

Interaction between sex and rurality on the prevalence of diabetes in Guyana: a nationally representative study

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ABSTRACT

Introduction Diabetes prevalence has never been measured in Guyana. We conducted a nationally representative cross-sectional study to estimate the prevalence of diabetes and pre-diabetes, and the association between sex and diabetes.

Research design and methods In 2016, the Ministry of Public Health led Guyana's first national STEPS survey among adults aged 18–69 years. Half of the participants were randomly selected for hemoglobin A_{1c} and fasting blood glucose testing. We estimated the prevalence of diabetes and pre-diabetes and measured the association between sex and diabetes prevalence using logistic regression to compute adjusted ORs.

Results We included 805 adults (511 women, 294 men, mean age 41.8 (SD 14.4) years). The national prevalence of diabetes was 18.1% (95% CI: 15.4% to 20.8%), with higher rates among women (21.4%, 95% CI: 18.0% to 24.7%) than men (15.1%, 95% CI: 10.9% to 19.3%). Sex-specific diabetes prevalence varied significantly across urban and rural areas ($p=0.002$ for interaction). In rural areas, diabetes was twice as common among women (24.1%, 95% CI: 20.1% to 28.2%) compared with men (11.8%, 95% CI: 7.7% to 15.9%). After adjusting for prespecified covariates, rural women had double the odds of diabetes compared with rural men (OR 2.1, 95% CI: 1.20 to 3.82). This prevalence pattern was reversed in urban areas (diabetes prevalence, women: 13.9%, 95% CI: 8.7% to 19.0%; men: 22.0%, 95% CI: 12.9% to 31.1%), with urban women having half the odds of diabetes compared with urban men (OR 0.4, 95% CI: 0.20 to 0.99). We estimated that nearly one-third of women and over a quarter of men had diabetes or pre-diabetes.

Conclusions The burden of diabetes in Guyana is considerably higher than previously estimated, with an unexpectedly high prevalence among women—particularly in rural areas.

INTRODUCTION

Type 2 diabetes is a global epidemic. There are an estimated 463 million adults with diabetes worldwide,¹ and the International Diabetes Federation Atlas reports that North America and the Caribbean region have the world's highest raw prevalence of diabetes at 13.3%.¹ While accurate estimates of diabetes

Significance of this study

What is already known about this subject?

- The Caribbean has a unique over-representation of women versus men with diabetes, but this pattern has been poorly characterized previously, as epidemiological data on diabetes are scarce in this region.

What are the new findings?

- In this first nationally representative study of diabetes prevalence in Guyana, we found that approximately one in three women and one in four men had diabetes or pre-diabetes.
- Rural women had double the diabetes prevalence compared with rural men, while urban women had half the diabetes prevalence compared with urban men.
- After adjusting for obesity and other prespecified covariates, rural women had double the odds of diabetes compared with rural men, while urban women had half the odds of diabetes compared with urban men.

How might these results change the focus of research or clinical practice?

- Further interventions are required to address the unexpectedly high prevalence of diabetes among rural women, and more research is needed to understand how determinants of diabetes affect women and men differently in rural and urban settings globally.

burden are fundamental to improving public health, most countries have no national data on diabetes prevalence, relying instead on estimates based on extrapolation from other countries—a methodology that can be inappropriate or inaccurate.² In many countries, the only source of data on diabetes prevalence is the WHO “Stepwise Approach to Disease Surveillance” (STEPS) survey, which only uses fasting blood glucose (FBG) to identify diabetes. However, this approach may be misleading and could underestimate prevalence by 20% or more.³

Moreover, the prevalence of diabetes is typically higher among men than women,⁴

but the Caribbean is exceptional in its unique over-representation of women versus men with diabetes. This phenomenon is poorly understood due to the scarcity of data in this region.⁵ With rapidly changing risk factor distributions in rural and urban areas globally,^{6,7} there is an urgent need to better understand how obesity and other determinants of diabetes might affect women and men differently in the Caribbean.

