Published in final edited form as:

Diabetes Res Clin Pract. 2007 August ; 77(2): 269–279. doi:10.1016/j.diabres.2006.12.005.

High prevalence of glucose intolerance even among young adults in south India

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Abstract

India is experiencing an epidemic of type 2 diabetes (DM) in young adults. This study reports the prevalence of glucose intolerance, and insulin profiles, and their relationship to lifestyle factors in 2,218 young adults (aged 26–32 years; 997 urban, 1221 rural) in South India. They were drawn from a cohort of 10,691 individuals born during 1969–1973 in Vellore and nearby villages. Family history, socio-economic status, physical activity and tobacco and alcohol use were recorded. Oral glucose tolerance tests were performed for diagnosis (WHO recommendations). Insulin resistance and secretion were derived from plasma insulin concentrations. Median BMI was 20.0 kg/m². The prevalence of type 2 DM and IGT was higher in urban than in rural subjects (3.7% vs 2.1%, $p=0.02$; 18.9% vs 14.3%, $p=0.002$ respectively), while prevalence of IFG was similar in urban and rural populations (3.8% vs 3.4%, $p=0.04$). Type 2 DM, IGT, IFG or higher insulin resistance and increment were associated with higher socio-economic status (more household possessions) and higher percentage body fat, body mass index and waist/hip ratio. Insulin increment was lower in men with higher alcohol consumption. Our data suggest high levels of glucose intolerance in young rural and urban adults highlighting an urgent need for preventive action to avert a public health catastrophe in India.

Keywords

Impaired glucose tolerance (IGT); impaired fasting glycaemia (IFG); type 2 diabetes mellitus (Type 2 DM); insulin increment; insulin resistance

INTRODUCTION

The projected estimate of 79 million adults aged 20 years with diabetes mellitus in India by the year 2030 is alarming [1]. The expected 151% increase in prevalence is far in excess of the predicted global rise of 114% [1]. Economic growth, industrialization, urbanisation and

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Competing interests: None

improved nutrition in India over the last 20-30 years have ushered in the detrimental effects of obesity and reduced physical activity. These may compound a pre-existing susceptibility arising from genetic predisposition [2], undernutrition in early life [3-5] and other factors.

The rise in prevalence of type 2 DM is viewed as an urban phenomenon [3], with large Indian cities showing four-fold higher rates than rural populations [6,7]. Data from smaller towns is lacking. In contrast, the prevalence of impaired glucose tolerance (IGT) and impaired fasting glycaemia (IFG), considered pre-diabetic, appears to be common in both urban and rural communities [6,7]. This suggests a high burden of incipient disease in rural populations.

IGT in developing countries is observed increasingly in young adults [3,8]. The majority of people with Type 2 DM in developing countries is aged 45-64 years, in contrast to 65 years in developed countries [1]. In a recent Indian survey, 56% of individuals with Type 2 DM were diagnosed between 40 and 59 years of age and 25% between 20 and 39 years [6].

In the present study, we examined glucose tolerance and insulin profiles in a sample of young adults aged 26-32 years from a population-based birth cohort of individuals born during 1969-1973 in Vellore town and nearby rural villages. We recorded their anthropometry, current place of residence (urban or rural), physical activity, socio-economic status, smoking habits and alcohol consumption. The aim of this paper is to assess the current prevalence of glucose intolerance in the rural and urban Indian setting and to examine the relationship of glucose intolerance and insulin profiles to lifestyle factors in this population. The relationships of Type 2 DM and IGT, and measures of insulin resistance and secretion, to size at birth and childhood growth will be reported separately.

MATERIALS AND METHODS

Original cohort

The study sample was from an original cohort of people born during 1969-1973 in North Arcot (now Vellore) district in Tamilnadu State, southern India and measured at birth as part of a research study [9-11]. Twenty four wards in Vellore town, representing a broad range of socio-economic status, and 25 out of 41 contiguous villages from the Kizhvazhithunaiyankuppam rural community near Vellore were selected [9-11]. All non-pregnant married women of reproductive age (total 20,626) were recruited (Figure 1). The weight and height of the women and their husbands were recorded at recruitment. The women were visited regularly by trained health workers to record menstrual dates and to follow up pregnancies. Of 14,147 pregnancies, there were 3,359 fetal deaths, 97 multiple births and 10,691 single live births. Of the latter, 47% of babies were born outside the study area and were unavailable for neonatal examination. All the others were measured (birth weight, length, head and chest circumferences) at birth and later in infancy (1-3 months of age), childhood (6-8 years) and adolescence (10-15 years).

