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Prevalence and determinants of raised blood glucose among adults in Bangladesh: results from a population-based national survey

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-029674
Article Type:	Research
Date Submitted by the Author:	05-Feb-2019
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Keywords:	non-communicable diseases, chronic disease, raised blood glucose, Bangladesh

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Manuscripts

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6 a population-based national survey
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29 **Abstract**

30 Objectives: With the increasing burden of non-communicable diseases in low- and middle-
31 income countries, biological risk factors such as raised blood glucose are a major public health
32 concern in Bangladesh. Nationally representative data of raised blood glucose prevalence
33 starting from age ≥ 18 years are currently unavailable for Bangladeshi adults. The objective of
34 this study was to assess the prevalence and determinants of raised blood glucose among adults
35 in Bangladesh aged ≥ 18 years.

36
37 Study Design: Cross-sectional, population-based study

38
39 Setting and Participants: Data for this analysis were collected from a population-based
40 nationally representative sample of 1843 adults, aged ≥ 18 years, from both urban and rural
41 areas of Bangladesh. Demographic information, capillary blood glucose, blood pressure, height,
42 weight, waist circumference, and treatment history were recorded.

43
44 Primary Outcome Measures: Raised blood glucose was defined as a random capillary blood
45 glucose level of ≥ 11.1 mmol/L or currently taking medication to control diabetes, based on self-
46 report.

47
48 Results: Overall, the prevalence of raised blood glucose was 5.5% (95% CI: 4.5-6.6) and was
49 significantly higher among urban (9.8%, 95%CI: 7.7-12.2) than rural residents (2.8%, 95% CI:
50 1.9 – 3.9). The age-standardized prevalence of raised blood glucose was 5.6% (95% CI: 4.6 –
51 6.8). Among both urban and rural residents, associated determinants of raised blood glucose
52 included hypertension, and abdominal obesity. About 5% of the total population self-reported to
53 have been previously diagnosed with diabetes; among these adults, over 25% were not taking
54 medications to control their diabetes.

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2
3 55 Conclusions: Our study found that about 1 out of 20 Bangladeshi adults aged ≥ 18 years have
4
5 56 raised blood glucose. To control and prevent the development of diabetes, data from this study
6
7 57 can be used to inform public health programming and provide descriptive information on
8
9 58 surveillance of progress towards controlling diabetes in Bangladesh.
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14 60 **Keywords:** non-communicable diseases, Bangladesh, raised blood glucose, diabetes, chronic
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Article Summary

Strengths and Limitations of the Study

- This study utilized a multistage, geographically clustered, probability-based sampling approach to produce nationally representative data for Bangladesh.
- We included Bangladeshi adults aged 18 to 29 years to obtain novel data on the prevalence of diabetes and relevant non-communicable disease risk factors starting from this age group.
- We were able to estimate the prevalence of raised blood glucose using capillary blood glucose measured at random. However, we were unable to measure the prevalence of prediabetes and diabetes as we did not obtain blood sugar levels using standardized methods, such as fasting blood glucose or 2-hour post-prandial measurements.
- Due to the cross-sectional nature of the study design, we were unable to assess temporality of risk factors identified and our outcomes of interest.
- We assessed diabetes medication history based on self-report, however, we were unable to obtain medical records or prescription records of participants to confirm the self-reported data.

108 **Background**

109 Globally, diabetes mellitus (DM), characterized by raised blood glucose, is a leading
110 cause of premature mortality and disability¹. The global prevalence of DM has been on the rise
111 over the past several decades^{1 2}. Recent estimates reflect the global prevalence of diabetes has
112 nearly doubled among adults aged 18 years and above, rising from 4.7% in 1980 to 8.5% in
113 2014³. This growing burden is most prominent in low- and middle-income countries⁴ particularly
114 the Indian sub-continent⁵. South and Southeast Asia accounts for close to one-fifth of all
115 diabetes cases worldwide and the prevalence of diabetes in this region is projected to increase
116 by 71% by 2035⁶. In Bangladesh, specifically, the International Diabetes Federation projects the
117 prevalence of diabetes will increase to more than 50% in the next 15 years⁶.

118 The increase in prevalence of diabetes among Bangladeshi adults over the past few
119 decades has been documented: Based on a meta-analysis of studies conducted from 1995 –
120 2010, the prevalence of diabetes among Bangladeshi adults aged 30 years and above
121 increased from 4% in 1995 to 2000 and 5% in 2001 to 2005 to 9% in 2006 to 2010⁷. Studies to
122 assess the burden of diabetes has been conducted in Bangladesh in both urban and rural
123 populations over the last decades⁸. However, national data on the prevalence of diabetes or
124 raised blood glucose starting at age 18 years are currently unavailable⁸⁻¹¹. These data are
125 valuable for monitoring progress made towards one of the nine global non-communicable
126 disease (NCD) targets of the year 2025, set forth by the World Health Organization's (WHO)
127 NCD Global Monitoring Framework: To observe a 0% increase in age-standardized prevalence
128 of raised blood glucose or diabetes among persons aged ≥ 18 years¹². As such in response to
129 the WHO Global Action Plan for the Prevention and Control of NCDs¹³, descriptive
130 epidemiological data on the burden of raised blood glucose among adults starting at 18 years
131 are needed to monitor national progress of interventions implemented to reduce the burden of
132 DM in Bangladesh¹⁴⁻¹⁶. Here, using a nationally representative sample, we present data on
133 prevalence and determinants of raised blood glucose by various sociodemographic factors such

1
2
3 134 as age, sex, and area of residence among Bangladeshi adults aged 18 years and above,
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5 135 residing in both urban and rural areas of the country. Additionally, we explore treatment
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7 136 patterns, and control of raised blood glucose among participants in our sample of Bangladeshi
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9 137 adults.

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13 139 **Methods**

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15
16 140 Data for this analysis were collected as part of a national assessment of the burden of
17
18 141 musculoskeletal disorders in Bangladesh conducted by investigators from the Bangabandhu
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20 142 Sheikh Mujib Medical University (BSMMU) with technical assistance from the WHO Country
21
22 143 Office for Bangladesh, as previously described¹⁷. The study was a population-based cross-
23
24 144 sectional study carried out from November to December 2015 and followed the WHO STEP-
25
26 145 wise approach to Surveillance of NCD risk factors (STEPS)¹⁸. The target population of this
27
28 146 survey was men and women aged ≥ 18 years residing in rural and urban areas of Bangladesh.
29
30 147 The exclusion criteria included, tourists and the institutionalized, including residents of hospitals,
31
32 148 prisons, nursing homes, and army barracks.

33 149 Sampling Methods

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36
37 150 To obtain a population-based sample of Bangladesh, this survey adopted a multistage,
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39 151 geographically clustered, probability-based sampling approach. Population statistics were
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41 152 obtained using the updated national census conducted by Bangladesh Bureau of Statistics
42
43 153 (BBS) in 2009¹⁹. To obtain our primary sampling unit (PSU), we utilized the following
44
45 154 geographical distribution described: In Bangladesh, there are seven divisions, which are the
46
47 155 largest administrative units of the country. Each division is divided into several districts (*Zila*)
48
49 156 and within each district, there are several sub-districts (*Upazila*). Within sub-districts, *mauzas*
50
51 157 and *mahallas* (commonly known as neighborhoods or blocks) are the smallest units within
52
53 158 defined territories in rural and urban areas respectively. *Mauzas* and *mahallas* were considered
54
55 159 the PSU for the study's sampling approach. The households within the *mauzas* and *mahallas*

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2
3 160 were the secondary sampling units. We utilized the BBS' definition of household which is as
4
5 161 follows: "a dwelling in which persons either related or unrelated were living together and taking
6
7 162 food from the same kitchen"¹⁹.
8

9 163 The power analysis and sample size calculations were completed based on the
10
11 164 standardized approach outlined in WHO STEPS methodology ¹⁸. Using the WHO STEPS
12
13 165 methodology, the minimum number of participants required was 296 in each group (rural males,
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15 166 rural females, urban males, and urban females). Assuming a design effect of 1.5 adjusted within
16
17 167 cluster population homogeneity, the necessary sample size was 1776. We assumed a response
18
19 168 rate of 90% and determined we would need to contact at least 1973 adults. For simplicity, our
20
21 169 target sample size was 2000. Twenty PSUs (8 urban and 12 rural) were randomly selected from
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23 170 7 divisions of the country, with the probability proportional to the population size of each
24
25 171 division. In each PSU, 100 consecutive households were selected. The even numbered
26
27 172 households were designated as a "male household" and odd numbered households as a
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29 173 "female household." Finally, one male or female was approached to participate from each
30
31 174 respective household as designated.
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33

34 Data collection

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36
37 176 Through a structured survey, we collected data on the following topics: musculoskeletal
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39 177 disorders²⁰, health history, and demographic data such as age, area of residence, education,
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41 178 current (last 12 month) occupation, tobacco use and physical activity. Physical measurements
42
43 179 such as height, weight, waist circumference, blood glucose levels, and blood pressure were
44
45 180 collected. To measure blood glucose levels, we obtained random blood glucose samples ³, per
46
47 181 the clinical guidelines of diabetes diagnostic criteria of Bangladesh²¹. Capillary blood samples
48
49 182 were consistently taken from the index finger of the right arm using a glucometer, namely Accu-
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51 183 chek Advantage (Roche Diagnostics Division, Grenzachstrasse, Switzerland).
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54 184 Each participant's history of diabetes was assessed based on self-report. Specifically,
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56 185 participants were asked: 1. Have you ever been diagnosed with diabetes by a health care
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3 186 professional? 2. If yes, are you receiving treatment for diabetes? Treatment history of diabetes
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5 187 was confirmed by prescription, including medicine strips or insulin injection vials, or medical
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7 188 record when possible. Medicine strips or injection vials were checked when possible. The
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9 189 questionnaire was translated from English to Bengali, adapted and validated as per standard
10
11 190 procedure. Data collection procedures were standardized across study sites through
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13 191 coordinated training of field staff conducted by epidemiologists, study physicians, and WHO
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15 192 staff members.

16
17
18 193 Blood pressure was measured by a trained field interviewer using the LifeSource UA-
19
20 194 767+ blood pressure monitor, as recommended by the WHO, and appropriately sized arm cuffs.
21
22 195 Blood pressure measurements were consistently taken on each participant's right arm at the
23
24 196 level of the heart and elbow-assisted. The initial measurement was performed after five minutes
25
26 197 of rest. After two minutes, the second measurement was taken. The mean of these two blood
27
28 198 pressure readings was utilized as the final blood pressure for each participant.

29
30
31 199 Following data collection, participants were scheduled a visit with the study research
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33 200 physician within the following five-days. The research physician assessed the participant's
34
35 201 medical history, either through self-report or using medical records when possible. Study
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37 202 physicians examined each participant to confirm the results of data collection through classical
38
39 203 symptom assessment. When necessary, the participant was also evaluated by the divisional
40
41 204 investigator for a second opinion of relevant diagnoses.

42 43 205 Outcome definitions

44
45 206 Our primary outcome of interest was prevalence of raised blood glucose. We utilized the
46
47 207 American Diabetes Association (ADA) guidelines to define a diagnosis of raised blood glucose
48
49 208 using random or casual plasma glucose test and symptom review by the study physician ²². An
50
51 209 individual was considered to have raised blood glucose if the plasma glucose level was 11.1
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53 210 mmol/L or higher with classic symptoms of hyperglycemia, and/or if they self-reported to take
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55 211 medication to control their diabetes. Our secondary outcome of interest was prevalence of self-

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3 212 reported diabetes mellitus. An individual was categorized as diabetic if they self-reported to
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5 213 have been previously diagnosed with diabetes by a health care provider.
6

7 214 Covariates
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9 215 The following variables were assessed as covariates for analysis: area of residence,
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11 216 sex, age, education, occupation, wealth index, body mass index (BMI), BP, and waist
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13 217 circumference. Education was categorized into four groups: no education, primary education
14
15 218 (completed grade ≤ 5), secondary education (completed \leq grade 10), and above secondary
16
17 219 education (completed \geq grade 12). Occupation was categorized into five groups. These groups
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19 220 included: professional employment (field staff, police officer, guard, doctor, engineer,
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21 221 professional, business man, desk job), unemployed or retired, industrial worker or day laborer,
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23 222 housewife, and other (shop keeper, weaver, driver, student, beggar, cook, carpenter, tailor,
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25 223 migrant workers and fishermen).
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27

28 224 Data on physical activity was collected based on self-report. First, respondents were
29
30 225 asked the number of days they engaged in in vigorous, moderate, or light physical activity
31
32 226 throughout a typical week. The following definitions were used to define (1) vigorous, (2)
33
34 227 moderate, and (3) light physical activity, respectively: (1) vigorous activity was defined as any
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36 228 activity that causes large increases in breathing or heart rate, if continued for at least 10 minutes
37
38 229 (e.g. running, carrying heavy loads, digging or construction work); (2) Moderate activity was
39
40 230 defined as any activity that causes small increase in breathing or heart rate, if continued for at
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42 231 least 10 minutes (brisk walking or carrying light loads); and (3) Light physical activity was
43
44 232 defined as activities such as office work. Next, we asked participants to estimate how many
45
46 233 minutes per day they engaged in the activity. MET-minute was calculated using the STEPS
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48 234 protocol²³ as follows: one minute of light activity was equivalent to 1 MET-minute; one minute in
49
50 235 moderate-intensity activity related activities was equivalent to 4 MET-minutes, and one minute
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52 236 of vigorous-intensity was equivalent to 8 MET-minutes. Physical activity was then categorized
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54 237 based on total MET-minutes per week. Participants who spent 3000 or more MET-minutes per
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3 238 week were categorized in the vigorous physical activity group, 600-3000 MET-minutes were
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5 239 categorized as moderate physical activity, and <600 MET-minutes were categorized as low
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7 240 physical activity.
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9 241 The wealth index was constructed using principal component analysis. Asset information
10
11 242 collected covered information on household ownership of nineteen items, including: electricity,
12
13 243 flush toilet, land telephone, cell phone, television, radio, refrigerator, car, motorcycle, washing
14
15 244 machine, bicycle, sewing machine, wardrobe, table, bed or cot, chair or bench, watch or clock.
16
17 245 Additionally, we assessed the main type of material used to build each participant's home (i.e.
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19 246 cement, tin, bamboo, or thatched straw). Each asset was assigned a weight (factor score)
20
21 247 generated through principal components analysis, and the resulting asset scores were
22
23 248 standardized to a normal distribution with a mean of zero and standard deviation of one. Each
24
25 249 household was then assigned a score for each asset, and the scores were summed up;
26
27 250 individuals were ranked according to the total score of the household in which they resided. The
28
29 251 sample was then divided into quartiles from quartile one (lowest) to quartile four (highest).
30
31 252 Using height (centimeters) and weight (kilograms) measurements, we calculated BMI
32
33 253 (height/weight²). BMI was categorized in the following groups: underweight (≤ 18.5), normal
34
35 254 (≤ 25), overweight (25.1-30) and obese (>30). Waist circumference was measured in centimeters
36
37 255 (cm). Participants were categorized as abdominally obese if waist circumference was 90 cm and
38
39 256 above for men, or 80 cm and above for women. Prehypertension was defined as SBP ≥ 120
40
41 257 mmHg but < 140 mmHg and/or DBP ≥ 80 mmHg but < 90 mmHg and not taking anti-
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43 258 hypertensive medication at the time of the survey. We utilized the WHO's guidelines for cut-off
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45 259 points to define hypertension²⁴. An individual was considered to have hypertension if systolic
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47 260 blood pressure (SBP) was ≥ 140 mmHg (millimeters of mercury) and/or, diastolic blood pressure
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49 261 (DBP) ≥ 90 mmHg, and/or taking anti-hypertensive medication based on self-report.
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56 263 Age-Standardized Prevalence Estimates

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3 264 To facilitate comparison of overall raised blood glucose among Bangladeshi adults
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5 265 across global populations with different age compositions we calculated age-standardized
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7 266 prevalence estimates with 95% confidence intervals (CIs) using the WHO's World Standard
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9 267 Population²⁵. The World Standards database (WHO 2000-2025) provided population estimates
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11 268 for 18 and 19 age groups, as well as single year ages. To derive single ages from the 5-year
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13 269 age group proportions publically available, we used the Beers "Ordinary" Formula²⁶. The
14
15 270 following formula was utilized for standardization:
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17
18 271 $\sum p_i * w_i / \sum w_i$, where p = observed prevalence and w = world population weight.
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20 272

21 22 273 Data Analysis

23
24 274 Sociodemographic variables were presented with mean and standard deviation (SD) for
25
26 275 continuous variables, and using proportions for categorical variables. For bivariate analyses,
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28 276 study participants were divided by sex and into four age groups (18-29, 30-44, 45-54 and ≥55
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30 277 years). We calculated the prevalence of our primary outcome by key demographic variables and
31
32 278 calculated 95% CIs using the binomial exact method.
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34

35 279 To estimate determinants of raised blood glucose, we computed prevalence ratios with
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37 280 Poisson regression using robust estimation of standard errors²⁷⁻²⁹. Potential variables for
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39 281 inclusion in the model were assessed using prior published literature and bivariate Poisson
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41 282 regression analysis; an arbitrary p-value of <0.10 was used as criteria to include the variable in
42
43 283 the multivariable Poisson regression model to control for confounding effects. For multivariable
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45 284 Poisson regression models, adjusted prevalence ratios (aPR), and 95% CIs for each
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47 285 independent variable were calculated. Additionally, <0.05 was used as the level of significance.
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49 286 Multivariable Poisson regression models were generated separately for urban and rural
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51 287 participants to account for possible effect measure modification. Collinearity was assessed
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53 288 using the variance inflation factor to ensure a strong linear relationship among independent
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289 variables included in the model was not present. All statistical procedures were performed using
290 Stata/SE 15.0 (StataCorp LP, Texas, USA) software package.

291

292 **Results**

293 Background Characteristics

294 Of the 2000 adults approached, 1843 agreed to participate in our study leading to a
295 response rate of 92.1%. Twenty-four female participants were pregnant and were dropped from
296 subsequent analyses to ensure those with gestational diabetes were not included. There were
297 892 (49.0%) male and 927 (50.9%) female respondents (Table 1). Age of our participants
298 ranged from 18 to 90 years. The mean age and education level of participants was 40.5
299 (SD=14.7) years and 5.7 (SD=5.1) years, respectively. The majority of the population was
300 married (88.0%) and employed as either an industrial worker/day laborer (26.5%) or housewife
301 (39.9%). Almost half of the population never used some form of tobacco. The majority of
302 participants engaged in vigorous physical activity over an average week (69.3%). The mean
303 BMI was 22.1 (SD = 4.1) and mean waist circumference was 78.4 cm (SD = 11.6). Overall, the
304 mean systolic blood pressure was 116.1 mmHg (SD = 17.1) and diastolic blood pressure was
305 76.1 mmHg (SD=10.5). The mean blood glucose level was 6.4 mmol/L (SD = 2.4). Figure 1
306 presents the distribution of blood glucose levels by various demographic factors.