Guyana is an English-speaking Caribbean nation located in South America, with an estimated population of 783 000 people (2019).⁸ Diabetes prevalence has never been measured in this upper-middle-income country. We conducted a nationally representative cross-sectional study to estimate the prevalence of diabetes and pre-diabetes in Guyana and to examine the associations between diabetes and sex as well as other potential correlates.

RESEARCH DESIGN AND METHODS

Study design and setting

In 2002, the WHO initiated a risk factor surveillance framework for non-communicable diseases known as STEPS.⁹ The STEPS instrument consists of a standard questionnaire assessing demographic characteristics and behavioral risk factors, anthropometric measurements (weight, height, waist circumference, blood pressure), and biochemical measurements including FBG. In 2016, the Ministry of Public Health led Guyana's first national STEPS survey using the Pan American Health Organization version of the STEPS instrument,^{9,10} which we augmented to include hemoglobin A_{1c} (A1C) measurements. Compared with FBG, A1C is a more stable and convenient measure that reflects average blood glucose levels.¹¹ A total of 74 staff were trained to collect survey data, and 16 healthcare workers were trained to collect blood samples.

We derived the nationally representative study sample using a multistage cluster sampling strategy.⁹ The sample size was calculated by the Guyana Bureau of Statistics to estimate diabetes prevalence in four strata at a 95% confidence level, assuming a 66.7% response rate¹² and a 50% diabetes prevalence rate (conservatively high assumption given the lack of previous studies). The sampling frame consisted of 3605 census enumeration districts defined by the Bureau of Statistics, located within the 10 administrative regions of Guyana.¹³ The Bureau of Statistics then selected a random sample of 288 districts, stratified by region. From each selected district, 12 households were randomly sampled, and 1 participant from each household was identified using a table of preassigned random numbers.

Half of the participants were randomly selected for A1C and FBG testing by whole venous blood collection. Samples were refrigerated (2°C–8°C) and processed within 7 days. We measured A1C using high-performance liquid chromatography (D-10 System; Bio-Rad Laboratories, Hercules, California, USA).¹⁴ We defined diabetes

as self-reported diabetes or A1C $\geq 6.5\%$ (48 mmol/mol) or FBG ≥ 7.0 mmol/L (126 mg/dL), pre-diabetes (intermediate hyperglycemia) as A1C $\geq 6.0\%$ (42 mmol/mol) or FBG ≥ 5.5 mmol/L (100 mg/dL), and dysglycemia as either pre-diabetes or diabetes.¹⁵ Although ethnicity may affect mean A1C levels,¹⁶ these A1C thresholds are applicable across ethnicities.¹¹ We linked test results to survey responses using anonymous identification codes.

Study population

We included men and women aged 18 to 69 years living in Guyana. Pregnant women and institutionalized or bedridden persons were excluded.

Statistical analysis

We described baseline characteristics, stratified by sex. We estimated the prevalence of diabetes, pre-diabetes, and dysglycemia with 95% CIs using SAS (V.9.4; Cary, North Carolina; procedure SURVEYREG). We accounted for clustering at the district level and weighted estimates according to the sampling probability (sex and region) based on the 2012 census (online supplementary appendix table 1).¹³ We used 2016 sex-specific population figures from the United Nations Population Division to standardize by age and to estimate the total number of people with diabetes and pre-diabetes.⁸ For international comparisons, we additionally generated prevalence estimates using the WHO population for age standardization.¹⁷

We measured the association between sex and diabetes prevalence using logistic regression (SAS procedure LOGISTIC) to compute adjusted ORs independent of prespecified covariates.¹⁸ These covariates included age, ethnicity, rurality, education, income, employment, smoking, region, waist circumference, and an interaction term between sex and waist circumference due to the sex-specific effects of waist circumference.¹⁹ Because the sex-specific diabetes prevalence differed based on urban or rural place of residence, we tested for an interaction between sex and urban or rural residence. We excluded eight records (1.0%) due to missing covariate data.

