BMC Public Health

Cardiovascular disease risk factors in a Nigerian population with impaired fasting blood glucose level and diabetes mellitus

Victor M. Oguoma[1*], Ezekiel U. Nwose[2,3], Ifeoma I. Ulasi[4], Adeseye A. Akintunde[5], Ekene E. Chukwukelu[6], Phillip T. Bwititi[7], Ross S. Richards[2] and Timothy C. Skinner[1]

Abstract

Background: Diabetes is a risk factor for cardiovascular diseases (CVDs) and there are reports of increasing prevalence of prediabetes in Nigeria. This study therefore characterised CVDs risk factors in subjects with impaired fasting glucose (IFG) and diabetes.

Methods: Data from 4 population-based cross-sectional studies on 2447 apparently healthy individuals from 18 - 89 years were analysed. Anthropometric, blood pressure and biochemical parameters were collected and classified. Individuals with IFG (prediabetes) and diabetes were merged each for positive cases of dyslipidaemia, high blood pressure (HBP) or obesity. Optimal Discriminant and Hierarchical Optimal Classification Tree Analysis (HO-CTA) were employed.

Results: Overall prevalence of IFG and diabetes were 5.8% (CI: 4.9 – 6.7%) and 3.1% (CI: 2.4 – 3.8%), respectively. IFG co-morbidity with dyslipidaemia (5.0%; CI: 4.1 – 5.8%) was the highest followed by overweight/obese (3.1%; CI: 2.5 – 3.8%) and HBP (1.8%; CI: 1.3 – 2.4%). The predicted age of IFG or diabetes and their co-morbidity with other CVD risk factors were between 40 – 45 years. Elevated blood level of total cholesterol was the most predictive co-morbid risk factor among IFG and diabetes subjects. Hypertriglyceridaemia was an important risk factor among IFG-normocholesterolaemic-overweight/obese individuals.

Conclusion: The higher prevalence of co-morbidity of CVD risk factors with IFG than in diabetes plus the similar age of co-morbidity between IFG and diabetes highlights the need for risk assessment models for prediabetes and education of individuals at risk about factors that mitigate development of diabetes and CVDs.

Keywords: Diabetes, Co-morbidity, CVD risk factors, Impaired fasting glucose, Nigeria, Prediabetes

Background

Impaired fasting glucose (IFG) is a hyperglycaemic condition that predisposes individuals to high risk of developing type II diabetes (T2D) and cardiovascular disease (CVD) [1]. It is characterised by insulin resistance, beta cell dysfunction, increased lipolysis, inflammation, sub-optimal incretin effect and hepatic glucose overproduction [2].

There have been debates on whether IFG, a component of prediabetes, should be considered in the same manner with T2D since in both conditions there is hyperglycaemic-induced toxicity [3, 4]. It is noted that progression from IFG to T2D can occur due to worsening oxidative stress [3], insulin resistance or beta cell dysfunction [4], and in the long term predisposes to increased risk of CVD. This is where routine screening can be beneficial in aiding early identification and application of management practices, since the process of progression is not abrupt.

* Correspondence: victormaduabuchi.oguoma@cdu.edu.au;
oguomavm@yahoo.com
[1]School of Psychological and Clinical Sciences, Charles Darwin University, Darwin, NT 0909, Australia
Full list of author information is available at the end of the article

Oguoma *et al. BMC Public Health* (2017) 17:36

Page 2 of 9

In Africa, more than two thirds of people with diabetes are undiagnosed [5], giving room for complete transition of the early stages of impaired glucose regulation to overt disease condition. About 14.2 and 34.9 million adults of age 20 – 79 years have diabetes and prediabetes with estimated prevalence of 3.2% (2.1 – 6.7%) and 7.9% (4.8 – 21.9%), respectively. However, the most glaring part is the indication that the prevalence of prediabetes will double by the year 2040 and this is more than that projected for T2D [5]. Based on the 2013 Global Burden of Disease study [6], about 90.5% of stroke burden was attributable to lifestyle-related risk factors, cluster of metabolic risk factors (high blood pressure, IFG, elevated total cholesterol and low glomerular infiltration) and environmental factors. Lifestyle-related risk factors and metabolic risk factors contributed to 74.2% and 72.4% stoke burden, respectively and the population attributable fraction of risk factors in low-middle-income countries increased from 1990 to 2013 [6]. Such observations therefore call for periodic screening, monitoring and appraisal of data on risk factors for metabolic diseases.

CVD risk screening in Nigeria is sub-optimal, even though evidence indicates early onset of disease burden [7, 8], which in part contributes to the low life expectancy and quality of life of Nigerians [9]. One of the effective approaches to early identification of CVD risk is the utilisation of risk assessment models and these have been shown to be better than clinical judgement [10]. Although the assessment of co-occurrence of risk factors for CVD is largely studied in diabetic patients [11–14], the extent that these trends affect the seemingly healthy populations with IFG in Nigeria needs to be documented.

The use of risk assessment models, which provide the bedrock for early identification of diabetes and consequential CVD within a resource constraint population are unclear within African population [15]. Therefore, this study seeks to characterise CVD risk factors in subjects with impaired fasting glucose (IFG) and diabetes by specifically predicting the age of IFG and diabetes comorbidity with CVD risk factors and to classify the risk factors in IFG in a large apparently healthy Nigerian population.

Methods
Study population, setting and ethics clearance
This was a consolidation of data from 4 population-based cross-sectional studies on apparently healthy individuals from 18 to 89 years in 4 geopolitical zones of Nigeria as reported [16]. Participants were drawn from a representative sample populations in Ndokwa West Local Government Area (LGA) of Delta State and indigenes of Ndokwa residing in Lagos State; Enugu North LGA and Enugu Municipality of Enugu State; and FCT

Abuja. Participants gave informed consent and were recruited if they confirmed that they had no case or history of chronic kidney disease and diabetes and, were not pregnant or under treatment for high blood pressure.

