Title: Epidemiology of prediabetes and diabetes in Namibia, Africa: a multilevel analysis

Running Title: Prediabetes and diabetes in Namibia

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Abstract

Background: Diabetes is a leading cause of progressive morbidity and early mortality worldwide. Little is known on the burden of diabetes and pre-diabetes in Namibia, a Sub-Saharan African (SSA) country that is undergoing a demographic transition.

Methods: We estimated the prevalence and correlates of diabetes (defined as fasting [capillary] blood glucose [FBG] ≥126 mg/dL) and prediabetes (defined by World Health Organization [WHO] and American Diabetes Association [ADA] criteria [FBG 110-125 mg/dL and 100-125 mg/dL, respectively]) in a random sample of 3278 participants aged 35-64 from the 2013 Namibia Demographic and Health Survey.

Results: The prevalence of diabetes was 5.1% (95% Confidence Interval [CI]: 4.2-6.2), with no evidence of gender differences (p=0.45). The prevalence of prediabetes was 6.8% (5.8-8.0) and 20.1% (18.4-21.9) using WHO and ADA criteria, respectively. Male sex, older age, higher body mass index (BMI) and occupation independently increased the odds of diabetes in Namibia, while higher BMI was associated with the higher odds of prediabetes and residing in household categorized as middle wealth index were associated with lower odds of prediabetes (Adjusted odds ratio [aOR] = 0.71; 95% Credible Interval [CrI] = 0.46-0.99). There was significant clustering of prediabetes and diabetes at the community-level.

Conclusions: One in five adult Namibians has prediabetes by ADA criteria. Resources should be invested at the community level to promote efforts to prevent progression of this disease and its complications.

Keywords: Diabetes; socioeconomic status; community factors; multilevel analysis; Namibia

Highlights:

- There is considerable community level clustering in dysglycemia, providing logic for considering community-based prevention strategies.
- Positive association of diabetes with higher socioeconomic status.
- Strong association of body mass index with pre-diabetes and diabetes and our findings suggest the trends are interlinked.

Introduction

Diabetes is a leading cause of progressive morbidity and early mortality worldwide [1 2]. Physical inactivity, poor diet, and associated weight gain are well-recognized precursors to incident diabetes among adults. A growing body of epidemiological data has begun to find links between these risk factors and diabetes in Sub-Saharan Africa (SSA), where, until recently, diabetes was thought to be rare [3]. While the accumulating evidence suggests that morbidity and mortality due to diabetes in SSA will likely continue to increase in coming years [4-8], there is limited nationally representative individual-level data to examine the social patterning of diabetes within individual countries [9-12].

With some exceptions [13], data on the burden of diabetes in SSA are rarely based on nationally representative data, relying principally on hospital-based studies, local surveys, or extrapolation from neighboring countries or sub-populations using statistical models [14 15]. Thus, existing studies have lacked the generalizability needed to aid in the development of tailored and targeted prevention and treatment programs. Therefore, the objective of this study is to provide a detailed examination of the prevalence of diabetes and pre-diabetes using a nationally representative cross-sectional survey from Namibia, an upper-middle income country in SSA in an advanced state of economic growth compared to its neighboring region [16].

Methods

Study population and survey design

The 2013 Namibia Demographic Health Survey (NDHS) was designed to provide nationally-representative estimates of key population and health indicators for the country overall, as well as for urban and rural areas [17]. Participating households were selected using a

partial update of the 2011 Namibia Population and Housing Census [17]. Briefly, in the first stage, 554 enumeration areas (EA, the smallest administrative unit in Namibia, 269 in urban and 285 in rural areas) were selected. In the second stage, 20 households were identified in each of the 554 EAs. For the primary survey, 11,080 households were selected (n=5,380 urban and n=5,700 rural households) with a 92.3% response rate. Only pre-selected households were surveyed to prevent sampling bias. For all consenting households, an adapted DHS household questionnaire was used to collect information on household characteristics. Using this questionnaire, eligible males and females were selected to participate in a more detailed "male survey" or "female survey" which included several components including the serologic data used in this study. Specifically, anthropometric and biologic data were collected from all eligible males and females, aged 35-64, in a sub-sample of half of the survey households selected to participate in the male survey component. The anthropometric measurements (weight, height and waist circumference) were measured by trained survey staff using standardized methods (i.e., same methods/equipment in all households selected for this survey) [17].

Measurement of blood glucose and diabetes definition

After a fasting period of ≥8 hours, NDHS participants had a capillary blood sample obtained from their middle or ring finger. If they were not fasting at the time of the interview, an appointment was made for the next morning to collect and test a fasting capillary blood sample. Capillary fasting blood glucose (FBG) was measured using the HemoCue 201+ blood glucose analyzer (HemoCue Ab, Angelholm, Sweden). The analyzer displayed blood glucose measurements in millimoles per litre (mmol/L).