Present study

All subjects who were singleton births and had complete parental and birth measurements recorded (n=4,092) were considered eligible. A total of 2,572 individuals (24% of the original cohort) living in the study area, nearby villages, towns or major cities (Chennai and Bangalore) were traced and contacted at home by trained health workers. The rural villages in our study currently range in population from 22 to 5249 (data from 1997 census) and are between 12 and 25 kms distant from Vellore town. The families subsist predominantly through agriculture as there are no major industries in the region. The study protocol was approved by the Institutional Research and Ethics Committees of the Christian Medical

College, Vellore, and written informed consent was obtained from the participants. The study was carried out during 1999-2002.

Questionnaire

A questionnaire was administered by trained interviewers to record previous history of diabetes mellitus requiring treatment, family history of diabetes in a first-degree relative, parental consanguinity, parity (women only), physical activity, smoking habits and alcohol consumption. Work-related activity was classified on a 6-point scale ranging from 'almost entirely sedentary' to 'heavy physical work'. Additional time spent in domestic activities (eg. sweeping, washing clothes) and leisure activities (eg. jogging, yoga) was recorded. Distances walked and cycled with and without a load were recorded and converted into approximate times spent in these activities. Periods of time for each activity were then multiplied by metabolic constants derived from the relative energy expenditure of different activities [12] and summed to arrive at a physical activity score. Subjects were defined as current tobacco users or non-users, including all forms of tobacco (smoking, chewing and snuff). Frequency and quantity of consumption of beer, wine and spirits were recorded and converted into units of alcohol per week (1 unit = beer 574 ml, wine 125 ml or 23 ml spirits). Occupation and education level were each recorded in 7 groups from no occupation or no schooling (group 1) to professional level. The number of material possessions from a list of 17 household items (gas-stove, bicycle, electricity, fan, electric mixer, radio, television, cable television, satellite television antenna, telephone, wet grinder, washing machine, air cooler, air conditioner, computer, motorized 2-wheeler, car) was obtained as a measure of socio-economic status.

The reliability of the physical activity score was determined in 40 cohort subjects (rural 20; urban 20) by two raters. The same subjects were reassessed after two weeks by the same rater. The inter- and intra-rater reliability using intra-class correlation coefficient (95% CI) were 0.81(0.71-0.92) and 0.86(0.78-0.94) respectively.

Clinic investigations

Subjects from the town and cities were invited for examination at the main hospital and those from the villages to the rural clinic after an overnight fast of 10-12 hours. Pregnant women were advised to attend 6-10 months after delivery. Body weight, waist and hip circumferences, skinfold thickness (biceps, triceps, subscapular and supra-iliac), height, and blood pressure (using an automated device OMRON 711, USA) were recorded. Throughout the study all body measurements were made according to standard protocols by one of two measurers, who were trained, and their methods standardized, before the start of the study. Percentage body fat was calculated using the equation: $[(4.95/\text{density}) - 4.50] \times 100$, where density was calculated from the sum of four skinfolds [13,14].

Fasting venous blood samples were obtained for measurement of plasma glucose and insulin and serum lipid concentrations (total, low density lipoprotein (LDL) and high density lipoprotein (HDL) cholesterol and triglycerides). Subjects were then given a standard oral glucose load of 75g anhydrous glucose in 300 ml water. After the glucose load, blood samples were collected at 30 and 120 minutes for measurement of plasma glucose (in sodium fluoride tubes) and plasma insulin concentrations (in EDTA tubes). All blood samples were analyzed in the main hospital, whence the samples from the rural clinic were transported in ice packs and centrifuged within 3 hours of collection. Samples for plasma insulin estimation were preserved at -80°C until analysis.

Biochemical estimations

Plasma glucose concentrations were measured using glucose oxidase/peroxidase methods, and serum lipid concentrations using commercial enzymatic kits (Roche Diagnostics, Germany) on a Hitachi 911 autoanalyser (USA). Plasma insulin concentrations were measured by immunoradiometric assay using Coat-a-count kits (Diagnostic Products Corporation, USA). The quality of these measurements was assessed using Roche Precinorm and Precipath controls for glucose and lipids and BioRad Lyphocheck Immunoassay controls for insulin. Intra- and inter-assay coefficients of variation for insulin estimations were 8.0-14.5% and 8.2-13.0% respectively.