In each of the study location, participants were drawn from both rural and urban settings. The main occupation of participants from rural populations is farming, while those in the urban setting are majorly employed as artisans, traders and in white-collar jobs. Yearly average temperature of study areas is 24°C (19 - 33°C). Participants were mobilised to attend designated study sites located at churches, town halls, school premises and primary health centres. Sample size was calculated based on two estimates since several CVD risk factors with different prevalence were involved. Firstly, estimated 5% prevalence of diabetes [17] at 5% confidence interval and at 95% confidence level gave a minimum sample size of 73. In regards to other CVD risk factors, minimum estimate of 384 sample size was also required given a projected 50% prevalence of hypertension and dyslipidaemia [18, 19] at 5% confidence interval and at 95% confidence level. However, the total sample size of 2447 in this study was above the minimum estimates for the various CVD risk factors assessed. The Human Research Ethics Committee of Charles Darwin University, Australia (HREC Ref: H14003); HREC of Novena University Nigeria. Ethics Review Committee (ERC) of the University of Nigeria Teaching Hospital, and ERC of Enugu State Ministry of Health. ERC of Benue State University Nigeria; Abuja Municipal and Kuje Area Councils Ethical Committees, approved the study.

Anthropometric and blood pressure measurements
The standard techniques and procedures for measurement of waist circumference, weight and height were as reported [20–24]. The body mass index (BMI) was calculated by dividing the weight with height square (Kg/m^2). BMI values were grouped into underweight ($<18.5\ Kg/m^2$), normal weight ($18.5 – 24.9\ Kg/m^2$), overweight ($25.0 – 29.9\ Kg/m^2$) and obese ($>30\ Kg/m^2$). Three readings of the systolic (SBP) and diastolic blood pressures (DBP) were taken using Omron® (Australia) digital and Accoson® mercury sphygmomanometer then the average of 2nd and 3rd readings was used to ascertain the blood pressure for all the study sites.

Biochemical parameters
Participants fasted for at least 8 h before blood samples were collected for fasting blood glucose (FBG) and lipids analyses. Blood sample collections were carried out in different locations, such as town halls, health centres and churches, based on convenience of participants. EasyLog EL-USB-1® (Lascar Electronics, Australia)

Oguoma *et al. BMC Public Health* (2017) 17:36

Page 3 of 9

temperature data logger was used to monitor and ensure optimal operational temperature and humidity for point of care blood analysis. The temperature data logger was set 19.5°C low alarm and 30.5°C high alarm. For analysis using clinical laboratory techniques, blood sample were collected in fluoride oxalate bottles. Based on manufacturers' guideline, the following screening techniques were used based on study location as earlier described [16].

Fasting blood glucose: CardioChek® Professional Point of Care Diagnostic Analyser (Polymer Technology Systems, Inc, IN, USA) [site 1] and Accuchek® Point of Care Diagnostic Analyser (Roche Diagnostics, UK) [site 2] were employed. At sites 3 and 4, FBG was assessed by the glucose oxidase method in the reference laboratories in Abuja and Enugu, Nigeria, respectively.

Lipids profile: Clinical laboratory techniques were used for screening total cholesterol (TC), triglycerides (TG) and high density lipoprotein cholesterol (HDL-C) at reference laboratories in sites 2, 3 and 4. TC and TG were measured by enzymatic colorimetric method and HDL-C by differential precipitation followed by enzymatic colorimetry using semi-autoanalyser Mitra Photometer (Linear Chemicals S.L., Barcelona, Spain [site 2], Randox Laboratories, UK [site 3] and Teco Diagnostics, USA [site 3]).

The point of care analytical systems (Polymer Technology Systems and Roche Diagnostics) are certified by the Centre for Disease Control and Prevention (CDC) to meet clinical laboratory reference standards [25]. In addition, Cardio-Chek® Professional Point of Care Diagnostic Analyser has been shown to demonstrate good clinical agreement with clinical laboratory reference methods for TC (97%), TG (92.4%) and HDL-C (92.9%) [26].

Classification of CVD risk factors
The blood glucose level range of 100 – 125 mg/dL (5.6 – 6.9 mmol/L) was used to define impaired fasting glucose (IFG) and values ≥126 mg/dL (7 mmol/L) for diabetes when participants fasted for at least 8 h. The cut-off values employed for the other CVD risk components are as proposed [27]:

- High blood pressure: Systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg [28].
- Hypertriglyceridaemia: Serum triglyceride level of ≥150 mg/dL (1.7 mmol/L) and/or receiving current medication for the condition [29].
- Low HDL-C: Serum HDL-C level of ≤40 mg/dL (1 mmol/L) in males and ≤50 mg/dL (1.3 mmol/L) in females [29].
- Hypercholesterolaemia: Serum total cholesterol level of ≥200 mg/dL (5.2 mmol/L) and/or receiving current medication for the condition [29].

Dyslipidaemia was defined when at least one lipid disorder (hypertriglyceridaemia, hypercholesterolaemia and or low HDL-C) was identified.

Statistical analysis
A total of 2809 individuals were pooled from the 4 population-based cross-sectional studies. Study participants missing values of key study variables such as FBG, TG, TC, HDL-C, BMI, and SBP/DBP were excluded. After the exclusion ($n = 362$), 2447 participants were used. Descriptive analysis of the study population was performed showing the mean and standard deviation of all CVD risk variables across gender. In order to determine number of participants with IFG/diabetes co-morbid CVD risk factors, participants with positive tests for IFG or diabetes were merged with positive cases of dyslipidaemia, HBP, overweight/obese (based on BMI).

Frequency distribution of IFG and diabetes with their co-morbid states were calculated and tabulated. Bootstrapping was applied based on 1000 bootstrap samples and 95% confidence interval generated.

Optimal Discriminant Analysis (ODA) was carried out to predict the age at which IFG or diabetes co-morbidity with CVD risk factors occur across the entire study population. In this analysis, IFG and diabetes with their co-morbid risk factors were treated as class variables, with age of participants as the attribute variable (See Additional file 1).

