Association between urban–rural location and prevalence of type 2 diabetes and impaired fasting glucose in West Africa: a cross-sectional population-based epidemiological study

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ABSTRACT

Objectives We investigated the association between urban/rural location and both type 2 diabetes mellitus (T2DM) and pre-diabetes among populations of five West African countries.

Design Cross-sectional studies, using the WHO Stepwise (STEPS) survey data.

Setting National representative data of both urban and rural areas from Benin, Burkina Faso, Ghana, Liberia and Mali.

Participants Adults comprising 15468 participants (6774 men and 8746 women; 7663 urban and 7805 rural residents) aged between 25 and 64 years.

Results The age and sex-adjusted prevalence of T2DM was 6.2% for urban areas and 2.5% for rural areas. The prevalence of impaired fasting glucose (IFG) was 6.6% for urban areas, and 3.0% for rural areas. No differences by sex were observed. The crude relative risk (RR) and 95% CI of T2DM and IFG in urban compared with rural areas were 2.69 (1.85 to 3.91) and 2.37 (1.53 to 3.66), respectively. This reduced to RR: 2.03, 95% CI (1.34 to 3.08) and RR: 2.04, 95% CI (1.27 to 3.28), respectively, after adjusting for covariates.

Conclusion The prevalence of both T2DM and IFG was more than two times as high in urban areas compared with rural areas in West Africa. Behavioural risk factors are common among urban populations, with ongoing urbanisation expected to drive increases in the prevalence of T2DM. These results could guide planning for T2DM screening, preventive strategies and resource allocation in West Africa.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) has emerged as a significant public health burden in Africa and is expected to reach pandemic levels by 2045. The International Diabetes Federation (IDF) estimates that T2DM will increase by 134% in sub-Saharan Africa (SSA) from 2021 to 2045 compared with a 46% increase in the rest of the world. The global burden of disease study suggests that between 1990 and 2017, total disability-adjusted life years (DALYs) lost due to non-communicable disease (NCDs), including T2DM, in SSA populations, increased from 90.6 million to 151.3 million. These estimates confirm IDF’s projections that unless the NCD burden, including T2DM prevalence, is urgently addressed, SSA will face the largest global burden of DALYs and premature death in the coming decades.

The T2DM epidemic in Africa is driven by rapid urbanisation accompanied by increases in the proportion of older people and the prevalence of potentially modifiable risk factors such as poor diet, physical inactivity and obesity. Though rapid urbanisation is associated with advantages such as economic opportunities and access to social services, education and quality healthcare systems, it also has potential disadvantages, including pollution, overcrowding, unemployment and urban stress. Urbanisation is currently
increasing faster annually in African cities (at an average rate of 4.5%) compared with other regions, including Asia-Pacific (an average rate of 2.8%) and Europe (an average rate of 0.5%). By 2050, African cities will be home to an additional 950 million people, in part due to high migration to urban areas among younger groups for education and employment, contributing to increasingly large urban areas in Africa.

The net effect of urbanisation on NCD risk is attributed to an epidemiological transition that encompasses both dietary changes such as shifts from traditional diets to consumption of saturated fats and sugar and changes in physical activity behaviour including shifts away from high levels of occupational and incidental-based physical activity to more sedentary lifestyles. In a 2004 study from Cameroon, the number of years lived in urban areas was strongly associated with levels of blood glucose, blood pressure and body mass index (BMI). Studies in SSA show that urban lifestyles, defined as spending greater than 40% of the lifetime in cities, are associated with more than a two-fold increased risk of NCDs, including T2DM and impaired fasting glucose (IFG). IFG is a transition state before diabetes and predicts future burden, including DALYs and premature death. Risk factor surveillance for NCDs in Africa suggests that the majority of African individuals are exposed to at least one underlying risk factor for T2DM and IFG, including high consumption of alcohol or discretionary food, tobacco use, physical inactivity and obesity. These risk factors for the development and progression of T2DM are geographically patterned, being more common in urban compared with rural areas.

Despite the escalating T2DM prevalence in Africa, and the recognition of the need to address the risks related to urbanisation, few studies have explored the prevalence of both T2DM and IFG, as well as their risk factors, among both urban and rural populations in Africa (and none in West Africa). Previous studies have instead focused on either urban or rural areas in isolation. As such, this study aims to examine the association between urban/rural location and the prevalence of both T2DM and IFG. It further examined how differences in the prevalence of T2DM and IFG are explained by sociodemographic, behavioural and biological risk factors among a large, multi-country West African study.

