Prevalence and risk factors of diabetes in a community-based study in North India: The Chandigarh Urban Diabetes Study (CUDS)

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Abstract

Aims. – As there have been few studies in North India of the prevalence of diabetes within the past decade, this study aimed to assess the prevalence and risk factors associated with diabetes in the North Indian city of Chandigarh.

Methods. – This cross-sectional survey of 2227 subjects (response rate: 94%), aged ≥ 20 years and representative of the urban Chandigarh population, was conducted from April 2008 to June 2009. Fasting plasma glucose (FPG) and 2-h plasma glucose (2hPG) following ingestion of 75 g of anhydrous glucose equivalent were estimated by glucometer in all subjects except those with known diabetes, in whom only FPG was measured. Diagnosis of diabetes was based on 1999 WHO criteria. The collected prevalence data was age-standardized for the Chandigarh population, and multivariate logistic-regression analysis was used to correlate risk factors with the presence of diabetes.

Results. – A total of 349 subjects (15.7%, 95% CI: 13.9–16.9) were diabetic, comprising 210 (9.4%) with known diabetes and 139 (6.2%) with newly diagnosed diabetes, and 344 (15.4%, 95% CI: 14.3–17.1) subjects were prediabetic. The age-standardized prevalence of diabetes and prediabetes were 11.1% (95% CI: 9.7–12.4) and 13.2% (95% CI: 11.8–14.6), respectively. Age ≥ 50 years, a family history of diabetes, BMI ≥ 23 kg/m², abdominal obesity and hypertension were significantly and positively associated with the presence of diabetes, whereas educational status was negatively associated with diabetes (P < 0.001 for all).

Conclusion. – The age-standardized prevalence of diabetes and prediabetes were 11.1% and 13.2%, respectively. Older age, family history of diabetes, obesity and hypertension were positively related, while educational status was negatively related, to the presence of diabetes.

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Keywords: Diabetes; Epidemiology; Urban population; India; Fasting plasma glucose; Oral glucose tolerance test; Prediabetes; Prevalence

Résumé

Prévalence et facteurs de risque de diabète de type 2 : étude en population urbaine de l’Inde du Nord : Chandigarh Urban Diabetes Study (CUDS).

Objectifs. – Peu d’études portant sur la prévalence du diabète ont été réalisées en Inde du Nord au cours de la dernière décennie. Cette étude visait à évaluer la prévalence et les facteurs de risque associés à la présence d’un diabète dans une ville du Nord de l’Inde, Chandigarh.

Méthodes. – Enquête transversale en population sur un échantillon pris au hasard réalisée d’avril 2008 à juin 2009 chez 2227 sujets âgés de 20 ans et plus, avec un taux de réponse de 94 %. La glycémie à jeun (FPG) et 2 h après 75 g de glucose (2hPG) ont été dosées avec un lecteur de glycémies capillaires, sauf chez les patients qui avaient un diabète déjà connu, chez qui seule la glycémie à jeun a été dosée. Le diagnostic du diabète a reposé sur les critères OMS de 1999. Les données de prévalence recueillies dans la présente étude ont été normalisées selon l’âge pour la population de Chandigarh. Une analyse multivariée par régression logistique a été utilisée pour chercher une corrélation entre les facteurs de risque et la présence d’un diabète.

Résultats. – Un diabète était présent chez 349 sujets (15,7 % ; IC à 95 % 13,9–16,9), dont 210 (9,4 %) avaient un diabète déjà connu. Trois cent quarante-quatre sujets (15,4 % ; IC 14,3–17,1) avaient un prédiabète. La prévalence du diabète et celle du prédiabète normalisées selon l’âge étaient respectivement de 11,1 % (IC 9,7–12,4) et 13,2 % (IC 11,8–14,6). L’âge (≥ 50 ans), les antécédents familiaux de diabète, un IMC ≥ 23 kg/m², une obésité abdominale et une hypertension artérielle étaient associés de manière significative avec l’existence d’un diabète, une corrélation inverse étant mise en évidence entre le niveau d’éducation et le diabète (P < 0,001 pour toutes les corrélations).