Finally, Hierarchical Optimal Classification Tree Analysis (HO-CTA) using Optimal Discriminant Analysis (ODA) methods [30] was applied to predict the risk factors that are associated with IFG as well as to generate a decision model. HO-CTA has been shown to be better than linear models that are based on legacy general linear model and maximum-likelihood paradigms [31]. It is a nonlinear multivariate classification method and has an advantage of not requiring any assumptions of multi-colinearity, multivariate normality, equality of group sizes, or number of variables [32].

For the HO-CTA, IFG was the dependent (class) variable, while hypercholesterolaemia, hypertriglyceridaemia, HBP, low serum HDL-C level, age, overweight/obese (based on BMI), smoking and alcohol status, and population (rural vs. urban) were fitted as independent covariates or attribute variables. Leave-one-out re-sampling was used to identify the most stable predictor (attribute) variables that maximise generalisability of the HO-CTA model. The Effect Strength for Sensitivity (ESS) was used to assess predictor performance in classification of IFG. ESS is an index of effect strength normed against chance, where 0 represents classification accuracy expected by chance and 100 represents errorless classification [30]. Analysis was carried out using IBM SPSS (Version 22 for Windows, IL, USA), UniODA (American

Oguoma *et al. BMC Public Health* (2017) 17:36

Page 4 of 9

Psychological Association, USA) and CTA (Optimal Data Analysis LLC, USA) statistical packages. Level of significance was set at 0.05.

Results

Baseline characteristics of study population

Table 1 on characteristics of the study population shows that 2447 participants were selected consisting of 1151 males and 1296 females. The age ($p = 0.700$) and fasting blood glucose levels ($p = 0.377$) of participants were relatively the same across gender.

Prevalence of co-morbid states of IFG and diabetes

The overall prevalence of IFG (5.8%; CI: 4.9 – 6.7%) was higher than that of diabetes (3.1%; CI: 2.4 – 3.8%). The highest co-morbid risk factor with IFG was dyslipidaemia (5.0%; CI: 4.1 – 5.8%), followed by overweight/obese (3.1%; CI: 2.5 – 3.8%), then HBP (1.8%; CI: 1.3 – 2.4%). In diabetes, the prevalence of co-morbid conditions followed the same trend as in IFG, where co-morbidity with dyslipidaemia (2.7%; CI: 2.0 – 3.3%) was the highest and HBP, the lowest prevalent (1.3%; CI: 0.9 – 1.8%) (Table 2).

Co-morbidity of IFG and diabetes with other CVD risk factor across age groups

Across the different age groups, the results show that co-morbidity of IFG and dyslipidaemia was dominant more than the other risk conditions (Table 3). The lowest age group, (18 – 29 years) also had a sizeable prevalence of IFG and its co-morbid risk factors. The age group, 40 – 49 years had the highest proportion of individuals with risk conditions both in IFG and diabetes.

Table 1 Baseline characteristics of study population

	All population N = 2447	Female N = 1296	Male N = 1151	p-values
Age (years)	43.4 ± 14.8	43.3 ± 14.6	43.4 ± 15.1	0.700
Weight (Kg)	65.3 ± 18.1	64.6 ± 21.8	66.0 ± 12.5	<0.0001
Height (m)	1.6 ± 0.08	1.6 ± 0.07	1.7 ± 0.08	<0.0001
WC (cm)	84.0 ± 10.9	85.1 ± 11.9	82.9 ± 9.7	<0.0001
BMI (Kg/m^2)	24.8 ± 6.2	25.6 ± 7.6	24.1 ± 4.0	<0.0001
WHtR	0.52 ± 0.07	0.54 ± 0.07	0.50 ± 0.06	<0.0001
SBP (mmHg)	122.2 ± 20.4	121.1 ± 21.3	123.5 ± 19.3	<0.0001
DBP (mmHg)	78.1 ± 14.2	77.4 ± 15.6	78.8 ± 12.3	<0.0001
TC (mg/dL)	167.5 ± 52.9	173.5 ± 56.1	160.7 ± 48.1	<0.0001
HDL (mg/dL)	50.9 ± 16.8	52.7 ± 17.5	48.7 ± 15.8	<0.0001
TG (mg/dL)	120.0 ± 49.4	117.1 ± 45.5	123.2 ± 53.3	0.042
FBG (mg/dL)	79.9 ± 30.0	79.7 ± 28.9	80.0 ± 31.3	0.377

WC waist circumference, *BMI* body mass index, *WHtR* waist to height ratio, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *TC* total cholesterol, *HDL* high density lipoprotein cholesterol, *TG* triglycerides, *FBG* fasting blood glucose

Table 2 Prevalence of IFG and diabetes co-morbidity with CVD risk factors

CVD risk factors	Proportion (N = 2447)	Prevalence (%)	95% confidence interval		SE
			Lower	upper	
HBP	566	23.1	21.5	24.8	0.8
Hypercholesterolaemia	634	25.9	24.2	27.7	0.9
Hypertriglyceridaemia	572	23.4	21.6	25.1	0.9
Low HDL-C	1073	43.8	41.8	45.7	1.0
Overweight/obese	979	40.0	38.0	42.1	1.0
IFG	141	5.8	4.9	6.7	0.5
IFG + dyslipidaemia	122	5.0	4.2	5.9	0.4
IFG + HBP	64	2.6	2.0	3.3	0.3
IFG + overweight/obese	76	3.1	2.5	3.8	0.4
Diabetes	76	3.1	2.4	3.8	0.4
Diabetes + dyslipidaemia	65	2.7	2.0	3.4	0.3
Diabetes + HBP	47	1.9	1.4	2.5	0.3
Diabetes + overweight/ obese	48	2.0	1.4	2.6	0.3

IFG impaired fasting glucose, + with, *HDL* high density lipoprotein cholesterol, *HBP* high blood pressure, *SE* standard error

Predicted age of IFG and diabetes co-morbidity with other CVD risk factors

There was no statistical significant difference between predicted age of participants with or without IFG, and IFG co-morbidity with dyslipidaemia and HBP (Table 4). On the other hand, only diabetes (p = 0.018) and its co-morbidity with HBP (p = 0.010) showed a statistical significant difference. In all, predicted age of IFG, diabetes and their co-morbid risk conditions were between 40 – 45 years old.