**METHODS**

This study is based on the WHO Stepwise (STEPS) approach for the surveillance of NCD risk factors. A pooled analysis of individual respondent-level data in urban and rural areas of selected townships in five different West African countries (Burkina Faso, Benin, Mali, Liberia and Ghana) was conducted. The data were collected in different years, between 2006 (in Ghana) and 2013 (in Burkina Faso). The STEPS survey is a standardised way of measuring NCD risk factors, designed for participants living in WHO member states. The survey assessed components of behavioural and lifestyle data from interviews (step 1); physical measurements of anthropometry and blood pressure (step 2) and biochemical factors from laboratory testing (step 3). In step 3, consenting participants were asked to fast for at least 8 hours (overnight). Those who complied were eligible for finger-pricked blood sample collection and fasting blood glucose was measured using Accutrend Plus machines (Roche, Mannheim, Germany). All countries employed a multistage cluster sampling technique with randomly selected participants. The sampling units were the households and one individual residing in each selected household was included. Detailed information about the study population and design is available for each of the countries and reported on the WHO website. The study followed the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology Checklist for cross-sectional studies (online supplemental table 1).

**Variables and definitions**

Definitions and diagnostic criteria for T2DM and IFG were based on the WHO criteria. The presence of T2DM was defined as either (1) insulin users or those taking hypoglycaemic agents or (2) a fasting plasma glucose (FBG) of ≥7.0 mmol/L. Smoking was categorised as ‘yes’ or ‘no’ to the question ‘Do you currently smoke tobacco products?’. IFG was defined as FBG of between 6.1 and <7.0 mmol/L. Alcohol consumption was defined as regular consumption of alcohol, regardless of quantity, categorised as never, sometimes but <1 time per week, 1–4 times per week, 5–6 times per week and every day. A 16-item Global Physical Activity Questionnaire was used to assess physical activity levels (metabolic equivalent (MET) min per week) in various life domains, such as transportation, work and leisure. Physical activity was categorised as low, medium and high based on the amount of walking, moderate-intensity or vigorous-intensity activities an individual engaged in for at least 3000, 600, or less than 600 MET.min/week, respectively. High levels of physical activity were defined as engaging in any combination of walking, moderate- or vigorous-intensity activities for at least 7 days per week. Moderate levels were defined as engaging in such activities for at least 5 days per week, while low levels were defined as not meeting either of these requirements. Additionally, due to the low consumption of fruits and vegetables in this population, individuals who consumed less than two servings per day (or <14 per week) were categorised as having low fruit or vegetable consumption.

BMI was calculated as weight in kilograms divided by height in metres squared (kg/m²) and was categorised into normal (<25 kg/m²), overweight (25 kg/m² to <30 kg/m²) and obese (≥30 kg/m²). Obesity based on waist circumference (WC) measurement was defined as ≥80 cm for women and ≥94 cm for men. Waist to hip ratio (WHR) and waist to height ratio (WHtR) were calculated as WC divided by hip circumference (HC) and height, respectively. Elevated WHR was defined as WHR...
≥0.85 for women and ≥0.90 for men. Elevated WHtR was defined as ≥0.50. High blood pressure (HBP) was defined as ≥140 mm Hg systolic blood pressure or ≥90 mm Hg diastolic blood pressure or being on any antihypertensive treatment. Sociodemographic variables assessed included sex, age, education, marital status and location (urban or rural). Age was categorised as 25–34, 35–44, 45–54, 55–64 years. Marital status was categorised as single, married/cohabitating and divorced/widowed. Education was classified as: no formal education; completed primary education; completed secondary/tertiary education, and the location was dichotomised into urban/rural.

**Analysis**

All analyses were accounted for the complex survey design and weighting, using survey weights provided by countries. The proportion of missing data was very low and varied slightly by country. Due to the low proportion of missing values, complex approaches to missingness such as multiple imputations were not necessary. We previously conducted a sensitivity analysis to determine the potential effect of data not being missing at random on a prior analysis using this data, which we reported on in Issaka et al. In this sensitivity analysis, we found that the OR estimate was unaffected by missing values.

In addition to the sensitivity analysis, we carried out robust validity checks. We ensured that no records with incompatible variable values were included, and that all records of variable values agreed with each other to check for internal consistency and reliability of the data. To ensure all values were realistic, we excluded implausible values using the cut-off values from the WHO STEPS Manual 2008.

To compare the prevalence of T2DM and IFG between urban and rural samples, we standardised the data to the age and sex distribution of the African standard. We used multinomial logistic regression to calculate the relative risks (RR) and their 95% CIs for the association between urban/rural location and both T2DM and IFG.

Based on previous studies that utilised directed acyclic graphs as a framework, we identified and incorporated sociodemographic confounding factors, such as age, sex, education and profession, into our first model (see figure 1). In our second model, we also included additional potential confounders, such as fruit and vegetable consumption, alcohol consumption, physical activity, smoking, WC and obesity (BMI).