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1. Introduction

The prevalence of diabetes is increasing worldwide and is expected to reach 4.4% by 2030 [1]. India, China and the US are the three countries with the largest numbers of people with diabetes. According to the US National Institutes of Health (NIH), the prevalence of diabetes was 7.8% across all ages, and 10.7% in those aged ≥ 20 years in 2007 [2] while, in the UK, it was reported to be 4.3% in those aged 10–79 years in 2005 [3] and, in China, 5.5% in those aged 35–74 years in 2001 [4]. Estimates of diabetes prevalence in India have varied widely (from 4.3% to 19.5%) [5–12], and most of the studies were from southern parts of the country. Two nationwide studies – the Prevalence of Diabetes in India Study (PODIS), involving a population aged ≥ 25 years in 1999–2002 [5], and the National Urban Diabetes Study (NUDS), which had a study population aged ≥ 20 years in 2000 [6] – reported a diabetes prevalence of 4.3% (urban: 5.6%; rural: 2.7%) and 12.1%, respectively. However, these studies were fraught with methodological problems, including selection of subjects, criteria used to define diabetes and dosages of glucose administered. Chandigarh, a North Indian city, is unique among other Indian states in that it has a high literacy rate, the highest income per capita and a standard of living that approaches those of many Western countries. However, as it has an urban population of 76%, the prevalence data from the rest of the country cannot be extrapolated to this population. To the best of our knowledge, there has been only one study of the prevalence of diabetes in Chandigarh, conducted in 1995–2000 [7]. It relied mostly on history of diabetes, with oral glucose tolerance tests (OGTTs) performed in only a small number (n = 188) of subjects. Thus, the true prevalence of diabetes could not be estimated.

Known risk factors for diabetes include increasing age [1,5,11], family history of diabetes [1,5,11], obesity [11], hypertension [13], coronary artery disease [14], physical inactivity [5,15], socioeconomic status [1] and level of education [15]. Only a few studies have examined the risk factors associated with the presence of diabetes. Therefore, the present study aimed to examine the prevalence and risk factors associated with diabetes in urban Chandigarh.

2. Methods

2.1. Study subjects

This cross-sectional study of a representative sample of more than 2000 people living in urban Chandigarh was conducted from April 2008 to June 2009. According to the 2001 census, the total population of Chandigarh was 900,635 at the time. Assuming a diabetes prevalence of 10%, achieving an absolute value < 1.7% (95% CI: 8.3–11.7) required a sample size of 1250 subjects. To further strengthen the data, the study was expanded to include more than 2000 subjects. Urban Chandigarh is a well-planned city with 56 sectors. Stratified systematic random sampling was used to select the study population. The entire city was divided into three zones according to socioeconomic status, using two straight major roads as dividers. Two sectors within each zone were selected by simple random sampling. Subsequently, within each sector, a subsector and one house was again selected by simple random sampling, using standard methods. All individuals ≥ 20 years of age were consecutively screened from the selected house onwards until 375 individuals had been surveyed in that sector; this was the number of subjects needed from each sector to obtain the target sample of 2000 people. The prevalence data collected from the present study were age-standardized for the size of the Chandigarh population according to the 2001 census.

2.2. Sampling procedures

The objectives and procedures to be followed for the study were explained in detail by the study investigator, who visited each household the day before the data and blood samples were to be collected. Informed and written consent was obtained from all eligible individuals. An overnight fast of 8–14 h, with no alcohol consumption on the previous night, was requested and ensured before proceeding with the tests. Both fasting plasma glucose (FPG) and 2-h plasma glucose post-glucose load (2hPG) were measured in all eligible subjects, except for patients with known diabetes, in whom only FPG was collected. Known diabetes mellitus (KDM) was defined as diabetes previously diagnosed by a physician and/or the use of antidiabetic drugs, while newly diagnosed diabetes mellitus (NDM) was defined as diabetes detected for the first time during the study.

All subjects were asked to take 75 g of anhydrous glucose in 200 mL of water within 5 min (equivalent to 82.5 g of Glucon-D [Heinz-India Pvt Ltd, Mumbai, India]). Subjects were asked not to indulge in any physical activity or to smoke during the study period. Capillary plasma glucose was estimated in the fasting state and at 2 h from the time that glucose administration began, using the OneTouch Ultra 2 blood glucose meter (Johnson & Johnson, Mumbai) by the gluco kinase method. The glucometer was calibrated every day, using the standard solution supplied by the manufacturer, and used only if the values were within the defined range.