Classification tree of IFG co-morbid risk factors

Figure 1 shows the order of independent predictive performance of the risk factors in classifying IFG. The highest and statistically significant independent predictors of IFG was elevated blood total cholesterol level (ESS = 17.66%, $p < 0.0001$), followed by overweight/obese (ESS = 14.74%, $p = 0.001$), hypertriglyceridaemia (ESS = 12.82%, $p = 0.001$) and high blood pressure (ESS = 9.32%, $p = 0.013$). However, age (ESS = 8.06%, $p = 0.248$), low blood HDL-C level (ESS = 5.89%, $p = 0.189$), cigarette smoking (ESS = 4.12%, $p = 0.292$), alcohol consumption (ESS = 2.90%, $p = 0.609$) and population (rural vs. urban) [ESS = 0.44%, $p = 0.930$] were not statistically significant.

The classification tree model shown in Fig. 2 also indicates that high level of blood total cholesterol concentration is the most prominent/important co-morbid risk factor among IFG subjects. The result further shows that among 141 (5.8%) subjects with IFG, 60 (9.5%) have elevated total cholesterol. Among 81

Oguoma *et al. BMC Public Health* (2017) 17:36

Page 5 of 9

Table 3 Prevalence of IFG and diabetes co-morbidity with other CVD risk factors across age groups

Age Group(years)	IFG co-morbidity with CVD risks				Diabetes co-morbidity with CVD risks			
	IFG n (%)	IFG with dyslipidaemia n (%)	IFG with HBP n (%)	IFG with overweight/obese n (%)	Diabetes n (%)	Diabetes with dyslipidaemia n (%)	Diabetes with HBP n (%)	Diabetes with overweight/obese n (%)
18-29	30 (5.3)	24 (4.2)	9 (1.6)	11 (1.9)	12 (2.1)	11 (1.9)	5 (0.9)	8 (1.4)
30-39	21 (4.2)	19 (3.8)	4 (0.8)	13 (2.6)	9 (1.8)	8 (1.6)	3 (0.6)	5 (1.0)
40-49	35 (6.9)	29 (5.8)	13 (2.6)	19 (3.8)	19 (3.8)	16 (3.2)	10 (2.0)	12 (2.4)
50-59	25 (5.8)	23 (5.3)	11 (2.6)	17 (4.0)	16 (3.7)	13 (3.0)	8 (1.9)	10 (2.3)
60-69	28 (8.0)	25 (7.2)	7 (2.0)	15 (4.3)	11 (3.2)	9 (2.6)	6 (1.7)	10 (2.9)
70-89	2 (2.1)	2 (2.1)	1 (1.1)	1 (1.1)	9 (9.6)	8 (8.5)	1 (1.1)	3 (3.2)
Total	141 (5.8)	122 (5.0)	45 (1.8)	76 (3.1)	76 (3.1)	65 (2.7)	33 (1.3)	48 (2.0)

(4.5%) IFG subjects without high level of total cholesterol, 39 (6.3%) are overweight/obese. Hypertriglyceridaemia is a risk factor in subjects with IFG and are overweight/obese even if they do not have elevated blood level of total cholesterol.

Discussion

This study shows that there is higher prevalence of IFG than undiagnosed diabetes among the study Nigerian population. Further, co-morbidity of modifiable risk factors for chronic diabetes and CVD, such as dyslipidaemia and HBP, were more predominant in IFG than diabetes subjects. Several studies report that the

Table 4 Age (years) of IFG and diabetes co-morbidity with CVD risk factors

CVD risk factors	Status	Predicted age (years)	N	% satisfied	ESS	p-value
IFG	Yes	≥40	1376	6.54	8.06	0.253
	No	<40	1071	4.76		
IFG with Dyslipidaemia	Yes	≥41	1274	5.97	10.77	0.091
	No	<41	1173	3.92		
IFG with HBP	Yes	≥41	1274	2.43	17.14	0.096
	No	<41	1173	1.19		
IFG with Overweight/Obese	Yes	≥41	1274	4.00	15.52	0.033
	No	<41	1173	2.13		
Diabetes	Yes	≥40	1376	4.00	16.65	0.018
	No	<40	1071	1.96		
Diabetes with Dyslipidaemia	Yes	≥44	1169	3.51	15.72	0.052
	No	<44	1278	1.88		
Diabetes with HBP	Yes	≥40	1376	1.82	19.79	0.010
	No	<40	1071	0.75		
Diabetes with Overweight/Obese	Yes	≥42	1255	2.63	17.81	0.063
	No	<42	1192	1.26		

N number of observations in a given predicted class category, *% satisfied* percentage of observations in a given class category, *ESS* effect strength for sensitivity, *HBP* high blood pressure

transition to westernised ways of life, which may lead to unhealthy eating and physical inactivity, is possibly responsible for this increase in multi-morbidity [33–35]. It has been shown that the relative risk of coronary heart disease in individuals with 1, 2 or >3 CVD risk factors is up to 2, 4 and 7-folds, respectively [14]. More so, the fact that the hyperglycaemic condition of IFG worsens the already frail state of endothelial dysfunction and insulin resistance [4], prompts for action on community-wide implementation of diabetes and CVD risk factor identification and prevention.