There were 202 (25.1%) and 171 (21.2%) participants with missing FBG and A1C values, respectively (online supplementary appendix figure 1). However, everyone in the study cohort had at least one A1C or FBG measurement, and our analyses assumed that diabetes status could be accurately classified using the available data. We conducted extensive sensitivity analyses to test the validity of this assumption. We used logistic regression to determine whether any characteristics were associated with a higher likelihood of missing values and found that some regions had a significantly greater proportion of missing values. To assess whether our prevalence estimates would have differed if we had only used FBG only (as in the standard STEPS instrument), we repeated the analysis excluding the A1C variable, weighting estimates to account for the proportion of missing FBG values in each region. We repeated this procedure using only A1C data

(excluding FBG values), similarly accounting for missing A1C by region.

RESULTS

The study cohort included 805 adults (online supplementary appendix figure 1). Baseline characteristics are shown in [table 1](#) and online supplementary appendix table 2. There were more women (63.5%) than men (35.4%), but age distributions were similar across sexes (mean age 41.8 (SD 14.4) years). Obesity was more than twice as common among women (36.6%) than men (16.0%), while blood pressure was similar across sexes. A quarter of men (24.8%) smoked versus 2.0% of the women. Most (83.0%) men and half (49.7%) of the women were employed. Most participants attained primary school education or higher. There were more women than men in the lowest income bracket (43.1% vs 35.4% respectively). Nearly half (45.3%) of the study population lived in Demerara-Mahaica, and most participants (72.3%) resided in rural areas. The most common ethnicity was East Indian (41.2%), followed by African (29.1%) and Amerindian (Indigenous, 9.3%). Most participants (76.1%) reported two or less servings of fruit or vegetables per day. More men (61.9%) than women (37.8%) reported ≥ 10 hours of moderate to vigorous physical activity per week.

The national prevalence of diabetes was 18.1% (95% CI: 15.4% to 20.8%; [table 2](#); online supplementary appendix table 3), with higher rates among women (21.4%, 95% CI: 18.0% to 24.7%) than men (15.1%, 95% CI: 10.9% to 19.3%). Sex-specific diabetes prevalence varied significantly across urban and rural areas ($p=0.002$ for interaction). In rural areas, diabetes was twice as common among women (24.1%, 95% CI: 20.1% to 28.2%) compared with men (11.8%, 95% CI: 7.7% to 15.9%). After adjusting for prespecified covariates, rural women had double the odds of diabetes compared with rural men (adjusted OR 2.1, 95% CI: 1.20 to 3.82; [figure 1](#); online supplementary appendix table 4). This prevalence pattern was reversed in urban areas (diabetes prevalence, women: 13.9%, 95% CI: 8.7% to 19.0%; men: 22.0%, 95% CI: 12.9% to 31.1%), with urban women having half the odds of diabetes compared with urban men (OR 0.4, 95% CI: 0.20 to 0.99). Among women, rural residence was associated with double the odds of diabetes versus urban residence (OR 2.2, 95% CI: 1.17 to 4.06), while rural men had half the odds of diabetes versus urban men (OR 0.5, 95% CI: 0.21 to 0.99). Diabetes prevalence appeared to differ by ethnicity, with the highest estimates among East Indians (19.7%, 95% CI: 15.5% to 24.0%) and Africans (17.1%, 95% CI: 11.6% to 22.5%; online supplementary appendix table 4). Older age was associated with a higher prevalence of diabetes (OR 6.3, 95% CI: 2.9 to 13.7, for age 60–69 vs 18–29 years). Pre-diabetes rates were similar among women (10.4%, 95% CI: 7.4% to 13.4%) and men (12.0%, 95% CI: 7.9% to 16.1%), but varied by ethnicity, with the highest rates among East Indians

(12.5%, 95% CI: 8.3% to 16.8%). Using only FBG values, weighted national estimates (accounting for missingness by region) of diabetes and pre-diabetes prevalence were lower than estimates using A1C only, with the exception of pre-diabetes among women, which displayed the opposite pattern (online supplementary appendix tables 5–6).

We estimated that nearly one-third of women (70 000 of 220 000) and over a quarter of men (60 000 of 221 000) in Guyana had diabetes or pre-diabetes in 2016 ([figure 2](#); online supplementary appendix table 7). Over half (47 000 women and 33 000 men) of them had diabetes, and most of them lived in rural areas. The estimated number of women and men with diabetes dropped by 37.0% and 51.1% when using FBG only, and by 21.4% and 13.0% when using A1C only. A similar pattern was observed among men with pre-diabetes, but the estimated number of women with pre-diabetes was 11.3% higher using FBG only, and 20.5% lower using A1C only. Around two-thirds (women: 70.5%, men: 63.8%) of the participants with diabetes were aware of their diagnosis (online supplementary appendix table 8).