307

308 Prevalence and Risk Factors for Raised Blood Glucose

309 The prevalence of raised blood glucose was 5.5% (95% CI: 4.5-6.6). This prevalence
310 was significantly higher among urban participants (9.8%, 95%CI: 7.7-12.2) than rural
311 participants (2.8%, 95% CI: 1.9 – 3.9) (Table 2) and increased as age increased (Figure 2). The
312 highest prevalence of raised blood glucose was observed among those aged ≥ 55 years, at
313 8.2% (95% CI: 4.6-13.1) among men and 9.4% (95% CI: 5.4-14.8) among women. The age-
314 standardized prevalence of raised blood glucose was 5.6% (95% CI: 4.6 – 6.8). The age-

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2
3 315 standardized prevalence of raised blood glucose among urban and rural residents was 10.5%
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5 316 (95% CI: 9.2-12.1) and 2.8% (95% CI: 2.1-3.7), respectively. Among men and women, the age-
6
7 317 standardized prevalence of raised blood glucose was 4.9% (95% CI: 3.9-6.0) and 6.0% (95% CI:
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9 318 4.9-7.2), respectively.
10

11 319

12 13 14 320 Self-Reported Diabetes Mellitus and Raised Blood Glucose

15
16 321 Ninety-five participants (5.2%) self-reported to have been previously diagnosed with
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18 322 diabetes by a health care provider. However, 25 of these individuals did not meet our criteria of
19
20 323 diagnosis of raised blood glucose as they did not take medication to control their diabetes and
21
22 324 their plasma glucose was below 11.1 mmol/L. Therefore, 69.3% of those with raised blood
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24 325 glucose, per the study definition, were previously diagnosed with diabetes by a health care
25
26 326 provider. The proportion of men and women who were previously diagnosed with diabetes by a
27
28 327 health care based on self-report was higher among urban residents (men: 8.4%; women: 9.1%)
29
30 328 than among rural residents (men: 2.9%; women: 3.0%) (Figure 3a). However, overall, the large
31
32 329 majority (81.8%) reported they did not know if they had been previously diagnosed with
33
34 330 diabetes; this proportion was higher among rural residents (87.8%) than urban residents
35
36 331 (72.2%). Among participants previously diagnosed with diabetes based on self-report, 72.6%
37
38 332 reported to take medication to control their diabetes. Urban women more frequently (96.7%)
39
40 333 self-reported to take diabetes medication than urban men (62.1%) (Figure 3b).

41
42
43 334 Among participants who were diagnosed with raised blood glucose at study
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45 335 measurement, over one-third (37.9%), of urban men self-reported to have diabetes, however,
46
47 336 did not take any medication to control their diabetes. Among rural participants, the proportion of
48
49 337 women who did not take medication to control their self-reported diabetes was higher (52.9%)
50
51 338 than men (31.3%). Although three quarters of self-reported diabetic participants reported to take
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53 339 medication to control their diabetes, 31% continued to have high blood sugar levels indicating
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55 340 uncontrolled diabetes at study measurement (Figure 4).
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341
342 **Determinants of Raised Blood Glucose**

343 Table 2 presents results of multivariable Poisson regression with robust variance
344 analyses to identify determinants of raised blood glucose. Among urban participants, those of
345 older age, lowest wealth quartile, hypertension, low physical activity, and with abdominal obesity
346 based on waist circumference, were more likely to have raised blood glucose. The prevalence
347 of raised blood glucose was significantly highest among those aged ≥ 55 years (aPR 3.92, 95%
348 CI: 1.48 – 10.39) compared to individuals aged 18-29 years of age. When compared to those in
349 the 4th (highest) wealth quartile, urban residents in the first (lowest) wealth quartile had 3.18
350 times the prevalence of raised blood glucose. For urban individuals with hypertension, the
351 prevalence of raised blood glucose was 2.65 (95% CI: 1.30-5.38) times that of individuals
352 without hypertension. The prevalence of raised blood glucose among those with low physical
353 activity was 3.01 (95% CI: 1.42- 6.38) times that of urban participants with vigorous physical
354 activity. Abdominal obesity also significantly increased the prevalence of raised blood glucose
355 among urban participants (aOR: 2.54, 95% CI: 1.35-4.77). Among rural participants, the only
356 observed determinants of raised blood glucose were hypertension (aPR: 5.39, 95% CI: 1.94 –
357 14.96) and abdominal obesity (aPR: 2.95, 95% CI: 1.32 – 6.58).

358
359 **Discussion**

360 Using data from this nationally representative sample, we estimate that about one in
361 twenty Bangladeshi adults aged ≥ 18 years have raised blood glucose. The prevalence of raised
362 blood glucose was higher among urban residents (9.8%), than rural residents (2.8%).
363 Prevalence of raised blood glucose increased with age, urban residence, abdominal obesity,
364 low physical activity, and hypertension. As diabetes is characterized by raised blood glucose,
365 targeting high-risk groups identified in this analysis could be prioritized for organized diabetes
366 preventive programs in Bangladesh. Bangladesh has adopted the goals and targets set forth by

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2
3 367 the WHO's Global Monitoring Framework for the Prevention and Control of NCDs for the year
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5 368 2025¹². One of these targets is to ensure there is a 0% increase in the age-standardized
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7 369 prevalence of raised blood glucose among adults aged ≥ 18 years by the year 2025. To our
8
9 370 knowledge, the present study is the first to report national estimates on prevalence of raised
10
11 371 blood glucose starting at age 18 years in both urban and rural areas of Bangladesh. Data
12
13 372 gathered from this national-level study are critical towards the measurement of progress
14
15 373 towards the nine global targets for Bangladesh for 2025.

16
17
18 374 In our study, the age-standardized prevalence of raised blood glucose was 5.6%, and
19
20 375 was significantly higher in urban areas than rural areas. This may be due to differences in life
21
22 376 style factors such as physical activity, diet, and tobacco use. These findings are similar to prior
23
24 377 studies conducted to measure the prevalence of diabetes among adults in Bangladesh^{8 10 11 30 31}.
25
26 378 A recently published review, identified about 22 studies conducted to estimate the prevalence of
27
28 379 diabetes in different settings, including rural and urban, and varying age groups including ≥ 20
29
30 380 years, ≥ 30 years, and ≥ 35 years⁸. Estimates of diabetes prevalence ranged from 4.5% and
31
32 381 35%, however, the pooled estimate was 7.4% (95% CI: 7.2-7.6). The pooled estimate is higher
33
34 382 than our study's findings, however, our cohort is generally younger and this may lead to the
35
36 383 lower prevalence estimate.

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39 384 Significant determinants of raised blood glucose in both urban and rural areas of our
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41 385 assessment included hypertension, low physical activity, and abdominal obesity. Interestingly,
42
43 386 there was no association of diabetes identified for increasing body mass index (BMI). This
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45 387 indicates that abdominal obesity may be a more significant factor to consider than BMI. Prior
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47 388 studies conducted in Bangladesh have also identified a positive association of central (or
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49 389 abdominal) obesity with diabetes³². Interestingly, our assessment found a decrease in odds of
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51 390 diabetes with increasing wealth quartile. Prior studies have conflicting findings on the risk of
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53 391 diabetes and other NCDs, among the wealthy based on demographic features such as area of
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55 392 residence. One prior study conducted in Bangladesh found that people from the highest wealth
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3 393 quintile are significantly more likely to have diabetes than people from the lowest wealth
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5 394 quintile³³. However, another found a high burden of selected NCDs, including diabetes, among
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7 395 the lowest wealth quintile populations in rural areas and wealthy populations in urban areas³⁴.
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9 396 Further study is warranted to assess the reliability of wealth indices as a measurement of
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11 397 socioeconomic status and wealth among Bangladeshi adults.

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14 398 In our study, a high proportion (~70%) of those with raised blood glucose self-reported to
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16 399 have been previously diagnosed with diabetes and therefore, aware of their condition.
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18 400 Additionally, 72% reported to take medication to control their diabetes. However, we found that
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20 401 almost one-third of those who self-reported to take medication for their diabetes, continued to
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22 402 have raised blood glucose. Efforts should be made to ensure diabetics in Bangladesh are
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24 403 treated for their condition and secondary prevention of complications of diabetes, such as
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26 404 diabetic retinopathy. This is of particular concern in developing countries where resources are
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28 405 limited and cost-effective solutions for chronic disease treatment should be prioritized. A
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30 406 recently published study found that healthcare expenditure in persons with diabetes in
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32 407 Bangladesh is six times higher than in persons without diabetes¹⁵. Prevention and management
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34 408 of diabetes is likely to be a cost-saving approach for Bangladesh through the utilization of
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36 409 community health workers adequately trained to effectively screen for, and identify, people with
37
38 410 diabetes³⁵.

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41 411 This study has several strengths. Data collected for our study was of a nationally
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43 412 representative sample indicating our results are highly generalizable to the total population of
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45 413 Bangladeshis aged 18 years and above. Our sample of 1843 allowed us to do an effective
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47 414 analysis of further subgroups. However, several limitations should also be considered when
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49 415 interpreting the results of this analysis. We assessed blood glucose levels using random
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51 416 capillary blood samples, however, we did not assess history of classical symptoms of
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53 417 hyperglycemia, which is necessary to diagnose diabetes according to the ADA guidelines²².
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55 418 Additionally, we were unable to measure factors such as family history of diabetes, and obtain
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3 419 blood glucose samples in fasting or two-hour post-prandial status to also assess prediabetes.
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5 420 Future studies should consider the addition of glycosylated hemoglobin measurement when
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7 421 assessing the prevalence of diabetes as this method could provide more long-term and stable
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9 422 diagnosis of diabetes mellitus. As such, we have an adequate sample size to measure
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11 423 prevalence of diabetes. Finally, due to the cross-sectional nature of this study, we were unable
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13 424 to define temporality of certain determinants of raised blood glucose identified and therefore,
14
15 425 unable to assess causality.
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19 20 427 **Conclusion**

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22 428 Data from this nationally-representative sample of Bangladeshi adults aged 18 years
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24 429 and above will be critical to inform the progress of NCD control in Bangladesh per the WHO's
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26 430 Global Monitoring Framework and goals for 2025. We found that about one in twenty
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28 431 Bangladeshi adults aged ≥ 18 years have raised blood glucose. Among urban residents, we
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30 432 found that about one in ten Bangladeshi adults aged ≥ 18 years have raised blood glucose .
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32 433 Bangladeshi adults with hypertension and abdominal obesity are high-risk groups for the
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34 434 development of diabetes and should be targeted for routine screening for diabetes. Preventive
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36 435 methods such as lifestyle changes and medication should be recommended by primary care
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38 436 providers in Bangladesh to avoid the future development of CVDs among this group. In order to
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40 437 control the prevalence of raised blood glucose, and reduce the burden of diabetes and
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42 438 associated risk factors, national initiatives such as training community health workers to deliver
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44 439 primary care and implementing universal health coverage should be implemented to curb the
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46 440 spread of NCDs in Bangladesh.
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3 445 Figures
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5 446 Figure 1: Urban and Rural differences in distribution of blood glucose levels based on random
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7 447 capillary blood measurement among (A) All Participants, and (B) Men and Women (n = 1819)
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9 448 Figure 2: Prevalence of raised blood glucose among Bangladeshi adults aged 18 years and
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11 449 above by sex and age group, 2015 (n = 1819)
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13 450 Figure 3: Bangladeshi adults aged 18 years and above with (A) self-reported diabetes and (B)
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15 451 self-reported diabetics on diabetes medications, 2015
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17 452 Figure 4: Self-reported diabetics aged 18 years or older who take diabetes medication with
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19 453 raised blood glucose on study measurement (≥ 11.0 mmol/L)
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3 471 **Abbreviations**
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5 472 WHO: World Health Organization
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7 473 ADA: American Diabetes Association
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9 474 aPR: Adjusted prevalence ratio
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11 475 BBS: Bangladesh Bureau of Statistics
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13 476 BMI: Body mass index
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15 477 BP: Blood pressure
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17 478 BSMMU: Bangabandhu Sheikh Mujib Medical University
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19 479 CI: Confidence interval
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21 480 CVD: Cardiovascular disease
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23 481 MET: Metabolic equivalent
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25 482 mmHg: Millimeter of mercury
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27 483 mmol/L: Millimoles per litre
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29 484 NCD: Non-communicable disease
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31 485 SBP: Systolic blood pressure
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33 486 DBP: Diastolic blood pressure
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35 487 PSU: Primary sampling unit
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37 488 SD: Standard deviation
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39 489 STEPS: STEPwise approach to surveillance
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3 497 **Footnotes**
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5 498 Ethics approval and consent to participate: Ethical guidelines as outlined by the Declaration of
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7 499 Helsinki were followed throughout the study. Ethical clearance was obtained from Institutional
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9 500 Review Board of Bangabandhu Sheikh Mujib Medical University (BSMMU). We obtained
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11 501 permission from the relevant administrative units of the surveyed districts. Orientations with
12
13 502 community leaders (elected representatives of the local government offices) were conducted
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15 503 prior to data collection for community engagement in the study's implementation process.
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17 504 Written (or thumb impression if unable to write) consent was obtained from the respondents in
18
19 505 Bangla as per BSMMU Institutional Review Board (IRB) guidelines.
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21

22 506 Consent to publish: All authors consent to the publication of this manuscript.
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24 507 Availability of data and materials: The datasets used and/or analyzed during the current study
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26 508 are available from the corresponding author on reasonable request.
27

28 509 Competing Interests: The authors declare no competing interests. The authors alone are
29
30 510 responsible for views expressed in this article and they do not necessarily represent the views,
31
32 511 decisions or policies of the institutions with which they are affiliated.
33

34 512 Funding: The study was conducted with technical and financial assistance of the World Health
35
36 513 Organization Country Office for Bangladesh.
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38 514 Authors contributions: JYI: analyzed data, interpreted results, and drafted the manuscript. MMZ:
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40 515 designed the study, interpreted results critically, conceptualized the manuscript, guided
41
42 516 manuscript writing, and critically reviewed it. MRB, SAH, SA, ZAQ: trained the field team,
43
44 517 implemented the survey, processed and analyzed data, and reviewed the manuscript.
45
46

47 518 Acknowledgements: The authors thank Mr. Hassanuzzaman Khan for his efforts on data
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49 519 management.
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Table 1: Background Characteristics of Bangladeshi adult participants, 2015 (n = 1819)

Characteristic	Total (n = 1819)			Urban (n = 708)			Rural (n = 1111)		
	Mean (SD)	n	%	Mean (SD)	n	%	Mean (SD)	n	%
Gender									
Male		892	49.0		345	48.7		547	49.2
Female		927	50.9		363	51.3		564	50.8
Age(years)	40.5 (14.7)			39.1 (13.9)			41.4 (15.1)		
Education (Years) ^a	5 (0 - 9)			8 (3-12)			4 (0-8)		
Marital Status									
Never Married		110	6.1		54	7.6		56	4.9
Married		1601	88.0		619	87.4		982	88.4
Separated/Divorced/Widowed		108	5.9		35	4.9		73	6.5
Occupation									
Professional employment ^b		279	15.2		189	26.7		90	8.1
Unemployed/retired		98	5.3		43	6.1		55	4.9
Industrial worker/Day Laborer		483	26.6		120	16.9		363	32.7
Housewife		726	39.9		247	34.9		479	43.2
Other ^c		232	12.8		109	15.4		123	11.1
Wealth Index ^d									
1st Wealth Quartile		407	22.4		110	15.5		297	26.7
2nd Wealth Quartile		533	29.3		171	24.2		362	32.6
3rd Wealth Quartile		429	23.6		179	25.3		250	22.5
4th Wealth Quartile		450	24.7		248	35.0		202	18.2
Tobacco Use ^e									
Never		859	47.2		389	54.9		470	42.3
Current Use		821	45.1		268	37.9		553	49.8
Past Use		139	7.6		51	7.2		88	7.9
Smoking Tobacco Use ^f									
Every day / Occasionally		494	27.2		169	23.9		325	29.3
Past Use		104	5.7		38	5.4		66	5.9
Never		1221	67.1		501	70.8		720	64.8
Smokeless Tobacco Use ^g									
Every day / Occasionally		529	29.1		150	21.2		379	34.1
Past Use		51	2.8		21	2.9		30	2.7
Never		1239	68.1		537	75.9		702	63.2
Physical Activity ^h									
Vigorous		1268	69.7		445	62.9		823	74.1
Moderate		464	25.5		234	33.1		230	20.7
Low		87	4.7		29	4.1		58	5.2

1	Body Mass Index ⁱ	22.1 (4.1)	23.3 (4.5)	21.3 (3.7)
2	Waist Circumference (cm)	78.4 (11.6)	81.8 (12.6)	76.2 (10.3)
3	Blood Pressure			
4	Systolic Blood Pressure (mmHg)	116.1 (17.1)	117.9 (16.6)	115.0 (17.3)
5	Diastolic Blood Pressure (mmHg)	76.1 (10.5)	77.9 (10.9)	74.9 (10.1)
6	Blood Glucose Level (mmol/l)	6.4 (2.4)	6.6 (2.9)	6.3 (2.1)

8 Abbreviations: SD, standard deviation

9 ^a Calculated median and interquartile range for education as the data are skewed

10 ^b Professional occupation includes: Field staff, police officer, guard, doctor, engineer, professional, business man, desk job

11 ^c Other occupation includes: Shop keeper, weavers, driver, student, beggar, cook, carpenter, tailor, migrant workers and fishermen

12 ^d Wealth index was calculated using principal component analysis using data collected on household ownership of the following items: electricity, flushable toilet, land phone, cell phone, television, radio, refrigerator, private car, motor cycle, washing machine, bicycle, sewing machine, almirah/wardrobe, table, bed, chair/bench, watch/clock, as well as, type of main material used to build their homes roof, walls and floor

13 ^e Includes both smokeless tobacco and smoke tobacco

14 ^f Smoking tobacco use includes cigarettes, biri, hookah, etc.

15 ^g Smokeless tobacco use includes jodda, paan, white leaf, etc.

16 ^h Measured in MET-minutes; 1 MET stands for the amount of oxygen you consume and the number of calories you burn at rest.