Definitions

We defined obesity and overweight using International Obesity Task Force criteria for Asian populations (BMI ≥ 25 kg/m² and ≥ 23 kg/m²) [15]. Type 2 DM was defined as a fasting glucose concentration ≥ 7.0 mmol/l (≥ 126 mg/dl) or a 120-minute concentration ≥ 11.1 mmol/l (≥ 200 mg/dl), IGT as a fasting plasma glucose concentration <7.0 mmol/l (<126 mg/dl) and a 120-minute value ≥ 7.8 mmol/l (≥ 140 mg/dl) but <11.1 mmol/l (<200 mg/dl), and IFG as a fasting plasma glucose value of ≥ 6.1 mmol/l (≥ 110 mg/dl) and <7.0 mmol/l (<126 mg/dl) [16]. Relative insulin resistance was calculated using the homeostasis model assessment (HOMA) equation [17]. The 30-minute insulin increment [(insulin concentration at 30 minutes – fasting insulin concentration)/glucose concentration at 30 minutes] was used as a measure of insulin secretion [18,19].

Statistical methods

Positively skewed variables (weight, waist and hip circumferences, skinfold thicknesses, insulin and triglyceride concentrations, insulin resistance and increment values) were log transformed, while BMI and fasting glucose were inverted, to attain normality. Student's t tests and Chi squared tests were used to compare anthropometric, lifestyle and biochemical variables between sexes and between rural and urban populations. The relationships of lifestyle and anthropometric factors to IFG, IGT or Type 2 DM, and insulin resistance and the 30-minute insulin increment, were assessed using multiple logistic or linear regression as appropriate with all variables included simultaneously. Analyses were performed using SPSS 11.5 and STATA 8.0 programmes.

RESULTS

Of the target sample of 2,572 re-traced men and women (Figure 1), 2,218 (86%) agreed to take part in the study. Their mean $\pm$ SD age was 28 (1.2) years. Median (inter-quartile range) BMI was 20.0 (17.8 – 23.2) kg/m². Hindus formed the majority (94%), while Muslims and Christians were 5% and 1% respectively.

Differences between the subjects studied and the original cohort

To examine the representativeness of our study sample (n=2,218), we compared their data with that of the remainder (n=8,452) from the original cohort. Fewer of their mothers were primiparous (studied 12%; not studied 20%; $p<0.001$). There were statistically significant differences in the education level of the head of the household at the time of their birth, but these were small (illiterate: 9% and 9%; attended school ≥ 5 standard: 30% and 24%; 6-11 standard: 23% and 27%; college graduate: 3% and 4%) ($p<0.001$). There were no significant differences in parental weight and height. Subjects studied were heavier at birth (2,813g vs. 2,762g; $p=0.002$) and 3 months of age (4,859g vs. 4,704g; $p<0.001$), but there were no significant differences in measurements during childhood and adolescence.

Urban-rural differences in anthropometry and lifestyle factors

Men and women living in Vellore town or a major city (Bangalore or Chennai) had higher BMI, skinfold thicknesses, percentage body fat and waist/hip ratios, and were more likely to be overweight or obese than rural subjects (Table 1). Rural subjects were more physically active, less likely to have a positive family history of diabetes, and more likely to have consanguineous parents. Few women used tobacco or drank alcohol, while percentages of men who were tobacco users were 40%, 51% and 37% in rural, town and city dwellers respectively. Alcohol consumption was higher in urban (mild – 36%, moderate – 19%, heavy – 6%) than rural (mild – 28%, moderate – 16%, heavy – 6%) men. A higher percentage of men in the town or cities worked in non-manual skilled, managerial and professional jobs, compared with rural men, but educational status was similar. In contrast, urban women were better educated than rural women, and a higher percentage described themselves as housewives. Rural subjects had fewer household possessions than town and city dwellers. For all these factors, the differences between town and city were small and for further analyses we combined these into one (urban) group.