We used two alternative criteria to define diabetes and pre-diabetes, respectively. First, for the primary analysis, we used the World Health Organization (WHO) cutoffs, which define diabetes as a FBG ≥126 mg/dL (7.0 mmol/L) and impaired fasting glycemia (pre-diabetes) as a FBG from 110-125 mg/dL (6.1 to 6.9 mmol/L) [18]. We examined this data two ways: first, we used the raw data values, and then to account for potential underestimation due to the use of capillary glucose, we modified/adjusted the reported DHS values by 1.1% [13 19] and presented results using cut-offs on this adjusted value. Second, we applied the American Diabetes Association (ADA) criteria that use the same cut-offs for diabetes, but have a lower threshold for prediabetes,100-125 mg/dL (5.6 to 6.9 mmol/L) [20].

Assessment of socioeconomic factors and geographic location

To assess the socioeconomic position (SEP) of participants, we focused on four of the commonly utilized SEP indicators that could be derived from questionnaire responses: relative household wealth, education level, employment status, and geographic location (urban vs. rural residence) [21 22].

The 2013 NDHS provided a derived wealth index, which was created using a three-step principal component analysis of household assets [23 24]. This standardized metric is estimated in every DHS survey [25] and is an asset-based wealth index that conceptualizes wealth (or economic status) as an underlying unobserved dimension that can be estimated using latent variable techniques [26 27]. As a standardized metric from a country-specific distribution, households that score low on this index are poor relative to households within the same country, though absolute poverty is not directly estimated by this index.

Self-reported level of educational attainment was grouped into four different categories: no formal education, primary, secondary, and higher education. Employment status of the participants was grouped into three different categories: not working, manual labor, or white collar. Finally, we included a binary variable for geographic location as provided by the 2013 NDHS, which categorized each household as being either urban or rural. The DHS defines urban areas as large cities (capital cities and cities with over one million population), small cities (population over 50,000), and towns (other urban areas). Any locations that did not meet any of these three criteria were assumed to be rural.

Assessment of community-level factors

We used the term community to describe clustering within the same geographical living environment. Communities were based on sharing a common primary sampling unit (PSU) within the DHS data. We considered the following community-level factors in our analysis: poverty rate, illiteracy rate, and unemployment rate. The poverty rate was defined as the proportion of households living below poverty level (wealth index below 20%, poorest quintile). Illiteracy rate was defined as the proportion of people in the community with no formal education. The unemployment rate was defined as the proportion of people who are unemployed in the communities. For each community level factor, the median value was used to categorize the PSU as high, middle or low in these factors.

Ethical Considerations

This study was based on analysis of existing survey datasets from the archive of the DHS who granted us permission for use of anonymised data. The instruments and conduct of the 2013

NDHS was approved by the Institutional Review Board (IRB) of ICF Macro International in the United States. This research is limited to the use of previously collected anonymised data.

Statistical analysis

For all analyses, all available participants with data were used (i.e., complete case analysis). Descriptive statistics of the NDHS participants were contrasted by diabetes status using χ^2 tests for categorical variables and student t-test for continuous variables. The prevalence of prediabetes or diabetes was estimated for the whole study population and for population subgroups. The age-adjusted prevalence of prediabetes and diabetes was obtained using logistic regression models. Prevalence estimates accounted for the complex survey design as well as sampling weights.

Four multivariable multilevel logistic regression models were constructed to assess the individual and community level factors associated with prediabetes and diabetes in Namibia [28]. The initial model (Model 1), did not include any independent variables. The purpose of this model is to decompose the amount of variance that existed at each level i.e. individual and community levels. In the second model, *a priori* selected participant characteristics, i.e., age, sex, body mass index (BMI), education, occupation and family wealth index, were included. In the third model (model 3), a *priori* selected community level variables including poverty rate, illiteracy rate, unemployment rate and urban vs rural locality, were included. The last model (model 4) included all participant and community variables simultaneously. The effect estimates of the participant and community variables (i.e., fixed effects) are presented as adjusted odds ratios (aOR) with corresponding 95% credible intervals (CrIs), derived using Markov Chain Monte Carlo (MCMC) methods. Measures of random effects included intra-cluster correlation

(ICC) and median odds ratio (MOR) [29 30]. The ICC was calculated by the linear threshold according to the formula used by Snijders et al [31] while MOR is a measure of unexplained cluster heterogeneity.

Descriptive statistics and prevalence rate analyses were derived using Stata statistical software for windows version 14 [32] and multilevel models were built using MLwiN 2.36 [33] on the platform of Stata statistical software for windows version 14 using (runmlwin routine). A p-value <0.05 was used to define statistical significance.

Results

Analyses involved up to 3278 participants (59% females), with a mean age of 47 years (standard error [SE] of 0.15). Of these, 178 (5.4 %) survey participants had diabetes and 225 (6.9 %) participants had pre-diabetes (Table 1). Participants with a diabetic range FBG were more likely to be older, obese, within the richest wealth index, and to reside in communities with low illiteracy rate and in urban areas (Table 1).

Prevalence of pre-diabetes and diabetes

The age-adjusted prevalence of prediabetes was 6.7% (5.9 - 7.9) using WHO criteria and 20.0% (18.2 - 21.8) using ADA criteria. The age-adjusted prevalence of diabetes was 5.0% (95% CI: 4.0 – 6.0) (Tables 2 & 3). The prevalence of dysglycemia (combination of prediabetes and diabetes) was 13% and 25%, by WHO and ADA criteria, respectively. There was no significant difference in the prevalence of diabetes or prediabetes between male and female participants (Table 2). Participants with a white-collar job had the highest age-adjusted prevalence of diabetes compared to those not working and those in the manual job category (Table 2).