To assess urban/rural differences in sociodemographic and behavioural variables as well as the prevalence of T2DM and IFG, χ² tests and Wald tests were employed. All analyses were carried out using Stata V.17.0. Statistical significance was determined by a p value of less than 0.05. Burkina Faso was excluded in all analyses that included WHR as HC data were not collected in that country. Additionally, Benin and Ghana were excluded from all analyses that involved marital status and HBP, respectively, as data on these variables were not available for these countries.

**Patient and public involvement**

This study used the WHO STEPS survey data and was designed and conducted without patient and public involvement. The results will be disseminated to the public through publication in this journal.

**RESULTS**

The data set analysed included a total of 15 468 participants, of whom 7663 (49.5%) resided in urban areas and 7805 (50.5%) resided in rural areas. Female
participants accounted for slightly more of the sample (52.2%) than male participants (47.8%), and a higher proportion of urban participants were aged 25–34 years (40.0%) compared with those in rural areas (37.2%). The percentage of participants with higher levels of education was also higher in urban areas (51.3%) compared with rural areas (7.3%), as was unemployment (urban=33.3%; rural=22.1%). High level of physical activity was common in rural (77.6%) compared with urban areas (61.6%). Urban participants had higher rates of obesity, as measured by both BMI (23.1% vs 6.1%) and WC (54.9% vs 23.7%). Similarly, the proportion of participants with hypertension was higher in urban areas compared with rural areas (30.0% vs 24.7%). The percentage of participants with higher levels of education was also higher in urban areas (51.3%) compared with rural areas (7.3%), as was unemployment (urban=33.3%; rural=22.1%). High level of physical activity was common in rural (77.6%) compared with urban areas (61.6%). Urban participants had higher rates of obesity, as measured by both BMI (23.1% vs 6.1%) and WC (54.9% vs 23.7%). Similarly, the proportion of participants with hypertension was higher in urban areas compared with rural areas (30.0% vs 24.7%). For complete participants’ characteristics, see online supplemental table 2.

The crude prevalence of T2DM in urban and rural areas was 6.6% and 2.6%, respectively, while the prevalence of IFG was 6.6% in urban areas and 3.0% in rural areas, with no significant gender differences in the proportion of men and women in urban (p=0.53) and rural (p=0.94) areas classified as having IFG. Unlike for T2DM, the prevalence of IFG was similar across age groups, with the highest prevalence found among participants aged 44–55 years in both urban and rural areas.

Table 2 shows the RR and 95% CI of both T2DM and IFG in rural compared with urban dwellers. In the crude model, the RR of T2DM was higher for urban dwellers (RR=2.69, 95% CI (1.85 to 3.91), p≤0.001). After adjusting for potential sociodemographic confounding factors, the prevalence of T2DM remained significantly higher in urban (6.2%) than in rural areas (2.5%) (p=0.001). There were no significant sex differences in the proportion of men and women with T2DM in either urban (p=0.84) or rural (p=0.43) areas (table 1). The prevalence of T2DM increased with age and was highest among the 55–64-year age group. The age and sex-standardised prevalence of IFG was 6.6% in urban areas and 3.0% in rural areas, with no significant gender differences in the proportion of men and women in urban (p=0.53) and rural (p=0.94) areas classified as having IFG. Unlike for T2DM, the prevalence of IFG was similar across age groups, with the highest prevalence found among participants aged 44–55 years in both urban and rural areas.

### Table 1: Prevalence of both T2DM and IFG stratified by urban and rural location among 25–64-year-old West African citizens*