Type 2 DM, IGT and IFG

The overall prevalence rates of Type 2 DM, IGT and IFG were 2.8%, 16.3% and 3.6% respectively. Among 62 individuals with diabetes, 8 (13%) were diagnosed prior to the study but only one required insulin. The prevalence of Type 2 DM and IFG was similar in men and women ($p=0.7$), while that of IGT was higher in women ($p=0.05$). Table 2 shows the results of the oral glucose tolerance test and prevalence of glucose intolerance in the men and women studied. Among men, the prevalence of Type 2 DM was lowest in the rural area (1.5%), higher in Vellore town (4.3%), and highest in large cities (5.2%). In women, it was similar in all three settings (2.7%, 2.4% and 3.4%). The prevalence of IGT was high in both sexes in all three locations, but was higher among women in Vellore town (23%) and major cities (20.2%) than in the villages (15.1%). There was a significantly higher prevalence of diabetes in the major cities than in Vellore town ($p=0.001$) while the prevalence of IFG was higher in Vellore ($p<0.001$). There was no difference in the prevalence of IGT between Vellore and major cities ($p=0.7$).

Relationships of lifestyle and anthropometric factors to Type 2 DM, IGT and IFG

In both sexes, Type 2 DM, IGT and IFG were associated with urban residence, a higher number of household possessions, a positive family history of diabetes, and higher percentage body fat, BMI and waist/hip ratio (Table 3). It was not related to subscapular/triceps skinfold ratio. In a multivariate analysis, number of household possessions, higher percentage body fat and increased waist/hip ratio remained significant factors.

Insulin resistance (HOMA) and secretion

Insulin resistance was highest in subjects with Type 2 DM (median = 2.5), lower in those with IGT (1.1) and lowest in those with normal glucose tolerance (1.0). Thirty-minute insulin increment was lowest in subjects with Type 2 DM (median = 8.3), higher in those with IGT (12.8) and highest in those with normal glucose tolerance (13.5). Insulin resistance and increment were positively correlated in subjects with normal glucose tolerance (Spearman correlation coefficient $r=0.30$), and in those with IGT ($r=0.37$), but only weakly in those with Type 2 DM ($r=0.14$). Rural subjects had a lower median insulin increment (11.7) than urban individuals (15.9) ($P<0.001$). Men had a lower median insulin increment (12.1) than women (14.3) ($p=0.002$).

Associations with lifestyle factors were similar in both sexes (Table 3). In univariate analysis, higher insulin resistance was associated with younger age, more household

possessions, a higher education level, less physical activity, a positive family history of diabetes, a higher percentage body fat, BMI and waist/hip ratio, but it was not related to alcohol intake or subscapular/triceps ratio. In addition, higher insulin resistance was noted in non-tobacco users. In a multivariate analysis, younger age, rural residence, more household possessions, less physical activity, positive family history of diabetes, and increased waist/hip ratio were significantly associated with insulin resistance. Insulin secretion showed several relationships that were similar to those with insulin resistance but insulin increment was lower in rural subjects and inversely related to alcohol intake.

DISCUSSION

We studied 2,218 young adults from an original cohort born in rural and urban areas of Vellore and traced to their current place of residence, either in the rural villages near Vellore, in Vellore town, or in large industrialized cities nearby.

The original birth study was population-based, but the sampling frame for the follow-up study was limited to those with complete birth data, who could be traced. Main reasons for having incomplete birth data would have been late notification of the birth to the study team or migration of the mothers to their parents' homes for the delivery. The next stage at which there was a major loss to follow-up was in the tracing process, and here we would lose subjects who moved out of the study area. We cannot quantify the effects of these factors. However, we think it is unlikely that in a large sample, the effects of the lifestyle factors, which we considered *within* the sample, would be systematically biased. Some individuals with known Type 2 DM or symptoms may have been more willing to take part, which could lead to a misleadingly high prevalence. On the other hand, others may have avoided participation for fear of being branded as having disease. For all these reasons, we consider that the study sample is fairly representative.

Even at the young age of 26-32 years, 3.6% had IFG, 16.3% had IGT and 2.8% had Type 2 DM. The prevalence of Type 2 DM was similar in both sexes; but IGT was higher in women. Urban residence, a positive family history, and higher percentage body fat and waist/hip ratio, were associated with a higher risk for developing Type 2 DM/IGT/IFG. Several risk factors associated with insulin resistance and increment may simply reflect the high correlation between them. In men, higher alcohol consumption was associated with a lower 30-minute insulin increment.