However, the age-adjusted prevalence of diabetes among those from the richest families was three times the prevalence of those from the poorest families (8.5% vs. 2.4%) (Table 2). The age-adjusted prevalence of prediabetes was higher among rural dwellers compared to urban dwellers (6.8% vs. 6.5%) (Table 2).

Correlates of prediabetes

Table 4 shows the individual and community level factors associated with prediabetes in multilevel multivariable models. Obese participants were more likely to have prediabetes than those with normal BMI (adjusted odds ratio [aOR] 1.82; 95% CrI 1.36 – 2.37, $p < 0.001$). Moreover, participants from households with middle wealth index had lower odds of pre-diabetes compared to those from poorest households (aOR, 0.71; 95% CrI 0.46 – 0.99).

As shown in Table 4 with respect to empty model, there was statistically significant variation in the odds of having prediabetes (τ =0.417, 0.217 – 0.653) across communities in Namibia. The ICC indicated that 11.3% of the variance in the odds of prediabetes could be attributed to community-level factors. These variations across the communities remained statistically significant after controlling for individual-level factors (in model 2), community-level factors (in model 3) or both (in model 4). Results of the MOR showed evidence of community dependent phenomenon modifying the odds of prediabetes. The MOR for prediabetes was 1.85 in the empty model; this relatively moderate MOR suggests that the clustering effect was moderate. The unexplained community heterogeneity in prediabetes remained relatively unchanged after adding individual and community-level factors in the final model.

Correlates of diabetes

Table 5 shows results of multilevel models for individual and community level factors associated with diabetes. Among the individual level factors, age, sex, BMI and occupation were significantly associated with the odds of diabetes in the multilevel multivariable model that included all the factors. The odds of diabetes increased by 1.03-fold (95% CrI, 1.01-1.05) for every one-year increase in a participant's age. Female participants had lower odds diabetes compared to male participants (aOR, 0.61; 95% CrI 0.41 – 0.86). Overweight and obese participants were 76% and 168% more likely to have diabetes, respectively, compared to those with normal BMI. Participants in the manual job category had lower odds of having diabetes compared to those not working (aOR, 0.62; 95% CrI 0.36 – 0.99).

Table 5 shows random effect results from the multilevel analysis of factors associated with diabetes. In model 1, there was no significant variation in the log odds of diabetes (τ =1.435, 0.795 – 2.170) in all the communities included in the study. According to ICC indicated by the calculated intercept variance, 30.4% of the variation could be linked to community-level factors. In each of the models adjusted for (individual-level, community-level and both simultaneously in the final model), the variance across the communities remained statistically significant. The MOR of 3.12 in model 1 which increased to 3.38 in the final model indicates that the clustering effect is high.

Discussion

Herein, we examined a large population-based sample of the 2013 NDHS to describe the epidemiology of diabetes and prediabetes in Namibia. To our knowledge, our study provides the first nationally representative estimate of dysglycemia among Namibians that accounts for

individual-level and community-level factors. We found a relatively low prevalence of diabetes (5%) in Namibia, but a wide discrepancy in prediabetes prevalence depending on the definition used (7 % by WHO criteria and 20% by ADA criteria). Of note, the ADA adopted its prediabetes criteria because, compared to the higher WHO cut-off, a lower threshold for FPG generated prevalence estimates for pre-diabetes that more closely corresponded to estimates derived from glucose tolerance testing[20]. In our analysis, the prevalence of diabetes and prediabetes was highest among overweight and obese individuals, with individuals from the highest family wealth index having highest prevalence of diabetes.

Further, the vast majority of prior studies on dysglycemia among African populations have mainly focused on diabetes, with limited inclusion of prediabetes [13 34 35]. Our finding of the potentially large burden of prediabetes in Namibia portends a potentially large future epidemic of diabetes, underscoring the need for Namibian health authorities to prepare to manage commonly concurrent burdens of vascular disease and kidney disease among its citizens. Moreover, Namibia and other SSA countries are undergoing a demographic transition that may hasten the population's progression to diabetes; as death from infection declines, these populations age and develop other risk factors including obesity that can hasten the onset of diabetes and its complications [36]. Our findings of significant clustering of diabetes and pre-diabetes at the community level supports preventative efforts that address communities in addition to individuals, and future studies are needed to determine additional community-level factors that contribute to dysglycemia risk.

The associations we found between diabetes and age and BMI are similar to those observed around the world. The positive associations we found between these two factors and diabetes have also been observed previously in South Africa,[37] Nigeria[38] and Zambia[39].

Our findings of an increased odds of diabetes among individuals with the highest family wealth aligns with the epidemiological transition theory, which postulates that the burden of new diseases related to lifestyle would be first concentrated among the wealthy, before shifting to those of a lower socioeconomic position. Similar findings have been noted recently in previous studies conducted in some sub-Saharan Africa countries[40-42]. One commonly posited explanation for this association is that higher socioeconomic status increases access to high calorie foods and decreases the need for physical activity. Future studies are warranted to examine more specific factors that may explains these associations.