| Sociodemographic risk factors | Urban % (95% CI) | Rural % (95% CI) | Total % (95% CI) | \( \chi^2 \) test† | P value
<table>
<thead>
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</thead>
<tbody>
<tr>
<td><strong>Prevalence of T2DM</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6.2 (5.1 to 7.4)</td>
<td>2.5 (1.9 to 3.2)</td>
<td>4.4 (3.8 to 4.9)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6.2 (4.7 to 7.7)</td>
<td>2.7 (1.8 to 3.6)</td>
<td>4.4 (3.7 to 5.1)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>6.3 (5.2 to 7.4)</td>
<td>2.3 (1.6 to 3.1)</td>
<td>4.3 (3.6 to 4.9)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>P value‡</td>
<td>0.84</td>
<td>0.42</td>
<td></td>
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<tr>
<td>Age group, years</td>
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<td></td>
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<tr>
<td>25–34</td>
<td>3.0 (2 to 4.1)</td>
<td>1.5 (0.9 to 2.1)</td>
<td>2.2 (1.7 to 2.8)</td>
<td>0.008</td>
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<tr>
<td>35–44</td>
<td>5.9 (4.2 to 7.6)</td>
<td>2.9 (2 to 3.9)</td>
<td>4.4 (3.5 to 5.3)</td>
<td>0.002</td>
<td></td>
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<tr>
<td>45–54</td>
<td>7.7 (6 to 9.5)</td>
<td>3.4 (2.3 to 4.5)</td>
<td>5.5 (4.7 to 6.4)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>55–64</td>
<td>14.2 (12 to 16.5)</td>
<td>3.5 (2.1 to 5)</td>
<td>8.8 (7.3 to 10.3)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>P value‡</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Prevalence of IFG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6.6 (4.5 to 8.8)</td>
<td>3.0 (2.4 to 3.6)</td>
<td>4.8 (3.9 to 5.6)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6.9 (4.5 to 9.2)</td>
<td>3 (2.2 to 3.8)</td>
<td>4.9 (3.9 to 5.8)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>6.4 (4.3 to 8.6)</td>
<td>3.1 (2.3 to 3.8)</td>
<td>4.7 (3.8 to 5.5)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>P value‡</td>
<td>0.53</td>
<td>0.94</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Age group to years</td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>25–34</td>
<td>6.1 (4 to 8.1)</td>
<td>3 (2.2 to 3.8)</td>
<td>4.4 (3.5 to 5.3)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>35–44</td>
<td>6.9 (4.2 to 9.7)</td>
<td>2.8 (2 to 3.6)</td>
<td>4.8 (3.7 to 5.9)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>45–54</td>
<td>7.3 (4.7 to 10)</td>
<td>3.3 (2 to 4.5)</td>
<td>5.3 (4.1 to 6.4)</td>
<td>0.003</td>
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<tr>
<td>55–64</td>
<td>6.6 (4.2 to 9)</td>
<td>3.4 (2.1 to 4.6)</td>
<td>4.9 (3.8 to 6)</td>
<td>0.02</td>
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</tr>
<tr>
<td>P value‡</td>
<td>0.56</td>
<td>0.83</td>
<td></td>
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</table>

*Both urban and rural samples were age/sex standardised to the African standard population.
†\( \chi^2 \) test: p values for the difference in prevalence between urban and rural samples stratified by gender and age groups.
‡Wald test: p values for the difference in prevalence between gender and age groups for urban and rural populations separately.

IFG, impaired fasting glucose; T2DM, type 2 diabetes mellitus.
Table 2  Relative risk (RR) of T2DM based on location (rural and urban), and other potential risk factors, in adults aged 25–64 years in West Africa