The distribution of missing A1C values (21.2%) was similar across most demographic characteristics (online supplementary appendix table 9). There were fewer missing A1C values among Amerindian (Indigenous) people versus East Indians (OR 0.2, 0.0–0.8) and in the Pomeroon-Supenaam region versus Demerara-Mahaica (OR 0.1, 0.0–0.5). Missing FBG values (25.1%) were similarly distributed across most characteristics except for region; four regions had a significantly higher OR of missing FBG values.

CONCLUSIONS

This is the first nationally representative study describing diabetes prevalence and its correlates among men and women in Guyana. Using a combination of A1C and FBG tests, we found that the diabetes prevalence rate was 21.4% among women and 15.1% among men, and that approximately one in three women and one in four men in Guyana had diabetes or pre-diabetes in 2016. These estimates are substantially higher than those using FBG only or previous estimates using data from other countries,²⁰ thus demonstrating that A1C measurements would significantly improve on the accuracy of diabetes prevalence estimation in STEPS surveys. After accounting for obesity and other important covariates, we found that rural women had double the odds of diabetes compared with rural men, while urban women had half the odds of diabetes compared with urban men—an unexpected interaction that has never been previously described. Furthermore, rural women had double the odds of diabetes versus urban women, whereas rural men had half the odds of diabetes versus urban men. Considering that one-third of the people with diabetes were previously undiagnosed, these stark findings emphasize the urgent need to address the substantial burden of diabetes in Guyana—especially among rural women.

Table 1 Baseline characteristics among men and women in the study.

Characteristic	Men n=294	Women n=511	Total n=805
Age group (years)			
18–29	71 (24.1)	140 (27.4)	211 (26.2)
30–39	56 (19.0)	107 (20.9)	163 (20.2)
40–49	64 (21.8)	117 (22.9)	181 (22.5)
50–59	50 (17.0)	89 (17.4)	139 (17.3)
60–69	53 (18.0)	58 (11.4)	111 (13.8)
Waist circumference (cm; mean, SD)	93 (16.7)	96 (16.2)	95 (16.4)
Body mass index (kg/m ²)*			
<25	156 (53.1)	170 (33.3)	326 (40.5)
25–29	91 (31.0)	154 (30.1)	245 (30.4)
≥30	47 (16.0)	187 (36.6)	234 (29.1)
Blood pressure (mm Hg; mean, SD)			
Systolic	130 (19.4)	126 (39.0)	128 (33.3)
Diastolic	80 (14.8)	80 (38.2)	80 (31.7)
Smoking	73 (24.8)	10 (2.0)	83 (10.3)
Employment			
Employed	244 (83.0)	254 (49.7)	498 (61.9)
Homemaker	0 (0.0)	176 (34.4)	176 (21.9)
Retired	23 (7.8)	25 (4.9)	48 (6.0)
Unemployed	26 (8.8)	54 (10.6)	80 (9.9)
Unknown	1 (0.3)	2 (0.4)	3 (0.4)
Education			
None	4 (1.4)	11 (2.2)	15 (1.9)
Primary	144 (49.0)	256 (50.1)	400 (49.7)
Secondary	101 (34.4)	179 (35.0)	280 (34.8)
Post-secondary	44 (15.0)	64 (12.5)	108 (13.4)
Unknown	1 (0.3)	1 (0.2)	2 (0.2)
Household income†			
≤G\$700 000	104 (35.4)	220 (43.1)	324 (40.2)
G\$700 001–G\$1 100 000	75 (25.5)	100 (19.6)	175 (21.7)
G\$1 100 001–G\$2 300 000	39 (13.3)	59 (11.5)	98 (12.2)
>G\$2 300 000	29 (9.9)	29 (5.7)	58 (7.2)
Unknown	47 (16.0)	103 (20.2)	150 (18.6)
Region			
1 Barima-Waini	3 (1.0)	3 (0.6)	6 (0.7)
2 Pomeroon-Supenaam	22 (7.5)	40 (7.8)	62 (7.7)
3 Essequibo Islands-West Demerara	62 (21.1)	75 (14.7)	137 (17.0)
4 Demerara-Mahaica	133 (45.2)	232 (45.4)	365 (45.3)
5 Mahaica-Berbice	17 (5.8)	40 (7.8)	57 (7.1)
6 East Berbice-Corentyne	22 (7.5)	68 (13.3)	90 (11.2)
7 Cuyuni-Mazaruni	9 (3.1)	18 (3.5)	27 (3.4)
8 Potaro-Siparuni	2 (0.7)	2 (0.4)	4 (0.5)
9 Upper Takatu-Upper Essequibo	12 (4.1)	13 (2.5)	25 (3.1)
10 Upper Demerara-Berbice	12 (4.1)	20 (3.9)	32 (4.0)

