Diabetes screening and the distribution of blood glucose levels in rural areas of North India

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INTRODUCTION

Genetics and environment have both been implicated in the exponential rise in the prevalence of diabetes mellitus that affects 65.1 million people, and leads to a mortality of 1 million people every year in India. This study was devised to obtain the trends of the distribution of blood glucose, and sociodemographic characteristics in rural areas of a North Indian state. 

Materials and Methods: A cross-sectional study was conducted at eight centers in five districts. A camp-based approach was followed in the diabetes screening conducted in rural areas. Blood glucose measurements were obtained after informed consent by trained staff using a reflectance photometer instrument. Descriptive statistics, distribution curves, log transformations, and tests for bimodality were obtained. Results: 45,318 participants consisting of 44.4% males and 55.6% females were screened. Ages ranged from 18 to 98 years with the mean age of 39.9 ± 14.44 years. 86.5% were normal (random blood sugar [RBS] <140 mg/dl), 10.6% were prediabetic (RBS 140–200 mg/dl) and 2.9% were diabetic (RBS > 200 mg/dl). The median blood glucose level steadily rose with increasing age. The prediabetic to diabetic ratio was 4:1. The distribution curve of RBS was right skewed. A log transformation was applied, and bimodality was tested using the Hartigan’s dip test. The dip statistic (D) was 0.0162 with a simulated $P < 0.001$. Conclusion: Mass screening for diabetes provides benefits from a clinical standpoint by helping to estimate the prevalence (diabetes) and the hidden burden of the disease (prediabetes). Screening programs can strengthen healthcare system initiatives and reduce the growing burden of diabetes in India.

Key words: Blood glucose distribution, diabetes screening, rural
factors in the complex interplay between genes and the environment in the occurrence of diabetes\([9]\) are going on. Diabetes inflicts an enormous burden on the healthcare system and economics, and primordial prevention, health education, communication of behavior change and lifestyle modifications are being utilized to reduce this burden.\([9]\)

India has been termed as the “diabetes capital” of the world owing to the very high prevalence of metabolic syndrome including diabetes, hypertension, hypercholesterolemia, and obesity.\([8]\) India had 65.1 million diabetics and had a mortality of one million as a result of diabetes in 2013.\([1]\) Indians are particularly susceptible to diabetes by virtue of their genome and environment. The socioeconomic distribution of the disease has also changed, and people in low and middle-income countries are now contributing to the largest burden of the disease. Relative malnutrition in utero and the abundance of nutrition in early and middle adulthood may explain the epidemic in Indians. The westernization of diet and lifestyle, synergistic with the genetic background has also been postulated as an explanation for the rapidly growing prevalence in this population.\([3]\)

Large-scale screening to identify asymptomatic individuals who are likely to have diabetes is of particular value because of the long lead time of diabetes, the minimal observable symptoms, the large number of undetected individuals owing to the iceberg phenomenon in the community, and the advantage of early diagnosis. Both mass screening and high-risk screening offer their own advantages and disadvantages. In a country with a high burden such as India, the yield of mass screening could be equivalent to high risk screening, as high-risk conditions for diabetes include a family history of diabetes and belonging to the Asian race, criteria that a large proportion of the population satisfies.\([7]\) Various screening tests for diabetes, including fasting blood glucose and oral glucose tolerance test, are available. While fasting blood glucose test is the preferred one for screening, random blood glucose confers the advantage of time and convenience to the study participants.\([8]\)

The current cross-sectional study was formulated to screen individuals for diabetes and to obtain the trends of distribution of blood glucose by age and gender. Awareness of the recognition of symptoms with a special focus on gestational diabetes was generated among people. Through information education communication (IEC) campaigns, people in the rural areas of a North Indian state were made aware of screening tests and when to seek healthcare.

MATERIALS AND METHODS

A cross-sectional study was conducted in a Northern state of India, Uttar Pradesh. Five districts out of the 72 districts in the state were selected based on concerns about programming including the population in the districts, grant amount, and the location of existing infrastructure. The cumulative population of the five districts, namely, Lalitpur, Maharaiganj, Sitapur, Shajahanpur, and Varanasi was 15,073,666. The sex ratio in these districts was 904 females to 1000 males. In these districts, eight nodal centers were identified for the screening for diabetes. The nodal centers were Secondary Care Hospitals affiliated with the project. The selection criterion was based on the affiliation with the implementing organization and project grant. These eight centers carried out screening activities in the villages of the five districts over a period of 2 years from April 2012 to March 2014. IEC and screening activities were conducted with the support of a grant provided by the World Diabetes Foundation (WDF 11-647).

A camp-based approach was followed. During the study period, 899,960 people were made aware by means of IEC activities of the recognition of symptoms of diabetes, screening tests and the search for healthcare through 399 camps. Random blood sugar (RBS) samples were obtained from a convenient sample of 52,633 (5.8%) participants attending these camps, who fulfilled the age (more than 18 years) and study criteria (located in the project area, attended the camp and were willing to provide verbal informed consent). The procedure was explained, and verbal permission was obtained from the respondents before the samples were taken. Age, gender, and RBS values were obtained from the people who underwent screening. Subjects who were known diabetics or aged <18 years were excluded from the blood glucose measurement.

A 1-day training was conducted for 8 physicians, 7 nurses, and 25 paraprofessionals by diabetologists in the nodal centers on the study protocol, the use of the glucometer instrument, and procedures to be followed to obtain consent and blood samples so that measurements in all centers are standardized. Random blood glucose measurements were obtained regardless of the time of the last meal. Measurements were obtained by trained staff using a reflectance photometer instrument (One Call Plus) with a finger prick to obtain fresh capillary whole blood. The enzyme method used, during the survey, was glucose oxidase. The instrument was calibrated to provide plasma equivalent results.

