and in the PUVs it increased from 27.3 to 34.8% ($Z = 4.6$, $P < 0.0001$).

In the total study group, age, BMI, family history of diabetes, waist circumference, and higher education were significantly associated with diabetes (Table 3). Compared with the PUVs, the city and the town had higher association with diabetes. Age, family history of diabetes, and waist circumference were associated with diabetes in all areas. In the city, high income showed a positive association, while school-based education showed an inverse relation with diabetes. BMI showed an independent association with diabetes only in the total group.

CONCLUSIONS — This study reports changes in diabetes prevalence based on population surveys in Southern India. There was a significant increase in diabetes not only in the city but also in PUVs since the last surveys. The prevalence of diabetes in the city and the town was similar. IGT decreased in all areas, most markedly in the city, concomitant with an increase in diabetes.

High prevalence of diabetes in the city and the town and a rapid increase in the PUVs could largely be due to urbanization. The influence of urban facilities penetrating into PUVs was evident in two of our previous studies (1,16). Urbanization in India is expected to reach 46% by 2030 (11); therefore, in the future a larger contribution to the diabetic population would be from rural areas.

Large proportions of known diabetic subjects indicated improved availability of medical facilities and awareness among the population. Medical facilities in villages throughout India are not comparable.

Prevalence of diabetes in Chennai was reported as 14.6% in 2004 by another group (4). A further 27% increase seen in 2 years might be from a rapid conversion of IGT to diabetes and might partially explain the sharp fall in IGT. Previous studies in rural and semi-urban populations showed higher prevalence of IGT than diabetes (1,16,18). The present unexpected lower prevalence of IGT and IFG could be due to the vulnerability of the subjects to environmental changes resulting in rapid conversion to diabetes. In a prospective study of IGT, we noted a high conversion rate to diabetes (55% in 3 years) (19). Alternatively, a rapid deterioration of susceptible normoglycemic subjects to diabetes could be occurring, as suggested by Mohan et al. (4). An increase in diabetes, particularly in youth, poses a severe societal burden.

In the city, a relative increase in diabetes in subjects aged >64 years with concomitant reduction in IGT probably indicated a rapid conversion to diabetes. The reason for the reduction in diabetes in this age-group in the town is unknown.

Generally, diabetes is less prevalent in rural than in urban areas. A rapid transition was seen in several developing countries. In rural Bangladesh, diabetes increased from 2.3 to 6.8% in 5 years (20). In suburban and rural areas in Nepal (21), Pakistan (22), and South Korea (9), diabetes increased as a result of urbanization.

In PUVs, diabetic subjects had higher BMI and waist circumference but the levels were significantly lower than in the urban counterparts. Increased waist circumference is usually a good reflection of insulin resistance. waist circumference showed a stronger independent association with diabetes in all areas and might be suggestive of the significant contribution of insulin resistance to diabetes. Sedentary physical activity was not an independent contributor, probably due to narrow differences and also the confounding influences of age and occupation on the activity level. The observation of lower HDL cholesterol in the rural population, despite low waist circumference values was unexpected and needs further analyses.

Dyslipidemia was present in >25% in all areas. Cardiometabolic risk variables were more common in the city and the town. Increasing prevalence of glucose intolerance would contribute further to cardiovascular disorders. Ongoing lifestyle changes in PUVs are likely to enhance risk of diabetes and cardiovascular disease. Metabolic syndrome is common in this population (23,24). However, we noted that it was not a determinant of conversion rate of IGT to diabetes in this population (25).

The most unexpected findings in the study were the marked increase in prevalence of diabetes in the PUVs and a sharp reduction in IGT in all areas. One of the limitations was that comparisons were made of studies done in different PUV locations. Therefore, temporal changes and geographic differences could have contributed to the differences. Demographic and population characteristics of the study populations were similar in these areas. The possible influence of birth weight on glucose intolerance in the adult population could not be analyzed because birth weights were unavailable. Moreover, we would need to study the interaction of birth weight and nutritional factors in early development to draw valid conclusions.

An analysis of Early Detection of Type 2 Diabetes and IGT (DETECT-2) data from Finland, India (Chennai), the Pacific Islands, and North America showed that the combined effect of demography, age at onset, and mortality could explain only 22% of the observed 6.2% increase in diabetes over a 5-year period in developing regions (26). In other words, nearly 80% of the increase in prevalence remains unexplained.

This study did not explore the possible differences in susceptibility factors. Unexplored parameters such as stress might show significant differences between the urban and rural groups and should be a focus of later studies.

Acknowledgments— We are grateful to LifeScan for their support.

We thank M/s.Equations Research for helping to conduct the field survey. The help of Sathish Cholayil Kizhakathil, Selvam Sundaram, Lalitha Manjula, Jayanthi Jothikannan, Catherine Seeli, Muruganantham Manian, and Subhashini Lakshmanan is acknowledged. We thank Bobby Alex and Vijaya Lakshminarayanan for secretarial assistance.

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