Continued

Table 1 Continued

Characteristic	Men n=294	Women n=511	Total n=805
Urban	81 (27.6)	142 (27.8)	223 (27.7)
Rural	213 (72.4)	369 (72.2)	582 (72.3)
Ethnicity			
East Indian	122 (41.5)	210 (41.1)	332 (41.2)
African	92 (31.3)	142 (27.8)	234 (29.1)
Amerindian (Indigenous‡)	28 (9.5)	47 (9.2)	75 (9.3)
Other	52 (17.7)	112 (21.9)	164 (20.4)
Diet (fruit and vegetable servings per day)			
0–2	226 (76.9)	387 (75.7)	613 (76.1)
3–4	46 (15.6)	98 (19.2)	144 (17.9)
≥5	18 (6.1)	20 (3.9)	38 (4.7)
Unknown	4 (1.4)	6 (1.2)	10 (1.2)
Physical activity (moderate to vigorous, minutes per week)			
<150	65 (22.1)	222 (43.4)	287 (35.7)
150–299	19 (6.5)	44 (8.6)	63 (7.8)
300–599	28 (9.5)	52 (10.2)	80 (9.9)
≥600	182 (61.9)	193 (37.8)	375 (46.6)

All values are counts (n) and percentages (%) unless otherwise indicated

*Body mass index <20 kg/m² was not observed.

†Guyanese dollars.

‡In Guyana, Indigenous people are known locally as “Amerindians.”

As we and others have reported, the over-representation of women with diabetes in Caribbean nations such as Guyana is a poorly understood phenomenon that appears isolated to the Caribbean and southern Africa.^{4 5 21} In adulthood, male sex is a biological risk factor associated with a higher type 2 diabetes risk than female sex, due in part to increased insulin resistance, at any given body mass index.^{19 22} This biological relationship may be offset by a relatively higher prevalence of obesity among Caribbean women versus men^{5 21}—a gender difference rooted in the sociocultural perception of obese women as being healthier.²³ We found that obesity was more than doubled among women versus men, which is similar to other Caribbean populations.²⁴ As waist circumference was a relatively stronger correlate of diabetes among women than men,¹⁹ the observed excess in female diabetes prevalence appeared to be partially attributable to a higher prevalence of female obesity.

However, diabetes prevalence was paradoxically highest among rural women, despite having a lower prevalence of obesity compared with urban women (34.2% vs 39.5%; online supplementary appendix table 10). After accounting for ethnicity and the sex-specific effects of obesity, female sex was independently associated with double the odds of diabetes versus male sex in rural areas, whereas urban women had half the odds of diabetes versus urban men. The reasons for this phenomenon—which

has never been previously reported to our knowledge—are unclear. In an exploratory post hoc analysis, physical activity was significantly higher among men versus women ($p<0.0001$; online supplementary appendix figure 2). Weekly moderate to vigorous physical activity appeared higher among rural versus urban men (median 22.0 vs 12.0 min per week, $p=0.1$), whereas women appeared less active in rural versus urban areas (median 3.7 vs 6.0 min per week, $p=0.06$). However, these self-reported values varied widely, and subjective measures of physical activity may be unreliable.^{25 26} Other correlates such as income, education, employment, and smoking were not independently associated with diabetes in our study. Further research is required to understand whether objectively measured physical activity, dietary differences, or novel risk factors may explain the interaction between sex and rurality, and the especially high prevalence of diabetes among rural women.