There are limitations to this work that must be considered when evaluating the results. First, repeat blood glucose levels were not done among survey participants. In the absence of a confirmatory fasting sample, there is a potential for measurement error. Second, as the 2013 NDHS did not conduct 2 hours oral glucose tolerance testing (2hOGTT) nor measure glycated hemoglobin (HbA1c) among its participants, we relied solely on FBG to classify pre-diabetes and diabetes. A large scale multi-country study conducted by NCD Risk Factor Collaboration group[43] indicates that diabetes prevalence based on fasting plasma glucose alone is lower than that based on the combination of fasting plasma glucose, HbA1c and 2hOGTT. Other studies[44-48] have also shown that HbA1c is more sensitive and less susceptible to fluctuations due to stress, acute illness, and diurnal variations and reflects glucose homeostasis at a given point in time. Therefore, as prevalence estimates of dysglycemia may be higher when utilizing HbA1c and 2hOGTT thresholds compared to FBG thresholds[49], our results may represent a conservative estimate of the prevalence of diabetes and prediabetes in the population studied. Third, the measures obtained were of capillary blood glucose, which produces disparate estimates of glucose concentration compared to venous blood. However, capillary blood glucose

measurement may be the most practical approach in large-scale studies, especially in resource limited areas, and has been used in past studies as large as the ICMR-INDIAB study [50] and WHO studies. Fourth, this work was done in a cross-sectional sample. Consequently, causal pathways cannot be assumed; rather, we can only describe associations between a priori and conceptually-selected variables. Finally, we used an updated release of the NDHS dataset for this analysis ("NMPR61FL") which included 184 more individuals than were reported in the published NDHS report[17].

This study has several strengths. First, the DHS program is a well-standardized and long-standing program that rigorously collects nationally-representative data in low and middle resource settings for decades. Accordingly, our estimate of diabetes in Namibia is consistent with a prior global epidemiologic analysis of diabetes prevalence rates that included the majority of SSA countries[4]. Secondly, the sampling framework used in the NDHS follows closely from national census and thus provides a diverse sample from Namibia. Lastly, there are advantages to studying factors associated with diabetes using a multilevel approach, as community level analyses are better equipped to describe the economic and social context in which individual lives and experiences health outcomes. This additional level of granularity is needed to facilitate targeted interventions and preventative measures that will be needed to stem the burden of diabetes and other vascular disease in the developing world.

Conclusions

To summarize, this work adds to a growing evidence base that several countries in SSA are experiencing a rapidly evolving epidemiological transition marked by an increase in chronic diseases (1, 2). Our results underscore the importance of future public health policies in SSA that

shift focus from management of acute conditions to chronic conditions. Further, our finding of the potentially large burden of pre-diabetes in Namibia points to the need to develop preventive care and education efforts [51], ideally targeting both at risk individuals and communities.

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Disclosure

All authors declared that they have no conflicts of interest to declare: no support from any organization for the submitted work; no financial relationships except as noted above with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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Tables

Table 1: Characteristics of the study population aged 35 years or more, Namibia, 2013

Characteristics	All (n = 3278)	No diabetes (n = 3100)	Diabetes (n = 178)	P – value
Individual level factors				
Age in years, mean ± SE	46.85 ± 0.15	46.71 ± 0.15	49.30 ± 0.65	<0.001
Sex				0.527
Female	1, 916 (58.5)	1, 816(58.6)	100 (56.2)	
Male	1, 362 (41.5)	1, 284(42.4)	78 (43.8)	
Body Mass Index (Kg/m^2)				<0.001
Underweight	365 (11.2)	352 (11.5)	13 (7.3)	
Normal weight	1, 502 (46.2)	1, 450 (47.2)	52 (29.4)	
Overweight	726 (22.4)	677 (22.0)	49 (27.7)	
Obese	656 (20.2)	593 (19.3)	63 (35.6)	
Education attainment of participants				0.066
No education	521 (16.0)	502 (16.3)	19 (10.7)	
Primary	1, 092 (33.5)	1, 036 (33.6)	56 (31.7)	
Secondary	1, 400 (42.9)	1, 318 (42.7)	82 (46.3)	
Higher	249 (7.6)	229 (7.4)	20 (11.3)	
Wealth index of family				<0.001
Poorest	572 (17.5)	556 (17.9)	16 (9.0)	
Poorer	599 (18.3)	578 (18.7)	21 (11.8)	
Middle	649 (19.8)	624 (20.1)	25 (14.0)	
Richer	762 (23.2)	709 (22.9)	53 (29.8)	
Richest	696 (21.2)	633 (20.4)	63 (35.4)	
Occupation of participants				0.206
Not working	1, 721 (54.3)	1, 622 (54.1)	99 (57.9)	
White collar	559 (17.6)	525 (17.5)	34 (19.9)	
Manual	890 (28.1)	852 (28.4)	38 (22.2)	
Community level factors				
Poverty rate				<0.001
Low	1, 837(56.1)	1, 714(55.3)	123(69.1)	
Middle	368(11.2)	347(11.2)	21(11.8)	
High	1, 073(32.7)	1, 039(33.5)	34(19.1)	
Illiteracy rate				0.004
Low	1, 463 (44.6)	1, 362 (43.9)	101 (56.8)	
Middle	820(25.0)	784(25.3)	36(20.2)	
High	995 (30.4)	954(30.8)	41(23.0)	
Unemployment rate				0.404
Low	1, 126(34.4)	1, 063(34.3)	63 (35.4)	
Middle	1, 106(33.7)	1, 040(33.5)	66(37.1)	
High	1, 046 (31.9)	997 (32.2)	49 (27.5)	
Place of residence				<0.001
Urban	1, 530 (46.7)	1, 422 (45.9)	108 (60.7)	
Rural	1, 748 (53.3)	1, 678 (54.1)	70 (39.3)	

