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Increasing Prevalence of Type 2 Diabetes in a Rural Bangladeshi Population: A Population Based Study for 10 Years

Bishwajit Bhowmik[1], Faria Afsana[2], Lien My Diep[1,3], Sanjida Binte Munir[4], Erica Wright[5], Sharif Mahmood[6], A. K. Azad Khan[2], Akhtar Hussain[1]

[1]Department of Community Medicine, Institute of Health and Society, University of Oslo Faculty of Medicine, Oslo, Norway,
[2]Department of Endocrinology, Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders (BIRDEM), Dhaka, Bangladesh,
[3]Unit for Biostatistics and Epidemiology, Oslo University Hospital, Oslo, Norway,
[4]Executive Diabetes Care Centre, NHN, Diabetic Association of Bangladesh, Dhaka, Bangladesh,
[5]ACT Diabetes Service, Division of Medicine, Canberra Hospital, Canberra, Australia,
[6]Institutes of Statistical Research and Training, University of Dhaka, Dhaka, Bangladesh

Background: To observe changes in the prevalence of type 2 diabetes mellitus (DM) and impaired fasting glucose (IFG) and its associated risk factors in a rural Bangladeshi population over a 10-year period.
Methods: Three cross-sectional studies were undertaken in a rural community (aged ≥20 years) in 1999, 2004, and 2009. Structured questionnaires including sociodemographic parameters, anthropometric measurements, blood pressure, and blood glucose values were recorded. DM and IFG were diagnosed using 1999 World Health Organization criteria.
Results: Age standardized prevalence of DM increased significantly ($P<0.001$) from 1999 to 2009 (2.3%, 6.8%, and 7.9% in 1999, 2004, and 2009, respectively). The prevalence of IFG increased significantly ($P=0.011$) from 4.6% to 5.8% between 1999 and 2004 but then decreased from 5.8% to 5.3% during 2004 to 2009. Significant linear trends were shown in both sexes for general and central obesity as indicated by body mass index, waist circumference, and waist hip ratio (WHR). Increasing age and systolic blood pressure were significant risk factors for DM in all three studies. WHR for males was also significantly associated with the risk of DM in all three studies. WHR for females was only significantly associated with DM in 2009.
Conclusion: A significant rise in the prevalence of DM was observed in this population over 10 years. This increase was seen in both sexes, and in all age groups. A significant increase in the prevalence of the associated risk factors of general and central obesity was observed in both sexes.

Keywords: Bangladesh; Diabetes mellitus; Impaired fasting glucose; Population based study; Prevalence

INTRODUCTION

The prevalence of diabetes mellitus (DM) continues to increase worldwide, especially in Asia [1]. In 2010, an estimated 140 million people living in Asia had DM and globally 60% of the people with DM were of Asian descent [2]. In addition, to a possible genetic predisposition, other environmental factors, have been identified as contributing to the DM epidemic in Asia. These includes rapid socioeconomic change, urbanization, sedentary lifestyle, and changes in dietary patterns. Recent epidemiological studies have shown an increased prevalence of DM in India (12.1%), Pakistan (11.1%), and China (6.1%) [3-5]. In recent years, Bangladesh has experienced rapid urbanization [6,7]. A number of population based studies

Corresponding author: Bishwajit Bhowmik
Department of Community Medicine, Institute of Health and Society, University of Oslo Faculty of Medicine, P.O. Box 1130, Blindern, N-0317 Oslo, Norway
E-mail: doctorbiplob@gmail.com

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conducted in Bangladesh have revealed an increasing prevalence of DM in both rural and urban populations [8-10]. However, there are major limitations in understanding the temporal changes in the prevalence of DM in Bangladesh from these studies due to the different study populations, methodologies, and the times at which the studies were conducted. In 1999, 2004 and 2009, we conducted three consecutive cross-sectional studies in an area called Chandra, located approximately 40 km from Dhaka, the capital of Bangladesh. These studies aimed to evaluate and compare the temporal change in the prevalence of diabetes, and, identify associated risk factors in a rural area of Bangladesh.

METHODS

The same methodology was applied in the same population in the three studies. Each study participant was allocated a unique identification number which included their household number.