As the first national diabetes study in Guyana and one of the first STEPS studies to include both A1C and FBG, our results suggest that the use of FBG only would have substantially underestimated diabetes prevalence in our population. The International Diabetes Federation Atlas (2017) previously proposed lower prevalence estimates of diabetes (11.3%, 9.7%–15.2% for ages 20–79 years) by extrapolating from other nations.²⁰ While STEPS surveys are often the only reliable source of national

Table 2 National and subnational prevalence estimates of diabetes, pre-diabetes, and dysglycemia among men and women aged 20 to 69 years in Guyana during 2016

	Diabetes			Pre-diabetes			Dysglycemia		
	Men	Women	Total	Men	Women	Total	Men	Women	Total
National	15.1 (10.9 to 19.3)	21.4 (18.0 to 24.7)	18.1 (15.4 to 20.8)	12.0 (7.9 to 16.1)	10.4 (7.4 to 13.4)	11.1 (8.6 to 13.6)	27.1 (21.7 to 32.5)	31.8 (27.8 to 35.7)	29.2 (25.9 to 32.5)
Age group (years)									
20–29	5.9 (0.0 to 12.7)	7.5 (3.4 to 11.7)	6.8 (3.0 to 10.6)	4.5 (0.0 to 9.6)	7.7 (2.9 to 12.6)	6.3 (2.8 to 9.8)	10.4 (0.0 to 18.7)	15.3 (9.0 to 21.5)	13.1 (8.1 to 18.1)
30–39	11.7 (3.2 to 20.1)	12.6 (5.9 to 19.3)	12.1 (6.8 to 17.5)	14.4 (4.3 to 24.6)	6.6 (2.0 to 11.2)	10.4 (5.0 to 15.7)	26.1 (13.6 to 38.5)	19.2 (11.3 to 27.1)	22.5 (15.0 to 30.0)
40–49	16.5 (7.7 to 25.2)	32.4 (23.4 to 41.4)	24.7 (18.3 to 31.0)	17.5 (6.7 to 28.3)	4.9 (1.0 to 8.7)	11.0 (5.2 to 16.8)	34.0 (21.0 to 46.9)	37.2 (27.7 to 46.7)	35.7 (27.8 to 43.5)
50–59	27.9 (14.4 to 41.4)	26.5 (17.4 to 35.6)	27.2 (19.0 to 35.4)	13.8 (3.5 to 24.0)	21.4 (12.4 to 30.4)	17.6 (10.7 to 24.5)	41.7 (26.9 to 56.5)	47.8 (36.5 to 59.2)	44.8 (35.5 to 54.0)
60–69	27.7 (15.2 to 40.1)	50.3 (37.8 to 62.7)	36.6 (27.3 to 45.9)	14.4 (5.0 to 23.8)	20.2 (10.1 to 30.3)	16.7 (9.8 to 23.6)	42.1 (27.7 to 56.5)	70.4 (58.8 to 82.1)	53.3 (42.5 to 64.1)
Urban	22.0 (12.9 to 31.1)	13.9 (8.7 to 19.0)	17.9 (12.7 to 23.2)	9.8 (4.4 to 15.2)	10.3 (4.9 to 15.7)	9.8 (6.0 to 13.7)	31.8 (21.1 to 42.5)	24.1 (17.5 to 30.8)	27.8 (21.8 to 33.7)
Rural	11.8 (7.7 to 15.9)	24.1 (20.1 to 28.2)	17.9 (14.7 to 21.0)	13.4 (8.1 to 18.7)	10.4 (6.8 to 14.0)	11.8 (8.7 to 14.9)	25.2 (19.1 to 31.2)	34.5 (29.8 to 39.3)	29.7 (25.7 to 33.6)
Ethnicity									
East Indian	3.4 (7.4 to 19.4)	26.1 (20.3 to 31.9)	19.7 (15.5 to 24.0)	15.9 (8.5 to 23.3)	9.7 (5.7 to 13.6)	12.5 (8.3 to 16.8)	29.3 (21.0 to 37.7)	35.8 (29.7 to 41.8)	32.3 (27.3 to 37.2)
African	17.3 (9.1 to 25.4)	17.6 (11.6 to 23.7)	17.1 (11.6 to 22.5)	10.0 (4.6 to 15.4)	14.3 (8.2 to 20.4)	12.0 (7.6 to 16.3)	27.2 (17.9 to 36.6)	31.9 (24.7 to 39.1)	29.0 (22.8 to 35.2)
Amerindian (Indigenous)	5.7 (0.0 to 12.7)	18.0 (8.9 to 27.1)	12.6 (6.4 to 18.9)	10.0 (0.0 to 20.7)	3.7 (0.0 to 8.1)	9.5 (1.9 to 17.2)	15.7 (2.8 to 28.6)	21.7 (11.6 to 31.7)	22.2 (12.3 to 32.0)
Other	27.4 (13.5 to 41.4)	17.1 (10.7 to 23.6)	20.4 (14.5 to 26.4)	5.2 (0.0 to 10.8)	8.2 (3.1 to 13.4)	7.3 (3.3 to 11.2)	32.7 (17.8 to 47.5)	25.4 (17.7 to 33.0)	27.7 (21.1 to 34.3)