*Numbers may not sum to total sample size (n = 3, 278) for certain characteristics because of missing data; SE, standard error

Table 2: **Prevalence of prediabetes and diabetes in individuals by characteristics using WHO and modified WHO classification criteria, Namibia, 2013**

Characteristics	Prediabetes prevalence (WHO), % (95%CI)		Prediabetes prevalence (modified WHO), % (95%CI)		*Diabetes prevalence, % (95%CI)	
	Unadjusted	Age-adjusted	Unadjusted	Age-adjusted	Unadjusted	Age-adjusted
Overall prevalence	6.8(5.8 – 8.0)	6.7(5.9 – 7.9)	9.2(8.0 – 10.4)	9.0(7.8 – 10.3)	5.1(4.2 – 6.2)	5.0(4.0 – 6.0)
Individual level factors						
Sex						
Female	7.2(5.9 – 8.7)	7.0(5.6 – 8.4)	9.4(8.0 – 11.1)	9.3(7.8 – 10.8)	4.9(3.8 – 6.2)	4.7(3.5 – 5.9)
Male	6.3(4.9 – 8.1)	6.2(4.6 – 7.8)	8.7(7.1 – 10.7)	8.7(6.8 – 10.5)	5.5(4.1 – 7.2)	5.4(3.9 – 6.9)
Body Mass Index (Kg/m^2)						
Underweight	8.3(5.5 – 12.5)	8.2(4.8 – 11.6)	12.4(9.0 – 16.8)	12.3(8.4 – 16.2)	3.4(1.8 – 6.3)	3.3(1.2 – 5.5)
Normal weight	6.4(4.9 – 8.3)	6.3(4.6 – 8.0)	8.6(6.9 – 10.6)	8.6(6.7 – 10.4)	3.1(2.3 – 4.2)	3.1(2.1 – 4.0)
Overweight	4.3(3.0 – 6.2)	4.2(2.6 – 5.7)	6.1(4.4 – 8.3)	6.0(4.1 – 7.9)	6.3(4.5 – 8.8)	6.1(4.1 – 8.2)
Obese	9.8(7.3 – 12.9)	9.5(6.8 – 12.2)	12.0(9.4 – 15.4)	11.8(8.9 – 14.7)	10.0(7.6 – 13.2)	9.7(7.0 – 12.4)
Education attainment of participants						
No education	7.0(5.0 – 9.9)	6.4(4.0 – 8.8)	8.7(6.4 – 11.9)	8.1(5.4 – 10.7)	3.7(2.1 – 6.6)	3.1(1.2 – 5.0)
Primary	6.8(5.3 – 8.7)	6.4(4.7 – 8.1)	9.5(7.8 – 11.5)	9.0(7.2 – 10.9)	4.5(3.3 – 6.1)	4.0(2.7 – 5.4)
Secondary	5.5(4.2 – 7.1)	5.8(4.3 – 7.2)	7.9(6.4 – 9.8)	8.2(6.5 – 10.0)	5.7(4.4 – 7.3)	6.0(4.5 – 7.5)
Higher	12.4(8.5 – 17.7)	12.1(7.7 – 16.6)	14.2(10.1 – 19.8)	14.1(9.4 – 18.8)	6.7(3.9 – 11.3)	6.4(2.9 – 9.9)
Wealth index of family						
Poorest	6.8(4.6 – 10.0)	6.6(3.9 – 9.3)	10.9(8.2 – 14.3)	10.6(7.6 – 13.6)	2.6(1.5 – 4.5)	2.4(1.0 – 3.9)
Poorer	7.0(5.0 – 9.9)	6.9(4.5 – 9.4)	9.1(6.7 – 12.1)	9.0(6.3 – 11.7)	2.8(1.5 – 4.9)	2.7(1.1 – 4.2)
Middle	5.0(3.5 – 7.0)	4.9(3.2 – 6.6)	7.8(6.0 – 10.1)	7.8(5.7 – 9.8)	4.0(2.5 – 6.2)	3.9(2.1 – 5.7)
Richer	5.6(4.0 – 7.8)	5.5(3.7 – 7.3)	7.2(5.4 – 9.6)	7.1(5.1 – 9.2)	7.1(4.8 – 10.2)	6.8(4.3 – 9.4)
Richest	9.6(7.3 – 12.5)	9.5(7.0 – 12.1)	11.0(8.6 – 13.9)	10.9(8.3 – 13.5)	8.6(6.1 – 11.9)	8.5(5.6 – 11.3)
Occupation of participants						
Not working	7.2(5.8 – 8.8)	6.8(5.2 – 8.4)	9.9(8.4 – 11.7)	9.6(7.9 – 11.3)	5.5(4.2 – 7.2)	5.1(3.6 – 6.7)
White collar	7.8(5.6 – 10.9)	8.0(5.3 – 10.7)	9.8(7.4 – 13.0)	10.0(7.2 – 12.9)	5.2(3.6 – 7.4)	5.3(3.4 – 7.2)
Manual	5.6(4.1 – 7.7)	5.8(4.0 – 7.6)	7.6(5.7 – 10.0)	7.8(5.7 – 10.0)	4.0(2.7 – 5.8)	4.1(2.5 – 5.7)
Community level factors						
Poverty rate						
Low	6.8(5.5 – 8.3)	6.8(5.4 – 8.2)	8.5(7.1 – 10.2)	8.6(7.0 – 10.1)	6.5(5.1 – 8.3)	6.5(4.9 – 8.1)
Middle	6.8(4.5 – 9.9)	6.3(3.8 – 8.9)	10.2(7.5 – 13.7)	9.8(6.8 – 12.7)	5.5(2.7 – 10.6)	5.0(1.4 – 8.6)
High	6.9(5.1 – 9.4)	6.7(4.5 – 8.8)	9.8(7.7 – 12.4)	9.6(7.3 – 11.9)	2.9(2.0 – 4.2)	2.7(1.6 – 3.8)
Illiteracy rate						
Low	6.7(5.3 – 8.5)	6.7(5.1 – 8.3)	9.1(7.5 – 10.9)	9.1(7.4 – 10.8)	6.1(4.7 – 7.9)	6.0(4.4 – 7.6)
Middle	6.9(4.9 – 9.7)	6.8(4.4 – 9.1)	9.4(7.1 – 12.3)	9.3(6.7 – 11.9)	3.9(2.6 – 5.9)	3.8(2.2 – 5.4)