Urban living is clearly associated with an increased risk of disease [7] and is reflected in our data even from a small town like Vellore. We compared our data with a 1988-89 study of subjects of similar age from nearby Chennai, which included urban and rural Dravidian subjects of similar age [7]. The prevalence of Type 2 DM was considerably higher in our study (urban men 4.6% v 1.1%, urban women 2.7% v 0.6%, and rural men 1.5% v 1.9%, rural women 2.7% v 0%). The prevalence of IGT was also higher (urban men 16.4% v 6.8%, urban women 21.9% v 7.9%, rural men 13.5% v 5.6%, rural women 15.1% v 1.9%). Although comparisons between different communities should be made with caution, these data suggest an alarming rise in glucose intolerance over about 14 years, especially in rural women. Two recent surveys of the prevalence of diabetes and IGT in urban Indian populations show similar prevalence rates and a worrying shift to the left in the age of onset of disease [6, 20]. The prevalence of type 2 DM in the Vellore urban group was comparable to that in a similar birth cohort in New Delhi [21] (3.7 vs. 4.4%). IGT in rural Vellore was higher (14.3%) and urban Vellore even higher (18.9%) than in New Delhi (10.8%). This may reflect rapid urbanization occurring in the villages and smaller towns of India.

As in other studies from India, the low BMI of our subjects was impressive. At any level of BMI, Asians have a higher percentage body fat than white Caucasians. Percentages of overweight and obese individuals were approximately twice in the urban group as compared to the rural. Measures of adiposity were strongly related to the risk of Type 2 DM or IGT or IFG. Even a unit change in BMI significantly increases the risk of developing glucose intolerance. An optimistic corollary is that even minor weight loss has been shown to reduce the prevalence or postpone the advent of Type 2 DM [22,23].

Earlier data from India on insulin resistance and secretion [24] were from a small study sample. We used the HOMA equation and 30-minute insulin increment widely employed in epidemiological studies as proxies for insulin resistance [17] and secretion respectively [18,19]. IGT and Type 2 DM were associated with increased insulin resistance and a reduced 30-minute insulin increment. Similar relationships have been reported elsewhere, and are consistent with the concept that T2DM is the result of insulin resistance followed by β -cell exhaustion [25,26]. As expected, insulin resistance was related to body fat. Unexpected findings were that insulin resistance was higher in younger men and women, and, after adjusting for their lower body fat and other lifestyle factors, higher in rural than urban subjects. However, it should be emphasized here that the absolute values of insulin resistance between the rural and urban groups by univariate analysis were not significantly different ($p=0.2$, Table 3). We speculate that these rural individuals have a lower muscle mass than the urban cohort, resulting from nutritional deprivation in early life or the phenomenon may reflect rapid transition occurring in the rural environment currently.

The positive association observed between a higher 30-minute insulin increment and percentage body fat is likely to reflect the close correlation between insulin resistance and secretion. The pancreas matches increasing insulin resistance by increasing insulin secretion until β -cell failure supervenes. However, higher alcohol consumption was associated with a lower insulin increment in men (few women drank alcohol). Alcohol may hasten β -cell failure and the deterioration from IGT to Type 2 DM. Alcohol is a well-recognised cause of chronic pancreatitis, and in turn Type 2 DM. Several large studies in other populations have suggested that mild-moderate alcohol intake *protects* against Type 2 DM but heavy alcohol consumption may be a risk factor [27-30]. Alcohol consumption could be a preventable cause of Type 2 DM in Indian populations and this requires further research. Another unexpected finding was a lower mean 30-minute insulin increment in rural compared with urban men and women, despite similar or higher levels of insulin resistance. This was true in all glucose tolerance groups, and was not explained by the lifestyle factors we recorded. There may be environmental factors associated with rural living that impair insulin secretion.

In conclusion, our data showed a remarkably high prevalence of Type 2 DM and IGT at a young age in rural and urban southern Indian communities and suggest rapidly increasing disease in both settings. While this situation is alarming, it provides an opportunity for intervention programmes to help young adults to lead healthier lives. The longitudinal growth measurements recorded for this cohort from birth to adolescence offer the potential to further understand the causation of IGT and Type 2 DM. The effect of these early variables in the Vellore cohort will be presented in a subsequent paper.

Acknowledgments

This study was supported by the British Heart Foundation. We are thankful to all the subjects who participated in the study, field and laboratory staff, and R Selvakumar for their kind co-operation.