Age distribution of IFG and co-morbidity of IFG with CVD risk factors showed upward trend from the lowest age group, plateauing at 40 – 49 years. This finding agrees with other studies on independent CVD risk factors, which showed an increase in prevalence with increase in age [36, 37]. No significant predicted age difference was observed in population with and without IFG and IFG co-morbidity with risk factors, except in overweight/obese. In other words, IFG or its co-morbid risk condition do not have age preference unlike in diabetes where the age difference was found to be statistically significant ($p < 0.018$) between age of occurrence (Table 4). However, the fact that co-existence of other risk factors with impaired glucose regulation increases the risk of chronic diabetes and CVD [38], underscores the need for frequent risk assessment for prediabetes in this population. Establishment of opportunistic screening strategies using already available communicable disease screening centres would be a cost-efficient approach.

Our findings also showed that predicted age of IFG, diabetes and their co-occurrence with other risk factors were within same range (40 – 45 years). Evidence shows that risk assessment models for CVD have diabetes as dichotomous (Yes or No) and considers subjects from 40 years of age. It is argued that the problem of such dichotomy is that hyperglycaemia in impaired fasting glucose or impaired glucose tolerance is missed via a NO

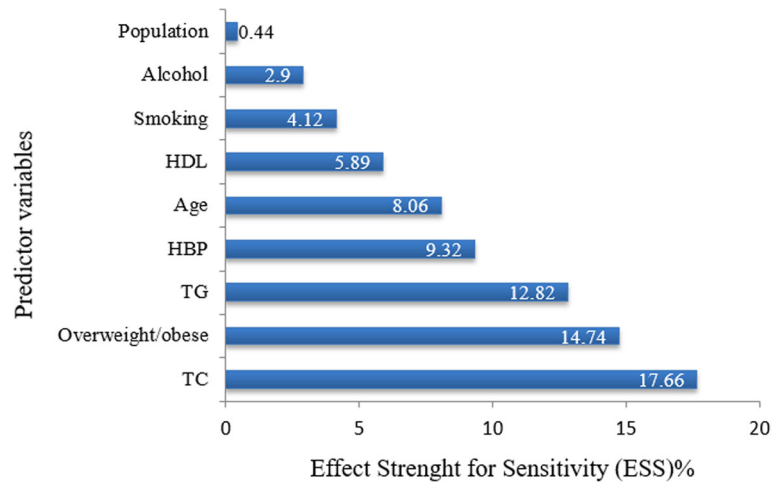Oguoma *et al. BMC Public Health* (2017) 17:36

Page 6 of 9

Fig. 1 Order of independent predictive performance of the risk factors in classifying IFG. TC = elevated total cholesterol, TG = hypertrglyceridemia, HDL = High density lipoprotein cholesterol. Overweight/obese is based on body mass index, population = rural *vs* urban population

answer, when assessment and treatment of CVD risk in prediabetes should be as in diabetes [39, 40]. The implication is that information pertaining to the primordial forms of glucose dysregulation are not brought to fore in Nigeria to aid early identification of the 'at risk' population, since risk of an individual is usually not assessed until overt diabetes that surfaces with huge symptoms. This emphasises that intervention based on outcome of utilisation of available risk assessment tools would not identify a substantial proportion of the population at increased risk of CVD, given the proportion of IFG individuals with co-morbid risk factors.

Furthermore, our findings delineated high level of blood total cholesterol as the most important risk factor predominant in population with IFG. Some studies in Nigeria identified high prevalence of risk factors [41–43], and insight into the order of importance and occurrence would assist in screening and treatment of the at-risk individuals. However, based on chain of events as shown in Figs. 1 and 2, it may seem important to integrate screening for hypertriglyceridaemia in risk assessment models for prediabetes conditions in the Nigerian population, as it strongly contributes to the co-morbidity in IFG-normocholesterolaemic-overweight/obese-nonhypertensive individuals. This implies that in the absence of HBP, there is increased chance of dyslipidaemia (high total cholesterol and/or triglyceride levels) and overweight/obese among the sample population with IFG. Furthermore, hypertriglyceridaemia was found to have higher independent predictive ability in classifying IFG than age. It was opined to be an essential risk factor contributing to discordance of results from the use of the ATPIII/Framingham risk score and metabolic syndrome in screening individuals at 10-year risk of CVD [44].

The increasing identification of IFG and undiagnosed diabetes is an issue for concern, requiring concerted and pragmatic approach. It is important to emphasise the need for screening of IFG at least, based on the evidence of high co-morbid CVD risk factors associated with it. The feasibility of screening by measuring FBG levels leads to increased chances of early identification when targeted at patients with multiple risk factors [45]. The epidemiological evidence that the majority of cases of diabetes/CVD are undiagnosed in this part of the world is an indication that assessment and management of CVD risk based on screening for diabetes in subjects with high blood pressure [46] may miss out early identification of other risk factors that co-exist in individuals without evidence of hypertension. This is on the premise that the etiological mechanisms of clustering of the CVD risk factors are not well understood. However, one of the factors undermining risk screening of dyslipidaemia in Nigeria is the high cost [20, 47], and although obesity screening is affordable, there is no evidence regarding its assessment against mortality outcome other than metabolic outcome, and in most cases the proportion of metabolically healthy obese phenotype is not accounted for in studies reporting high prevalence of obesity. Therefore, future studies exploring association of these phenotypes with prediabetes and other risk factors are required to elucidate the order of magnitude of IFG/IGT co/multi-morbidity with CVD risk factors in sub-Sahara Africa.