High	6.9(5.2 – 9.0)	6.6(4.7 – 8.4)	9.1(7.1 – 11.6)	8.8(6.7 – 11.0)	4.6(2.9 – 7.2)	4.3(2.3 – 6.3)
Unemployment rate						
Low	6.1(4.6 – 8.1)	6.3(4.5 – 8.1)	7.8(6.2 – 9.9)	8.1(6.2 – 10.0)	5.1(3.7 – 7.0)	5.3(3.6 – 7.0)
Middle	7.5(5.8 – 9.7)	7.3(5.4 – 9.2)	10.0(8.1 – 12.4)	9.9(7.8 – 12.0)	6.1(4.4 – 8.2)	5.8(4.0 – 7.6)
High	7.0(5.2 – 9.2)	6.6(4.5 – 8.7)	9.7(7.7 – 12.2)	9.4(7.1 – 11.6)	4.3(2.7 – 6.5)	3.9(2.1 – 5.7)
Place of residence						
Urban	6.4(5.1 – 8.1)	6.5(5.0 – 8.0)	8.3(6.8 – 10.0)	8.4(6.8 – 10.0)	6.7(5.1 – 8.7)	6.7(4.9 – 8.6)
Rural	7.2(5.7 – 8.9)	6.8(5.2 – 8.5)	9.9(8.3 – 11.3)	9.6(7.8 – 11.4)	3.7(2.8 – 5.0)	3.4(2.3 – 4.5)

CI, confidence interval; WHO, World Health Organisation; *the unadjusted and age-adjusted prevalence estimates of diabetes are the same using either WHO or modified WHO criteria

Table 3: **Prevalence of prediabetes and diabetes in individuals by characteristics using ADA classification criteria, Namibia, 2013**