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^s Urban = Vellore town

Figure 1.
The Vellore birth cohort

Table 1
 Characteristics of study population according to current place of residence (rural, Vellore town or major city)

		RURAL		VELLORE TOWN		MAJOR CITIES		p value ^b	p value ^c
		Men (n=617)	Women (n=604)	Men (n=372)	Women (n=334)	Men (n=172)	Women (n=119)		
Age (years)	mean (SD)	28.0 (1.0)	28.4 (1.0)	28.1 (1.2)	28.5 (1.0)	29.0 (1.1)	29.1 (1.1)	<0.001	<0.001
Education	n (%)								
Illiterate		35 (5.7)	105 (17.4)	17 (4.6)	47 (14.1)	3 (1.7)	7 (5.9)		
Primary school		68 (11.0)	151 (25.0)	57 (15.3)	68 (20.4)	19 (11.1)	21 (17.7)		
Middle school		145 (23.5)	146 (24.2)	88 (23.7)	75 (22.5)	28 (16.3)	18 (15.1)		
High school		242 (39.2)	159 (26.3)	102 (27.4)	73 (21.9)	63 (36.6)	36 (30.3)		<0.001
Vocational qualification		66 (10.7)	29 (4.8)	46 (12.4)	31 (9.3)	29 (16.9)	18 (15.1)		
Graduate		43 (7.0)	11 (1.8)	43 (11.6)	22 (6.6)	15 (8.7)	13 (10.9)		
Professional grade		18 (2.9)	3 (0.5)	19 (5.1)	18 (5.4)	15 (8.7)	6 (5.0)		
Occupation	n (%)								
None/housewife		2 (0.3)	284 (47.0)	7 (1.9)	202 (60.5)	–	93 (78.2)		
Not classified		21 (3.4)	22 (3.6)	3 (0.8)	13 (3.9)	2 (1.2)	1 (0.8)		
Partially skilled		205 (33.2)	196 (32.5)	86 (23.1)	59 (17.7)	14 (8.1)	7 (5.9)		
Manual skilled		309 (50.1)	89 (14.7)	170 (45.7)	34 (10.2)	97 (56.4)	8 (6.7)		<0.001
Non-manual skilled		45 (7.3)	8 (1.3)	67 (18.0)	11 (3.3)	30 (17.4)	3 (2.5)		
Managerial		26 (4.2)	5 (0.8)	30 (8.1)	11 (3.3)	22 (12.8)	5 (4.2)		
Professional		9 (1.5)	–	9 (2.4)	4 (1.2)	7 (4.1)	2 (1.7)		
Household possessions ^a		4 (2–6)	4 (1–6)	7 (4–10)	6 (4–9)	7 (4–9)	7 (4–10)	<0.001	0.2
Current tobacco use	n (%)	248 (40.2)	19 (3.2)	190 (51.1)	6 (1.8)	63 (36.6)	1 (0.8)	0.02	<0.001
Alcohol intake (units per week)	n (%)								
None (0)		311 (50.4)	604 (100)	153 (41.1)	333 (99.7)	63 (36.6)	119 (100)		
Mild (7)		172 (27.9)	–	120 (32.3)	1 (0.3)	75 (43.6)	–		
Moderate (8–21)		97 (15.7)	–	68 (18.3)	–	33 (19.2)	–	<0.001	<0.001
Heavy (>21)		37 (6.0)	–	31 (8.3)	–	1 (0.6)	–		
Physical activity score ^a		1470 (906–1938)	1932 (1495–2552)	1292 (755–1734)	1672 (1287–2172)	1460 (869–1892)	1994 (1516–2344)	<0.001	<0.001