Strength and Limitations of the study
One of the strength of the study is that it comprises of treatment naïve individuals for the assessed risk factors. Also, to the best of our knowledge, this is the only published study that has investigated the co-morbidity of
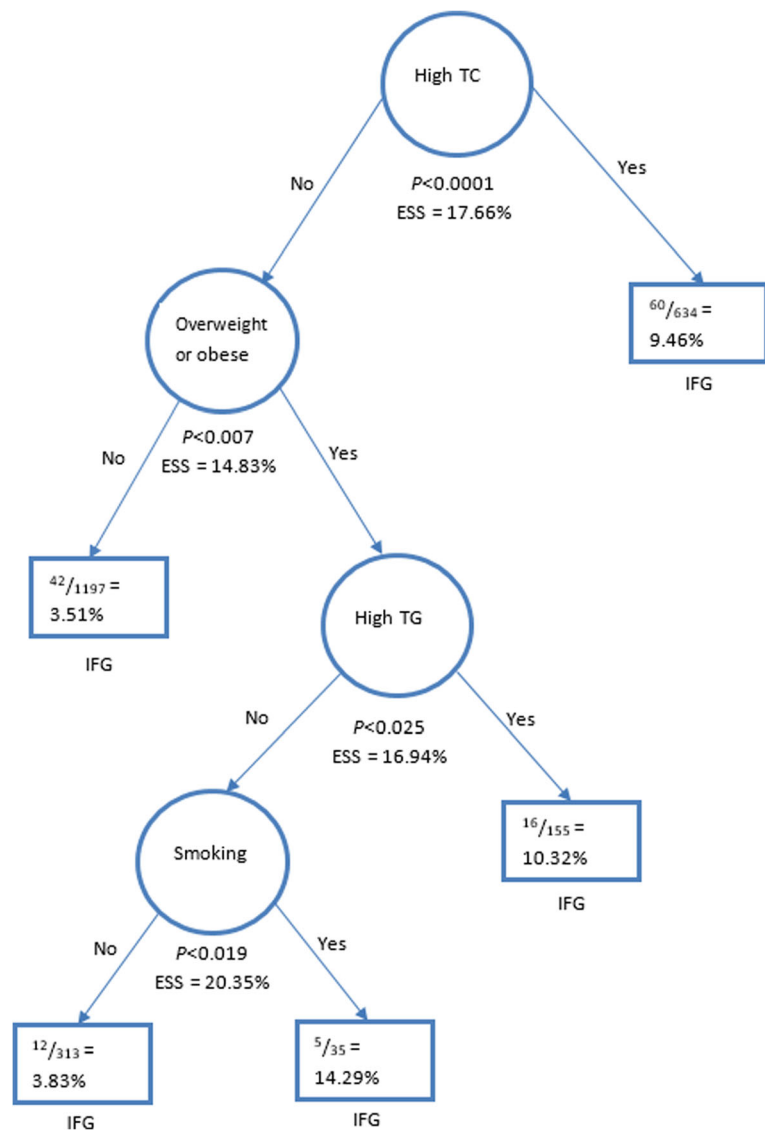
Oguoma *et al. BMC Public Health* (2017) 17:36

Page 7 of 9

Fig. 2 Hierarchically Optimal Classification Tree Analysis Model (via UniODA) of IFG subjects with risk factors. High TC = high level of total cholesterol; high TG = high level of triglyceride; overweight/obese is based on body mass index; ESS = effect strength for sensitivity

IFG with other modifiable CVD risk factors and the order of importance of the IFG co-morbid risk factors in apparently healthy Nigerians. The use of a nonlinear multivariate classification method that is not influenced by assumptions of multicolinearity, multivariate normality, equality of group sizes, or number of variables is an added strength. The point of care analysis was carried out within manufacturers recommended operational temperature range, and this was confirmed by device logs used.

Diabetes mellitus is known to be heterogeneous, where differences in glucose regulation exist among individuals with comparable diagnostic glucose levels [48]. One of the limitations of this study is use of FBG measurement to classify diabetes. Although cost prohibitive it would

be worth using HbA1c, which is now available as a point of care test as an additional screening tool.

Conclusion

The higher prevalence of co-morbidity of CVD risk factors with IFG than in diabetes mellitus shows that targeting only the older adult individuals presenting at health institutions for risk factors identification and intervention would not abate the increasing incidence of diabetes and CVD in Africa. There is need for appropriate risk assessment models for prediabetes considering that IFG and its co-morbid risk factors are relative prevalent in young adults and probably more in middle-aged adults.

Oguoma et al. BMC Public Health (2017) 17:36

Page 8 of 9

Additional file

Additional file 1: Result of the Optimal Discriminant Analysis via UniODA. (TXT 24 kb)

Abbreviations
ATPIII: Third adult treatment panel; BMI: Body mass index; CVD: Cardiovascular disease; DBP: Diastolic blood pressure; ESS: Effect strength for sensitivity; FBG: Fasting blood glucose; HbA1c: Glycated haemoglobin; HBP: High blood pressure; HDL-C: High density lipoprotein cholesterol; HO-CTA: Hierarchical optimal classification tree analysis; HREC: Human research ethics committee; IFG: Impaired fasting glucose; IGT: Impaired glucose tolerance; Kg/m²: Kilogram per meter squared; Mg/dL: Milligram per decilitre; mmHg: Millimetre hydrogen; mmol/L: Millimoles per litre; ODA: Optimal discriminant analysis; SBP: Systolic blood pressure; T2D: Type 2 diabetes; TC: Total cholesterol; TG: Triglyceride

Availability of data and material
Data are held at the School of Psychological and Clinical Sciences based on the provision of the ethics committee. All relevant data are within this paper.

Authors' contributors
OVM, EUN and TCS conceived the 'consolidated data' study, an integral part of PACCS conceived by EUN, RSR and PTB. VMO, IIU, AAA and EEC engaged in data acquisition. VMO carried out data analysis, interpretation and drafted the manuscript. PTB, IIU, TCS, EUN, AAA and RSR critically revised the manuscript for intellectual content. All authors read and approved the final manuscript.

Competing interests
The authors declared that they have no competing interests.

Consent for publication
All participants gave verbal or written consent for the data to be published in de-identified format.

Ethics approval and consent to participate
Informed consent was given by participants in each study population. Ethics Committees for each study group approved the study. These included Human Research Ethics Committee (HREC) of Charles Darwin University Australia (H140003); and HREC of Novena University Nigeria. Ethics Review Committee (ERC) of the University of Nigeria Teaching Hospital, and ERC of Enugu State Ministry of Health. ERC of Benue State University Nigeria; Abuja Municipal and Kuje Area Councils Ethical Committees.