17 ⁱ Body mass index (BMI) calculated by weight in kilogram divided by height in meter squared

Table 2: Determinants of raised blood glucose among Bangladeshi adults, 2015 (n = 1819)

Characteristic	Total (n = 1819)		Urban (n = 708)		Rural (n = 1111)	
	Diabetes ^a Prevalence %	Adjusted PR ^b (95% CI)	Diabetes ^a Prevalence %	Adjusted OR ^b (95% CI)	Diabetes ^a Prevalence %	Adjusted OR ^b (95% CI)
Area						
Urban	9.8	Ref.	-	-	-	-
Rural	2.8	0.44 (0.28 – 0.68)	-	-	-	-
Gender						
Male	4.9	Ref.	7.5	Ref.	3.3	Ref.
Female	5.9	1.05 (0.71 – 1.54)	11.9	1.26 (0.80 – 1.99)	2.2	0.61 (0.29 – 1.28)
Age (years)						
18 - 29	2.5	Ref.	2.5	Ref.	2.5	Ref.
30 - 44	4.9	1.48 (0.78 – 2.79)	8.4	2.55 (1.01 – 6.41)	2.5	0.76 (0.30 – 1.93)
45 - 54	7.4	2.18 (1.10– 4.31)	15.5	4.38 (1.62 – 11.59)	2.8	0.67 (0.25 – 1.83)
≥ 55	8.8	1.92 (0.95 – 3.86)	19.3	3.92 (1.48 – 10.39)	3.4	0.53 (0.17 – 1.67)
Educational Status						
No Education	3.4	Ref.	7.0	Ref.	2.1	Ref.
Primary Education	3.7	1.00 (0.53 – 1.86)	7.6	1.00 (0.44 – 2.30)	2.1	0.84 (0.30 – 2.30)
Secondary Education	6.9	1.67 (0.95 – 2.93)	12.1	1.94 (0.95 – 3.97)	2.9	1.01 (0.40 – 2.54)
Above Secondary Education	9.8	1.48 (0.77 – 2.84)	10.4	1.54 (0.71 – 3.33)	8.1	2.24 (0.68 – 7.41)
Wealth Index^c						
1st Wealth Quartile	7.7	2.58 (1.57 – 4.24)	18.9	3.18 (1.80 – 5.62)	3.6	1.37 (0.53 – 3.49)
2nd Wealth Quartile	4.3	1.23 (0.71 – 2.14)	9.4	1.50 (0.82 – 2.77)	1.9	0.70 (0.24 – 2.05)
3rd Wealth Quartile	3.7	0.86 (0.47 – 1.58)	6.0	0.96 (0.48 – 1.92)	2.0	0.55 (0.18 – 1.73)
4th Wealth Quartile	6.6	Ref.	8.8	Ref.	3.9	Ref.
Blood Pressure						
Normal Blood Pressure	1.9	Ref.	3.5	Ref.	1.1	Ref.
Pre-Hypertension ^d	5.7	1.74 (1.00 – 3.01)	8.3	1.37 (0.69 – 2.74)	3.8	2.32(0.91 – 5.92)
Hypertension ^e	18.9	3.57 (2.01 – 6.34)	27.4	2.65 (1.30 – 5.38)	8.8	5.39(1.94 –14.96)
Physical Activity						
Vigorous	3.9	Ref.	6.9	Ref.	2.3	Ref.
Moderate	8.2	1.18 (0.78 – 1.77)	13.8	1.22 (0.77 – 1.93)	2.1	0.65 (0.22 – 1.88)
Low	14.9	3.04 (1.69 – 5.47)	20.7	3.01 (1.42 – 6.38)	12.1	2.58 (0.95 – 7.04)
Body Mass Index^f						
Underweight (<18.5)	1.1	0.37 (0.12 – 1.13)	1.8	0.38 (0.07 – 1.95)	0.7	0.42 (0.09 – 2.02)

1							
2	Normal (18.5 - 25)	4.7	Ref.	8.2	Ref.	2.8	Ref.
3	Overweight (25.1 - 30)	10.4	1.06 (0.68 – 1.65)	14.0	1.05 (0.61 – 1.80)	6.2	1.22 (0.51 – 2.91)
4	Obese (>30)	20.9	1.49 (0.87 – 2.57)	26.5	1.46 (0.81 – 2.64)	5.6	0.95 (0.12 – 7.60)
5	Waist Circumference (cm)						
6	Normal ^g	2.3	Ref.	3.8	Ref.	1.6	Ref.
7	Abdominally Obese ^h	13.3	2.49 (1.53 – 4.07)	18.1	2.54 (1.35 – 4.77)	6.8	2.95 (1.32 – 6.58)

8 Abbreviations: PR = prevalence ratio, CI = confidence intervals, Ref = referent category

9 ^a Raised blood glucose was defined as a capillary blood glucose level greater than or equal to 11.1 mmol/L or self-reported diabetes medication use

10 ^b Model adjusted for all variables included in table: sex, age, education, wealth index, blood pressure, body mass index, self-reported physical activity, and waist circumference

11 ^c Wealth index was calculated using principal component analysis using data collected on household ownership of the following items: electricity, flushable toilet, land phone, cell phone, television, radio, refrigerator, private car, motor cycle, washing machine, bicycle, sewing machine, almirah/wardrobe, table, bed, chair/bench, watch/clock, as well as, type of main material used to build their homes roof, walls and floor

12 ^d Pre-Hypertension was defined as SBP \geq 120 mmHg but $<$ 140 mmHg and/or DBP \geq 80 mmHg but $<$ 90 mmHg and not taking anti-hypertensive medication at the time of the survey

13 ^e Hypertension was defined as systolic blood pressure (SBP) was \geq 140 mmHg (millimeters of mercury) and/or, diastolic blood pressure (DBP) \geq 90 mmHg and/or taking any-hypertensive medication

14 ^f Body mass index (BMI) calculated by weight in kilogram divided by height in meter squared

15 ^g Defined as $<$ 90 cm M; $<$ 80 cm F

16 ^h Defined as \geq 90 cm M; \geq 80 cm F

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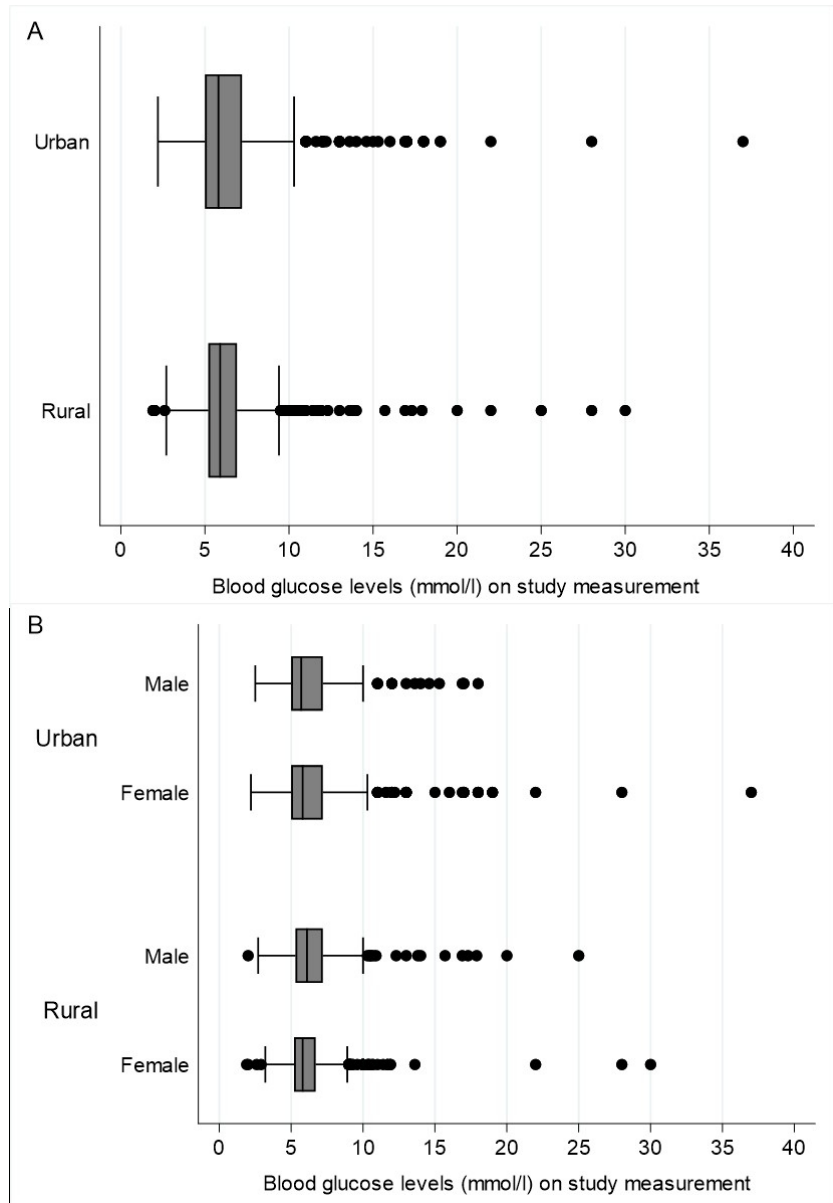


Figure 1: Urban and Rural differences in distribution of blood glucose levels based on random capillary blood measurement among (A) All Participants, and (B) Men and Women (n = 1819)

140x202mm (150 x 150 DPI)

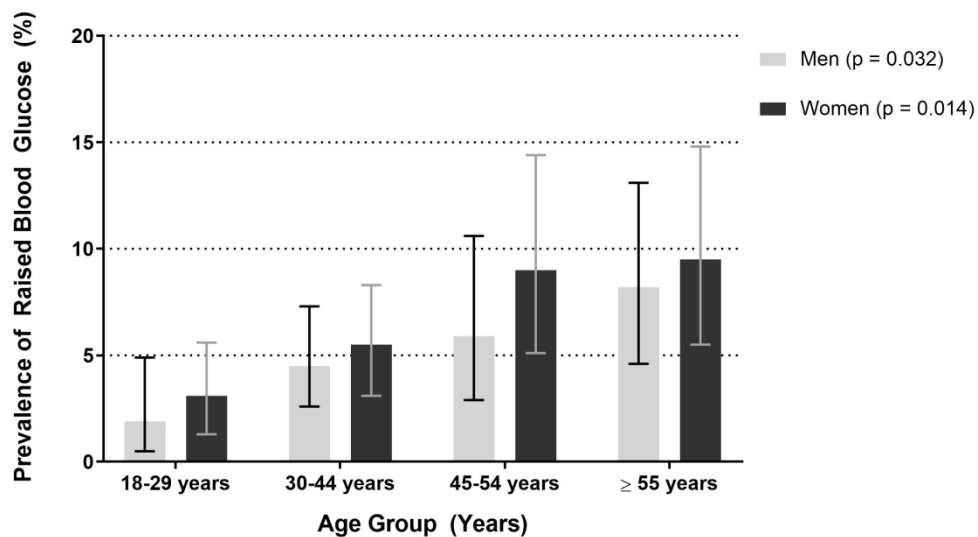


Figure 2: Prevalence of raised blood glucose among Bangladeshi adults aged 18 years and above by sex and age group, 2015 (n = 1819)

209x117mm (300 x 300 DPI)

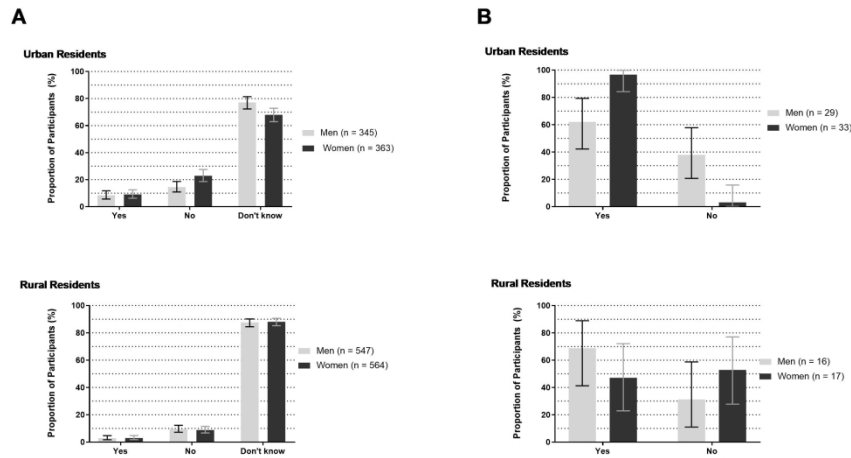


Figure 3: Bangladeshi adults aged 18 years and above with (A) self-reported diabetes and (B) self-reported diabetics on diabetes medications, 2015

245x120mm (300 x 300 DPI)

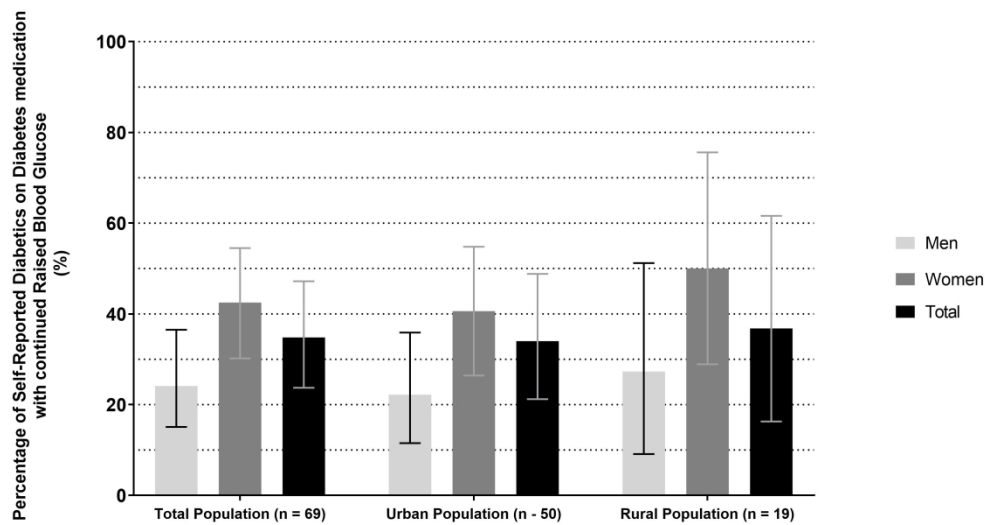


Figure 4: Self-reported diabetics aged 18 years or older who take diabetes medication with raised blood glucose on study measurement ($\geq 11.0\text{mmol/L}$)

286x154mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	6-7 & 11
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	11
		(b) Describe any methods used to examine subgroups and interactions	11
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(b) Report category boundaries when continuous variables were categorized	9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Prevalence and determinants of hyperglycemia among adults in Bangladesh: results from a population-based national survey

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-029674.R1
Article Type:	Research
Date Submitted by the Author:	17-May-2019
Complete List of Authors:	Islam, Jessica; World Health Organization Country Office for Bangladesh, ; University of North Carolina at Chapel Hill Gillings School of Global Public Health, Department of Epidemiology Zaman, MM; World Health Organization, Dhaka, Bangladesh, Bhuiyan, Mahfuz; World Health Organization Country Office for Bangladesh Haq, Syed; Bangabandhu Sheikh Mujib Medical University, Rheumatology Ahmed, Shamim; Bangabandhu Sheikh Mujib Medical University Al-Qadir, Zahid; Bangabandhu Sheikh Mujib Medical University
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Diabetes and endocrinology, Global health
Keywords:	non-communicable diseases, chronic disease, raised blood glucose, Bangladesh

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Manuscripts

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10 3 Jessica Y. Islam^{1,2}, M. Mostafa Zaman^{*2}, Mahfuzur Rahman Bhuiyan², Syed Atiqul Haq³,
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41 21 **Manuscript word count: 4,200**
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30 **Abstract**

31 Objectives: With the increasing burden of non-communicable diseases in low- and middle-
32 income countries, biological risk factors such as hyperglycemia are a major public health
33 concern in Bangladesh. Hyperglycemia is an excess of glucose in the bloodstream and is often
34 associated with type-2 diabetes mellitus. Nationally representative data of hyperglycemia
35 prevalence starting from age ≥ 18 years are currently unavailable for Bangladeshi adults. The
36 objective of this study was to assess the prevalence and determinants of hyperglycemia among
37 adults in Bangladesh aged ≥ 18 years.

38
39 Study Design: Cross-sectional, population-based study

40
41 Setting and Participants: Data for this analysis were collected from a population-based
42 nationally representative sample of 1843 adults, aged ≥ 18 years, from both urban and rural
43 areas of Bangladesh. Demographic information, capillary blood glucose, blood pressure, height,
44 weight, waist circumference, and treatment history were recorded.

45
46 Primary Outcome Measures: Hyperglycemia was defined as a random capillary blood glucose
47 level of ≥ 11.1 mmol/L (i.e. in the diabetic range) or currently taking medication to control type-2
48 diabetes, based on self-report.

49
50 Results: Overall, the prevalence of hyperglycemia was 5.5% (95% CI: 4.5-6.6) and was
51 significantly higher among urban (9.8%, 95% CI: 7.7-12.2) than rural residents (2.8%, 95% CI:
52 1.9-3.9). The age-standardized prevalence of hyperglycemia was 5.6% (95% CI: 4.6-6.8).
53 Among both urban and rural residents, the associated determinants of hyperglycemia included
54 hypertension and abdominal obesity. About 5% of the total population self-reported to have

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2
3 55 been previously diagnosed with type-2 diabetes; among these adults, over 25% were not taking
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5 56 medications to control their diabetes.
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7 57 Conclusions: Our study found that about 1 out of 20 Bangladeshi adults aged ≥ 18 years have
8
9 58 hyperglycemia. To control and prevent the development of type-2 diabetes, data from this study
10
11 59 can be used to inform public health programming and provide descriptive information on
12
13 60 surveillance of progress towards controlling diabetes in Bangladesh.
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18 62 **Keywords:** non-communicable diseases, Bangladesh, hyperglycemia, diabetes, chronic
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Article Summary

Strengths and Limitations of the Study

- This study utilized a multistage, geographically clustered, probability-based sampling approach to produce nationally representative data for Bangladesh.
- Currently, nationally representative data for the prevalence of hyperglycemia in the diabetic range is unavailable for adults aged 18-29 years. A strength of our study is that we included Bangladeshi adults aged 18 years and above to obtain novel data on the prevalence of hyperglycemia, and relevant non-communicable disease risk factors
- We were able to estimate the prevalence of hyperglycemia using capillary blood glucose measured at random. However, we were unable to measure the prevalence of prediabetes and diabetes as we did not obtain blood sugar levels using standardized methods, such as fasting blood glucose or 2-hour post-prandial measurements.
- Due to the cross-sectional nature of the study design, we were unable to assess temporality of risk factors identified and our outcomes of interest.
- We assessed type-2 diabetes medication history based on self-report and we were able to obtain medicine strips or vials records or prescription records of participants to confirm the self-reported data.

108 **Background**

109 Globally, diabetes mellitus (DM), characterized by hyperglycemia, is a leading cause of
110 premature mortality and disability. Globally, almost half of all deaths attributable to high blood
111 glucose occur before the age of 70 years, and the WHO estimates that diabetes was the
112 seventh leading cause of mortality in 2016. The global prevalence of DM has been on the rise
113 over the past several decades^{1,2}. Estimates reflect the global prevalence of diabetes has nearly
114 doubled among adults aged 18 years and above, rising from 4.7% in 1980 to 8.5% in 2014³.
115 This growing burden is most prominent in low- and middle-income countries particularly the
116 Indian sub-continent⁴, which accounts for close to one-fifth of all diabetes cases worldwide. The
117 prevalence of diabetes in this region is projected to increase by 71% by 2035⁵. In Bangladesh,
118 specifically, the International Diabetes Federation projects the prevalence of diabetes will
119 increase to more than 50% in the next 15 years⁵.

120 The increasing prevalence of diabetes among Bangladeshi adults over the past few
121 decades has been documented: Based on a meta-analysis of studies conducted from 1995 –
122 2010, the prevalence of diabetes among Bangladeshi adults aged 30 years and above
123 increased from 4% in 1995 to 2000 and 5% in 2001 to 2005 to 9% in 2006 to 2010⁶. Studies to
124 assess the burden of diabetes have been conducted in Bangladesh in both urban and rural
125 populations over the last decades⁷. However, national data on the prevalence of diabetes or
126 hyperglycemia in the diabetic range starting at age 18 years are currently unavailable⁷⁻¹⁰. These
127 data are valuable for monitoring progress made towards one of the nine global non-
128 communicable disease (NCD) targets of the year 2025, set forth by the World Health
129 Organization's (WHO) NCD Global Monitoring Framework: To observe a 0% increase in age-
130 standardized prevalence of hyperglycemia or diabetes among persons aged ≥ 18 years¹¹. As
131 such in response to the WHO Global Action Plan for the Prevention and Control of NCDs¹²,
132 descriptive epidemiological data on the burden of hyperglycemia among adults starting at 18
133 years are needed to monitor the national progress of interventions implemented to reduce the

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3 134 burden of DM in Bangladesh¹³⁻¹⁵. Here, using a nationally representative sample, we present
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5 135 data on prevalence and determinants of hyperglycemia by various sociodemographic factors
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7 136 such as age, sex, and area of residence among Bangladeshi adults aged 18 years and above,
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9 137 residing in both urban and rural areas of the country. Additionally, we explore treatment patterns
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11 138 and control of hyperglycemia among participants in our sample of Bangladeshi adults.
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15 16 140 **Methods**

17
18 141 Data for this analysis were collected as part of a national assessment of the burden of
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20 142 musculoskeletal disorders in Bangladesh conducted by investigators from the Bangabandhu
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22 143 Sheikh Mujib Medical University (BSMMU) with technical assistance from the WHO Country
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24 144 Office for Bangladesh, as previously described¹⁶. The study was a population-based cross-
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26 145 sectional study carried out from November to December 2015 and followed the WHO STEP-
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28 146 wise approach to Surveillance of NCD risk factors (STEPS)¹⁷. The target population of this
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30 147 survey was men and women aged ≥ 18 years residing in rural and urban areas of Bangladesh.
31
32 148 The exclusion criteria included tourists and the institutionalized, including residents of hospitals,
33
34 149 prisons, nursing homes, and army barracks.
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38 39 151 Sampling Methods

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41 152 To obtain a population-based sample of Bangladesh, this survey adopted a multistage,
42
43 153 geographically clustered, probability-based sampling approach. Population statistics were
44
45 154 obtained using the updated national census conducted by the Bangladesh Bureau of Statistics
46
47 155 (BBS) in 2009¹⁸. To obtain our primary sampling unit (PSU), we utilized the following
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49 156 geographical distribution described: In Bangladesh, there are seven divisions, which are the
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51 157 largest administrative units of the country. Each division is divided into several districts (*Zila*)
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53 158 and within each district, there are several sub-districts (*Upazila*). Within sub-districts, *mauzas*
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55 159 and *mahallas* (commonly known as neighborhoods or blocks) are the smallest units within
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3 160 defined territories in rural and urban areas respectively. *Mauzas* and *mahallas* were considered
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5 161 the PSU for the study's sampling approach. The households within the *mauzas* and *mahallas*
6
7 162 were the secondary sampling units. We utilized the BBS' definition of a household which is as
8
9 163 follows: "a dwelling in which persons either related or unrelated were living together and taking
10
11 164 food from the same kitchen"¹⁸.