Estimates are weighted by sampling probability and age-standardized to the Guyanese national population (2016; see online supplementary appendix table 3 for comparative estimates age-standardized to the WHO population). All values are percentages with 95% CIs.

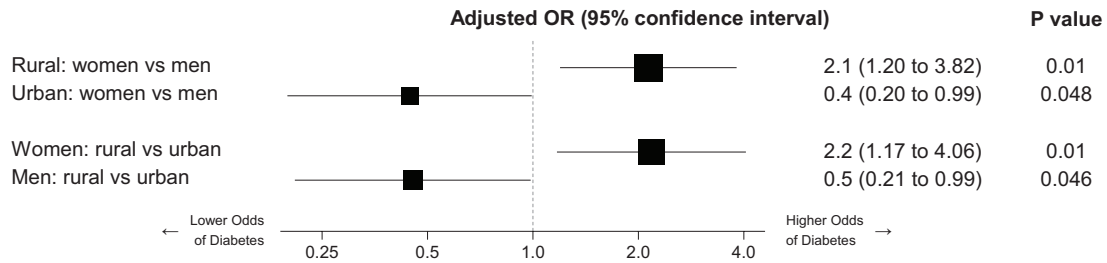


Figure 1 Association between sex and diabetes prevalence, stratified by rural and urban residence, in the Stepwise Approach to Surveillance Survey (2016). The area of each square is proportional to the sample size. The logistic regression model adjusted for age, ethnicity, education, income, employment smoking, region, waist circumference, and the interaction between waist circumference and sex (see online supplementary appendix table 5 for additional results).

diabetes data in low- and middle-income countries,²⁰ the STEPS protocol only includes FBG measurements to diagnose diabetes.^{9 10} In this study, we additionally included A1C measurements, which are increasingly accessible and potentially cheaper to collect as a single, untimed test.²⁷ We found that FBG underestimated the prevalence of diabetes versus A1C, which is consistent with a meta-analysis reporting similar patterns in Caribbean and South Asian nations.²⁸ However, this pattern was not observed in other regions and was reversed in high-income western countries,²⁸ suggesting that A1C measurements may be uniquely important in Caribbean populations to accurately estimate diabetes burden. For example, a cross-sectional survey in Barbados reported that nearly two-thirds of people were classified as having dysglycemia using A1C and FBG versus one quarter using FBG only.²⁹ Future prevalence studies in the Caribbean region should consider including A1C tests at least among a subset of participants of different ethnicities,¹⁶

as previous Caribbean studies using only FBG values may have underestimated the true prevalence of diabetes.