Author details
[1]School of Psychological and Clinical Sciences, Charles Darwin University, Darwin, NT 0909, Australia. [2]School of Community Health, Charles Sturt University, Orange, NSW, Australia. [3]Department of Public and Community Health, Novena University, Ogume, Delta State, Nigeria. [4]College of Medicine, University of Nigeria and University of Nigeria Teaching Hospital, Nsukka, Nigeria. [5]Department of Internal Medicine, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. [6]Department of Chemical Pathology, College of Medicine, University of Nigeria Teaching Hospital, Ituku Ozalla, Nigeria. [7]School of Biomedical Sciences, Charles Sturt University, Wagga Wagga, NSW, Australia.

References
1. Levitzky YS, Pencina MJ, D'Agostino RB, Meigs JB, Murabito JM, Vasan RS, Fox CS. Impact of impaired fasting glucose on cardiovascular disease: the Framingham Heart Study. J Am Coll Cardiol. 2008;51(3):264–70.
2. Brannick B, Wynn A, Dagogo-Jack S. Prediabetes as a toxic environment for the initiation of microvascular and macrovascular complications. Exp Biol Med. 2016;241(12):1323–31.
3. Bwititi PT, Nwose EU. Screening of cardiovascular disease risk in diabetes: questions concerning prediabetes and low-mid income countries. North Am J Med Sci. 2014;6(6):284–6.
4. Ferrannini E. Definition of intervention points in prediabetes. Lancet Diabetes Endocrinol. 2014;2(8):667–75.
5. IDF Diabetes Atlas, 7th edn [http://diabetesatlas.org/]. Accessed 16 Aug 2016.
6. Feigin VL, Roth GA, Naghavi M, Parmar P, Krishnamurthi R, Chugh S, Mensah GA, Norrving B, Shiue I, Ng M, et al. Global burden of stroke and risk factors in 188 countries, during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet Neurol. 2016;15(9):913–24.
7. Sagui E. Stroke in sub-Saharan Africa. Med Trop. 2007;67(6):596–600.
8. Onwuchekwa AC, Onwuchekwa RC, Asekomeh EG. Stroke in young Nigerian adults. J Vasc Nurs. 2009;27(4):98–102.
9. Fasanmade OA, Dagogo-Jack S. Diabetes Care in Nigeria. Ann Glob Health. 2015;81(6):821–9.
10. Grover SA, Lowensteyn I, Esrey KL, Steinert Y, Joseph L, Abrahamowicz M. Do doctors accurately assess coronary risk in their patients? Preliminary results of the coronary health assessment study. BMJ. 1995;310(6985):975.
11. Balogun WO, Salako BL. Co-occurrence of diabetes and hypertension: pattern and factors associated with order of diagnosis among nigerians. Ann Ib Postgrad Med. 2011;9(2):89–93.
12. Selby JV, Peng T, Karter AJ, Alexander M, Sidney S, Lian J, Arnold A, Pettitt D. High rates of co-occurrence of hypertension, elevated low-density lipoprotein cholesterol, and diabetes mellitus in a large managed care population. Am J Manag Care. 2004;10(2 Pt 2):163–70.
13. Formiga F, Ferrer A, Sanz H, Marengoni A, Alburquerque J, Pujol R. Octabaix study m: Patterns of comorbidity and multimorbidity in the oldest old: the Octabaix study. Eur J Intern Med. 2013;24(1):40–4.
14. Merry AH, Erkens PM, Boer JM, Schouten LJ, Feskens EJ, Verschuren WM, Gorgels AP, van den Brandt PA. Co-occurrence of metabolic factors and the risk of coronary heart disease: a prospective cohort study in the Netherlands. Int J Cardiol. 2012;155(2):223–9.
15. Mbanya V, Hussain A, Kengne AP. Application and applicability of non-invasive risk models for predicting undiagnosed prevalent diabetes in Africa: A systematic literature search. Prim care diabetes. 2015;9(5):317–29.
16. Oguoma VM, Nwose EU, Ulasi II, Akintunde AA, Chukwukelu EE, Araoye MA, Edo AE, Ijoma CK, Onyia IC, Ogbu II, et al. Maximum accuracy obesity indices for screening metabolic syndrome in Nigeria: A consolidated analysis of four cross-sectional studies. Diabetes Metab Syndr. 2016;10(3):121–7.
17. Oputa R, Chinenye S. Diabetes in Nigeria-a translational medicine approach. Afr J Diabetes Med. 2015;23(1):7–10.
18. Akinlua JT, Meakin R, Umar AM, Freemantle N. Current Prevalence Pattern of Hypertension in Nigeria: A Systematic Review. PLoS One. 2015;10(10):e0140021.
19. Oguejiofor OC, Onwukwe CH, Odenigbo CU. Dyslipidemia in Nigeria: prevalence and pattern. Ann Afr Med. 2012;11(4):197–202.
20. Oguoma VM, Nwose EU, Skinner TC, Digban KA, Onyia IC, Richards RS. Prevalence of cardiovascular disease risk factors among a Nigerian adult population: relationship with income level and accessibility to CVD risks screening. BMC Public Health. 2015;15(1):397.
21. Ulasi II, Ijoma CK, Onodugo OD. A community-based study of hypertension and cardio-metabolic syndrome in semi-urban and rural communities in Nigeria. BMC Health Serv Res. 2010;10:71.
22. Nwose EU, Oguoma VM, Bwititi PT, Richards RS. Metabolic syndrome and prediabetes in ndokwa community of Nigeria: preliminary study. N Am J Med Sci. 2015;7(2):53–8.
23. Adediran O, Akintunde AA, Edo AE, Opadijo OG, Araoye AM. Impact of urbanization and gender on frequency of metabolic syndrome among native Abuja settlers in Nigeria. J Cardiovasc Dis Res. 2012;3(3):191–6.
24. Chukwukelu E, Ogbu I, Onyeanusi C. Prevalence of metabolic syndrome in some Urban and Rural Communities in Enugu State, Nigeria. Internet J Lab Med. 2013;5:1.