<table>
<thead>
<tr>
<th>Location and potential risk factors</th>
<th>Crude model</th>
<th>Model 1*</th>
<th>Model 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR (95% CI)</td>
<td>P value</td>
<td>RR (95% CI)</td>
</tr>
<tr>
<td>Rural</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
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<tr>
<td>Urban</td>
<td>2.69 (1.85 to 3.91)</td>
<td>&lt;0.001</td>
<td>2.03 (1.34 to 3.08)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Male</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Female</td>
<td>0.97 (0.78 to 1.20)</td>
<td>0.78</td>
<td>1.0 (0.8 to 1.22)</td>
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<td>Age group, years</td>
<td></td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>25–34</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>35–44</td>
<td>2.01 (1.57 to 2.57)</td>
<td>&lt;0.001</td>
<td>2.18 (1.71 to 2.78)</td>
</tr>
<tr>
<td>45–54</td>
<td>2.60 (2.04 to 3.31)</td>
<td>&lt;0.001</td>
<td>2.90 (2.28 to 3.68)</td>
</tr>
<tr>
<td>55–64</td>
<td>4.26 (3.13 to 5.80)</td>
<td>&lt;0.001</td>
<td>4.76 (3.63 to 6.22)</td>
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<td>Marital status</td>
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<td>Single</td>
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</tr>
<tr>
<td>Married/cohabitating</td>
<td>0.38 (0.29 to 0.51)</td>
<td>&lt;0.001</td>
<td>0.37 (0.30 to 0.45)</td>
</tr>
<tr>
<td>Divorced/widowed</td>
<td>0.82 (0.61 to 1.11)</td>
<td>0.2</td>
<td>0.48 (0.34 to 0.68)</td>
</tr>
<tr>
<td>Profession</td>
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<td>Reference</td>
</tr>
<tr>
<td>Employed</td>
<td>Reference</td>
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</tr>
<tr>
<td>Unemployed</td>
<td>1.87 (1.55 to 2.26)</td>
<td>&lt;0.001</td>
<td>1.97 (1.53 to 2.53)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>None</td>
<td>Reference</td>
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<td>Reference</td>
</tr>
<tr>
<td>Primary</td>
<td>1.11 (0.85 to 1.42)</td>
<td>0.48</td>
<td>1.33 (1.03 to 1.72)</td>
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<tr>
<td>Secondary/tertiary</td>
<td>2.16 (1.58 to 2.95)</td>
<td>&lt;0.001</td>
<td>2.49 (1.03 to 1.72)</td>
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<td>Physical activity</td>
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<tr>
<td>High</td>
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<td>Reference</td>
</tr>
<tr>
<td>Medium</td>
<td>2.15 (1.66 to 2.78)</td>
<td>&lt;0.001</td>
<td>1.61 (1.25 to 2.09)</td>
</tr>
<tr>
<td>Low</td>
<td>2.17 (1.77 to 2.66)</td>
<td>&lt;0.001</td>
<td>1.89 (1.55 to 2.31)</td>
</tr>
<tr>
<td>Fruit per week</td>
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<td>Reference</td>
</tr>
<tr>
<td>0–13</td>
<td>Reference</td>
<td></td>
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</tr>
<tr>
<td>14+</td>
<td>0.82 (0.64 to 1.04)</td>
<td>0.1</td>
<td>0.73 (0.57 to 0.94)</td>
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<td>Vegetable per week</td>
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<tr>
<td>0–13</td>
<td>Reference</td>
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<td>Reference</td>
</tr>
<tr>
<td>14+</td>
<td>1.26 (0.99 to 1.61)</td>
<td>0.6</td>
<td>1.15 (0.87 to 1.52)</td>
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<td>Smoking</td>
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</tr>
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<td>No</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Yes</td>
<td>1.44 (1.08 to 1.92)</td>
<td>0.01</td>
<td>1.79 (1.31 to 2.44)</td>
</tr>
<tr>
<td>Alcohol</td>
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<td>Reference</td>
</tr>
<tr>
<td>Never</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Sometimes but&lt;1 per week</td>
<td>0.45 (0.32 to 0.63)</td>
<td>&lt;0.001</td>
<td>0.40 (0.28 to 0.56)</td>
</tr>
<tr>
<td>1–4 times per week</td>
<td>0.56 (0.43 to 0.74)</td>
<td>&lt;0.001</td>
<td>0.53 (0.41 to 0.68)</td>
</tr>
<tr>
<td>5–6 times per week</td>
<td>0.83 (0.46 to 1.49)</td>
<td>0.52</td>
<td>0.81 (0.46 to 1.43)</td>
</tr>
<tr>
<td>Every day</td>
<td>0.46 (0.30 to 0.72)</td>
<td>&lt;0.001</td>
<td>0.39 (0.25 to 0.61)</td>
</tr>
</tbody>
</table>

BMI

| Normal                              | Reference   |          | Reference   |          | Reference   |          |

Continued
observed between location and risk of IFG with RR=1.35, confounders in model 2, no significant association was found for additional confounders in model 2, the association between location and T2DM remained significant, with an RR of 1.61 (95% CI (1.11 to 2.36), p=0.01)). Compared with T2DM, the RRs and 95% CI for IFG were lower for location and other risk factors. In the crude model, the RR of IFG among urban dwellers relative to rural dwellers was 2.37, 95% CI ((1.53 to 3.66), p≤0.001). After adjusting for age, sex, education and profession in model 1, the association between location on the risk of IFG was slightly lower with RR=2.04, 95% CI ((1.27 to 3.28) p=0.001). However, after further adjustment for confounders in model 2, no significant association was observed between location and risk of IFG with RR=1.35, 95% CI ((0.83 to 2.18), p=0.2) (table 3).

Online supplemental tables 3,4 present the prevalence of T2DM and IFG, respectively, stratified by a range of risk factors, for both urban and rural participants. In urban areas, participants with low levels of physical activities had higher prevalence of T2DM than those with high levels (9.5% vs 5.3%). Additionally, urban smokers had a higher prevalence of T2DM than their rural counterparts (6.5% vs 3.6%). However, no such trend was found among alcohol drinkers in both urban and rural areas (online supplemental table 2). Compared with rural participants, those from urban areas had a higher prevalence of IFG among those who are smokers (9.6% vs 2.6%), single or not married (11.6 vs 10.2), had low level of physical activity (10.5% vs 4.8%) and had low education (7.5% vs 2.6%) (see online supplemental table 3).

**DISCUSSION**

This study is one of the largest analyses of both T2DM and IFG in urban and rural areas globally. The results demonstrate a significant difference in the prevalence of T2DM and IFG between urban and rural areas of West Africa. Some, but not all, of the differences were explained by associated risk factors such as physical inactivity, smoking, obesity, diet, hypertension. Similar prevalence differences have been reported in Cameroon, Nigeria and in an older review of West African studies in rural and urban areas, as well as in South Asian countries and elsewhere. These findings underscore the impact of urbanisation on the prevalence of T2DM and pre-diabetes in Africa.