13 165

16 166 Sample size estimation

18 167 The power analysis and sample size calculations were completed based on the
19
20 168 standardized approach outlined in the WHO STEPS methodology¹⁷. Using the WHO STEPS
21
22 169 methodology, the minimum number of participants required was 296 in each group (rural males,
23
24 170 rural females, urban males, and urban females). Assuming a design effect of 1.5 adjusted within
25
26 171 cluster population homogeneity, the necessary sample size was 1776. We assumed a response
27
28 172 rate of 90% and determined we would need to contact at least 1973 adults. For simplicity, our
29
30 173 target sample size was 2000. Twenty PSUs (8 urban and 12 rural) were randomly selected from
31
32 174 7 divisions of the country, with the probability proportional to the population size of each
33
34 175 division. In each PSU, 100 consecutive households were selected. The even numbered
35
36 176 households were designated as a "male household" and odd numbered households as a
37
38 177 "female household." Finally, one male or female was approached to participate from each
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40 178 respective household as designated.

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45 180 Data collection

47 181 Through a structured survey, we collected data on the following topics: musculoskeletal
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49 182 disorders¹⁹, health history, and demographic data such as age, area of residence, education,
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51 183 current (last 12 months) occupation, tobacco use, and physical activity. Physical measurements
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53 184 such as height, weight, waist circumference, blood glucose levels, and blood pressure were
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55 185 collected. To measure blood glucose levels, we obtained random blood glucose samples³, per

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3 186 the clinical guidelines of diabetes diagnostic criteria of Bangladesh²⁰. Capillary blood samples
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5 187 were consistently taken from the index finger of the right arm using a glucometer, namely Accu-
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7 188 chek Advantage (Roche Diagnostics Division, Grenzacherstrasse, Switzerland).
8

9 189 Each participant's history of diabetes was assessed based on self-report. Specifically,
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11 190 participants were asked: 1. Have you ever been diagnosed with diabetes by a health care
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13 191 professional? 2. If yes, are you receiving treatment for diabetes? Treatment history of diabetes
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15 192 was confirmed by prescription, including medicine strips or insulin injection vials, or medical
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17 193 records. The questionnaire was translated from English to Bengali, adapted and validated per
18
19 194 standard procedure. Data collection procedures were standardized across study sites through
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21 195 coordinated training of field staff conducted by epidemiologists, study physicians, and WHO
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23 196 staff members.
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26 197 Blood pressure was measured by a trained field interviewer using the LifeSource UA-
27
28 198 767+ blood pressure monitor, as recommended by the WHO, and appropriately sized arm cuffs.
29
30 199 Blood pressure measurements were consistently taken on each participant's right arm at the
31
32 200 level of the heart and elbow-assisted, while the participant was in a seated position. The initial
33
34 201 measurement was performed after five minutes of rest. After two minutes, the second
35
36 202 measurement was taken. The mean of these two blood pressure readings was utilized as the
37
38 203 final blood pressure for each participant.
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41 204 Following data collection, participants scheduled a visit with the study research physician
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43 205 within the following five days. The research physician assessed the participant's medical history,
44
45 206 either through self-report or using medical records when possible. Study physicians examined
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47 207 each participant to confirm the results of data collection through classical symptom assessment.
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49 208 When necessary, the participant was also evaluated by the divisional investigator for a second
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51 209 opinion of relevant diagnoses.
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56 211 Patient and public involvement
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3 212 There was no patient or public involvement in the implementation of this study or interpretation
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5 213 of analytic results.
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9 215 Outcome definitions

11 216 Our primary outcome of interest was the prevalence of hyperglycemia. We utilized the
12
13 217 American Diabetes Association (ADA) guidelines to define a diagnosis of hyperglycemia using
14
15 218 random or casual plasma glucose test and symptom review by the study physician ²¹. An
16
17 219 individual was considered to have hyperglycemia if the plasma glucose level was 11.1 mmol/L
18
19 220 or higher (i.e. in the diabetic range) and/or if they self-reported to take diabetes medication. Our
20
21 221 secondary outcome of interest was the prevalence of self-reported type-2 diabetes mellitus. An
22
23 222 individual was categorized as diabetic if they self-reported to have been previously diagnosed
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25 223 with diabetes by a health care provider.
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28 224

30 225 Covariates

32 226 The following variables were assessed as covariates for analysis: area of residence,
33
34 227 sex, age, education, occupation, wealth index, body mass index (BMI), BP, and waist
35
36 228 circumference. Education was categorized into four groups: no education, primary education
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38 229 (completed grade ≤ 5), secondary education (completed \leq grade 10), and above secondary
39
40 230 education (completed \geq grade 12). Each participant's occupation was categorized into five
41
42 231 groups, including: professional employment (field staff, police officer, guard, doctor, engineer,
43
44 232 professional, businessman, desk job), unemployed or retired, industrial worker or day laborer,
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46 233 housewife, and other (shop keeper, weaver, driver, student, beggar, cook, carpenter, tailor,
47
48 234 migrant workers and fishermen).
49

51 235 Data on physical activity was collected based on self-report. First, respondents were
52
53 236 asked the number of days they engaged in vigorous, moderate, or light physical activity
54
55 237 throughout a typical week. The following definitions were used to define (1) vigorous, (2)

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3 238 moderate, and (3) light physical activity, respectively: (1) vigorous activity was defined as any
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5 239 activity that caused a large increase in breathing or heart rate, if continued for at least 10
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7 240 minutes (e.g. running, carrying heavy loads, digging or construction work); (2) moderate activity
8
9 241 was defined as any activity that caused a small increase in breathing or heart rate, if continued
10
11 242 for at least 10 minutes (brisk walking or carrying light loads); and (3) light physical activity was
12
13 243 defined as activities such as office work. Next, we asked participants to estimate how many
14
15 244 minutes per day they engaged in the activity. MET-minute was calculated using the STEPS
16
17 245 protocol²² as follows: one minute of light activity was equivalent to 1 MET-minute; one minute in
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19 246 moderate-intensity activities was equivalent to 4 MET-minutes, and one minute of vigorous-
20
21 247 intensity was equivalent to 8 MET-minutes. Physical activity was then categorized based on
22
23 248 total MET-minutes per week. Participants who spent 3000 or more MET-minutes per week were
24
25 249 categorized in the vigorous physical activity group, 600-3000 MET-minutes were categorized as
26
27 250 moderate physical activity, and <600 MET-minutes were categorized as low physical activity.

30
31 251 The wealth index was constructed using principal component analysis. Asset information
32
33 252 collected covered information on household ownership of nineteen items, including electricity,
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35 253 flush toilet, land telephone, cell phone, television, radio, refrigerator, car, motorcycle, washing
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37 254 machine, bicycle, sewing machine, wardrobe, table, bed or cot, chair or bench, watch or clock.
38
39 255 Additionally, we assessed the main type of material used to build each participant's home (i.e.
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41 256 cement, tin, bamboo, or thatched straw). Each asset was assigned a weight (factor score)
42
43 257 generated through principal components analysis, and the resulting asset scores were
44
45 258 standardized to a normal distribution with a mean of zero and standard deviation of one. Each
46
47 259 household was then assigned a score for each asset, and the scores were summed up;
48
49 260 individuals were ranked according to the total score of the household in which they resided. The
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51 261 sample was then divided into quartiles from quartile one (lowest) to quartile four (highest).
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53 262 Using height (centimeters) and weight (kilograms) measurements, we calculated BMI
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55 263 (height/weight²). BMI was categorized in the following groups: underweight (≤ 18.5), normal

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3 264 (≤ 25), overweight (25.1-30) and obese (>30). Waist circumference was measured in centimeters
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5 265 (cm). Participants were categorized as abdominally obese if waist circumference was 90 cm and
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7 266 above for men, or 80 cm and above for women. Prehypertension was defined as SBP ≥ 120
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9 267 mmHg but < 140 mmHg and/or DBP ≥ 80 mmHg but < 90 mmHg and not taking antihypertensive
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11 268 medication at the time of the survey. We utilized the WHO's guidelines for cut-off points to
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13 269 define hypertension²³. An individual was considered to have hypertension if systolic blood
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15 270 pressure (SBP) was ≥ 140 mmHg (millimeters of mercury) and/or, diastolic blood pressure (DBP)
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17 ≥ 90 mmHg, and/or taking antihypertensive medication based on self-report.
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21 22 273 Age-Standardized Prevalence Estimates

23
24 274 To facilitate comparison of overall hyperglycemia among Bangladeshi adults across
25
26 275 global populations with different age compositions we calculated age-standardized prevalence
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28 276 estimates with 95% confidence intervals (CIs) using the WHO's World Standard Population ²⁴.
29
30 277 The World Standards database (WHO 2000-2025) provided population estimates for 18 and 19
31
32 278 age groups, as well as single year ages. To derive single ages from the 5-year age group
33
34 279 proportions publically available, we used the Beers "Ordinary" Formula²⁵. The following formula
35
36 280 was utilized for standardization:

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38
39 281 $\sum p_i * w_i / \sum w_i$, where p = observed prevalence and w = world population weight.
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42 43 283 Data Analysis

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45 284 Sociodemographic variables were presented with mean and standard deviation (SD) for
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47 285 continuous variables, and using proportions for categorical variables. For bivariate analyses,
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49 286 study participants were divided by sex and into four age groups (18-29, 30-44, 45-54 and ≥ 55
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51 287 years). We calculated the prevalence of our primary outcome by key demographic variables and
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53 288 calculated 95% CIs using the binomial exact method.
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3 289 To estimate determinants of hyperglycemia in the diabetic range, we computed
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5 290 prevalence ratios with Poisson regression using robust estimation of standard errors²⁶⁻²⁸.
6
7 291 Potential variables for inclusion in the model were assessed using prior published literature and
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9 292 bivariate Poisson regression analysis; an arbitrary p-value of <0.10 was used as criteria to
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11 293 include the variable in the multivariable Poisson regression model to control for confounding
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13 294 effects. For multivariable Poisson regression models, adjusted prevalence ratios (aPR), and
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15 295 95% CIs for each independent variable were calculated. Additionally, <0.05 was used as the
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17 296 level of significance. Multivariable Poisson regression models were generated separately for
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19 297 urban and rural participants to account for possible effect measure modification. Collinearity was
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21 298 assessed using the variance inflation factor to ensure a strong linear relationship among
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23 299 independent variables included in the model was not present. All statistical procedures were
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25 300 performed using Stata/SE 15.0 (StataCorp LP, Texas, USA) software package.
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302 **Results**

303 Background Characteristics

304 Of the 2000 adults approached, 1843 agreed to participate in our study leading to a
305 response rate of 92.1%. Twenty-four female participants were pregnant and were dropped from
306 subsequent analyses to ensure those with gestational diabetes were not included. Additionally,
307 no participants reported having been previously diagnosed with type-1 diabetes. There were
308 892 (49.0%) male and 927 (50.9%) female respondents (Table 1). The age of our participants
309 ranged from 18 to 90 years. The mean age and education level of participants were 40.5 (SD =
310 14.7) years and 5.7 (SD = 5.1) years, respectively. The majority of the study population was
311 married (88.0%) and employed as either an industrial worker/day laborer (26.5%) or housewife
312 (39.9%). Almost half of participants never used some form of tobacco. The majority of
313 participants engaged in vigorous physical activity over an average week (69.3%). The mean
314 BMI was 22.1 (SD = 4.1) and the mean waist circumference was 78.4 cm (SD = 11.6). Overall,

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3 315 the mean systolic blood pressure was 116.1 mmHg (SD = 17.1) and diastolic blood pressure
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5 316 was 76.1 mmHg (SD = 10.5). The mean blood glucose level was 6.4 mmol/L (SD = 2.4). Figure
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7 317 1 presents the distribution of blood glucose levels by various demographic factors.
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11 319 Prevalence and Risk Factors for Hyperglycemia

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14 320 The prevalence of hyperglycemia was 5.5% (95% CI: 4.5-6.6). This prevalence was
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16 321 significantly higher among urban participants (9.8%, 95%CI: 7.7-12.2) than rural participants
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18 322 (2.8%, 95% CI: 1.9-3.9) (Table 2) and increased as age increased (Figure 2). The highest
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20 323 prevalence of hyperglycemia was observed among those aged ≥ 55 years, at 8.2% (95% CI: 4.6-
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22 324 13.1) among men and 9.4% (95% CI: 5.4-14.8) among women. The age-standardized
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24 325 prevalence of hyperglycemia was 5.6% (95% CI: 4.6-6.8). The age-standardized prevalence of
25
26 326 hyperglycemia among urban and rural residents was 10.5% (95% CI: 9.2-12.1) and 2.8% (95%
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28 327 CI: 2.1-3.7), respectively. Among men and women, the age-standardized prevalence of
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30 328 hyperglycemia was 4.9% (95% CI: 3.9-6.0) and 6.0% (95% CI: 4.9-7.2), respectively.
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34 330 Self-Reported Diabetes Mellitus and Hyperglycemia

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36
37 331 Ninety-five participants (5.2%) self-reported to have been previously diagnosed with
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39 332 type-2 diabetes by a health care provider. However, 25 of those participants did not meet our
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41 333 criteria of diagnosis of hyperglycemia as they did not take medication to control their diabetes
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43 334 and their plasma glucose was below 11.1 mmol/L. Therefore, 69.3% of those with
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45 335 hyperglycemia, per the study definition, were previously diagnosed with diabetes by a health
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47 336 care provider.
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50 337 The proportion of men and women who were previously diagnosed with diabetes by a
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52 338 health care provider based on self-report was higher among urban residents (men: 8.4%;
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54 339 women: 9,1%) than among rural residents (men: 2.9%; women: 3.0%) (Figure 3a). However,
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56 340 overall, the large majority (81.8%) reported they did not know if they had been previously
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3 341 diagnosed with diabetes; this proportion was higher among rural residents (87.8%) than urban
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5 342 residents (72.2%).

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7 343 Among participants previously diagnosed with type-2 diabetes based on self-report,
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9 344 72.6% reported taking medication to control their diabetes (Table 1). Urban women more
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11 345 frequently (96.7%) self-reported to take diabetes medication than urban men (62.1%) (Figure
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13 346 3b). We were able to confirm 100% of participant's self-reported diabetes treatment history by
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15 347 checking prescriptions or medicine strips/vials.

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18 348 Among participants who were categorized as hyperglycemic during study measurement,
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20 349 over one-third (37.9%) of urban men self-reported to have diabetes, however, they did not take
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22 350 any medication to control their diabetes. Among rural participants, the proportion of women who
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24 351 did not take medication to control their self-reported diabetes was higher (52.9%) than men
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26 352 (31.3%). Although three-quarters of self-reported diabetic participants reported taking
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28 353 medication to control their diabetes, 31% continued to have high blood sugar levels indicating
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30 354 uncontrolled diabetes at study measurement (Figure 4).

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34 356 Determinants of Hyperglycemia

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37 357 Table 2 presents the results of multivariable Poisson regression with robust variance
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39 358 analyses to identify determinants of hyperglycemia. Among urban participants, those of older
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41 359 age, lowest wealth quartile, hypertension, low physical activity, and with abdominal obesity
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43 360 based on waist circumference, were more likely to have hyperglycemia. The prevalence of
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45 361 hyperglycemia was significantly highest among those aged ≥ 55 years (aPR 3.92, 95% CI: 1.48-
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47 362 10.39) compared to individuals aged 18-29 years of age. When compared to those in the 4th
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49 363 (highest) wealth quartile, urban residents in the first (lowest) wealth quartile had 3.18 times the
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51 364 prevalence of hyperglycemia. For urban individuals with hypertension, the prevalence of
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53 365 hyperglycemia was 2.65 (95% CI:1.30-5.38) times that of individuals without hypertension. The
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55 366 prevalence of hyperglycemia among those with low physical activity was 3.01 (95% CI: 1.42-

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3 367 6.38) times that of urban participants with vigorous physical activity. Abdominal obesity also
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5 368 significantly increased the prevalence of hyperglycemia among urban participants (aOR: 2.54,
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7 369 95% CI: 1.35-4.77). Among rural participants, the only observed determinants of hyperglycemia
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9 370 were hypertension (aPR: 5.39, 95% CI: 1.94-14.96) and abdominal obesity (aPR: 2.95, 95% CI:
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11 371 1.32-6.58).

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373 Discussion

374 Using data from this nationally representative sample, we estimate that about one in
375 twenty Bangladeshi adults aged ≥ 18 years have hyperglycemia. The prevalence of
376 hyperglycemia was higher among urban residents (9.8%) than rural residents (2.8%). Risk
377 factors of hyperglycemia included older with age, urban residence, abdominal obesity, low
378 physical activity, and hypertension. As diabetes is characterized by hyperglycemia, targeting
379 high-risk groups identified in this analysis could be prioritized for effective diabetes preventive
380 programs in Bangladesh. Bangladesh has adopted the goals and targets set forth by the WHO's
381 Global Monitoring Framework for the Prevention and Control of NCDs for the year 2025¹¹. One
382 of these targets is to ensure there is a 0% increase in the age-standardized prevalence of
383 hyperglycemia among adults aged ≥ 18 years by the year 2025. To our knowledge, the present
384 study is the first to report national estimates on the prevalence of hyperglycemia starting at age
385 18 years in both urban and rural areas of Bangladesh. Data gathered from this national-level
386 study are critical towards the measurement of progress towards the nine global targets for
387 Bangladesh for 2025.

388 Globally, the number of adults living with diabetes has risen from 108 million in 1980 to
389 422 million in 2013, and low- and middle-income countries (LMICs) have seen the most rapid
390 rise in diabetes prevalence³. Several lifestyle factors have been attributed to the increase in
391 prevalence across LMICs including, globalization of food production, extensive marketing of
392 low-cost and energy-dense foods, increased sedentary behavior and rapid urbanization²⁹. In

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3 393 recent decades, the increase in the prevalence of diabetes in South Asia has been greater than
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5 394 that seen in high-income countries⁴. The prevalence of diabetes in adults across countries in
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7 395 South Asia is similar, excluding Nepal which has a low prevalence in comparison to neighboring
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9 396 countries (8.8% in India, 8.6% in Sri Lanka, 6.9% in Bangladesh, 7.9% in Bhutan, 6.9% in
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11 397 Pakistan, and 4.0% in Nepal)³⁰. In our study, we observed a prevalence of 5.6% hyperglycemia
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13 398 in the diabetic range among adults aged 18 years and above. This prevalence is lower than
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15 399 previous studies conducted in Bangladesh and neighboring countries. In fact, a scoping review
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17 400 estimated the pooled prevalence of type-2 diabetes to be 7.4%⁷. Our estimated prevalence was
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19 401 lower due to a younger study population (18 years and above compared to the WHO estimate
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21 402 among adults aged 30 years and above), and a higher percentage of participants from rural
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23 403 areas (61.1%, as is representative of Bangladesh). Indeed, when we restrict our analytic sample
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25 404 to 30 years and above, the prevalence of hyperglycemia is 6.7%, which is similar to the 2017
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27 405 WHO estimate of diabetes (6.9%). Significant heterogeneity in diabetes and its determinants
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29 406 may exist within one country due to variations in the level of urbanization by state, ethnic
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31 407 phenotypes, and socioeconomic status of specific sub-populations³¹.