Study area and population

In 1999, the demographic and social characteristic profile of the general population of Chandra, was described as rural, without urban facilities. The main livelihood of the population was agricultural and other agrarian activities. Ten villages were randomly selected from five areas. The total population of these villages was approximately 20,000 aged ≥20 years. During the recruitment period all persons aged ≥20 years, willing to participate and able to communicate were included in the study. Pregnant women and those with a diagnosed acute physical or mental illness were excluded. Description of the population and recruitment process were described earlier in brief [10]. In 1999, 5,000 subjects were recruited and of these 4,757 (95%) agreed to participate. In 2004, 5,000 subjects were again recruited and of these 3,981 (80%) subjects participated. In 2009, 3,000 of same age group subjects were randomly selected and among them 2,376 (79.2%) participated. After exclusion of 83 participants with missing glucose values, 2,293 participants were included for the analysis.

Ethics

Verbal consent was obtained from each participant prior to their inclusion in the study as the majority of participants were illiterate. This procedure was adopted to avoid selection bias and individual discrimination. Information, explaining the study objectives and protocol were read aloud to the participants, including, their right to refuse and withdraw at any stage of the study or to exclude their data from analyses. The protocol was approved by the Norwegian National Committee for Medical and Health Research Ethics and the Ethical Review Committee of the Diabetic Association of Bangladesh.

Diabetes survey and data collection

On completion of the selection procedure, participants were requested to visit a nearby field centre. In the 1999 and 2004 studies, capillary whole blood was used to measure the fasting blood glucose (FBG) after an overnight fast of 8 to 12 hours, using a Hemocue blood glucose analyzer. Internal quality control tests were conducted each day, using recommended glucose solutions, to ensure accuracy and reliability of the results. DM and impaired fasting glucose (IFG) were diagnosed using World Health Organization (WHO) criteria [11]. Diagnosis of DM was made if the FBG was ≥6.1 mmol/L. IFG was diagnosed if the FBG was between ≥5.6 to <6.1 mmol/L. In 2009, venous plasma glucose (VPG) samples were collected on the morning following an overnight fast. DM was diagnosed if the FBG value was ≥7.0 mmol/L. IFG was diagnosed if the FBG was between ≥6.1 to <7.0 mmol/L [11]. In addition, known DM was defined by the use insulin or oral antidiabetic medication(s) and self-reported DM. VPG samples were collected in a tube containing sodium fluoride and were centrifuged on site within 30 minutes of collection. Separated plasma samples were sent to the Bangladesh Institute of Research and Rehabilitation in Diabetes, Endocrine and Metabolic Disorders (BIRDEM) in ice gel packed cooling boxes and stored at minus 70°C until laboratory assays. Plasma glucose was measured by the glucose oxidase method using Dimension RxL Max (Siemens AG, Erlangen, Germany) on the same day. In the 2009 study, quality control on the blood glucose measurement was checked by measuring the fasting plasma glucose values using the glucose oxidase method in every 10th sample. The intra-assay coefficient of variation was 1.24% at a mean of 5.86 mmol/L, and the inter-assay coefficient of variation was 2.10% at a mean of 5.23 mmol/L. The correlation between capillary whole blood (using point of care meter) and venous plasma blood was calculated using Pearson's correlation methods (r=0.94, P<0.001). All study participants were informed of their glucose tolerance status as soon as the results were available.

Interview

Socioeconomic and demographic information, parental and personal health history were verbally obtained using standardised questionnaires and anthropometric measurements were recorded. These were carried out through trained researchers.

Measurements of height, weight, and waist circumference (WC), and hip circumference (HC) were taken with participants in light clothes and without shoes. For height, the participant stood erect against a wall, with the occiput, back, hip, and heels in contact with the wall while looking straight ahead and keeping the tragus and lateral orbital margin in the same horizontal plane. WC was measured by placing a plastic tape horizontally midway between 12th rib and iliac crest on the midaxillary line. Similarly, HC was measured by placing the tape measure at the level of maximum posterior extension of the buttocks and horizontal around the body. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). Obesity was defined as a BMI of 25 kg/m^2 or greater for Asian Indians [12,13]. Central obesity indicated by WC ≥90 cm for male and ≥80 cm for female and waist hip ratio (WHR) ≥0.90 for male, ≥0.80 for female. Blood pressure (BP) was measured by 1) ensuring the participant rested for 10 minutes prior to the BP being measured, 2) using standard cuffs for adults fitted with a standard mercury sphygmomanometer, and 3) placing the stethoscope bell lightly over the pulsatile brachial artery on the right arm. The average of two BP readings taken at a 5-minute interval in both sitting and standing positions was recorded. Hypertension (HTN) was defined as a systolic BP (SBP) of ≥140 mm Hg and/or diastolic BP (DBP) of ≥90 mm Hg or diagnosed HTN by a physician prior to the survey and reported regular in place of daily use of antihypertensive medication(s).