External quality control was also ensured by sending every 10th sample, stored in a vial with oxalate–sodium fluoride, to the reference laboratory for glucose estimation with an auto analyzer (Hitachi 902, Tokyo, Japan), using the glucose oxidase–peroxidase method, within 4–6 h of sampling. The
correlation coefficients for FPG and 2hPG values for capillary plasma glucose were 0.94 and 0.81, respectively, from the laboratory.

2.3. Data collection and anthropometry

For all study subjects, a detailed standardized form was filled out and included: demographic data; anthropometric measurements; personal history of coronary artery disease (CAD), including a documented history of angina, myocardial infarction, percutaneous transcoronary angioplasty and/or coronary artery bypass graft surgery; cerebrovascular accidents (CVA), including a history of transient ischaemic attacks and/or documented stroke; and family history of diabetes. Smokers were defined as those who had smoked ≥ 100 cigarettes in their entire lifetime and those currently smoking every day or on some days [16]. Alcohol consumers were defined as those who consumed ≥ 12 drinks a year, with each drink containing ≥ 14 g of alcohol [17]. Height was measured twice with a standard stadiometer to the nearest centimeter (cm), and weight by a digital weighing machine to the nearest 0.1 kg. Waist circumference (WC) was measured three times at the midpoint between the bottom edge of the rib cage and upper edge of the iliac crest, and the mean calculated for the analysis. Blood pressure was measured with a mercury sphygmomanometer in the right arm in sitting position after 5 min of rest. Socioeconomic status was determined according to the modified Kuppuswamy scale [18], and physical activity by the World Health Organization (WHO) validated Global Physical Activity Questionnaire (GPAQ) [19]. Educational status was evaluated on the basis of an interview with the study subjects.

For the diagnoses of diabetes and prediabetes, the 1999 WHO criteria for capillary plasma glucose [20] were used. Diabetes was defined as FPG ≥ 126 mg/dL (≥ 7 mmol/L) or 2hPG ≥ 220 mg/dL (≥ 12.2 mmol/L), or both. Prediabetes was diagnosed as the presence of isolated impaired fasting glucose (IFG), defined as FPG ≥ 110 mg/dL (≥ 6.1 mmol/L) and < 126 mg/dL (< 7 mmol/L), and 2hPG < 160 mg/dL (< 8.8 mmol/L) or isolated impaired glucose tolerance (IGT), defined as 2hPG ≥ 160 mg/dL (≥ 8.8 mmol/L) and < 220 mg/dL (< 12.2 mmol/L) and FPG < 110 < 120 mg/dL (< 6.1 mmol/L), or both IFG and IGT (as defined above).

HbA1c was measured from the samples available for 1972 subjects, using the D-10 Haemoglobin Analyzer (Bio-Rad Laboratories) and Diabetes Control and Complications Trial/National Glycohaemoglobin Standardization Program (DCCT/NGSP) reference intervals.

2.4. Statistical analysis

The study data, collected via a pretested questionnaire, and the results of the laboratory analyses were examined for completeness and consistency. Statistical analysis used SPSS, version 15.0 for Windows, software (SPSS Inc, Chicago, IL, USA). Descriptive statistical analysis was carried out for all variables, and expressed as means ± SD, medians and percentages. Associations between two continuous variables were assessed using Pearson’s correlation coefficients, and considered statistically significant when the P value was < 0.05. Student’s t test was used to compare differences between means, and the chi-square test to examine differences between proportions at a significance level of 0.05. Variables found to be significantly associated with outcome variables on univariate analysis were analyzed by multivariate regression analysis. The age-standardized prevalence of diabetes was calculated with the Chandigarh population, according to the 2001 census, using the direct-standardization method. Age-specific rates from the study population were applied to the standard population and, for each age group; the expected prevalence was obtained for the standard population. The prevalences for all age groups were then added together and divided by the total standard population to obtain the age-standardized prevalence.