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33
34 408 Significant determinants of raised blood glucose in both urban and rural areas of our
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36 409 assessment included hypertension, low physical activity, and abdominal obesity. Interestingly,
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38 410 there was no association of diabetes identified for increasing body mass index (BMI). This
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40 411 indicates that abdominal obesity may be a more significant factor to consider than BMI. Prior
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42 412 studies conducted in Bangladesh have also identified a positive association of central (or
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44 413 abdominal) obesity with diabetes³². Interestingly, our assessment found a decrease in odds of
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46 414 diabetes with increasing wealth quartile. Prior studies have conflicting findings on the risk of
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48 415 diabetes and other NCDs, among the wealthy based on demographic features such as the area
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50 416 of residence. One prior study conducted in Bangladesh found that people from the highest
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52 417 wealth quintile are significantly more likely to have diabetes than people from the lowest wealth
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54 418 quintile³³. However, another found a high burden of selected NCDs, including diabetes, among
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3 419 the lowest wealth quintile populations in rural areas and wealthy populations in urban areas³⁴.

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5 420 Further study is warranted to assess the reliability of wealth indices as a measurement of

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7 421 socioeconomic status and wealth among Bangladeshi adults.

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9 422 In our study, a high proportion (~70%) of those with hyperglycemia self-reported to have

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11 423 been previously diagnosed with diabetes and therefore, aware of their condition. Additionally,

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13 424 72% reported taking medication to control their diabetes. However, we found that almost one-

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15 425 third of those who self-reported to take medication for their diabetes continued to have

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17 426 hyperglycemia. Efforts should be made to ensure diabetics in Bangladesh are treated for their

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19 427 condition and secondary prevention of complications of diabetes, such as diabetic retinopathy.

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21 428 This is of particular concern in developing countries where resources are limited and cost-

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23 429 effective solutions for chronic disease treatment should be prioritized. A recently published

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25 430 study found that healthcare expenditure in persons with diabetes in Bangladesh is six times

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27 431 higher than in persons without diabetes¹⁴. Prevention and management of diabetes are likely to

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29 432 be a cost-saving approach for Bangladesh through the utilization of community health workers

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31 433 adequately trained to effectively screen for, and identify, people with diabetes³⁵.

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33 434 This study has several strengths. Data collected for our study was of a nationally

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35 435 representative sample indicating our results are generalizable to the population of Bangladeshi

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37 436 adults aged 18 years and above. Additionally, due to our large sample size, we were able to

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39 437 conduct precise subgroup analyses. However, several limitations should also be considered

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41 438 when interpreting the results of this analysis. We assessed blood glucose levels using random

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43 439 capillary blood samples, however, we did not assess each participant's history of classical

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45 440 symptoms of hyperglycemia, which is necessary to diagnose diabetes according to the ADA

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47 441 guidelines²¹. Additionally, we were unable to measure known determinants of type-2 diabetes

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49 442 factors such as diet or family history of diabetes. Further, we did not collect blood glucose

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51 443 samples in fasting or two-hour post-prandial status to also assess prediabetes. Future studies

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53 444 should consider the addition of glycosylated hemoglobin measurement when assessing the

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3 445 prevalence of diabetes as this method could provide a more long-term and stable diagnosis of
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5 446 diabetes mellitus. Finally, due to the cross-sectional nature of this study, we were unable to
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7 447 define temporality of certain determinants of hyperglycemia identified and therefore, unable to
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9 448 assess causality.

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11 12 13 14 450 **Conclusion**

15
16 451 Data from this nationally-representative sample of Bangladeshi adults aged 18 years
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18 452 and above will be critical to informing the progress of NCD control in Bangladesh per the WHO's
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20 453 Global Monitoring Framework and goals for 2025. We found that about one in twenty
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22 454 Bangladeshi adults aged ≥ 18 years have hyperglycemia. Among urban residents, we found that
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24 455 about one in ten Bangladeshi adults aged ≥ 18 years have hyperglycemia. Bangladeshi adults
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26 456 with hypertension and abdominal obesity are high-risk groups for the development of diabetes
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28 457 and should be targeted for routine screening for diabetes. Preventive methods such as lifestyle
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30 458 changes and medication should be recommended by primary care providers in Bangladesh to
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32 459 avoid the future development of CVDs among this group. In order to control the prevalence of
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34 460 hyperglycemia in the diabetic range, and reduce the burden of diabetes or associated risk
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36 461 factors, national initiatives such as training community health workers to deliver primary care
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38 462 and implementing universal health coverage should be implemented to curb the spread of
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40 463 NCDs in Bangladesh.

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5 472 Figure 1: Urban and Rural differences in the distribution of blood glucose levels based on
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7 473 random capillary blood measurement among (A) All Participants, and (B) Men and Women (n =
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9 474 1819)
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11 475 Figure 2: Prevalence of hyperglycemia among Bangladeshi adults aged 18 years and above by
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13 476 sex and age group, 2015 (n = 1819)
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15 477 Figure 3: Bangladeshi adults aged 18 years and above with (A) self-reported diabetes and (B)
16
17 478 self-reported diabetics on diabetes medications, 2015
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19 479 Figure 4: Self-reported diabetics aged 18 years or older who take diabetes medication with
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21 480 hyperglycemia on study measurement (≥ 11.0 mmol/L)
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3 497 **Abbreviations**
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5 498 WHO: World Health Organization
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7 499 ADA: American Diabetes Association
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9 500 aPR: Adjusted prevalence ratio
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11 501 BBS: Bangladesh Bureau of Statistics
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13 502 BMI: Body mass index
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15 503 BP: Blood pressure
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17 504 BSMMU: Bangabandhu Sheikh Mujib Medical University
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19 505 CI: Confidence interval
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21 506 CVD: Cardiovascular disease
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23 507 MET: Metabolic equivalent
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25 508 mmHg: Millimeter of mercury
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27 509 mmol/L: Millimoles per liter
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29 510 NCD: Non-communicable disease
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31 511 SBP: Systolic blood pressure
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33 512 DBP: Diastolic blood pressure
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35 513 PSU: Primary sampling unit
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37 514 SD: Standard deviation
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39 515 STEPS: STEPwise approach to Surveillance
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3 **523 Footnotes**
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5 **524 Ethics approval and consent to participate:** Ethical guidelines as outlined by the Declaration of
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7 **525** Helsinki were followed throughout the study. Ethical clearance was obtained from the
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9 **526** Institutional Review Board of Bangabandhu Sheikh Mujib Medical University (BSMMU) (Protocol
10
11 **527** Number: 1100). We obtained permission from the relevant administrative units of the surveyed
12
13 **528** districts. Orientations with community leaders (elected representatives of the local government
14
15 **529** offices) were conducted prior to data collection for community engagement in the study's
16
17 **530** implementation process. Written (or thumb impression if unable to write) consent was obtained
18
19 **531** from the respondents in Bangla as per BSMMU Institutional Review Board (IRB) guidelines.

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21
22 **532 Consent to publish:** All authors consent to the publication of this manuscript.
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24 **533 Availability of data and materials:** The de-identified participant data used and/or analyzed during
25
26 **534** the current study are available from the corresponding author on reasonable request. Please
27
28 **535** contact M. Mostafa Zaman at zamanm@who.int for further information and guidelines.
29

30
31 **536 Competing Interests:** The authors declare no competing interests. The authors alone are
32
33 **537** responsible for views expressed in this article and they do not necessarily represent the views,
34
35 **538** decisions or policies of the institutions with which they are affiliated.
36

37 **539 Funding:** The study was conducted with the technical and financial assistance of the World
38
39 **540** Health Organization Country Office for Bangladesh.
40

41 **541 Authors contributions:** JYI: conceptualized the manuscript, analyzed data, interpreted results
42
43 **542** critically, and drafted the manuscript. MMZ: designed the study, interpreted results critically,
44
45 **543** guided manuscript writing, and critically reviewed it. MRB, SAH, SA, ZAQ: trained the field team,
46
47 **544** implemented the survey, processed and analyzed data, and reviewed the manuscript.
48

49 **545 Acknowledgments:** The authors thank Mr. Hassanuzzaman Khan for his efforts on data
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51 **546** management.
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Table 1: Background Characteristics of Bangladeshi adult participants, 2015 (n = 1819)

Characteristic	Total (n = 1819)			Urban (n = 708)			Rural (n = 1111)		
	Mean (SD)	n	%	Mean (SD)	n	%	Mean (SD)	n	%
Sex									
Male		892	49.0		345	48.7		547	49.2
Female		927	50.9		363	51.3		564	50.8
Age(years)	40.5 (14.7)			39.1 (13.9)			41.4 (15.1)		
Education (Years) ^a	5 (0 - 9)			8 (3-12)			4 (0-8)		
Marital Status									
Never Married		110	6.1		54	7.6		56	4.9
Married		1601	88.0		619	87.4		982	88.4
Separated/Divorced/Widowed		108	5.9		35	4.9		73	6.5
Occupation									
Professional employment ^b		279	15.2		189	26.7		90	8.1
Unemployed/retired		98	5.3		43	6.1		55	4.9
Industrial worker/Day Laborer		483	26.6		120	16.9		363	32.7
Housewife		726	39.9		247	34.9		479	43.2
Other ^c		232	12.8		109	15.4		123	11.1
Wealth Index ^d									
1st Wealth Quartile		407	22.4		110	15.5		297	26.7
2nd Wealth Quartile		533	29.3		171	24.2		362	32.6
3rd Wealth Quartile		429	23.6		179	25.3		250	22.5
4th Wealth Quartile		450	24.7		248	35.0		202	18.2
Tobacco Use ^e									
Never		859	47.2		389	54.9		470	42.3
Current Use		821	45.1		268	37.9		553	49.8
Past Use		139	7.6		51	7.2		88	7.9
Smoking Tobacco Use ^f									
Every day / Occasionally		494	27.2		169	23.9		325	29.3
Past Use		104	5.7		38	5.4		66	5.9
Never		1221	67.1		501	70.8		720	64.8
Smokeless Tobacco Use ^g									
Every day / Occasionally		529	29.1		150	21.2		379	34.1
Past Use		51	2.8		21	2.9		30	2.7
Never		1239	68.1		537	75.9		702	63.2
Physical Activity ^h									
Vigorous		1268	69.7		445	62.9		823	74.1
Moderate		464	25.5		234	33.1		230	20.7
Low		87	4.7		29	4.1		58	5.2

1									
2	Body Mass Index ⁱ	22.1 (4.1)		23.3 (4.5)		21.3 (3.7)			
3	Waist Circumference (cm)	78.4 (11.6)		81.8 (12.6)		76.2 (10.3)			
4	Blood Pressure								
5	Systolic Blood Pressure (mmHg)	116.1 (17.1)		117.9 (16.6)		115.0 (17.3)			
6	Diastolic Blood Pressure (mmHg)	76.1 (10.5)		77.9 (10.9)		74.9 (10.1)			
7	Blood Glucose Level (mmol/l)	6.4 (2.4)		6.6 (2.9)		6.3 (2.1)			
8	Self-reported diabetes medication history ^j		69	72.6		50	80.6		19 57.6

9 Abbreviations: SD, standard deviation

10 ^a Calculated median and interquartile range for education as the data are skewed

11 ^b Professional occupation includes: Field staff, police officer, guard, doctor, engineer, professional, business man, desk job

12 ^c Other occupation includes: Shop keeper, weavers, driver, student, beggar, cook, carpenter, tailor, migrant workers and fishermen

13 ^d Wealth index was calculated using principal component analysis using data collected on household ownership of the following items: electricity, flushable toilet, land phone, cell phone, television, radio, refrigerator, private car, motor cycle, washing machine, bicycle, sewing machine, almirah/wardrobe, table, bed, chair/bench, watch/clock, as well as, type of main material used to build their homes roof, walls and floor

16 ^e Includes both smokeless tobacco and smoke tobacco

17 ^f Smoking tobacco use includes cigarettes, biri, hookah, etc.

18 ^g Smokeless tobacco use includes jarda, sada pata, pan mashala with tobacco leaf, gul etc.

19 ^h Measured in MET-minutes; 1 MET stands for the amount of oxygen you consume and the number of calories you burn at rest.

20 ⁱ Body mass index (BMI) calculated by weight in kilogram divided by height in meter squared

21 ^j Percentage reported out of participants who self-reported to have diabetes (Total n = 95; Urban n = 62; Rural n = 33)

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Table 2: Determinants of hyperglycemia among Bangladeshi adults, 2015 (n = 1819)

Characteristic	Total (n = 1819)		Urban (n = 708)		Rural (n = 1111)	
	Diabetes ^a Prevalence %	Adjusted PR ^b (95% CI)	Diabetes ^a Prevalence %	Adjusted OR ^b (95% CI)	Diabetes ^a Prevalence %	Adjusted OR ^b (95% CI)
Area						
Urban	9.8	Ref.	-	-	-	-
Rural	2.8	0.44 (0.28 – 0.68)	-	-	-	-
Sex						
Male	4.9	Ref.	7.5	Ref.	3.3	Ref.
Female	5.9	1.05 (0.71 – 1.54)	11.9	1.26 (0.80 – 1.99)	2.2	0.61 (0.29 – 1.28)
Age (years)						
18 - 29	2.5	Ref.	2.5	Ref.	2.5	Ref.
30 - 44	4.9	1.48 (0.78 – 2.79)	8.4	2.55 (1.01 – 6.41)	2.5	0.76 (0.30 – 1.93)
45 - 54	7.4	2.18 (1.10 – 4.31)	15.5	4.38 (1.62 – 11.59)	2.8	0.67 (0.25 – 1.83)
≥ 55	8.8	1.92 (0.95 – 3.86)	19.3	3.92 (1.48 – 10.39)	3.4	0.53 (0.17 – 1.67)
Educational Status						
No Education	3.4	Ref.	7.0	Ref.	2.1	Ref.
Primary Education	3.7	1.00 (0.53 – 1.86)	7.6	1.00 (0.44 – 2.30)	2.1	0.84 (0.30 – 2.30)
Secondary Education	6.9	1.67 (0.95 – 2.93)	12.1	1.94 (0.95 – 3.97)	2.9	1.01 (0.40 – 2.54)
Above Secondary Education	9.8	1.48 (0.77 – 2.84)	10.4	1.54 (0.71 – 3.33)	8.1	2.24 (0.68 – 7.41)
Wealth Index^c						
1st Wealth Quartile	7.7	2.58 (1.57 – 4.24)	18.9	3.18 (1.80 – 5.62)	3.6	1.37 (0.53 – 3.49)
2nd Wealth Quartile	4.3	1.23 (0.71 – 2.14)	9.4	1.50 (0.82 – 2.77)	1.9	0.70 (0.24 – 2.05)
3rd Wealth Quartile	3.7	0.86 (0.47 – 1.58)	6.0	0.96 (0.48 – 1.92)	2.0	0.55 (0.18 – 1.73)
4th Wealth Quartile	6.6	Ref.	8.8	Ref.	3.9	Ref.
Blood Pressure						
Normal Blood Pressure	1.9	Ref.	3.5	Ref.	1.1	Ref.
Pre-Hypertension ^d	5.7	1.74 (1.00 – 3.01)	8.3	1.37 (0.69 – 2.74)	3.8	2.32(0.91 – 5.92)
Hypertension ^e	18.9	3.57 (2.01 – 6.34)	27.4	2.65 (1.30 – 5.38)	8.8	5.39(1.94 – 14.96)
Physical Activity						
Vigorous	3.9	Ref.	6.9	Ref.	2.3	Ref.
Moderate	8.2	1.18 (0.78 – 1.77)	13.8	1.22 (0.77 – 1.93)	2.1	0.65 (0.22 – 1.88)
Low	14.9	3.04 (1.69 – 5.47)	20.7	3.01 (1.42 – 6.38)	12.1	2.58 (0.95 – 7.04)

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2	Body Mass Index ^f						
3	Underweight (<18.5)	1.1	0.37 (0.12 – 1.13)	1.8	0.38 (0.07 – 1.95)	0.7	0.42 (0.09 – 2.02)
4	Normal (18.5 - 25)	4.7	Ref.	8.2	Ref.	2.8	Ref.
5	Overweight (25.1 - 30)	10.4	1.06 (0.68 – 1.65)	14.0	1.05 (0.61 – 1.80)	6.2	1.22 (0.51 – 2.91)
6	Obese (>30)	20.9	1.49 (0.87 – 2.57)	26.5	1.46 (0.81 – 2.64)	5.6	0.95 (0.12 – 7.60)
7	Waist Circumference (cm)						
8	Normal ^g	2.3	Ref.	3.8	Ref.	1.6	Ref.
9	Abdominally Obese ^h	13.3	2.49 (1.53 – 4.07)	18.1	2.54 (1.35 – 4.77)	6.8	2.95 (1.32 – 6.58)

10 Abbreviations: PR = prevalence ratio, CI = confidence intervals, Ref = referent category

11 ^a Hyperglycemia was defined as a capillary blood glucose level greater than or equal to 11.1 mmol/L or self-reported diabetes medication use

12 ^b Model adjusted for all variables included in table: sex, age, education, wealth index, blood pressure, body mass index, self-reported physical activity, and waist circumference

13 ^c Wealth index was calculated using principal component analysis using data collected on household ownership of the following items: electricity, flushable toilet, land phone, cell phone, television, radio, refrigerator, private car, motor cycle, washing machine, bicycle, sewing machine, almirah/wardrobe, table, bed, chair/bench, watch/clock, as well as, type of main material used to build their homes roof, walls and floor

14 ^d Pre-Hypertension was defined as SBP ≥120 mmHg but < 140 mmHg and/or DBP ≥ 80 mmHg but <90 mmHg and not taking anti-hypertensive medication at the time of the survey

15 ^e Hypertension was defined as systolic blood pressure (SBP) was ≥140 mmHg (millimeters of mercury) and/or, diastolic blood pressure (DBP) ≥90 mmHg and/or taking any-hypertensive medication

16 ^f Body mass index (BMI) calculated by weight in kilogram divided by height in meter squared

17 ^g Defined as <90 cm M; <80 cm F

18 ^h Defined as ≥90 cm M; ≥80 cm F

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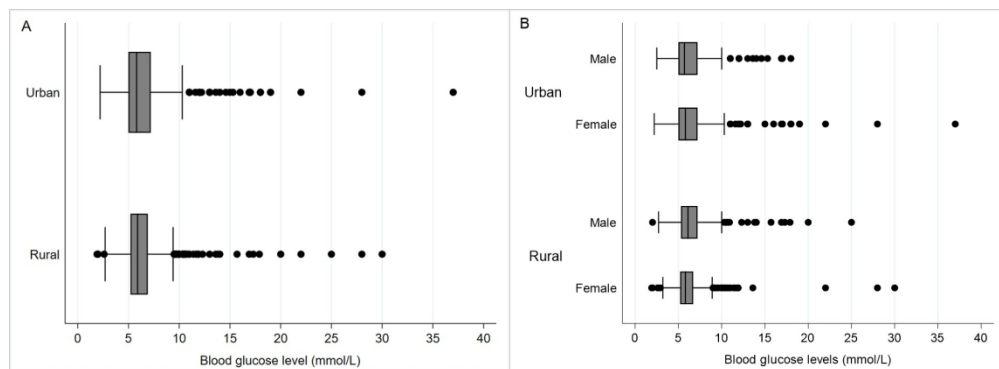
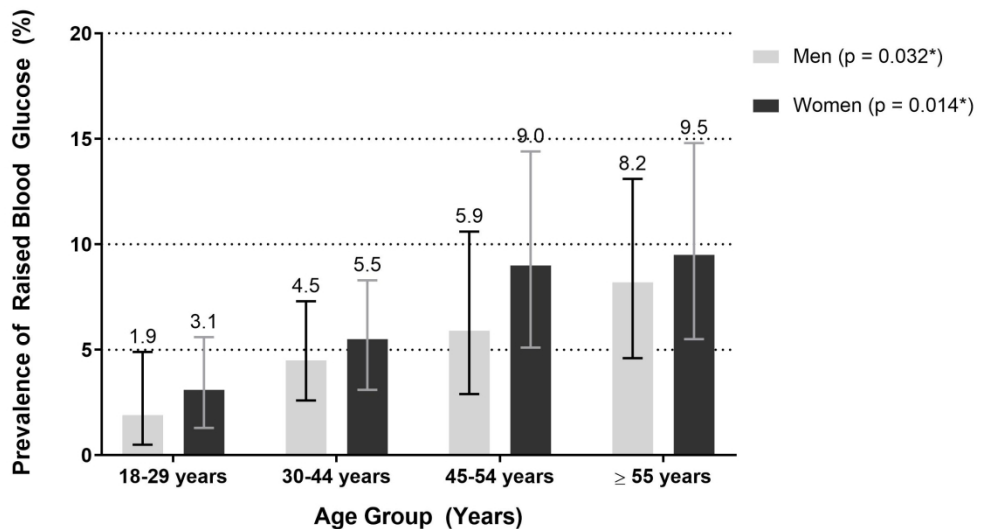