Statistical analysis

All the continuous variables were presented as mean (95% confidence interval [CI]) and categorical data as percentage (95% CI). Differences between the three study cohorts of means and proportions adjusted for age was tested by analysis of covariance (ANCOVA) and logistic regression respectively. Multiple comparisons were performed using the Bonferroni method. The prevalence of DM and IFG were age standardised by the direct standardization method. Age standardised prevalence was estimated on the basis of 1991 census data adjusted in 2000 for all three surveys [14]. Multiple logistic regression models were used to test for linear trends in the age standardised prevalence and estimate adjusted odds ratios with 95% CIs for all three studies. Two-sided *P* values were given and the significance level was set at 0.05. STATA 11 for Windows (STATA Co., College Station, TX, USA) was used to estimate the age standardized prevalence and creating the figures. Otherwise PASW statistics version 18 for Windows (SPSS Inc., Chicago, IL, USA) was used.

RESULTS

Table 1 shows the population characteristics of the three studies. The mean values and 95% CIs for age, BMI, WHR, WC increased significantly in both sexes (Table 1). A small mean reduction was observed for both SBP and DBP in 2009. There was a significant time-related change in the prevalence of general obesity indicated by BMI of ≥25 kg/m^2 ($P<0.001$) and central obesity indicated by WC (male ≥90, female ≥80 cm) ($P<0.001$) and WHR (male ≥0.90, female ≥0.80) ($P<0.001$) in 2009 compared to 1999 and 2004. The prevalence of obesity was higher in females than males in all three studies. Prevalence of HTN increased 22.3% from 1999 (14.3%) to 2004 (18.4%) but decreased by 23.9% from 2004 to 2009 (14.0%).

Fig. 1 shows the age and sex standardised prevalence of DM and IFG. The prevalence of DM in the study population was higher in 2009 compared to 1999 and 2004. The prevalence of DM increased 66% (from 2.3% to 6.8% during 1999 to 2004) and a further increase of 14% (from 6.8% to 7.9% during 2004 to 2009). The trend was statistically significant for DM (linear trend, $P<0.001$) in both sexes (linear trend, $P<0.001$). The prevalence of IFG increased 21% in the 5 years between the first two studies, from 4.6% (95% CI, 4.0%, 5.2%) to 5.8% (95% CI, 5.1%, 6.5%) but decreased 9% from 5.8% (95% CI, 5.1%, 6.5%) to 5.3% (95% CI, 4.4%, 6.2%) during 2004 to 2009. IFG among males showed a significant linear increasing trend ($P=0.031$). Female participants had a higher prevalence of DM and IFG in 1999 and 2004. Male participants had a higher prevalence of DM in 2009 with an associated higher prevalence of IFG. The prevalence of DM and IFG increased with age in both sexes in each of the studies.

Table 2 shows the association of risk factors with DM in the three studies. Increasing age and SBP were found to be significant risk factors for the occurrence of DM after controlling for potential confounders in all three studies. The increase in BMI was associated with increased prevalence of DM in 2004 and