The age and sex-standardised prevalence of T2DM among the West African population was 4.4%, which is consistent with the T2DM prevalence reported among low-income African countries in 2013 by Peer et al (also 4.4%). These findings are also comparable to those reported by the IDF in a 2017 report (4.2%) on T2DM prevalence among the SSA population. After standardising the urban and rural samples for age and sex, the prevalence of T2DM in the present study was 6.2% in urban and 2.5% in rural areas, with the prevalence of IFG 6.6% in urban and 3.0% in rural areas. The urban/rural difference in both T2DM and IFG prevalence in this study is related to different risk factors in the urban lifestyle, as previously reported.

Participants living in urban areas had a 2.7 and 2.3-times higher risk of T2DM and IFG, respectively, compared with their rural counterparts, with the risk of T2DM being elevated in urban residents (RR=1.6) even after adjustment for potential demographic, behavioural and biological confounders. Our findings are congruent with studies conducted previously in Cameroon, Guinea, Tanzania, Senegal and Kenya, which showed that urban residence is associated with a more than two-fold increased risk of T2DM or IFG. The high prevalence of pre-diabetes or IFG in the current study suggests that the prevalence of T2DM in the region may continue to increase as urbanisation continues. This highlights the need for targeted interventions to address the rising burden of diabetes in urban areas of West Africa.
### Table 3  Relative risk (RR) of IFG based on location (rural and urban), and other potential risk factors, among urban adults aged 25–64 years in West Africa

<table>
<thead>
<tr>
<th>Location and potential risk factors</th>
<th>Crude model</th>
<th>Model 1*</th>
<th>Model 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>RR (95% CI)</td>
<td>P value</td>
<td>RR (95% CI)</td>
</tr>
<tr>
<td>Rural</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Urban</td>
<td>2.37 (1.53 to 3.66)</td>
<td>&lt;0.001</td>
<td>2.04 (1.27 to 3.28)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Female</td>
<td>0.96 (0.79 to 1.16)</td>
<td>0.64</td>
<td>0.89 (0.81 to 1.10)</td>
</tr>
<tr>
<td><strong>Age group, years</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25–34</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>35–44</td>
<td>1.11 (0.90 to 1.36)</td>
<td>0.32</td>
<td>1.21 (0.98 to 1.48)</td>
</tr>
<tr>
<td>45–54</td>
<td>1.24 (0.96 to 1.60)</td>
<td>0.11</td>
<td>1.35 (1.05 to 1.73)</td>
</tr>
<tr>
<td>55–64</td>
<td>1.20 (0.94 to 1.54)</td>
<td>0.15</td>
<td>1.29 (0.99 to 1.67)</td>
</tr>
<tr>
<td><strong>Marital status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Married/cohabiting</td>
<td>0.41 (0.33 to 0.511)</td>
<td>&lt;0.001</td>
<td>0.45 (0.36 to 0.56)</td>
</tr>
<tr>
<td>Divorced/widowed</td>
<td>0.63 (0.47 to 0.86)</td>
<td>0.003</td>
<td>0.55 (0.37 to 0.83)</td>
</tr>
<tr>
<td><strong>Employment status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employed</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Unemployed</td>
<td>1.95 (1.53 to 2.49)</td>
<td>&lt;0.001</td>
<td>1.97 (1.53 to 2.53)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Primary</td>
<td>1.02 (0.80 to 1.31)</td>
<td>0.87</td>
<td>1.08 (0.84 to 1.28)</td>
</tr>
<tr>
<td>Secondary/tertiary</td>
<td>1.97 (1.28 to 3.03)</td>
<td>0.002</td>
<td>2.49 (1.8 to 3.36)</td>
</tr>
<tr>
<td><strong>Physical activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Medium</td>
<td>2.13 (1.60 to 2.83)</td>
<td>&lt;0.001</td>
<td>1.78 (1.33 to 2.38)</td>
</tr>
<tr>
<td>Low</td>
<td>2.14 (1.68 to 2.72)</td>
<td>&lt;0.001</td>
<td>1.92 (1.48 to 2.48)</td>
</tr>
<tr>
<td><strong>Fruit per week</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–13</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>14+</td>
<td>0.79 (0.59 to 1.05)</td>
<td>0.1</td>
<td>0.77 (0.59 to 1.02)</td>
</tr>
<tr>
<td><strong>Vegetable per week</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–13</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>14+</td>
<td>0.91 (0.96 to 1.19)</td>
<td>0.49</td>
<td>0.88 (0.66 to 1.19)</td>
</tr>
<tr>
<td><strong>Smoking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Yes</td>
<td>1.15 (0.85 to 1.56)</td>
<td>0.36</td>
<td>1.33 (0.97 to 1.81)</td>
</tr>
<tr>
<td><strong>Alcohol</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Sometimes but&lt;1 per week</td>
<td>0.67 (0.46 to 0.98)</td>
<td>0.04</td>
<td>0.61 (0.41 to 0.90)</td>
</tr>
<tr>
<td>1–4 times per week</td>
<td>0.59 (0.44 to 0.78)</td>
<td>&lt;0.001</td>
<td>0.59 (0.44 to 0.79)</td>
</tr>
<tr>
<td>5–6 times per week</td>
<td>0.44 (0.22 to 0.56)</td>
<td>0.02</td>
<td>0.44 (0.22 to 0.88)</td>
</tr>
<tr>
<td>Every day</td>
<td>0.58 (0.38 to 0.90)</td>
<td>0.02</td>
<td>0.59 (0.39 to 0.91)</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
</tbody>
</table>