Figure 1: Urban and Rural differences in the distribution of blood glucose levels based on random capillary blood measurement among (A) All Participants, and (B) Men and Women (n = 1819)

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*Exact test p-value to assess the relationship between prevalence of raised blood glucose and age group stratified by sex

Figure 2: Prevalence of hyperglycemia among Bangladeshi adults aged 18 years and above by sex and age group, 2015 (n = 1819)

211x137mm (300 x 300 DPI)

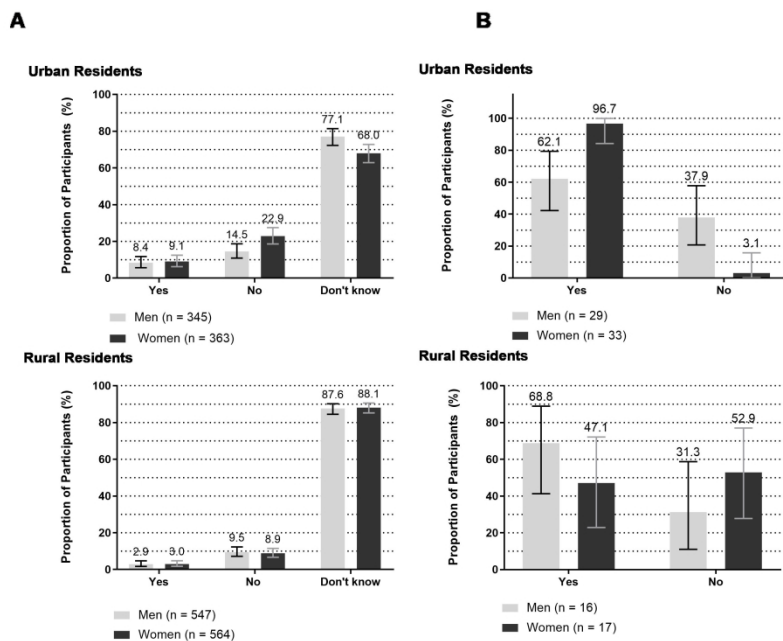


Figure 3: Bangladeshi adults aged 18 years and above with (A) self-reported diabetes and (B) self-reported diabetics on diabetes medications, 2015

284x190mm (300 x 300 DPI)

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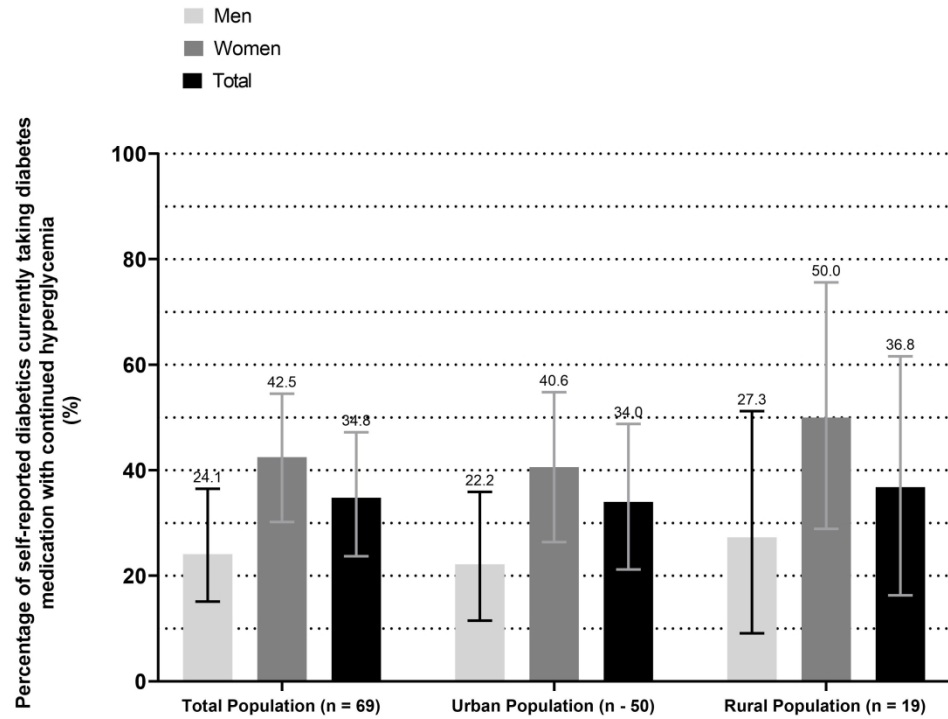


Figure 4: Self-reported diabetics aged 18 years or older who take diabetes medication with hyperglycemia on study measurement ($\geq 11.0\text{mmol/L}$)

284x210mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	6-7 & 11
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	11
		(b) Describe any methods used to examine subgroups and interactions	11
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(b) Report category boundaries when continuous variables were categorized	9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Prevalence and determinants of hyperglycemia among adults in Bangladesh: results from a population-based national survey

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-029674.R2
Article Type:	Research
Date Submitted by the Author:	29-Jun-2019
Complete List of Authors:	Islam, Jessica; World Health Organization Country Office for Bangladesh, ; University of North Carolina at Chapel Hill Gillings School of Global Public Health, Department of Epidemiology Zaman, MM; World Health Organization, Dhaka, Bangladesh, Bhuiyan, Mahfuz; World Health Organization Country Office for Bangladesh Haq, Syed; Bangabandhu Sheikh Mujib Medical University, Rheumatology Ahmed, Shamim; Bangabandhu Sheikh Mujib Medical University Al-Qadir, Zahid; Bangabandhu Sheikh Mujib Medical University
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Diabetes and endocrinology, Global health
Keywords:	non-communicable diseases, chronic disease, raised blood glucose, Bangladesh

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Manuscripts

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3 1 Prevalence and determinants of hyperglycemia among adults in Bangladesh: results from a
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21 **Manuscript word count: 4,200**
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30 **Abstract**

31 Objectives: With the increasing burden of non-communicable diseases in low- and middle-
32 income countries, biological risk factors such as hyperglycemia are a major public health
33 concern in Bangladesh. Hyperglycemia is an excess of glucose in the bloodstream and is often
34 associated with type-2 diabetes mellitus. Nationally representative data of hyperglycemia
35 prevalence starting from age ≥ 18 years are currently unavailable for Bangladeshi adults. The
36 objective of this study was to assess the prevalence and determinants of hyperglycemia among
37 adults in Bangladesh aged ≥ 18 years.

38
39 Study Design: Cross-sectional, population-based study

40
41 Setting and Participants: Data for this analysis were collected in November-December of 2015,
42 from a population-based nationally representative sample of 1843 adults, aged ≥ 18 years, from
43 both urban and rural areas of Bangladesh. Demographic information, capillary blood glucose,
44 blood pressure, height, weight, waist circumference, and treatment history were recorded.

45
46 Primary Outcome Measures: Hyperglycemia was defined as a random capillary blood glucose
47 level of ≥ 11.1 mmol/L (i.e. in the diabetic range) or currently taking medication to control type-2
48 diabetes, based on self-report.

49
50 Results: Overall, the prevalence of hyperglycemia was 5.5% (95% CI: 4.5-6.6) and was
51 significantly higher among urban (9.8%, 95% CI: 7.7-12.2) than rural residents (2.8%, 95% CI:
52 1.9-3.9). The age-standardized prevalence of hyperglycemia was 5.6% (95% CI: 4.6-6.8).
53 Among both urban and rural residents, the associated determinants of hyperglycemia included
54 hypertension and abdominal obesity. About 5% of the total population self-reported to have

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3 55 been previously diagnosed with type-2 diabetes; among these adults, over 25% were not taking
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5 56 medications to control their diabetes.
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7 57 Conclusions: Our study found that about 1 out of 20 Bangladeshi adults aged ≥ 18 years have
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9 58 hyperglycemia. To control and prevent the development of type-2 diabetes, data from this study
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11 59 can be used to inform public health programming and provide descriptive information on
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13 60 surveillance of progress towards controlling diabetes in Bangladesh.
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18 62 **Keywords:** non-communicable diseases, Bangladesh, hyperglycemia, diabetes, chronic
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Article Summary

Strengths and Limitations of the Study

- This study utilized a multistage, geographically clustered, probability-based sampling approach to produce nationally representative data for Bangladesh.
- Currently, nationally representative data for the prevalence of hyperglycemia in the diabetic range is unavailable for adults aged 18-29 years. A strength of our study is that we included Bangladeshi adults aged 18 years and above to obtain novel data on the prevalence of hyperglycemia, and relevant non-communicable disease risk factors
- We were able to estimate the prevalence of hyperglycemia using capillary blood glucose measured at random. However, we were unable to measure the prevalence of prediabetes and diabetes as we did not obtain blood sugar levels using standardized methods, such as fasting blood glucose or 2-hour post-prandial measurements.
- Due to the cross-sectional nature of the study design, we were unable to assess temporality of risk factors identified and our outcomes of interest.
- We assessed type-2 diabetes medication history based on self-report and we were able to obtain medicine strips or vials records or prescription records of participants to confirm the self-reported data.

108 **Background**

109 Globally, diabetes mellitus (DM), characterized by hyperglycemia, is a leading cause of
110 premature mortality and disability. Globally, almost half of all deaths attributable to high blood
111 glucose occur before the age of 70 years, and the WHO estimates that diabetes was the
112 seventh leading cause of mortality in 2016. The global prevalence of DM has been on the rise
113 over the past several decades^{1,2}. Estimates reflect the global prevalence of diabetes has nearly
114 doubled among adults aged 18 years and above, rising from 4.7% in 1980 to 8.5% in 2014³.
115 This growing burden is most prominent in low- and middle-income countries particularly the
116 Indian sub-continent⁴, which accounts for close to one-fifth of all diabetes cases worldwide. The
117 prevalence of diabetes in this region is projected to increase by 71% by 2035⁵. In Bangladesh,
118 specifically, the International Diabetes Federation projects the prevalence of diabetes will
119 increase to more than 50% in the next 15 years⁵.

120 The increasing prevalence of diabetes among Bangladeshi adults over the past few
121 decades has been documented: Based on a meta-analysis of studies conducted from 1995 –
122 2010, the prevalence of diabetes among Bangladeshi adults aged 30 years and above
123 increased from 4% in 1995 to 2000 and 5% in 2001 to 2005 to 9% in 2006 to 2010⁶. Studies to
124 assess the burden of diabetes have been conducted in Bangladesh in both urban and rural
125 populations over the last decades⁷. However, national data on the prevalence of diabetes or
126 hyperglycemia in the diabetic range starting at age 18 years are currently unavailable⁷⁻¹⁰. These
127 data are valuable for monitoring progress made towards one of the nine global non-
128 communicable disease (NCD) targets of the year 2025, set forth by the World Health
129 Organization's (WHO) NCD Global Monitoring Framework: To observe a 0% increase in age-
130 standardized prevalence of hyperglycemia or diabetes among persons aged ≥ 18 years¹¹. As
131 such in response to the WHO Global Action Plan for the Prevention and Control of NCDs¹²,
132 descriptive epidemiological data on the burden of hyperglycemia among adults starting at 18
133 years are needed to monitor the national progress of interventions implemented to reduce the

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3 134 burden of DM in Bangladesh¹³⁻¹⁵. Here, using a nationally representative sample, we present
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5 135 data on prevalence and determinants of hyperglycemia by various sociodemographic factors
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7 136 such as age, sex, and area of residence among Bangladeshi adults aged 18 years and above,
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9 137 residing in both urban and rural areas of the country. Additionally, we explore treatment patterns
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11 138 and control of hyperglycemia among participants in our sample of Bangladeshi adults.
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15 16 140 **Methods**

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18 141 Data for this analysis were collected as part of a national assessment of the burden of
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20 142 musculoskeletal disorders in Bangladesh conducted by investigators from the Bangabandhu
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22 143 Sheikh Mujib Medical University (BSMMU) with technical assistance from the WHO Country
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24 144 Office for Bangladesh, as previously described¹⁶. The study was a population-based cross-
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26 145 sectional study carried out from November to December 2015 and followed the WHO STEP-
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28 146 wise approach to Surveillance of NCD risk factors (STEPS)¹⁷. The target population of this
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30 147 survey was men and women aged ≥ 18 years residing in rural and urban areas of Bangladesh.
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32 148 The exclusion criteria included tourists and the institutionalized, including residents of hospitals,
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34 149 prisons, nursing homes, and army barracks.
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38 39 151 Sampling Methods

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41 152 To obtain a population-based sample of Bangladesh, this survey adopted a multistage,
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43 153 geographically clustered, probability-based sampling approach. Population statistics were
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45 154 obtained using the updated national census conducted by the Bangladesh Bureau of Statistics
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47 155 (BBS) in 2009¹⁸. To obtain our primary sampling unit (PSU), we utilized the following
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49 156 geographical distribution described: In Bangladesh, there are seven divisions, which are the
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51 157 largest administrative units of the country. Each division is divided into several districts (*Zila*)
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53 158 and within each district, there are several sub-districts (*Upazila*). Within sub-districts, *mauzas*
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55 159 and *mahallas* (commonly known as neighborhoods or blocks) are the smallest units within
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2
3 160 defined territories in rural and urban areas respectively. *Mauzas* and *mahallas* were considered
4
5 161 the PSU for the study's sampling approach. The households within the *mauzas* and *mahallas*
6
7 162 were the secondary sampling units. We utilized the BBS' definition of a household which is as
8
9 163 follows: "a dwelling in which persons either related or unrelated were living together and taking
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11 164 food from the same kitchen"¹⁸.
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166 Sample size estimation

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18 167 The power analysis and sample size calculations were completed based on the
19
20 168 standardized approach outlined in the WHO STEPS methodology¹⁷. Using the WHO STEPS
21
22 169 methodology, the minimum number of participants required was 296 in each group (rural males,
23
24 170 rural females, urban males, and urban females). Assuming a design effect of 1.5 adjusted within
25
26 171 cluster population homogeneity, the necessary sample size was 1776. We assumed a response
27
28 172 rate of 90% and determined we would need to contact at least 1973 adults. For simplicity, our
29
30 173 target sample size was 2000. Twenty PSUs (8 urban and 12 rural) were randomly selected from
31
32 174 7 divisions of the country, with the probability proportional to the population size of each
33
34 175 division. In each PSU, 100 consecutive households were selected. The even numbered
35
36 176 households were designated as a "male household" and odd numbered households as a
37
38 177 "female household." Finally, one male or female was approached to participate from each
39
40 178 respective household as designated.
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45 180 Data collection

46
47 181 Through a structured survey, we collected data on the following topics: musculoskeletal
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49 182 disorders¹⁹, health history, and demographic data such as age, area of residence, education,
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51 183 current (last 12 months) occupation, tobacco use, and physical activity. Physical measurements
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53 184 such as height, weight, waist circumference, blood glucose levels, and blood pressure were
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55 185 collected. To measure blood glucose levels, we obtained random blood glucose samples³, per
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3 186 the clinical guidelines of diabetes diagnostic criteria of Bangladesh²⁰. Capillary blood samples
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5 187 were consistently taken from the index finger of the right arm using a glucometer, namely Accu-
6
7 188 chek Advantage (Roche Diagnostics Division, Grenzacherstrasse, Switzerland).
8

9
10 189 Each participant's history of diabetes was assessed based on self-report. Specifically,
11
12 190 participants were asked: 1. Have you ever been diagnosed with diabetes by a health care
13
14 191 professional? 2. If yes, are you receiving treatment for diabetes? Treatment history of diabetes
15
16 192 was confirmed by prescription, including medicine strips or insulin injection vials, or medical
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18 193 records. The questionnaire was translated from English to Bengali, adapted and validated per
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20 194 standard procedure. Data collection procedures were standardized across study sites through
21
22 195 coordinated training of field staff conducted by epidemiologists, study physicians, and WHO
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24 196 staff members.
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26 197 Blood pressure was measured by a trained field interviewer using the LifeSource UA-
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28 198 767+ blood pressure monitor, as recommended by the WHO, and appropriately sized arm cuffs.
29
30 199 Blood pressure measurements were consistently taken on each participant's right arm at the
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32 200 level of the heart and elbow-assisted, while the participant was in a seated position. The initial
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34 201 measurement was performed after five minutes of rest. After two minutes, the second
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36 202 measurement was taken. The mean of these two blood pressure readings was utilized as the
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38 203 final blood pressure for each participant.
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41 204 Following data collection, participants scheduled a visit with the study research physician
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43 205 within the following five days. The research physician assessed the participant's medical history,
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45 206 either through self-report or using medical records when possible. Study physicians examined
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47 207 each participant to confirm the results of data collection through classical symptom assessment.
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49 208 When necessary, the participant was also evaluated by the divisional investigator for a second
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51 209 opinion of relevant diagnoses.
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56 211 Patient and public involvement
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3 212 There was no patient or public involvement in the implementation of this study or interpretation
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5 213 of analytic results.
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9 215 Outcome definitions

11 216 Our primary outcome of interest was the prevalence of hyperglycemia. We utilized the
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13 217 American Diabetes Association (ADA) guidelines to define a diagnosis of hyperglycemia using
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15 218 random or casual plasma glucose test and symptom review by the study physician ²¹. An
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17 219 individual was considered to have hyperglycemia if the plasma glucose level was 11.1 mmol/L
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19 220 or higher (i.e. in the diabetic range) and/or if they self-reported to take diabetes medication. Our
20
21 221 secondary outcome of interest was the prevalence of self-reported type-2 diabetes mellitus. An
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23 222 individual was categorized as diabetic if they self-reported to have been previously diagnosed
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25 223 with diabetes by a health care provider.
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30 225 Covariates

32 226 The following variables were assessed as covariates for analysis: area of residence,
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34 227 sex, age, education, occupation, wealth index, body mass index (BMI), BP, and waist
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36 228 circumference. Education was categorized into four groups: no education, primary education
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38 229 (completed grade ≤ 5), secondary education (completed \leq grade 10), and above secondary
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40 230 education (completed \geq grade 12). Each participant's occupation was categorized into five
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42 231 groups, including: professional employment (field staff, police officer, guard, doctor, engineer,
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44 232 professional, businessman, desk job), unemployed or retired, industrial worker or day laborer,
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46 233 housewife, and other (shop keeper, weaver, driver, student, beggar, cook, carpenter, tailor,
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48 234 migrant workers and fishermen).
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51 235 Data on physical activity was collected based on self-report. First, respondents were
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53 236 asked the number of days they engaged in vigorous, moderate, or light physical activity
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55 237 throughout a typical week. The following definitions were used to define (1) vigorous, (2)