Table 1. Details of population characteristics of 1999, 2004, and 2009 surveys

Variable	1999 (n=4,757)	2004 (n=3,981)	2009 (n=2,293)
Age, yr			
Total	37.5 (37.1-37.9)	37.2 (36.8-37.7)	41.8 (41.3-42.4)[a,b]
Male	40.1 (39.5-40.8)	39.0 (38.3-39.8)	44.3 (43.3-45.2)[a,b]
Female	35.5 (34.9-36.1)	36.0 (35.5-36.6)	40.4 (39.7-41.1)[a,b]
BMI, kg/m^2			
Total	19.5 (19.4-19.6)	20.7 (20.6-20.8)[a]	22.2 (22.1-22.4)[a,b]
Male	19.4 (19.2-19.5)	20.6 (20.4-20.8)[a]	22.6 (22.4-22.8)[a,b]
Female	19.4 (19.3-19.5)	20.8 (20.6-20.9)[a]	22.8 (22.6-22.9)[a,b]
BMI ≥25 kg/m^2, %			
Total	4.4 (3.8-5.0)	10.8 (9.7-11.7)[a]	26.6 (24.7-28.4)[a,b]
Male	4.1 (3.3-5.0)	9.6 (8.1-11.0)[a]	25.1 (22.2-28.1)[a,b]
Female	4.6 (3.8-5.4)	11.6 (10.3-12.8)[a]	27.3 (25.0-29.7)[a,b]
Waist, cm			
Total	68.5 (68.2-68.8)	73.2 (72.9-73.4)[a]	78.6 (78.3-80.0)[a,b]
Male	70.1 (69.8-70.5)	74.4 (73.9-74.9)[a]	81.7 (81.1-82.5)[a,b]
Female	66.4 (66.0-66.6)	72.4 (71.9-72.7)[a]	79.7 (72.2-80.3)[a,b]
Waist (male ≥90, female ≥80 cm), %			
Total	3.9 (3.3-4.4)	14.0 (12.9-15.1)[a]	39.7 (37.7-41.7)[a,b]
Male	1.9 (1.3-2.5)	4.8 (3.8-5.9)[a]	24.1 (21.2-27.0)[a,b]
Female	5.4 (4.5-6.3)	20.2 (18.6-21.8)[a]	48.2 (45.6-50.8)[a,b]
WHR			
Total	0.85 (0.84-0.86)	0.86 (0.85-0.88)	0.87 (0.86-0.88)[a]
Male	0.88 (0.87-0.89)	0.89 (0.88-0.90)	0.90 (0.89-0.92)[a,b]
Female	0.83 (0.82-0.84)	0.84 (0.83-0.85)[a]	0.86 (0.85-0.87)[a,b]
WHR (male ≥0.90, female ≥0.80), %			
Total	47.3 (45.9-48.7)	59.4 (57.9-61.0)[a]	70.7 (68.8-72.6)[a,b]
Male	31.3 (29.1-33.0)	39.3 (36.9-41.6)[a]	57.3 (53.9-60.6)[a,b]
Female	59.8 (58.0-61.7)	73.2 (71.4-75.0)[a]	77.6 (75.4-79.8)[a,b]
SBP, mm Hg			
Total	118.4 (117.0-118.8)	120.4 (120.0-121.1)[a]	115.4 (114.7-115.9)[a,b]
Male	118.1 (117.4-118.8)	119.6 (118.7-120.4)[a]	116.2 (114.8-117.1)[a,b]
Female	119.6 (119.0-120.2)	120.0 (119.3-120.6)	114.1 (113.3-114.9)[a,b]
DBP, mm Hg			
Total	76.5 (76.2-76.8)	77.5 (77.2-77.9)[a]	76.3 (75.9-76.7)[b]
Male	76.3 (75.8-76.7)	77.2 (76.7-77.7)	77.2 (76.5-77.9)
Female	77.1 (76.7-77.4)	77.0 (76.6-77.4)	75.9 (75.4-76.5)[a,b]
HTN, %			
Total	14.3 (13.4-15.3)	18.4 (17.2-19.6)[a]	14.0 (12.6-15.3)[b]
Male	13.2 (11.7-14.6)	18.7 (16.9-20.6)[a]	16.8 (14.6-19.2)[a]
Female	15.4 (14.1-16.7)	18.2 (16.7-19.7)[a]	12.1 (10.6-13.6)[a,b]
Family expenses (BDT/mo)[c]			
Total	3,485 (3,365-3,601)	5,408 (5,280-5,535)[a]	7,286 (7,132-7,441)[a,b]

Values are presented as means (95% confidence interval [CI]) or percentage (95% CI) adjusted for age as indicated.
Linear trend of general obesity: BMI ≥25 kg/m^2 (total, $P<0.001$; male, $P<0.001$; female, $P<0.001$).
Linear trend of central obesity: waist (male ≥90, female ≥80 cm) (total, $P<0.001$; male, $P<0.001$; female, $P<0.001$); WHR (male ≥0.90, female ≥0.80) (total, $P<0.001$; male, $P<0.001$; female, $P<0.001$).
BMI, body mass index; WHR, waist hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; HTN, hypertension; BDT, Bangladeshi taka (currency).
[a]$P<0.05$ vs. 1999, [b]$P<0.05$ vs. 2004, [c]1 USD=84 BDT.