3. Results

In the present study, 2368 individuals were approached, of whom 123 were non-responders. However, the latter’s baseline characteristics were similar to those of the study subjects in terms of age, gender distribution and body mass index (BMI). Of the remaining 2245 subjects, 18 were excluded because no 2hPG data were available, leaving 2227 subjects evaluable for the study with a response rate of 94% (Fig. 1). The baseline characteristics of the final study population are shown in Table 1: 85% were in the age group 20–60 years; mean BMI was 25.0 ± 4.7 kg/m²; the majority (84%) belonged to the upper socioeconomic group; and 61% indulged in light physical activity. A significant number had a family history of hypertension (24%) and diabetes (22.6%).

In addition, 349 (15.7%) subjects had diabetes, of whom 210 (9.4%) had KDM and 139 (6.2%) had NDM, with a crude prevalence of 15.7% (95% CI: 13.9–16.9) and age-standardized prevalence of 11.1% (95% CI: 9.7–12.4), and no gender predilection (P = 0.83). The age-standardized prevalence of KDM and NDM was 6.6 and 4.5%, respectively, with the latter constituting 40% of the total diabetes prevalence. Of 139 subjects with NDM, 35 (25%) had an isolated FPG ≥ 126 mg/dL (≥ 7 mmol/L), 53 (38%) had an isolated 2hPG ≥ 220 mg/dL (≥ 12.2 mmol/L) and 51 (37%) had both abnormal values. Using FPG alone would have underdiagnosed diabetes in 38% of cases. In the KDM group, 18.6% were following lifestyle modifications, but past medical records were consistent with a diagnosis of diabetes; their current mean FPG was 145.5 ± 55.9 mg/dL and HbA1c was 8.06 ± 1.9%. The crude prevalence of prediabetes included isolated IFG, isolated IGT, and both IFG and IGT, and was 5.8%, 6.6% and 3.1%, respectively (total: 15.5%; 95% CI: 14.3–17.1), and the age-standardized prevalence was 5.2%, 5.6% and 2.4%, respectively (total: 13.2%, 95% CI: 11.8–14.6; Table 2). Furthermore, the HbA1c cutoff level of 6.1% had a sensitivity and specificity of 81% for each, while the cutoff of 6.5% had a sensitivity and specificity of 65% and 89%, respectively, for diagnosing diabetes [21].

The prevalence of diabetes showed a rising trend with increasing age (P < 0.001); with a peak prevalence (n = 205) in those aged 40–60 years. Patients with diabetes were older (55 vs. 38 years old) and had greater mean weight, BMI, WC and
blood pressure than those with a normal glucose profile (all $P<0.001$). A family history of diabetes was significantly more frequently found in those with vs. without diabetes (25% vs. 12.8%; $P<0.001$). The prevalence of diabetes in those engaging in light, moderate and heavy physical activity was 16.6%, 14.6% and 9.4%, respectively ($P=0.12$). However, the prevalence of diabetes in the various socioeconomic strata did not significantly differ (upper: 14.7%; upper-middle: 16%; middle: 15.6%; and upper-lower: 10.5%; $P=0.54$).

On multivariate logistic-regression analysis, age $\geq 50$ years, family history of diabetes, hypertension, BMI $\geq 23$ kg/m$^2$, WC $\geq 90$ cm in men and $\geq 80$ cm in women, CAD and socioeconomic status had odds ratios (95% CI) of 4.5 (3.6–5.8), 2.5 (1.9–3.2), 2.4 (1.8–3.1), 2.2 (1.5–3.1), 1.6 (0.9–2.7) and 1.2 (0.9–1.6) for the presence of diabetes (Table 3). Physical activity (OR: 0.8, 95% CI: 0.6–1.0; $P=0.052$) and level of education (OR: 0.9, 95% CI: 0.8–1.0; $P<0.001$) were both significantly and negatively related to the presence of diabetes.

### 4. Discussion

The present study of 2227 subjects showed an age-standardized prevalence of diabetes and prediabetes of 11.1% (crude prevalence: 15.7%) and 13.2% (crude prevalence: 20.6%). The results are presented in Table 2.