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3 238 moderate, and (3) light physical activity, respectively: (1) vigorous activity was defined as any
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5 239 activity that caused a large increase in breathing or heart rate, if continued for at least 10
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7 240 minutes (e.g. running, carrying heavy loads, digging or construction work); (2) moderate activity
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9 241 was defined as any activity that caused a small increase in breathing or heart rate, if continued
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11 242 for at least 10 minutes (brisk walking or carrying light loads); and (3) light physical activity was
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13 243 defined as activities such as office work. Next, we asked participants to estimate how many
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15 244 minutes per day they engaged in the activity. Metabolic equivalent of task (MET)-minute was
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17 245 calculated using the STEPS protocol²² as follows: one minute of light activity was equivalent to 1
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19 246 MET-minute; one minute in moderate-intensity activities was equivalent to 4 MET-minutes, and
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21 247 one minute of vigorous-intensity was equivalent to 8 MET-minutes. Physical activity was then
22
23 248 categorized based on total MET-minutes per week. Participants who spent 3000 or more MET-
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25 249 minutes per week were categorized in the vigorous physical activity group, 600-3000 MET-
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27 250 minutes were categorized as moderate physical activity, and <600 MET-minutes were
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29 251 categorized as low physical activity.
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33 252 The wealth index was constructed using principal component analysis. Asset information
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35 253 collected covered information on household ownership of nineteen items, including electricity,
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37 254 flush toilet, land telephone, cell phone, television, radio, refrigerator, car, motorcycle, washing
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39 255 machine, bicycle, sewing machine, wardrobe, table, bed or cot, chair or bench, watch or clock.
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41 256 Additionally, we assessed the main type of material used to build each participant's home (i.e.
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43 257 cement, tin, bamboo, or thatched straw). Each asset was assigned a weight (factor score)
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45 258 generated through principal components analysis, and the resulting asset scores were
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47 259 standardized to a normal distribution with a mean of zero and standard deviation of one. Each
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49 260 household was then assigned a score for each asset, and the scores were summed up;
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51 261 individuals were ranked according to the total score of the household in which they resided. The
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53 262 sample was then divided into quartiles from quartile one (lowest) to quartile four (highest).
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3 263 Using height (centimeters) and weight (kilograms) measurements, we calculated BMI
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5 264 (height/weight²). BMI was categorized in the following groups: underweight (≤ 18.5), normal
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7 265 (≤ 25), overweight (25.1-30) and obese (>30). Waist circumference was measured in centimeters
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9 266 (cm). Participants were categorized as abdominally obese if waist circumference was 90 cm and
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11 267 above for men, or 80 cm and above for women. Prehypertension was defined as SBP ≥ 120
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13 268 mmHg but < 140 mmHg and/or DBP ≥ 80 mmHg but < 90 mmHg and not taking antihypertensive
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15 269 medication at the time of the survey. We utilized the WHO's guidelines for cut-off points to
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17 270 define hypertension²³. An individual was considered to have hypertension if systolic blood
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19 271 pressure (SBP) was ≥ 140 mmHg (millimeters of mercury) and/or, diastolic blood pressure (DBP)
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21 272 ≥ 90 mmHg, and/or taking antihypertensive medication based on self-report.
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25 26 274 Age-Standardized Prevalence Estimates

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28 275 To facilitate comparison of overall hyperglycemia among Bangladeshi adults across
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30 276 global populations with different age compositions we calculated age-standardized prevalence
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32 277 estimates with 95% confidence intervals (CIs) using the WHO's World Standard Population ²⁴.
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34 278 The World Standards database (WHO 2000-2025) provided population estimates for 18 and 19
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36 279 age groups, as well as single year ages. To derive single ages from the 5-year age group
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38 280 proportions publically available, we used the Beers "Ordinary" Formula²⁵. The following formula
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40 281 was utilized for standardization:
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43 282 $\sum p_i * w_i / \sum w_i$, where p = observed prevalence and w = world population weight.
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46 47 284 Data Analysis

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49 285 Sociodemographic variables were presented with mean and standard deviation (SD) for
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51 286 continuous variables, and using proportions for categorical variables. For bivariate analyses,
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53 287 study participants were divided by sex and into four age groups (18-29, 30-44, 45-54 and ≥ 55
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288 years). We calculated the prevalence of our primary outcome by key demographic variables and
289 calculated 95% CIs using the binomial exact method.

290 To estimate determinants of hyperglycemia in the diabetic range, we computed
291 prevalence ratios with Poisson regression using robust estimation of standard errors²⁶⁻²⁸.
292 Potential variables for inclusion in the model were assessed using prior published literature and
293 bivariate Poisson regression analysis; an arbitrary p-value of <0.10 was used as criteria to
294 include the variable in the multivariable Poisson regression model to control for confounding
295 effects. For multivariable Poisson regression models, adjusted prevalence ratios (aPR), and
296 95% CIs for each independent variable were calculated. Additionally, <0.05 was used as the
297 level of significance. Multivariable Poisson regression models were generated separately for
298 urban and rural participants to account for possible effect measure modification. Collinearity was
299 assessed using the variance inflation factor to ensure a strong linear relationship among
300 independent variables included in the model was not present. All statistical procedures were
301 performed using Stata/SE 15.0 (StataCorp LP, Texas, USA) software package.

302

303 **Results**

304 Background Characteristics

305 Of the 2000 adults approached, 1843 agreed to participate in our study leading to a
306 response rate of 92.1%. Twenty-four female participants were pregnant and were dropped from
307 subsequent analyses to ensure those with gestational diabetes were not included. Additionally,
308 no participants reported having been previously diagnosed with type-1 diabetes. There were
309 892 (49.0%) male and 927 (50.9%) female respondents (Table 1). The age of our participants
310 ranged from 18 to 90 years. The mean age and education level of participants were 40.5 (SD =
311 14.7) years and 5.7 (SD = 5.1) years, respectively. The majority of the study population was
312 married (88.0%) and employed as either an industrial worker/day laborer (26.5%) or housewife
313 (39.9%). Almost half of participants never used some form of tobacco. The majority of

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3 314 participants engaged in vigorous physical activity over an average week (69.3%). The mean
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5 315 BMI was 22.1 (SD = 4.1) and the mean waist circumference was 78.4 cm (SD = 11.6). Overall,
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7 316 the mean systolic blood pressure was 116.1 mmHg (SD = 17.1) and diastolic blood pressure
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9 317 was 76.1 mmHg (SD = 10.5). The mean blood glucose level was 6.4 mmol/L (SD = 2.4). Figure
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11 318 1 presents the distribution of blood glucose levels by various demographic factors.
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15 16 320 Prevalence and Risk Factors for Hyperglycemia

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18 321 The prevalence of hyperglycemia was 5.5% (95% CI: 4.5-6.6). This prevalence was
19
20 322 significantly higher among urban participants (9.8%, 95%CI: 7.7-12.2) than rural participants
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22 323 (2.8%, 95% CI: 1.9-3.9) (Table 2) and increased as age increased (Figure 2). The highest
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24 324 prevalence of hyperglycemia was observed among those aged ≥ 55 years, at 8.2% (95% CI: 4.6-
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26 325 13.1) among men and 9.4% (95% CI: 5.4-14.8) among women. The age-standardized
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28 326 prevalence of hyperglycemia was 5.6% (95% CI: 4.6-6.8). The age-standardized prevalence of
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30 327 hyperglycemia among urban and rural residents was 10.5% (95% CI: 9.2-12.1) and 2.8% (95%
31
32 328 CI: 2.1-3.7), respectively. Among men and women, the age-standardized prevalence of
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34 329 hyperglycemia was 4.9% (95% CI: 3.9-6.0) and 6.0% (95% CI: 4.9-7.2), respectively.
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38 39 331 Self-Reported Diabetes Mellitus and Hyperglycemia

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41 332 Ninety-five participants (5.2%) self-reported to have been previously diagnosed with
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43 333 type-2 diabetes by a health care provider. However, 25 of those participants did not meet our
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45 334 criteria of diagnosis of hyperglycemia as they did not take medication to control their diabetes
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47 335 and their plasma glucose was below 11.1 mmol/L. Therefore, 69.3% of those with
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49 336 hyperglycemia, per the study definition, were previously diagnosed with diabetes by a health
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51 337 care provider.
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54 338 The proportion of men and women who were previously diagnosed with diabetes by a
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56 339 health care provider based on self-report was higher among urban residents (men: 8.4%;

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3 340 women: 9,1%) than among rural residents (men: 2.9%; women: 3.0%) (Figure 3a). However,
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5 341 overall, the large majority (81.8%) reported they did not know if they had been previously
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7 342 diagnosed with diabetes; this proportion was higher among rural residents (87.8%) than urban
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9 343 residents (72.2%).

11 344 Among participants previously diagnosed with type-2 diabetes based on self-report,
12
13 345 72.6% reported taking medication to control their diabetes (Table 1). Urban women more
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15 346 frequently (96.7%) self-reported to take diabetes medication than urban men (62.1%) (Figure
16
17 347 3b). We were able to confirm 100% of participant's self-reported diabetes treatment history by
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19 348 checking prescriptions or medicine strips/vials.

22 349 Among participants who were categorized as hyperglycemic during study measurement,
23
24 350 over one-third (37.9%) of urban men self-reported to have diabetes, however, they did not take
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26 351 any medication to control their diabetes. Among rural participants, the proportion of women who
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28 352 did not take medication to control their self-reported diabetes was higher (52.9%) than men
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30 353 (31.3%). Although three-quarters of self-reported diabetic participants reported taking
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32 354 medication to control their diabetes, 31% continued to have high blood sugar levels indicating
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34 355 uncontrolled diabetes at study measurement (Figure 4).
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39 357 Determinants of Hyperglycemia

41 358 Table 2 presents the results of multivariable Poisson regression with robust variance
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43 359 analyses to identify determinants of hyperglycemia. Among urban participants, those of older
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45 360 age, lowest wealth quartile, hypertension, low physical activity, and with abdominal obesity
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47 361 based on waist circumference, were more likely to have hyperglycemia. The prevalence of
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49 362 hyperglycemia was significantly highest among those aged ≥ 55 years (aPR 3.92, 95% CI: 1.48-
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51 363 10.39) compared to individuals aged 18-29 years of age. When compared to those in the 4th
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53 364 (highest) wealth quartile, urban residents in the first (lowest) wealth quartile had 3.18 times the
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55 365 prevalence of hyperglycemia. For urban individuals with hypertension, the prevalence of
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3 366 hyperglycemia was 2.65 (95% CI:1.30-5.38) times that of individuals without hypertension. The
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5 367 prevalence of hyperglycemia among those with low physical activity was 3.01 (95% CI: 1.42-
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7 368 6.38) times that of urban participants with vigorous physical activity. Abdominal obesity also
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9 369 significantly increased the prevalence of hyperglycemia among urban participants (aPR: 2.54,
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11 370 95% CI: 1.35-4.77). Among rural participants, the only observed determinants of hyperglycemia
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13 371 were hypertension (aPR: 5.39, 95% CI: 1.94-14.96) and abdominal obesity (aPR: 2.95, 95% CI:
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15 372 1.32-6.58).

17 373

20 374 **Discussion**

21
22 375 Using data from this nationally representative sample, we estimate that about one in
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24 376 twenty Bangladeshi adults aged ≥ 18 years have hyperglycemia. The prevalence of
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26 377 hyperglycemia was higher among urban residents (9.8%) than rural residents (2.8%).
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28 378 Determinants of hyperglycemia included older age, urban residence, abdominal obesity, low
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30 379 physical activity, and hypertension. As diabetes is characterized by hyperglycemia, targeting
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32 380 high-risk groups identified in this analysis could be prioritized for effective diabetes preventive
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34 381 programs in Bangladesh.

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36 382 Bangladesh has adopted the goals and targets set forth by the WHO's Global Monitoring
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38 383 Framework for the Prevention and Control of NCDs for the year 2025¹¹. One of these targets is
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40 384 to ensure there is a 0% increase in the age-standardized prevalence of hyperglycemia among
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42 385 adults aged ≥ 18 years by the year 2025. To our knowledge, the present study is the first to
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44 386 report national estimates on the prevalence of hyperglycemia starting at age 18 years in both
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46 387 urban and rural areas of Bangladesh. Data gathered from this national-level study are critical
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48 388 towards the measurement of progress towards the WHO's nine global NCD control targets for
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50 389 Bangladesh for 2025.

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52 390 Globally, the number of adults living with diabetes has risen from 108 million in 1980 to
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54 391 422 million in 2013, and low- and middle-income countries (LMICs) have seen the most rapid

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3 392 rise in diabetes prevalence³. Several lifestyle factors have been attributed to the increase in
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5 393 prevalence across LMICs including, globalization of food production, extensive marketing of
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7 394 low-cost and energy-dense foods, increased sedentary behavior, and rapid urbanization²⁹. In
8
9 395 recent decades, the increase in the prevalence of diabetes in South Asia has been greater than
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11 396 that seen in high-income countries⁴. The prevalence of diabetes in adults across countries in
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13 397 South Asia is similar, excluding Nepal which has a low prevalence in comparison to neighboring
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15 398 countries (8.8% in India, 8.6% in Sri Lanka, 6.9% in Bangladesh, 7.9% in Bhutan, 6.9% in
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17 399 Pakistan, and 4.0% in Nepal)³⁰. In our study, we observed a prevalence of 5.6% hyperglycemia
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19 400 in the diabetic range among adults aged 18 years and above. This prevalence is lower than
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21 401 previous studies conducted in Bangladesh and neighboring countries. In fact, a scoping review
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23 402 estimated the pooled prevalence of type-2 diabetes to be 7.4%⁷. Our estimated prevalence was
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25 403 lower due to a younger study population (18 years and above compared to the WHO estimate
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27 404 among adults aged 30 years and above), and a higher percentage of participants from rural
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29 405 areas (61.1%, as is representative of Bangladesh). Indeed, when we restrict our analytic sample
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31 406 to 30 years and above, the prevalence of hyperglycemia is 6.7%, which is similar to the 2017
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33 407 WHO estimate of diabetes (6.9%). Significant heterogeneity in diabetes and its determinants
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35 408 may exist within Bangladesh due to variations in the level of urbanization by region, and
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37 409 socioeconomic status of specific sub-populations³¹.

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41 410 Important determinants of hyperglycemia in both urban and rural areas of our
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43 411 assessment included hypertension, low physical activity, and abdominal obesity. Interestingly,
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45 412 there was no association of diabetes identified for increasing BMI. This indicates that abdominal
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47 413 obesity may be a more significant factor to consider than BMI. Prior studies conducted in
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49 414 Bangladesh have also identified a positive association of central (or abdominal) obesity with
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51 415 diabetes³². Furthermore, our assessment found a decrease in prevalence of diabetes with
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53 416 increasing wealth quartile. Prior studies have conflicting findings on the risk of diabetes and
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55 417 other NCDs, among the wealthy based on demographic features such as the area of residence.

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3 418 One prior study conducted in Bangladesh found that people from the highest wealth quintile
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5 419 were more likely to have diabetes than people from the lowest wealth quintile³³. However,
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7 420 another found a high burden of selected NCDs, including diabetes, among the lowest wealth
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9 421 quintile populations in rural areas and wealthy populations in urban areas³⁴. Further study is
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11 422 warranted to assess the reliability of wealth indices as a measurement of socioeconomic status
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13 423 and wealth among Bangladeshi adults.

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16 424 In our study, a high proportion (~70%) of those with hyperglycemia self-reported to have
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18 425 been previously diagnosed with diabetes and therefore, aware of their condition. Additionally,
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20 426 72% reported taking medication to control their diabetes. However, we found that almost one-
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22 427 third of those who self-reported to take medication for their diabetes continued to have
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24 428 hyperglycemia. Efforts should be made to ensure diabetics in Bangladesh are treated for their
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26 429 condition and secondary prevention of complications of diabetes, such as diabetic retinopathy.
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28 430 This is of particular concern in developing countries where resources are limited and cost-
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30 431 effective solutions for chronic disease treatment should be prioritized. A recently published
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32 432 study found that healthcare expenditure in persons with diabetes in Bangladesh is six times
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34 433 higher than in persons without diabetes¹⁴. Prevention and management of diabetes are likely to
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36 434 be a cost-saving approach for Bangladesh through the utilization of community health workers
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38 435 adequately trained to effectively screen for, and identify, people with diabetes³⁵.

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41 436 This study has several strengths. Data collected for our study was of a nationally
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43 437 representative sample indicating our results are generalizable to the population of Bangladeshi
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45 438 adults aged 18 years and above. Additionally, due to our large sample size, we were able to
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47 439 conduct subgroup analyses to identify urban and rural differences. However, several limitations
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49 440 should also be considered when interpreting the results of this analysis. We were unable to
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51 441 measure the prevalence of prediabetes and diabetes directly as we did not obtain blood sugar
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53 442 levels using standardized methods, such as fasting blood glucose or 2-hour post-prandial
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55 443 measurements. Further, we did not assess each participant's history of classical symptoms of

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3 444 hyperglycemia, which is necessary to diagnose diabetes according to the ADA guidelines²¹. We
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5 445 were unable to measure known determinants of type-2 diabetes factors such as diet or family
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7 446 history of diabetes. Future studies should consider the addition of glycosylated hemoglobin
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9 447 measurement when assessing the prevalence of diabetes as this method could provide a more
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11 448 long-term and stable diagnosis of diabetes mellitus. Finally, due to the cross-sectional nature of
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13 449 this study, we were unable to define temporality of certain determinants of hyperglycemia
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15 450 identified and therefore, unable to assess causality.
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20 452 **Conclusion**

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22 453 Data from this nationally-representative sample of Bangladeshi adults aged 18 years
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24 454 and above will be critical to informing the progress of NCD control in Bangladesh per the WHO's
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26 455 Global Monitoring Framework and goals for 2025. As our data were collected in late 2015, more
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28 456 recent studies to estimate the prevalence of diabetes mellitus or hyperglycemia are warranted.
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30 457 Recent changes in risk factor distribution coupled with aging of the population may have led to
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32 458 changes prevalence of diabetes mellitus not reflected in our results, which will be important in
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34 459 measuring our progress as we approach 2025. We found that about one in twenty Bangladeshi
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36 460 adults aged ≥ 18 years have hyperglycemia. Among urban residents, we found that about one in
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38 461 ten Bangladeshi adults aged ≥ 18 years have hyperglycemia. Bangladeshi adults with
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40 462 hypertension and abdominal obesity are high-risk groups for the development of diabetes and
41
42 463 should be targeted for routine screening for diabetes. Preventive methods such as lifestyle
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44 464 changes and medication should be recommended by primary care providers in Bangladesh to
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46 465 avoid the future development of CVDs among this group. In order to control the prevalence of
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48 466 hyperglycemia in the diabetic range, and reduce the burden of diabetes or associated risk
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50 467 factors, national initiatives such as training community health workers to deliver primary care
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52 468 and implementing universal health coverage should be implemented to curb the spread of
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54 469 NCDs in Bangladesh.
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For peer review only

