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ORIGINAL ARTICLE

Prediabetes among Nigerian adolescents: A School-based study of the prevalence, risk factors and pattern of fasting blood glucose in Ibadan, Nigeria

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Abstract Prediabetes and type 2 diabetes (T2DM) are emerging public health challenges in sub-Saharan Africa which have been given little research focus among adolescents. The behavioural and cardiometabolic factors that drive these conditions have hardly been documented among adolescents in Nigeria. A cross-sectional study was conducted to investigate the prevalence and risk factors of prediabetes among 500 in-school adolescents and their fasting blood glucose pattern in Ibadan, Nigeria. Potential factors including blood pressure, anthropometric measurements and fasting blood glucose (FBG) levels were assessed. Prediabetes was defined as FBG between 100 –125 mg/dl. Data were analyzed using descriptive statistics and bivariate logistic regression at 5 % level of significance. The overall prevalence of prediabetes among the adolescents was 4.0 % 95 % CI (2.2–5.7 %) and the mean FBG of adolescents was 85.3 ± 8.2. Males compared to females had significantly higher levels of FBG—mean difference [1.65:95 % CI (0.017–3.14) $p = 0.03$]. Factors that increased the odds for prediabetes included frequent consumption of carbonated drinks (OR = 1.45; 95 % CI 0.46–3.30; p = 0.48), attending a private school (OR = 2.58; 95 % CI 0.77–9.0; $p = 0.66$) elevated blood pressure (OR = 2.04; 95 % CI 0.57–7.35; $p = 0.57$) and being overweight or obese (OR = 2.91; 95 % CI 0.38–22.3; $p = 0.30$). Correspondingly, while those who skipped breakfast [1.29;95 % CI (−0.23;−2.8) $p = 0.096$] had higher FBG, those who walked daily back from school [−2.07;95 % CI (−3.55; − 0.59) $p = 0.01$] had significantly lower FBG. Prediabetes and risk factors are prevalent among the secondary school adolescents in Ibadan. Surveillance of potential risk factors through school-based screening among adolescents is crucial for prevention and early intervention.

Keywords Prediabetes · Fasting blood glucose · Prevalence · Risk factors · Adolescents · Ibadan

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Introduction

Diabetes Mellitus (DM) has been described as a public health challenge of the twenty-first century [1, 2] with a reported global prevalence of 8.3 %, which translates to about 387 million people living with diabetes across the world of which 46.3 % remained undiagnosed [3]. DM used to be uncommon in sub-Saharan Africa few decades ago, but it is now increasing rapidly [4]. An estimated 14.2 million adults aged 20–79 years were reported to have DM in the region in 2015 and this has been projected to increase to 34.2 million by 2040 [3]. Even though, the epidemic is in its early phases in Africa, its drivers include rapid urbanization, ageing, reduced physical activity and unhealthy diet seem prevalent. Unfortunately, Nigeria accounts for the highest number of people with diabetes and impaired glucose tolerance (with approximately 1.6 (1.2–3.8) million and 3.85 million people affected, respectively [2, 5]. Prediabetes or impaired glucose tolerance, defined as the presence of elevated fasting blood glucose within the range of 100–125 mg/dl [6] is the intermediate and reversible stage in the natural history of type 2 diabetes (T2DM) [7, 8].

Increasingly, T2DM has been reported among adolescents especially in the developed countries [6, 9–12] a pattern that has begun to emerge in developing countries as well [4, 7, 13, 14]. The increase in prediabetes/T2DM among adolescents has been attributed to the rise of behavioural and cardiometabolic risk factors. For example, in the USA, prediabetes has been associated with childhood obesity [9]. T2DM is a chronic debilitating disease associated with severe complications such as kidney failure, blindness and cardiovascular disorders like coronary heart disease, stroke and peripheral arterial disease which poses severe risks for families, member states and the entire world. [12]. The progression of these complications is worse when the illness starts from childhood or adolescence [15]. More so, the onset of T2DM is insidious and asymptomatic with high prevalence of undiagnosed diabetes (50–85 %) being reported in both developed and developing countries [16]. Therefore routine screening becomes crucial for prevention, early detection and treatment because prediabetes is often a predictor of future development of T2DM [14] and the implication of late diagnosis of prediabetes/T2DM in the adolescent might be grave [17, 18].