Continued
to increase, as projected by IDF.\textsuperscript{1, 2} Urgent and robust programmes for the early detection of pre-diabetes and T2DM in West Africa are needed, given the fast pace of growth of African cities.\textsuperscript{5}

In this study, the prevalence of T2DM increased with age, with the highest prevalence among the 55–64-year-old group, consistent with previous studies in Africa\textsuperscript{6} and globally.\textsuperscript{1, 58} With a high rate of migration of younger adults to urban cities in search of higher education and employment,\textsuperscript{32, 33} and behavioural risks for T2DM in urban areas being significantly higher, the onset of T2DM is projected to shift to younger individuals.\textsuperscript{6} Because of this, and an ageing population in Africa,\textsuperscript{4, 6} it is not surprising that projections indicate that SSA may experience the highest T2DM burden globally in the coming decades,\textsuperscript{1, 3} if the risk is not tackled assertively.

The study found that similar consumption of fruit and vegetables was reported in urban and rural areas, with low fruit and vegetable consumption not associated with the risk of T2DM or IFG in either urban or rural areas, while the significant disparity in the prevalence of obesity between urban and rural areas suggests notable dietary differences between these populations. As a result, our findings may not have adequately captured the full range of dietary variations, making it challenging to draw definitive conclusions about the relationship between diet, and the risk of T2DM or IFG. In relation to alcohol consumption, the vast majority of participants in this study were either abstainers or low to moderate drinkers. Moderate alcohol consumption is protective against T2DM,\textsuperscript{34} as observed in this study, although excessive alcohol consumption is associated with T2DM risk.\textsuperscript{34} While smoking was more common among rural participants, a statistically significant difference in the prevalence of T2DM between smokers and non-smokers was only observed among rural participants. Overall, smokers had two and a half times the risk of T2DM compared with non-smokers after adjusting for all potential confounders (including rural/urban location). This finding is supported by various studies in SSA\textsuperscript{4, 35} and elsewhere.\textsuperscript{36}

Urban dwellers are exposed to additional psychosocial stressors such as overcrowding, competition, polluted environment, poor housing and poverty,\textsuperscript{5, 37} which can increase their risk of NCDs including T2DM and hypertension.\textsuperscript{10} Studies have shown that under stressful conditions, blood pressure tends to rise more rapidly over time and can be associated with metabolic and physiological changes,\textsuperscript{10} potentially explaining the higher prevalence of hypertension among urban populations compared with rural areas in this study. Participants with hypertension in this study were found to be two and a half times more likely to have T2DM than those with normal blood pressure, highlighting the importance of managing hypertension in reducing the prevalence of T2DM and IFG in both urban and rural areas.\textsuperscript{6, 10} These findings are consistent with previous research conducted among SSA, Chinese and Indian populations.\textsuperscript{10, 33, 36, 37}

Policymakers, governmental and non-governmental organisations and institutions, including the West African Health Organisation (WAHO), should prioritise targeting modifiable risk factors such as physical inactivity, smoking and unhealthy diets, and improving access to healthcare services, for effective management of T2DM, hypertension and other NCDs in both urban and rural areas of West Africa.\textsuperscript{38} WAHO, as a specialised health institution of the Economic Community of West African States (ECOWAS), seeks to improve the living standards and health outcomes of the West African population through socioeconomic integration. Therefore, initiatives should include educating the public on healthy lifestyle choices, promoting physical activity and addressing socioeconomic determinants of health, such as poor housing, particularly in urban areas. By doing so, ECOWAS, through WAHO and other governmental and non-governmental organisations, can contribute to reducing the burden of T2DM