Our study fills a major knowledge gap by providing directly measured national and subnational diabetes and pre-diabetes prevalence estimates, and uncovering an important interaction between sex and urban or rural residence on diabetes prevalence in Guyana. Strengths of our study include the nationally representative sample, the use of both A1C and FBG measurements for better diagnostic accuracy, and the inclusion of many detailed demographic, behavioral, and anthropometric variables for statistical adjustment. Study limitations include missing data for inaccessible and remote areas due to logistical difficulties. Although we weighted estimates to account for missingness by region, our findings should be considered conservative, as some participants with only one A1C or FBG test may have had unidentified diabetes. While the D-10 System measures A1C accurately in the presence of heterozygous hemoglobin variants,^{30 31}

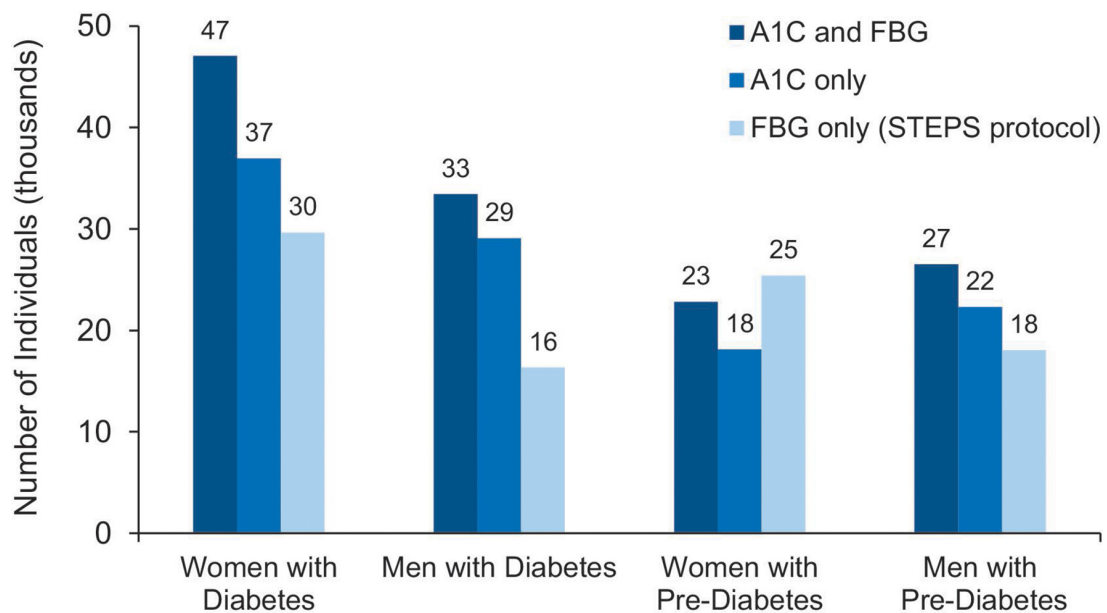


Figure 2 Number of men and women aged 20 to 69 years with diabetes and pre-diabetes in Guyana during 2016*, estimated using hemoglobin A_{1c} (A1C) and fasting blood glucose (FBG) data, A1C only, and FBG only. The Stepwise Approach to Surveillance (STEPs) standard protocol includes FBG only. All values are counts (thousands). *Population estimates from the United Nations Population Division. For urban and rural estimates, see online supplementary appendix table 7.

measurements among the small minority of people with compound heterozygous or homozygous hemoglobin variants (likely <0.4%^{32,33}) may have been falsely normal. As in other similar studies,³⁴ the relative lack of men present in the household during the survey may have introduced selection bias.

In conclusion, the burden of diabetes in Guyana is considerably higher than previously estimated, with a strikingly high prevalence of diabetes among women—particularly in rural areas. Further research is needed to characterize patterns of diabetes prevalence in other Caribbean settings, to understand how determinants of diabetes affect women and men differently across rural and urban areas, and to study how sex and age affect diabetes development and progression. There is an urgent need to improve diabetes awareness and identification, and to prevent or delay diabetes among people with pre-diabetes. While these efforts must be scaled carefully to ensure sufficient capacity within local health systems,^{29,35} future progress will require ongoing investment in the current initiatives of the Ministry of Public Health to improve diabetes screening,³⁶ management,³⁷ and outcomes.³⁸

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