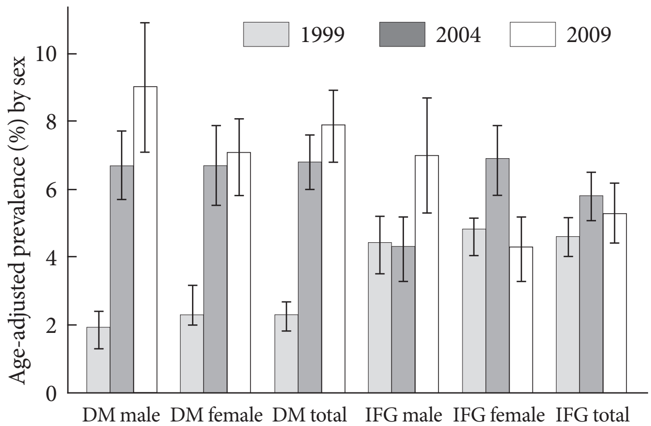

Fig. 1. Age-adjusted prevalence by sex of diabetes mellitus (DM) and impaired fasting glucose (IFG) in rural Bangladesh for 1999, 2004, and 2009. Linear trend of diabetes (total, $P<0.001$; male, $P<0.001$; female, $P=0.001$), linear trend of IFG (total, $P=0.357$; male, $P=0.031$; female, $P=0.49$).

2009. WHR was found to be a potential risk factor for men in all three studies. However, in females the WHR showed significant association with DM in 2009 only.

DISCUSSION

There is a significant increase in the age standardized prevalence of DM amongst study participants observed over the last 10 years. Prevalence in this rural Bangladesh population has increased more than threefold, from 2.3% to 7.9% in the last 10 years. Further, the prevalence in this population in 2009 is higher than the prevalence found in rural China 6.1% in 2005, India 6.4% in 2004, and Turkey 7.2% in 2002 [5,15,16]. However, the observed prevalence rate for DM reported here is lower than that of rural populations in Hawaii (20.4%) [17]. Differences in prevalence rates may be influenced by differential methodologies applied in different populations.

The age adjusted prevalence of IFG has moderately increased in the first 5 years, from 4.6% to 5.8% and then shown minor decrease to 5.3% in 2009. In 1999, we had observed a relatively high prevalence of IFG in a population where the prevalence of DM was moderate [18]. This may have indicated a lower prevalence of DM than IFG in this rural population of Bangladesh. The present lower prevalence of IFG could be due to vulnerability of the participants to environmental changes resulting in rapid conversion to DM. Alternatively, a rapid deterioration of susceptible normoglycemic subjects to DM could be occurring, as suggested by Mohan et al. [19]. The trend in decreasing prevalence of IFG was also noted in an urban population of India and Mauritius [20,21]. In 2009, we found a clear male predominance of IFG. This has been a consistent finding in many other populations [22,23].

A number of structural and industrial changes have occurred in the study region between 1999 and 2009, which may have changed rural life to a more sedentary lifestyle. Household expenses have increased 50% since 1999 in this population which may be related to rising economy. Recent studies have shown an association between urbanization, economic development and increased prevalence of DM in developing countries [15,20,24]. Mean values for BMI, WHR, and WC recorded in the studies have increased since the initial study in 1999. In between 2004 to 2009 the rate of increase in these factors has also risen when compared to the period between 1999 and 2004. The higher prevalence of DM in 2009, and the increased rate of change in risk factors in successive studies can be aligned with the increasing urbanization that has occurred in recent years.

Obesity is an established risk factor for DM. A significant association between higher BMI and the occurrence of DM was found in 2004 and 2009 study. It is of concern that mean BMI has significantly increased in last 10 years (mean BMI from 19.5 to 22.2 from the year 1999 to 2009). WHR was significantly associated with DM in men in all the studies. However, a significant association for women and WHR was only shown in 2009. The association between WHR and DM is also evident in previous studies conducted in Bangladesh [10,18]. The SBP was found to be associated with DM in all surveys.

A decreasing trend in HTN among new study participants was observed. Similar to our findings, a declining trend of mean BP and prevalence of HTN has also been observed in several general populations [25-28]. The reason for reduce prevalence of HTN found in our study and in both sexes is unclear. Increased awareness of HTN and increased efforts aimed at treating and controlling HTN in the last 10 years, especially among women, may be a contributing factor. The improved awareness and treatment of HTN among women has been consistently documented [29,30] however the reasons for these changes are not entirely clear. Differences in health seeking behaviour, and a greater opportunity for opportunistic BP screening, due to more frequent contacts with the health care system may contribute to this gender related difference. It should be also noted that availability of low-priced antihypertensive medications and nonpharmacological measures for

Table 2. Results of multiple logistic regression analysis following FBG showing association of risk factors with diabetes in rural Bangladesh for 1999, 2004, and 2009