Characteristics	Prediabetes prevalence, % (95%CI)		Diabetes prevalence, % (95%CI)	
	Unadjusted	Age-adjusted	Unadjusted	Age-adjusted
Overall prevalence	20.1(18.4 – 21.9)	20.0(18.2 – 21.8)	5.1(4.2 – 6.2)	5.0(4.0 – 6.0)
Individual level factors				
Sex				
Female	21.0(18.9 – 23.3)	20.9(18.7 – 23.1)	4.9(3.8 – 6.2)	4.7(3.5 – 5.9)
Male	18.7(16.3 – 21.3)	18.7(16.2 – 21.2)	5.5(4.1 – 7.2)	5.4(3.9 – 6.9)
Body Mass Index (Kg/m^2)				
Underweight	19.1(15.0 – 24.0)	19.1(14.6 – 23.6)	3.4(1.8 – 6.3)	3.3(1.2 – 5.5)
Normal weight	18.5(16.1 – 21.0)	18.5(16.0 – 21.0)	3.1(2.3 – 4.2)	3.1(2.1 – 4.0)
Overweight	17.2(14.3 – 20.6)	17.1(14.0 – 20.3)	6.3(4.5 – 8.8)	6.1(4.1 – 8.2)
Obese	27.9(24.0 – 32.1)	27.7(23.6 – 31.7)	10.0(7.6 – 13.2)	9.7(7.0 – 12.4)
Education attainment of participants				
No education	22.2(18.4 – 26.5)	21.5(17.5 – 25.6)	3.7(2.1 – 6.6)	3.1(1.2 – 5.0)
Primary	19.5(16.9 – 22.3)	19.1(16.4 – 21.8)	4.5(3.3 – 6.1)	4.0(2.7 – 5.4)
Secondary	18.8(16.3 – 21.6)	19.2(16.5 – 21.9)	5.7(4.4 – 7.3)	6.0(4.5 – 7.5)
Higher	20.1(18.3 – 21.9)	24.7(18.2 – 31.1)	6.7(3.9 – 11.3)	6.4(2.9 – 9.9)
Wealth index of family				
Poorest	23.6(20.2 – 27.4)	23.4(19.7 – 27.1)	2.6(1.5 – 4.5)	2.4(1.0 – 3.9)
Poorer	18.8(15.3 – 22.9)	18.8(15.0 – 22.6)	2.8(1.5 – 4.9)	2.7(1.1 – 4.2)
Middle	17.8(14.8 – 21.2)	17.8(14.6 – 21.0)	4.0(2.5 – 6.2)	3.9(2.1 – 5.7)
Richer	17.5(14.2 – 21.5)	17.5(13.9 – 21.0)	7.1(4.8 – 10.2)	6.8(4.3 – 9.4)
Richest	22.8(19.3 – 26.7)	22.8(19.1 – 26.6)	8.6(6.1 – 11.9)	8.5(5.6 – 11.3)
Occupation of participants				
Not working	20.9(18.6 – 23.4)	20.6(18.2 – 22.8)	5.5(4.2 – 7.2)	5.1(3.6 – 6.7)
White collar	21.3(17.6 – 25.5)	21.5(17.6 – 25.5)	5.2(3.6 – 7.4)	5.3(3.4 – 7.2)
Manual	18.1(15.2 – 21.3)	18.4(15.4 – 21.4)	4.0(2.7 – 5.8)	4.1(2.5 – 5.7)
Community level factors				
Poverty rate				
Low	18.7(16.5 – 21.1)	18.8(16.5 – 21.1)	6.5(5.1 – 8.3)	6.5(4.9 – 8.1)
Middle	21.3(16.0 – 27.8)	20.9(15.1 – 26.8)	5.5(2.7 – 10.6)	5.0(1.4 – 8.6)
High	21.8(18.9 – 25.0)	21.6(18.6 – 24.7)	2.9(2.0 – 4.2)	2.7(1.6 – 3.8)
Illiteracy rate				
Low	19.3(16.9 – 22.0)	19.4(16.9 – 21.9)	6.1(4.7 – 7.9)	6.0(4.4 – 7.6)
Middle	21.7(18.0 – 26.0)	21.7(17.7 – 25.7)	3.9(2.6 – 5.9)	3.8(2.2 – 5.4)
High	19.8(16.9 – 23.0)	19.6(16.6 – 22.5)	4.6(2.9 – 7.2)	4.3(2.3 – 6.3)
Unemployment rate				
Low	18.9(16.0 – 22.3)	19.2(16.0 – 22.4)	5.1(3.7 – 7.0)	5.3(3.6 – 7.0)
Middle	19.6(17.1 – 22.5)	19.5(16.8 – 22.2)	6.1(4.4 – 8.2)	5.8(4.0 – 7.6)
High	21.6(18.6 – 25.0)	21.3(18.1 – 24.6)	4.3(2.7 – 6.5)	3.9(2.1 – 5.7)
Place of residence				
Urban	18.2(15.8 – 20.7)	18.3(15.9 – 20.8)	6.7(5.1 – 8.7)	6.7(4.9 – 8.6)
Rural	21.8(19.3 – 24.4)	21.5(19.0 – 24.1)	3.7(2.8 – 5.0)	3.4(2.3 – 4.5)

CI, confidence interval; ADA, American Diabetes Association

Table 4: **Factors associated with prediabetes in Namibia identified by multilevel multivariable logistic regression models.**