### Table 2

<table>
<thead>
<tr>
<th>n (total n = 2227)</th>
<th>Crude prevalence (%)</th>
<th>Age-standardized prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>349</td>
<td>15.7</td>
</tr>
<tr>
<td>KDM</td>
<td>210</td>
<td>9.4</td>
</tr>
<tr>
<td>NDM</td>
<td>139</td>
<td>6.2</td>
</tr>
<tr>
<td>Prediabetes</td>
<td>344</td>
<td>15.4</td>
</tr>
<tr>
<td>IFG</td>
<td>130</td>
<td>5.8</td>
</tr>
<tr>
<td>IGT</td>
<td>146</td>
<td>6.6</td>
</tr>
<tr>
<td>IFG + IGT</td>
<td>68</td>
<td>3.1</td>
</tr>
<tr>
<td>Normal glucose</td>
<td>1534</td>
<td>68.9</td>
</tr>
</tbody>
</table>
Hypertension (16.9% and 83.1%, respectively) [6], PODIS (28.9% and 71.1%, respectively) [6], Kashmir study (8.09% and 6.1%, respectively) [12] and NUDS (14% and 12.1%, respectively) [6], whereas earlier studies from Chennai [9], where the prevalence of IGT was 10.2% compared with 14.3% for diabetes. In earlier studies, the prevalence of IGT exceeded that of diabetes, whereas later studies showed an opposite trend, suggesting rapid transition from IGT to diabetes.

Age, family history of diabetes, hypertension, BMI ≥ 23 kg/m², WC and educational status were all significantly related to the presence of diabetes. In the NUDS, the OR for age, family history of diabetes and waist-to-hip ratio were 1.78, 3.09 and 1.22, respectively [6]. Also, the strong association of a family history of diabetes with the presence of diabetes in our present study points to a genetic predisposition, as shown elsewhere [5,12], whereas individual levels of education were significantly and negatively associated with diabetes, as also shown previously [24,25], as the better-educated are more likely to undergo annual health check-ups and engage in regular physical activity. This also explains why the NDM rate was lower than the KDM rate in the present study. Physical activity increases insulin sensitivity and may even prevent diabetes [26]. However, in our present study, physical activity had only borderline statistical significance (P = 0.052) for a negative association with diabetes. In the past, diabetes was considered a disease of the upper socioeconomic stratum. However, there has been a demographic shift such that, in the present study, the prevalence of diabetes was almost equal across all socioeconomic groups. The upward economic transition among South Asian peoples in general may also be contributing to their diabetic tendencies, and may be the reason for the greater diabetes prevalence in India compared with other countries.

One of the strengths of the present study was that it included a large population selected by stratified systematic random sampling, thereby well representing the entire city population, given the high response rate of 94%. As an epidemiological study, however, it has its inevitable limitations of feasibility and resource constraints. Ideally, a laboratory estimation of venous plasma glucose is recommended for diagnosing diabetes, and the sample should also be processed as quickly as possible, which is not feasible in population studies. For this reason, many epidemiological studies have used capillary plasma glucose [27,28]. In any case, the appropriate internal and external quality controls were applied in our present study, which used a strip methodology to validate capillary plasma glucose measurements. Furthermore, as many pre-analytical factors can influence estimates of FPG, such as fasting for 8–10h or consuming alcohol in the 24 h prior to sampling, and having ongoing illnesses, these were ensured during our study. Analytical variability of the glucometers can also affect glucose estimation, and FPG has an inherent day-to-day within-individual variability of 6.6–11.4%.
[29]. Therefore, a single FPG value may not be appropriate for diagnosing diabetes and IFG. Similarly, the 2hPG has poor reproducibility (60–70%) and, again, a single value is insufficient for diagnosing diabetes and IGT [29]. For this reason, subsequent reconfirmation of glucose values is required to establish the diagnosis of diabetes, which is not practical in an epidemiological setting. One final point is that, while a cross-sectional study of a representative sample of the population is adequate for assessing the prevalence of any disease in a given geographical area, it does not allow any conclusions to be drawn on causality to determine predictors of the disease, as it can only establish associations between the disease – in this case, diabetes – and its risk factors.

5. Conclusion

In urban Chandigarh, the age-standardized prevalence of diabetes and prediabetes was 11.1% and 13.2%, respectively. Increasing age, and a family history of diabetes, obesity and hypertension, were positively associated with the presence of diabetes, while level of education was negatively related to the disease.

Conflict of interest statement

Nothing to declare.

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