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3 496 Figures
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5 497 Figure 1: Urban and Rural differences in the distribution of blood glucose levels based on
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7 498 random capillary blood measurement among (A) All Participants, and (B) Men and Women (n =
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9 499 1819)
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11 500 Figure 2: Prevalence of hyperglycemia among Bangladeshi adults aged 18 years and above by
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13 501 sex and age group, 2015 (n = 1819)
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15 502 Figure 3: Bangladeshi adults aged 18 years and above with (A) self-reported diabetes and (B)
16
17 503 self-reported diabetics on diabetes medications, 2015
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20 504 Figure 4: Self-reported diabetics aged 18 years or older who take diabetes medication with
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22 505 hyperglycemia on study measurement (≥ 11.0 mmol/L)
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3 **522 Abbreviations**
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5 523 WHO: World Health Organization
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7 524 ADA: American Diabetes Association
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9 525 aPR: Adjusted prevalence ratio
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11 526 BBS: Bangladesh Bureau of Statistics
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13 527 BMI: Body mass index
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15 528 BP: Blood pressure
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17 529 BSMMU: Bangabandhu Sheikh Mujib Medical University
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19 530 CI: Confidence interval
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21 531 CVD: Cardiovascular disease
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23 532 MET: Metabolic equivalent
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25 533 mmHg: Millimeter of mercury
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27 534 mmol/L: Millimoles per liter
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29 535 NCD: Non-communicable disease
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31 536 SBP: Systolic blood pressure
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33 537 DBP: Diastolic blood pressure
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35 538 PSU: Primary sampling unit
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37 539 SD: Standard deviation
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39 540 STEPS: STEPwise approach to Surveillance
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3 548 **Footnotes**
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5 549 Ethics approval and consent to participate: Ethical guidelines as outlined by the Declaration of
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7 550 Helsinki were followed throughout the study. Ethical clearance was obtained from the
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9 551 Institutional Review Board of Bangabandhu Sheikh Mujib Medical University (BSMMU) (Protocol
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11 552 Number: 1100). We obtained permission from the relevant administrative units of the surveyed
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13 553 districts. Orientations with community leaders (elected representatives of the local government
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15 554 offices) were conducted prior to data collection for community engagement in the study's
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17 555 implementation process. Written (or thumb impression if unable to write) consent was obtained
18
19 556 from the respondents in Bangla as per BSMMU Institutional Review Board (IRB) guidelines.
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21
22 557 Availability of data and materials: The de-identified participant data used and/or analyzed during
23
24 558 the current study are available from the corresponding author on reasonable request. Please
25
26 559 contact M. Mostafa Zaman at zamanm@who.int for further information and guidelines.
27

28 560 Competing Interests: The authors declare no competing interests. The authors alone are
29
30 561 responsible for views expressed in this article and they do not necessarily represent the views,
31
32 562 decisions or policies of the institutions with which they are affiliated.
33

34 563 Funding: The study was conducted with the technical and financial assistance of the World
35
36 564 Health Organization Country Office for Bangladesh.
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39 565 Authors contributions: JYI: conceptualized the manuscript, analyzed data, interpreted results
40
41 566 critically, and drafted the manuscript. MMZ: designed the study, interpreted results critically,
42
43 567 guided manuscript writing, and critically reviewed it. MRB, SAH, SA, ZAQ: trained the field team,
44
45 568 implemented the survey, processed and analyzed data, and reviewed the manuscript.
46

47 569 Acknowledgments: The authors thank Mr. Hassanuzzaman Khan for his efforts on data
48
49 570 management.
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Table 1: Background Characteristics of Bangladeshi adult participants, 2015 (n = 1819)

Characteristic	Total (n = 1819)			Urban (n = 708)			Rural (n = 1111)		
	Mean (SD)	n	%	Mean (SD)	n	%	Mean (SD)	n	%
Sex									
Male		892	49.0		345	48.7		547	49.2
Female		927	50.9		363	51.3		564	50.8
Age(years)	40.5 (14.7)			39.1 (13.9)			41.4 (15.1)		
Education (Years) ^a	5 (0 - 9)			8 (3-12)			4 (0-8)		
Marital Status									
Never Married		110	6.1		54	7.6		56	4.9
Married		1601	88.0		619	87.4		982	88.4
Separated/Divorced/Widowed		108	5.9		35	4.9		73	6.5
Occupation									
Professional employment ^b		279	15.2		189	26.7		90	8.1
Unemployed/retired		98	5.3		43	6.1		55	4.9
Industrial worker/Day Laborer		483	26.6		120	16.9		363	32.7
Housewife		726	39.9		247	34.9		479	43.2
Other ^c		232	12.8		109	15.4		123	11.1
Wealth Index ^d									
1st Wealth Quartile		407	22.4		110	15.5		297	26.7
2nd Wealth Quartile		533	29.3		171	24.2		362	32.6
3rd Wealth Quartile		429	23.6		179	25.3		250	22.5
4th Wealth Quartile		450	24.7		248	35.0		202	18.2
Tobacco Use ^e									
Never		859	47.2		389	54.9		470	42.3
Current Use		821	45.1		268	37.9		553	49.8
Past Use		139	7.6		51	7.2		88	7.9
Smoking Tobacco Use ^f									
Every day / Occasionally		494	27.2		169	23.9		325	29.3
Past Use		104	5.7		38	5.4		66	5.9
Never		1221	67.1		501	70.8		720	64.8
Smokeless Tobacco Use ^g									
Every day / Occasionally		529	29.1		150	21.2		379	34.1
Past Use		51	2.8		21	2.9		30	2.7
Never		1239	68.1		537	75.9		702	63.2
Physical Activity ^h									
Vigorous		1268	69.7		445	62.9		823	74.1
Moderate		464	25.5		234	33.1		230	20.7
Low		87	4.7		29	4.1		58	5.2

1	Body Mass Index ⁱ	22.1 (4.1)	23.3 (4.5)	21.3 (3.7)			
2	Waist Circumference (cm)	78.4 (11.6)	81.8 (12.6)	76.2 (10.3)			
3	Blood Pressure						
4	Systolic Blood Pressure (mmHg)	116.1 (17.1)	117.9 (16.6)	115.0 (17.3)			
5	Diastolic Blood Pressure (mmHg)	76.1 (10.5)	77.9 (10.9)	74.9 (10.1)			
6	Blood Glucose Level (mmol/l)	6.4 (2.4)	6.6 (2.9)	6.3 (2.1)			
7	Self-reported diabetes medication history ^j	69	72.6	50	80.6	19	57.6

9 Abbreviations: SD, standard deviation

10 ^a Calculated median and interquartile range for education as the data are skewed

11 ^b Professional occupation includes: Field staff, police officer, guard, doctor, engineer, professional, business man, desk job

12 ^c Other occupation includes: Shop keeper, weavers, driver, student, beggar, cook, carpenter, tailor, migrant workers and fishermen

13 ^d Wealth index was calculated using principal component analysis using data collected on household ownership of the following items: electricity, flushable toilet, land phone, cell phone, television, radio, refrigerator, private car, motor cycle, washing machine, bicycle, sewing machine, almirah/wardrobe, table, bed, chair/bench, watch/clock, as well as, type of main material used to build their homes roof, walls and floor

14 ^e Includes both smokeless tobacco and smoke tobacco

15 ^f Smoking tobacco use includes cigarettes, biri, hookah, etc.

16 ^g Smokeless tobacco use includes jarda, sada pata, pan mashala with tobacco leaf, gul etc.

17 ^h Measured in MET-minutes; 1 MET stands for the amount of oxygen you consume and the number of calories you burn at rest.

18 ⁱ Body mass index (BMI) calculated by weight in kilogram divided by height in meter squared

19 ^j Percentage reported out of participants who self-reported to have diabetes (Total n = 95; Urban n = 62; Rural n = 33)

Table 2: Determinants of hyperglycemia among Bangladeshi adults, 2015 (n = 1819)

Characteristic	Total (n = 1819)		Urban (n = 708)		Rural (n = 1111)	
	Diabetes ^a Prevalence %	Adjusted PR ^b (95% CI)	Diabetes ^a Prevalence %	Adjusted PR ^b (95% CI)	Diabetes ^a Prevalence %	Adjusted PR ^b (95% CI)
Area						
Urban	9.8	Ref.	-	-	-	-
Rural	2.8	0.44 (0.28 – 0.68)	-	-	-	-
Sex						
Male	4.9	Ref.	7.5	Ref.	3.3	Ref.
Female	5.9	1.05 (0.71 – 1.54)	11.9	1.26 (0.80 – 1.99)	2.2	0.61 (0.29 – 1.28)
Age (years)						
18 - 29	2.5	Ref.	2.5	Ref.	2.5	Ref.
30 - 44	4.9	1.48 (0.78 – 2.79)	8.4	2.55 (1.01 – 6.41)	2.5	0.76 (0.30 – 1.93)
45 - 54	7.4	2.18 (1.10 – 4.31)	15.5	4.38 (1.62 – 11.59)	2.8	0.67 (0.25 – 1.83)
≥ 55	8.8	1.92 (0.95 – 3.86)	19.3	3.92 (1.48 – 10.39)	3.4	0.53 (0.17 – 1.67)
Educational Status						
No Education	3.4	Ref.	7.0	Ref.	2.1	Ref.
Primary Education	3.7	1.00 (0.53 – 1.86)	7.6	1.00 (0.44 – 2.30)	2.1	0.84 (0.30 – 2.30)
Secondary Education	6.9	1.67 (0.95 – 2.93)	12.1	1.94 (0.95 – 3.97)	2.9	1.01 (0.40 – 2.54)
Above Secondary Education	9.8	1.48 (0.77 – 2.84)	10.4	1.54 (0.71 – 3.33)	8.1	2.24 (0.68 – 7.41)
Wealth Index^c						
1st Wealth Quartile	7.7	2.58 (1.57 – 4.24)	18.9	3.18 (1.80 – 5.62)	3.6	1.37 (0.53 – 3.49)
2nd Wealth Quartile	4.3	1.23 (0.71 – 2.14)	9.4	1.50 (0.82 – 2.77)	1.9	0.70 (0.24 – 2.05)
3rd Wealth Quartile	3.7	0.86 (0.47 – 1.58)	6.0	0.96 (0.48 – 1.92)	2.0	0.55 (0.18 – 1.73)
4th Wealth Quartile	6.6	Ref.	8.8	Ref.	3.9	Ref.
Blood Pressure						
Normal Blood Pressure	1.9	Ref.	3.5	Ref.	1.1	Ref.
Pre-Hypertension ^d	5.7	1.74 (1.00 – 3.01)	8.3	1.37 (0.69 – 2.74)	3.8	2.32(0.91 – 5.92)
Hypertension ^e	18.9	3.57 (2.01 – 6.34)	27.4	2.65 (1.30 – 5.38)	8.8	5.39(1.94 – 14.96)
Physical Activity						
Vigorous	3.9	Ref.	6.9	Ref.	2.3	Ref.
Moderate	8.2	1.18 (0.78 – 1.77)	13.8	1.22 (0.77 – 1.93)	2.1	0.65 (0.22 – 1.88)
Low	14.9	3.04 (1.69 – 5.47)	20.7	3.01 (1.42 – 6.38)	12.1	2.58 (0.95 – 7.04)

1							
2	Body Mass Index ^f						
3	Underweight (<18.5)	1.1	0.37 (0.12 – 1.13)	1.8	0.38 (0.07 – 1.95)	0.7	0.42 (0.09 – 2.02)
4	Normal (18.5 - 25)	4.7	Ref.	8.2	Ref.	2.8	Ref.
5	Overweight (25.1 - 30)	10.4	1.06 (0.68 – 1.65)	14.0	1.05 (0.61 – 1.80)	6.2	1.22 (0.51 – 2.91)
6	Obese (>30)	20.9	1.49 (0.87 – 2.57)	26.5	1.46 (0.81 – 2.64)	5.6	0.95 (0.12 – 7.60)
7	Waist Circumference (cm)						
8	Normal ^g	2.3	Ref.	3.8	Ref.	1.6	Ref.
9	Abdominally Obese ^h	13.3	2.49 (1.53 – 4.07)	18.1	2.54 (1.35 – 4.77)	6.8	2.95 (1.32 – 6.58)

Abbreviations: PR = prevalence ratio, CI = confidence intervals, Ref = referent category

^a Hyperglycemia was defined as a capillary blood glucose level greater than or equal to 11.1 mmol/L or self-reported diabetes medication use

^b Model adjusted for all variables included in table: sex, age, education, wealth index, blood pressure, body mass index, self-reported physical activity, and waist circumference

^c Wealth index was calculated using principal component analysis using data collected on household ownership of the following items: electricity, flushable toilet, land phone, cell phone, television, radio, refrigerator, private car, motor cycle, washing machine, bicycle, sewing machine, almirah/wardrobe, table, bed, chair/bench, watch/clock, as well as, type of main material used to build their homes roof, walls and floor

^d Pre-Hypertension was defined as SBP \geq 120 mmHg but < 140 mmHg and/or DBP \geq 80 mmHg but <90 mmHg and not taking anti-hypertensive medication at the time of the survey

^e Hypertension was defined as systolic blood pressure (SBP) was \geq 140 mmHg (millimeters of mercury) and/or, diastolic blood pressure (DBP) \geq 90 mmHg and/or taking any-hypertensive medication

^f Body mass index (BMI) calculated by weight in kilogram divided by height in meter squared

^g Defined as <90 cm M; <80 cm F

^h Defined as \geq 90 cm M; \geq 80 cm F

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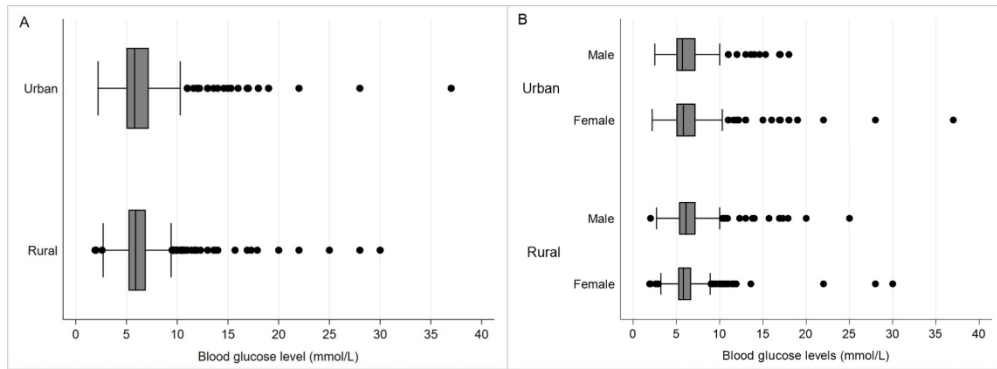
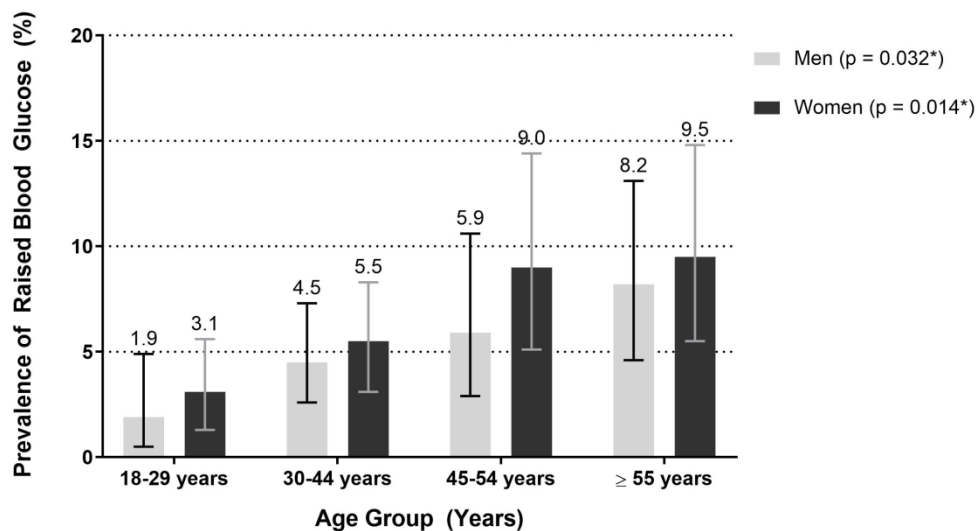


Figure 1: Urban and Rural differences in the distribution of blood glucose levels based on random capillary blood measurement among (A) All Participants, and (B) Men and Women (n = 1819)

327x119mm (150 x 150 DPI)



*Exact test p-value to assess the relationship between prevalence of raised blood glucose and age group stratified by sex

Figure 2: Prevalence of hyperglycemia among Bangladeshi adults aged 18 years and above by sex and age group, 2015 (n = 1819)

211x137mm (300 x 300 DPI)

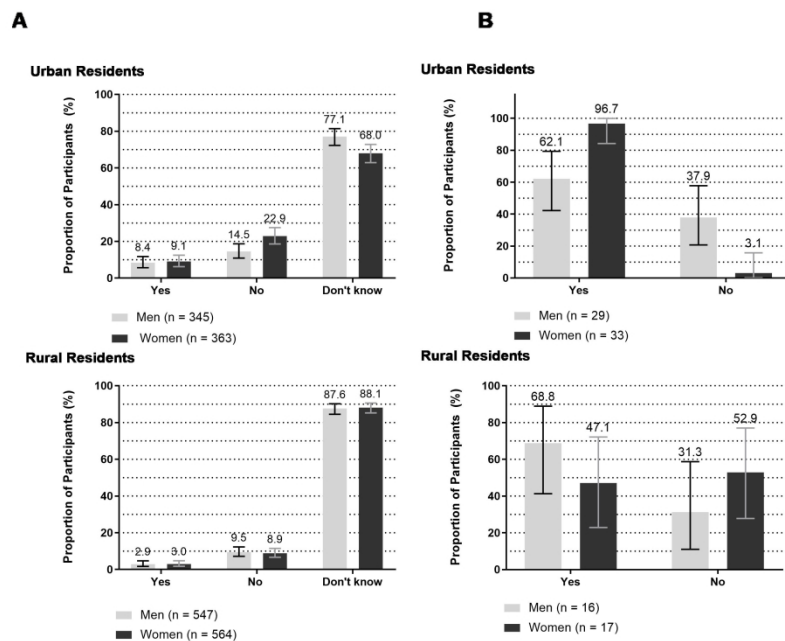


Figure 3: Bangladeshi adults aged 18 years and above with (A) self-reported diabetes and (B) self-reported diabetics on diabetes medications, 2015

284x190mm (300 x 300 DPI)

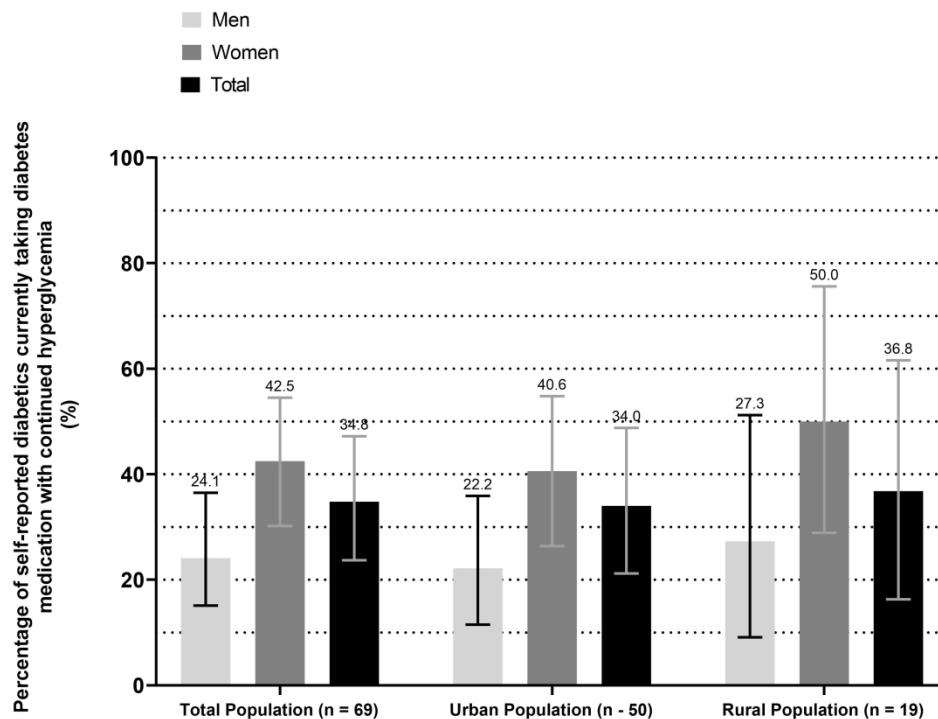


Figure 4: Self-reported diabetics aged 18 years or older who take diabetes medication with hyperglycemia on study measurement ($\geq 11.0\text{mmol/L}$)

284x210mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	6-7 & 11
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	11
		(b) Describe any methods used to examine subgroups and interactions	11
		(c) Explain how missing data were addressed	N/A
		(d) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(e) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(b) Report category boundaries when continuous variables were categorized	9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.