		RURAL		VELLORE TOWN		MAJOR CITIES		P value ^b	P value ^c
		Men (n=617)	Women (n=604)	Men (n=372)	Women (n=334)	Men (n=172)	Women (n=119)		
Family history of diabetes	n (%)	67 (10.9)	57 (9.4)	104 (28.0)	76 (22.8)	33 (19.2)	33 (27.7)	<0.001	0.2
Parental consanguinity	n (%)	262 (42.5)	245 (40.6)	101 (27.2)	108 (32.3)	49 (28.5)	43 (36.1)	<0.001	0.3
Height (cms)	mean (SD)	165.7 (6.3)	153.7 (6.0)	167.3 (6.9)	153.2 (5.6)	167.5 (6.8)	154.5 (5.2)	0.001	<0.001
Body mass index ^a	(kg/m ²)	19.4 (17.6–21.8)	19.0 (17.2–21.5)	21.0 (18.8–23.9)	22.1 (18.9–25.1)	21.3 (19.0–23.8)	22.0 (18.8–24.9)	<0.001	0.8
23	n (%)	105 (17.1)	107 (17.7)	122 (32.8)	145 (43.5)	58 (33.9)	47 (40.5)	<0.001	0.04
25	n (%)	51 (8.3)	52 (8.6)	63 (16.9)	87 (26.1)	27 (15.8)	27 (23.3)	<0.001	0.01
Waist circumference ^a	(cm)	74.0 (68.5–81.0)	67.1 (62.3–73.6)	79.1 (71.0–88.0)	73.9 (66.7–80.4)	77.9 (71.6–87.6)	73.0 (65.6–79.1)	<0.001	<0.001
Waist/hip ratio	mean (SD)	0.88 (0.06)	0.79 (0.05)	0.89 (0.07)	0.79 (0.05)	0.88 (0.06)	0.79 (0.05)	<0.001	<0.001
Skinfold measurements									
Subscapular ^a	(mm)	11.7 (8.8–19.3)	18.3 (12.7–27.4)	15.6 (10.6–25.6)	27.6 (17.4–38.4)	15.3 (11.0–24.5)	27.3 (16.7–37.2)	<0.001	<0.001
Triceps ^a	(mm)	7.2 (5.3–12.0)	11.0 (8.0–16.5)	10.1 (6.1–15.0)	17.8 (11.5–25.2)	10.6 (7.4–14.7)	18.4 (11.9–24.9)	<0.001	<0.001
SS/TR ratio	mean (SD)	1.7 (0.5)	1.7 (0.5)	1.8 (0.6)	1.6 (0.5)	1.7 (0.5)	1.5 (0.4)	0.01	<0.001
Body fat %	mean (SD)	16.1 (6.9)	28.5 (6.9)	19.1 (7.0)	33.1 (6.7)	19.6 (5.9)	32.9 (6.7)	<0.001	<0.001

^aMedian (IQR).^bComparison of rural v urban (urban=Vellore town and major cities combined).^cComparison of men v women.

Table 2

Results of oral glucose tolerance test and prevalence of glucose intolerance according to current place of residence (rural, Vellore town or major city)

	RURAL		VELLORE TOWN		MAJOR CITIES		P value ^b	P value ^c
	Men (n=617)	Women (n=604)	Men (n=372)	Women (n=334)	Men (n=172)	Women (n=119)		
Glucose (mmol/l) Fasting ^a	5.4 (5.1-5.7)	5.3 (5.0-5.6)	5.5 (5.1-5.8)	5.4 (5.1-5.8)	5.4 (5.0-5.8)	5.4 (5.1-5.7)	<0.001	0.003
120 min ^a	5.9 (5.2-7.0)	6.3 (5.4-7.3)	6.2 (5.2-7.4)	6.6 (5.7-7.7)	6.4 (5.6-7.5)	6.5 (5.7-7.7)	<0.001	<0.001
Insulin (mIU/ml) Fasting ^a	5.7 (2.9-9.2)	3.3 (1.2-5.9)	6.7 (3.1-11.4)	3.6 (1.4-7.0)	2.9 (0.6-6.8)	2.3 (0.8-5.5)	0.2	<0.001
120 min ^a	18.8 (11.6-34.4)	18.9 (9.8-32.0)	26.1 (16.3-49.9)	26.6 (11.8-46.7)	21.1 (9.1-37.6)	22.0 (11.3-33.0)	<0.001	<0.001
Insulin resistance ^a	1.4 (0.7-2.2)	0.8 (0.3-1.4)	1.6 (0.7-2.9)	0.9 (0.3-1.7)	0.7 (0.1-1.6)	0.5 (0.2-1.4)	0.4	<0.001
Insulin increment ^a	10.7 (5.1-19.3)	12.5 (6.8-22.4)	16.7 (7.2-34.2)	16.8 (8.1-33.4)	11.8 (5.1-24.2)	16.9 (9.2-30.4)	<0.001	<0.001
Type 2 DM n (%)	9 (1.5)	16 (2.7)	16 (4.3)	8 (2.4)	9 (5.2)	4 (3.4)	0.02	0.7
IGT @ n (%)	83 (13.5)	91 (15.1)	60 (16.1)	75 (22.5)	29 (16.9)	24 (20.2)	0.002	0.05
IFG n (%)	23 (3.7)	19 (3.2)	19 (5.1)	14 (4.2)	2 (1.2)	3 (2.5)	0.4	0.7

^aMedian (IQR).^bComparison of rural v urban (urban=Vellore town and major cities combined).^cComparison of men v women.