Variable	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
	aOR (CrI)	aOR (CrI)	aOR (CrI)	aOR (CrI)
FIXED-EFFECTS				
Individual level factors				
Age (in years)		1.01(1.00 – 1.02)		1.01(1.00 – 1.02)
Female (vs. male)		1.13(0.90 – 1.38)		1.12(0.90 – 1.38)
Body Mass Index (Kg/m^2)				
Underweight		0.94(0.67 – 1.28)		0.95(0.67 – 1.29)
Normal weight		1 (reference)		1 (reference)
Overweight		0.98(0.75 – 1.25)		0.99(0.76 – 1.28)
Obese		1.77(1.34 – 2.28)		1.82(1.36 – 2.37)
Education attainment of participants				
No education		1 (reference)		1 (reference)
Primary		1.08(0.81 – 1.43)		1.03(0.74 – 1.37)
Secondary		1.11(0.82 – 1.49)		1.06(0.75 – 1.45)
Higher		1.46(0.90 – 2.28)		1.35(0.79 – 2.19)
Wealth index of family				
Poorest		1 (reference)		1 (reference)
Poorer		0.72(0.51 – 0.96)		0.74(0.53 – 1.02)
Middle		0.66(0.46 – 0.90)		0.71(0.46 – 0.99)
Richer		0.62(0.42 – 0.86)		0.71(0.45 – 1.05)
Richest		0.72(0.47 – 1.05)		0.89(0.53 – 1.36)
Occupation of participants				
Not working		1 (reference)		1 (reference)
White collar		1.24(0.91 – 1.64)		1.25(0.89 – 1.72)
Manual		1.15(0.89 – 1.46)		1.18(0.88 – 1.55)
Community level factors				
Poverty rate				
Low			1 (reference)	1 (reference)
Middle			1.07(0.71 – 1.58)	1.15(0.72 – 1.73)
High			1.09(0.77 – 1.50)	1.04(0.68 – 1.50)
Illiteracy rate				
Low			1 (reference)	1 (reference)
Middle			1.00(0.72 – 1.35)	1.11(0.81 – 1.48)
High			0.89(0.66 – 1.15)	0.98(0.71 – 1.31)
Unemployment rate				
Low			1 (reference)	1 (reference)
Middle			0.89(0.66 – 1.18)	0.94(0.68 – 1.24)
High			0.93(0.66 – 1.25)	1.04(0.70 – 1.44)
Rural (vs. urban)			1.23(0.89 – 1.64)	1.27(0.91 – 1.72)
RANDOM-EFFECTS				
Community level				
Variance (SE)	0.417(0.217 – 0.653)	0.464(0.253 – 0.712)	0.446(0.253 – 0.664)	0.464(0.237 – 0.713)
Intra-community correlation (%)	11.3	12.4	11.9	12.4
MOR	1.85	1.91	1.89	1.91
Model fit statistics				
Bayesian DIC	3228.51	3059.80	3233.70	3065.06

[a]Model 1 is the empty model, a baseline model without any independent variable; [b]Model 2 is adjusted for individual level factors; [c]Model 3 is adjusted for community level factors; [d]Model 4 is adjusted for individual and community level factors; Abbreviations: SE; standard error, DIC; deviance information criterion, CrI; credible interval.

Table 5: **Factors associated with diabetes mellitus in Namibia identified by multilevel multivariable logistic regression models.**

Variable	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]
	aOR (CrI)	aOR (CrI)	aOR (CrI)	aOR (CrI)
FIXED-EFFECTS				
Individual level factors				
Age (in years)		1.03(1.01 – 1.05)		1.03(1.01 – 1.05)
Female (vs. male)		0.63(0.43 – 0.90)		0.61(0.41 – 0.86)
Body Mass Index (Kg/m^2)				
Underweight		1.06(0.50 – 0.97)		1.01(0.46 – 1.88)
Normal weight		1 (reference)		1 (reference)
Overweight		1.79(1.09 – 2.73)		1.76(1.03 – 2.74)
Obese		2.71(1.61 – 4.30)		2.68(1.58 – 4.27)
Education attainment of participants				
No education		1 (reference)		1 (reference)
Primary		1.30(0.67 – 2.44)		1.26(0.64 – 2.31)
Secondary		1.30(0.65 – 2.50)		1.24(0.62 – 2.42)
Higher		1.21(0.42 – 2.82)		1.23(0.43 – 2.85)
Wealth index of family				
Poorest		1 (reference)		1 (reference)
Poorer		1.28(0.58 – 2.43)		1.18(0.50 – 2.33)
Middle		1.41(0.65 – 2.68)		1.24(0.53 – 2.57)
Richer		2.28(1.05 – 4.30)		2.06(0.84 – 4.54)
Richest		3.09(1.34 – 6.04)		2.84(1.02 – 6.75)
Occupation of participants				
Not working		1 (reference)		1 (reference)
White collar		0.67(0.38 – 1.09)		0.72(0.40 – 1.20)
Manual		0.57(0.35 – 0.87)		0.62(0.36 – 0.99)
Community level factors				
Poverty rate				
Low			1 (reference)	1 (reference)
Middle			0.95(0.41 – 1.87)	1.31(0.52 – 2.71)
High			0.58(0.28 – 1.05)	0.96(0.42 – 1.91)
Illiteracy rate				
Low			1 (reference)	1 (reference)
Middle			0.71(0.38 – 1.19)	0.87(0.45 – 1.50)
High			0.77(0.44 – 1.24)	1.03(0.54 – 1.75)
Unemployment rate				
Low			1 (reference)	1 (reference)
Middle			1.52(0.90 – 2.37)	1.58(0.80 – 2.81)
High			1.64(0.86 – 2.85)	1.69(0.69 – 3.19)
Rural (vs. urban)			0.65(0.34 –1.10)	0.73(0.37 – 1.29)
RANDOM-EFFECTS				
Community level				
Variance (SE)	1.435(0.795 – 2.170)	1.447(0.764 – 2.394)	1.501(0.808 – 2.311)	1.646(0.857 – 2.669)
Intra-community correlation (%)	30.4	30.5	31.3	33.3
MOR	3.12	3.13	3.20	3.38
Model fit statistics				
Bayesian DIC	1297.02	1198.97	1290.44	1200.39

[a]Model 1 is the empty model, a baseline model without any independent variable; [b]Model 2 is adjusted for individual level factors; [c]Model 3 is adjusted for community level factors; [d]Model 4 is adjusted for individual and community level factors; Abbreviations: SE; standard error, DIC; deviance information criterion, CrI; credible interval