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Table 3  Continued

<table>
<thead>
<tr>
<th>Location and potential risk factors</th>
<th>Crude model</th>
<th>Model 1*</th>
<th>Model 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR (95% CI)</td>
<td>P value</td>
<td>RR (95% CI)</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.32 (1.0 to 1.73)</td>
<td>0.05</td>
<td>1.25 (0.97 to 1.60)</td>
</tr>
<tr>
<td>Obese</td>
<td>2.39 (1.74 to 3.29)</td>
<td>&lt;0.001</td>
<td>2.01 (1.59 to 2.54)</td>
</tr>
<tr>
<td>WC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
</tr>
<tr>
<td>Elevated</td>
<td>1.50 (1.16 to 1.92)</td>
<td>0.002</td>
<td>1.55 (1.17 to 2.04)</td>
</tr>
<tr>
<td>HBP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.28 (0.91 to 1.80)</td>
<td>0.16</td>
<td>1.28 (0.89 to 1.86)</td>
</tr>
</tbody>
</table>

*Adjusted for age, sex, employment status and education.
†Additionally, adjusted for smoking, fruit and vegetable intake, alcohol consumption, low physical activity, BMI and waist circumference.
BMI, body mass index; HBP, high blood pressure; IFG, impaired fasting glucose; WC, waist circumference.
in West Africa and improving the overall health and well-being of the region’s population. It is important to note that there may be variations in the association estimates between urban/rural location and the prevalence of diabetes across individual countries. However, the combined estimates in this study are critical for informing ECOWAS policies and interventions aimed at curbing diabetes in the region, given the countries’ shared geography, ethnicity, socioeconomic and health profiles. Additionally, these combined estimates enable comparability with data from the IDF, which typically extrapolates T2DM epidemiology data for SSA from comparable countries in the region due to limited data availability.

Strengths and limitations
This study has several strengths, including the use of the standardised WHO STEPS method, which ensure comparable results across countries. The large sample size for both rural and urban populations, and across five countries, as well as the objective assessment of both T2DM and IFG, were also important to the validity of this work. However, the study does have some limitations that should be considered. First, the study is cross-sectional, meaning that associations cannot be assumed to be causal. Second, some other potential factors associated with both diabetes and location such as socioeconomic status (e.g., income) were not assessed, which may have impacted the findings. Third, as discussed earlier, dietary assessment only included the consumption of fruit and vegetables, not unhealthy foods and drinks. Also, the fruit and vegetable consumption measures were not coded as per the WHO guidelines of five servings per day due to the low level of fruit and vegetable consumption in this subpopulation, which may limit comparability with other studies. Whether the association between location and T2DM observed in this study is moderated by unmeasured dietary risks (and residual confounding due to simple measures of physical activity and other risk factors) is unclear. Finally, the use of data from different time points (2006 and 2013) may be a limitation. However, the association between rurality and diabetes prevalence is not expected to change over time, and, therefore, this is unlikely to be a significant limitation. Overall, while this study provides valuable insights into the prevalence of T2DM and IFG in West Africa, the limitations should be considered when interpreting the results. Future studies should aim to address these limitations to provide a more comprehensive understanding of the factors associated with T2DM and its prevention and management in this region.

CONCLUSION
This study provides clear evidence of a higher prevalence of T2DM and IFG among participants living in urban areas compared with those living in rural areas of West Africa. The study also found noticeable differences in the prevalence of most risk factors (such as BMI, WC, WHR and WHtR, physical inactivity, smoking, HBP) between urban and rural areas, which partly explained the difference in the prevalence of T2DM. Given the high prevalence of IFG and T2DM in this population and increasing urbanisation in West Africa, there is an urgent need for measures to halt progression and reduce the prevalence of T2DM and its associated risk factors. Therefore, policies and prevention strategies targeting the reduction and prevention of risk factors for T2DM in urban areas should be a clear priority in this setting. This study could be important for planning of screening activities, preventive strategies, healthcare services and resource allocation in West Africa.
Research and Innovation (Deliberation Number 2012-12-092 on 5 December 2012). In Ghana, the study protocol was reviewed and approved by the Ghana Health Service Ethical Review Committee (Reference number: GH-ERC-7 on 30 March 2006). In Mali, the Ministry of Health and Public Hygiene ethical committee reviewed and approved the study in February 2007. In Liberia, the protocol was approved by the University of Liberia-Pacific Institute for Research and Evaluation (UL PIRE), Liberia in January 2011, and in Benin, the study protocol was reviewed and approved by the Ministry of Health Ethics Committee (now, the National Ethics Committee for Health Research (CNERS) of Benin) in July 2008. The study also received approval from the Deakin University Human Ethics Committee Advisory Group (DUEHREC) on 28 July 2017, before it was conducted. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The dataset(s) supporting our findings are available from the corresponding author upon reasonable request.

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REFERENCES