@ Among 362 with IGT, 41 had IFG in addition.

Table 3
Multiple regression analyses for Type 2 DM/IGT/IFG, insulin resistance (HOMA) and 30-minute insulin increment

	Type 2 DM/IGT/IFG					Insulin Resistance (HOMA)					Insulin Increment				
	Model adjusted for sex only			Multivariate model ^a		Model adjusted for sex only			Multivariate model ^a		Model adjusted for sex only			Multivariate model ^a	
	Odds ratio	95% CI	P value	Odds ratio	95% CI	P value	$e\beta$	95% CI	P value	$e\beta$	95% CI	P value	$e\beta$	95% CI	P value
Age (years)	1.01	0.93–1.11	0.8	0.97	0.88–1.07	0.5	0.75	0.71–0.79	<0.001	0.74	0.71–0.78	<0.001	0.97	0.92–1.01	0.1
Place of current residence (rural=0, urban=1)	1.47	1.20–1.79	<0.001	1.06	0.84–1.33	0.6	0.92	0.82–1.04	0.2	0.85	0.75–0.96	0.01	1.39	1.26–1.55	<0.001
Number of household possessions	1.10	1.07–1.13	<0.001	1.07	1.03–1.11	0.001	1.04	1.02–1.06	<0.001	1.03	1.01–1.05	0.01	1.06	1.05–1.08	<0.001
Education level (7 groups)	1.07	1.00–1.14	0.06	0.92	0.85–1.00	0.06	1.08	1.03–1.12	<0.001	1.02	0.98–1.07	0.3	1.08	1.04–1.12	<0.001
Physical activity score (5 groups)	0.96	0.89–1.03	0.2	1.01	0.94–1.09	0.8	0.93	0.89–0.97	<0.001	0.95	0.92–0.99	0.02	0.95	0.91–0.98	0.005
Current tobacco use (No=0, Yes=1)	0.87	0.66–1.15	0.3	0.85	0.62–1.16	0.3	0.80	0.68–0.93	0.004	0.92	0.78–1.09	0.3	0.90	0.78–1.03	0.1
Alcohol intake (4 groups)	1.12	0.96–1.30	0.1	1.17	0.99–1.39	0.07	0.96	0.88–1.05	0.3	1.09	1.00–1.20	0.06	0.87	0.80–0.94	<0.001
Parental consanguinity	1.05	0.85–1.29	0.7	1.18	0.95–1.46	0.1	1.03	0.91–1.16	0.6	1.03	0.91–1.15	0.7	0.94	0.84–1.04	0.2
Family history of diabetes (No=0, Yes=1)	1.70	1.33–2.18	<0.001	1.26	0.96–1.64	0.1	1.34	1.14–1.56	<0.001	1.21	1.03–1.41	0.02	1.17	1.02–1.34	0.03
Body fat (%)	1.07	1.06–1.09	<0.001	1.04	1.03–1.06	<0.001	1.04	1.03–1.04	<0.001	1.00	1.00–1.01	0.4	1.03	1.03–1.04	<0.001
BMI (kg/m ²)	1.11	1.09–1.14	<0.001		Not included		1.07	1.05–1.08	<0.001		Not included		1.06	1.05–1.07	<0.001
Waist/hip ratio	1.06	1.04–1.08	<0.001	1.03	1.01–1.05	<0.001	1.03	1.02–1.04	<0.001	1.04	1.03–1.05	<0.001	1.03	1.02–1.04	<0.001
Subscapular/triceps ratio	1.07	0.88–1.29	0.5		Not included		0.99	0.89–1.11	0.9		Not included		0.90	0.81–0.99	0.04

In addition to sex, all the variables listed in the left-hand column (except where stated) were included simultaneously in the regression model.

Estimates of effect size are given as odds ratios + 95% confidence intervals for the binary outcome (IGT/DM) and as exponentiated β -coefficients ($e\beta$) for the continuous logged variables insulin resistance and increment, to enable comparison of the effects of the different predictor variables. Exponentiated β values indicate the percentage change in the outcome per unit change in the predictor. For example an $e\beta$ of 0.75 (95% CI: 0.71 to 0.79) indicates that the outcome decreases by 25% (95% CI: 29% to 21%) per unit change in the predictor.