Variable	1999		2004		2009	
	No.	OR (95% CI)	No.	OR (95% CI)	No.	OR (95% CI)
Age						
20-30	2,080	1.0	1,613	1.0	548	1.0
31-40	1,252	1.4 (0.9-2.2)	1,106	2.7 (1.8-3.9)	702	1.6 (0.9-2.7)
41-50	655	2.0 (1.1-3.6)	609	2.9 (1.9-4.5)	562	2.0 (1.2-3.5)
≥51	770	2.6 (1.5-4.5)	653	4.5 (3.0-6.8)	481	1.9 (1.1-3.6)
Sex						
Male	2,037	1.0	1,598	1.0	842	1.0
Female	2,720	1.4 (1.0-2.2)	2,383	0.9 (0.7-1.2)	1,451	0. 6 (0.4-0.8)
SBP, mm Hg						
<140	4,432	1.0	3,642	1.0	2,069	1.0
≥140	325	2.0 (1.0-3.9)	339	2.0 (1.2-3.3)	224	2.0 (1.1-3.5)
DBP, mm Hg						
<90	4,445	1.0	3,705	1.0	1,989	1.0
≥90	312	0.7 (0.3-1.5)	276	0.8 (0.5-1.5)	304	1.2 (0.7-2.0)
BMI						
<16.0	372	0.8 (0.4-1.7)	163	0.7 (0.3-1.3)	59	0.9 (0.2-1.2)
16.0-18.4	1,649	0.7 (0.5-1.2)	915	0.9 (0.6-1.2)	269	0.5 (0.2-2.4)
18.5-24.9	2,547	1.0	2,479	1.0	1,364	1.0
25.0-29.9	165	1.6 (0.7-3.7)	378	2.2 (1.5-3.2)	514	1.5 (1.0-2.2)
≥30	24	4.1 (0.5-7.3)	46	2.8 (1.2-6.6)	87	1.7 (0.8-3.5)
WHR (male)						
<0.9	1,735	1.0	982	1.0	344	1.0
≥0.9	302	1.7 (1.1-2.7)	616	1.6 (1.0-2.5)	498	2.8 (1.4-5.7)
WHR (female)						
<0.8	847	1.0	645	1.0	307	1.0
≥0.8	1,873	1.0 (0.6-1.6)	1,738	0.8 (0.5-1.3)	1,144	3.7 (1.5-6.8)

Adjusted odds ratio (ORs) and 95% confidence intervals (CIs) by multiple logistic regressions using for age, sex, SBP, DBP, BMI, and WHR.
FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; WHR, waist hip ratio.

the prevention and management of HTN have been introduced to improve the possibilities for the effective lowering of BP in Bangladesh for the last couple of years. One recent study conducted by Centre for Control of Chronic Diseases in Bangladesh, International Centre for Diarrhoeal Disease Research, Bangladesh reported that in rural Bangladesh; village doctors (unqualified practitioners), played an almost equal role to graduate medical doctors in diagnosing HTN [31]. Village doctors and pharmacies supply as much as 67% of the primary health care in Bangladesh [32] as they are the preferred health-care providers because they are perceived to be more available, accessible, and affordable than other public health care options [33]. Longitudinal data obtained from a nationally representative sample are necessary to examine true causal relationships between BP and relevant factors.

Limitations of the study

Capillary whole blood was used in the first two studies and venous plasma blood in the third study. These methods were used to confirm the diagnosis of DM and IFG. WHO cutoff glucose values used should reflect equivalent glucose values for capillary and venous plasma blood. However, the use of point of care blood glucose meters in a multi operator setting in large populations may have adversely influenced the inter-rater reliability of the researchers' technique and glucose values in the first two studies. Health questionnaires were administered by researchers who obtained self-report information verbally and recorded it as the majority of the participants were illiterate. Therefore, the interpretation and recording of the results is a potential bias in the studies. The studies were conducted in a rural area of Bangladesh which during the 10-year period had undergone rapid urbanization and associated environmental change. Therefore the extent to which the results are generalizable or representative of other populations in Bangladesh is not known.

Conclusions

The prevalence of DM has continued to increase in the past 10 years in a rural population of Bangladesh. The higher prevalence of DM may also be indicative of other changing environmental factors where rapid urbanization as a pretext for economic development may have influenced individual lifestyles and dietary behaviors. The increased prevalence of risk factors for DM, amongst the study populations includes obesity and central obesity, as indicated by BMI, WC, and WHR. The significant increase of these risk indicators demonstrates the potential impact on health in a developing country. More large scale studies with control populations may be helpful in recognizing the confounding factors responsible for increased prevalence of DM and IFG in rural Bangladesh.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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