Oguoma et al. BMC Public Health (2017) 17:36

Page 9 of 9

25. Laboratory Quality Assurance and Standardization Programs: Clinical Laboratory Certification Program, Centers for Disease Control and Prevention [http://www.cdc.gov/labstandards/crmln_clinical.html]. Accessed 16 Aug 2016.

26. Gao Y, Zhu CG, Wu NQ, Guo YL, Liu G, Dong Q, Li JJ. Study on the reliability of CardioChek PA for measuring lipid profile. Beijing da xue xue bao Yi xue ban = Journal of Peking University Health sciences. 2016;48(3):523–8.

27. Alberti KG, Zimmet P, Shaw J, Group IDFETFC. The metabolic syndrome–a new worldwide definition. Lancet. 2005;366(9491):1059–62.

28. Whitworth JA. World Health Organization ISoHWG: 2003 World Health Organization (WHO)/International Society of Hypertension (ISH) statement on management of hypertension. J Hypertens. 2003;21(11): 1983–92.

29. Expert Panel on Detection E. Treatment of High Blood Cholesterol in A: Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). JAMA. 2001;285(19):2486–97.

30. Yarnold PR, Soltysik RC. Optimal data analysis. Washington DC: American Psychological Association; 2005.

31. Yarnold PR, Bryant FB. Obtaining a Hierarchically Optimal CTA Model via UniODA Software. Optimal Data Analysis. 2015;4:36–53.

32. Yarnold PR, Soltysik RC, Bennett CL. Predicting in-hospital mortality of patients with AIDS-related Pneumocystis carinii pneumonia: an example of hierarchically optimal classification tree analysis. Stat Med. 1997; 16(13):1451–63.

33. Kandala NB, Stranges S. Geographic variation of overweight and obesity among women in Nigeria: a case for nutritional transition in sub-Saharan Africa. PLoS One. 2014;9(6):e101103.

34. Ogbera AO, Ekpebegh C. Diabetes mellitus in Nigeria: The past, present and future. World J Diabetes. 2014;5(6):905–11.

35. Ogah OS, Okpechi I, Chukwuonye II, Akinyemi JO, Onwubere BJ, Falase AO, Stewart S, Sliwa K. Blood pressure, prevalence of hypertension and hypertension related complications in Nigerian Africans: A review. World J Cardiol. 2012;4(12):327–40.

36. Isara AR, Okundia PO. The burden of hypertension and diabetes mellitus in rural communities in southern Nigeria. Pan Afr Med J. 2015; 20:103.

37. Oluyombo R, Olamoyegun MA, Olaifa O, Iwuala SO, Babatunde OA. Cardiovascular risk factors in semi-urban communities in southwest Nigeria: Patterns and prevalence. J Epidemiol Glob Health. 2015;5(2):167–74.

38. Liu J, Grundy SM, Wang W, Smith Jr SC, Vega GL, Wu Z, Zeng Z, Wang W, Zhao D. Ten-year risk of cardiovascular incidence related to diabetes, prediabetes, and the metabolic syndrome. Am Heart J. 2007; 153(4):552–8.

39. Nwose EU, Richards RS, Digban K, Bwititi PT, Ennis G, Yee KC, Oguoma VM, Liberato S. Cardiovascular risk assessment in prediabetes and undiagnosed diabetes mellitus study: international collaboration research overview. North Am J Med Sci. 2013;5(11):625–30.

40. DeFronzo RA, Abdul-Ghani M. Assessment and treatment of cardiovascular risk in prediabetes: impaired glucose tolerance and impaired fasting glucose. Am J Cardiol. 2011;108(3 Suppl):3b–24b.

41. Ogedengbe SO, Ezeani IU. Profile of metabolic abnormalities seen in patients with type 2 diabetes mellitus and their first degree relatives with metabolic syndrome seen in Benin City, Edo state Nigeria. J Diabetes Metab Disord. 2014;13:61.

42. Awogbemi OT, Okoromah CA, Roberts AA. Hypercholesterolaemia in schoolchildren in Lagos, Nigeria: an indication of a growing threat of cardiovascular disease? Nig Q J Hosp Med. 2013;23(2):110–3.

43. Ogunleye OO, Ogundele SO, Akinyemi JO, Ogbera AO. Clustering of hypertension, diabetes mellitus and dyslipidemia in a Nigerian population: a cross sectional study. Afr J Med Med Sci. 2012;41(2):191–5.

44. Oguoma VM, Nwose EU, Skinner TC, Richards RS, Digban KA, Onyia IC. Association between metabolic syndrome and 10-year risk of developing cardiovascular disease in a Nigerian population. Int Health. 2016;8(5):354–9.

45. Lawrence JM, Bennett P, Young A, Robinson AM. Screening for diabetes in general practice: cross sectional population study. BMJ. 2001; 323(7312):548–51.

46. Mendis S, Johnston SC, Fan W, Oladapo O, Cameron A, Faramawi MF. Cardiovascular risk management and its impact on hypertension control in primary care in low-resource settings: a cluster-randomized trial. Bull World Health Organ. 2010;88(6):412–9.

47. Oguoma VM, Nwose EU, Bwititi PT. Cardiovascular disease risk prevention: preliminary survey of baseline knowledge, attitude and practices of a Nigerian rural community. North Am J Med Sci. 2014;6(9):466–71.

48. Faerch K, Hulman A, Solomon TP. Heterogeneity of Pre-diabetes and Type 2 Diabetes: Implications for Prediction, Prevention and Treatment Responsiveness. Curr Diabetes Rev. 2016;12(1):30–41.