American Diabetes Association Criteria were used to classify subjects into normal, prediabetic, and diabetic
RESULTS

For analysis, data were available at the end of the study period for 45,318 subjects, 44.4% of whom were male and 55.6% female. Ages ranged from 18 to 98 years with mean age of 39.9 ± 14.4 years; 59.2% of the respondents were below the age of 40, 32.2% between 41 and 60 years and 8.6% above the age of 60 years. The age and sex distribution of the sample are presented in Table 1.

In the sample, 39,220 (86.5%) were normal (RBS <140 mg/dl), 4806 (10.6%) were prediabetic (RBS 140–200 mg/dl) and 1292 (2.9%) were diabetic (RBS >200 mg/dl). Of the women, 2647 (10.5%) were prediabetic and 621 (2.5%) diabetic. Of the men, 2159 (10.7%) were prediabetic and 671 (3.3%) diabetic. Chi-square test was performed across gender and diabetes status and the results were significant ($\chi^2 = 31.57, P < 0.001$).

Of the subjects aged below 40 years, 1995 (4.4%) were prediabetic and 334 (0.7%) diabetic. Among persons aged 41–60 years, 2049 (4.5%) were prediabetic and 736 (1.6%) were diabetic, whereas, of the subjects aged above 60 years, 762 (1.7%) were prediabetic and 222 (0.5%) were diabetic. Chi-square test was performed across age, and diabetes status and the results were significant ($\chi^2 = 1491.15, P < 0.001$). The prediabetic to diabetic ratios for the three age groups, rounded off to the nearest whole number were 6:1, 3:1 and 3:1, respectively [Table 2].

The mean RBS of the sample was 115.49 ± 37.19 mg/dl. The mean RBS of the females was 115.13 ± 35.34 mg/dl and 115.95 ± 39.38 mg/dl in the males. The median blood glucose level steadily rose with increasing age and the medians for the age groups ≤40 years, 41–60 years and ≥61 years were 105 mg/dl, 111 mg/dl, and 117 mg/dl, respectively [Figure 1].

The distribution curve of RBS showed a right skewed distribution with skewness of 3.24 and a kurtosis of 15.69. A log transformation was applied to obtain an approximation to a normal distribution. Bimodality was tested using the Hartigan's dip test, and the dip statistic (D) was 0.0162 with a simulated $P < 0.001$. A bimodal curve was obtained with the log-transformed RBS with a skewness of 1.38 and kurtosis of 3.71. The kernel density plots of RBS and log transformed RBS are depicted in Figure 2.

CONCLUSION

This cross-sectional study approached a convenient sample in the rural areas of Uttar Pradesh, a Northern state of India. With a view to providing information, education and enhancing awareness on diabetes with a special focus on gestational diabetes, 899,960 people in rural areas were approached. Of this number 52,633 underwent random blood glucose testing and 45,318 subjects were included in the final analysis.

The number of women included in the sample exceeded the number of males, which was in conflict with the sex ratio of the area. This can be explained by the special focus on IEC activities among pregnant women for gestational diabetes. Besides, women in certain areas are more likely to participate in their decisions on health and participate in the camp activities because of the constraints of work for men. Most respondents were aged between 18–40 and 41–60 years; 9% of the respondents were above 60 years. The target population was ideal for IEC and screening for diabetes based on age. There was also a clear upward shift
The prevalence of undiagnosed prediabetes in the current study was 10.6% and that of undiagnosed diabetes 2.9%. The diabetes atlas of the International Diabetes Federation puts the prevalence of diabetes in India in 2013 at 9.1%, with a pooled prevalence of rural diabetes in low and middle-income countries at 5.6%. In a large-scale urban study in India, Ramachandran et al. observed a diabetes prevalence of 12.1%. Mohan et al. observed a self-reported physician diagnosed prevalence of diabetes at 3.1% in rural areas and 7.3% in urban areas. The prevalence of diabetes in the current study is within the range for similar geographical (rural areas in North India) areas, and variations can be explained by the differing definitions of diabetes, measurement used (RBS) and geographical variations. In addition, subjects with known diabetes were excluded from our study. The prediabetes prevalence recorded was higher than most studies. This can be explained by the use of RBS, which is more likely to reveal impaired glucose tolerance after a glucose load.

The distribution of blood glucose was right skewed, and a bimodal distribution was obtained after a log transformation. This is consistent with other similar studies conducted in large populations to estimate the prevalence of diabetes. In areas with a high prevalence of diabetes, right skewed distribution is obtained when blood glucose distribution is plotted. A log transformation can be applied to reduce the skewness, and typically, in such populations, a bimodal distribution is obtained after the application of the log transformation. This indicates the presence of two discrete sub-groups in the population; one group with a predisposition to developing diabetes. The current study supports two hypotheses with regard to diabetes: That impaired glucose tolerance is a natural sequel of increasing age, and that there are two naturally occurring groups with a genetic dichotomy toward the development of diabetes. The study by Butler et al. validates this hypothesis.

Mass screening for diabetes not only provides benefits from a clinical standpoint, but also helps to estimate the prevalence and the hidden burden of the disease, demonstrates the exponential rise in diabetes and prompts epidemiologists to explore the related etiological mechanisms. Selective screening of people aged above 40 years can have a higher yield of diabetic cases as evidenced in the study. Screening programs can strengthen healthcare system initiatives and reduce the growing burden of diabetes in India.

LIMITATIONS

The sampling of the subjects and selection of geographical areas was influenced by programming concerns and so may not be representative of trends in the country. For the same reason, RBS was measured rather than fasting blood glucose, which is a more sensitive indicator.

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Conflicts of interest
There are no conflicts of interest.

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