The prevalence of DM/prediabetes among the adolescent population has been poorly documented in Nigeria [14]. Bassey and her colleagues while screening in-school adolescents for DM carried out a cross-sectional study among 1008 adolescents aged 10 to 18 years in 12 secondary school in Port Harcourt [19]. Although urine glucose was used as a screening test, fasting blood glucose (FBG) is the recommended test by the World Health Organization (WHO) because of its higher sensitivity and specificity [20]. Screening of adolescents for DM or prediabetes is a cost-effective strategy for early prevention and management [21]. WHO described school health as “a strategic means to prevent important health risks among the youth”. Furthermore the WHO global school health initiative stated that “Research in both developed and developing countries demonstrates that school health programmes can simultaneously reduce common health problems, increase the efficiency of the educational system and advance public health education and social and economic development of a nation” (WHO). Schools can create a platform for screening children and adolescents for hyperglycemia, elevated blood pressure risk factors for other chronic disease [5]. Therefore, we conducted a school-based study to determine the pattern of (FBS), the prevalence and risk factors of prediabetes among adolescents in Ibadan, Nigeria.

Materials and methods

Setting and study design

The study was conducted in Ibadan, Oyo State in southwestern Nigeria, the third largest city in Nigeria after Lagos and Kano with 11 local government areas (5 urban and 6 semi-urban). The cross-sectional study was conducted in Ibadan South West Local Government Area (ISWLGA), an urban LGA with 81 government-approved secondary schools: 52 private owned and 29 public secondary schools. The Ethical Review Committee of the Oyo State Ministry of Health approved the study protocol. Permission to carry out the study was obtained from the Ministry of Education, Oyo State and the authorities of each of the selected school. Informed consent as obtained from the parents/guardian while the study participants gave their assent before data collection commenced. The sample size estimation for single proportion was used as estimated proportion of T2DM of 3.6 % among adolescents; the precision level of 2.5 %; $a = 0.05$; and a design effect of 2. A two-stage cluster sampling technique was used to recruit 500 in-school adolescents within the ages of 10 and 19 years. A total of ten schools were randomly selected from a list of all the schools in the LGA. Fifty students were selected from each school. Exclusion criteria for intending participants included students that were severely ill at the time of study and an unwillingness to participate in the study either by students or parents. The study was conducted between October and December 2014.

Diagnosis of type 2 diabetes

The WHO diagnostic criteria for the diagnosis of T2DM was used to assess the glycemic levels of the study participants using the FBG levels. The FBG level was obtained using a accu-check glucometer (active model:GU, serial no:GU03510010). Blood glucose metre reading was expressed as milligrams per deciliter. The study participants were categorized by their blood glucose levels as follows according to the basic training manual for healthcare professionals in developing countries: normal level <126 mg/dl (7 mmol/l), hypoglycemic 60 mg/dl (<3.3 mmol/l), impaired fasting glycemia 100–125 mg/dl and hyperglycemic >126 mg/dl (>7 mmol/l).

Data collection

Research assistants were trained on collection of data using pretested semi-structured questionnaires. Information was collected on seven broad items: sociodemographic characteristics, dietary pattern, physical activities, family history, fasting blood glucose, blood pressure, and anthropometric measurements of weight, height and family history of DM. Dietary habit was accessed using a 7-day food frequency questionnaire. The habit were classified as: Never: Ate the food 0 time in the past 7 days; Rarely: Ate the food 1–2 times in the past 7 days; Occasionally: Ate the food 3–4 times in the past 7 days; Frequently: Ate the food 5–7 times in the past 7 days. Physical activity was assessed by the average time spent on physical activity in the past 7 days. It was classified as: None: 0 days of Physical activity; Insufficient: 1–2 days of at least 60 min of moderate physical activity daily; Sufficient: 4 or more days of at least 60 min of moderate physical activity daily. Sedentary behaviour was measured by the average time spent on watching television (t.v) and playing video games daily. This was classified as present if participants reported more than 2 h of t.v viewing daily and absent if it was less than 2 h daily.

Anthropometric and clinical measurement

Anthropometric and blood pressure measurements were taken by investigators and research assistants who received adequate training in these procedures.

Weights were measured using a digital weighing scale: (Harson Emperor) after checking for zero error at each measurement and the reading was taken to the nearest 0.1 kg. Heights were measured with an Altimetro tape height measured to the nearest 0.5 cm with the subjects barefoot or with socks, standing erect with heels together and looking straight ahead; two measurements were required in order to reduce error and therefore obtain a more accurate calculation of BMI. The BMI for age was calculated by imputing the necessary information into WHO Anthro plus software version 1.0.4. WHO Anthro plus is a World Health Organization software for personal computers; it was developed to monitor the growth of school-age children and adolescents. Three indicators that are included in Anthro plus are weight-for-age, height-for-age and BMI-for-age. Blood pressure (BP) measurements were taken by using a digital sphygmomanometer (Omron). Three BP readings were obtained at a 5-min interval between readings, and the mean was recorded as the subject's blood pressure reading.

Statistical analysis

The dependent variables were prediabetic status (categorized into two groups) and mean FBS. The explanatory variables were sociodemographic and lifestyle characteristics and the cardiometabolic parameters. Frequency tables were used to present relevant variables. Quantitative variables were summarized with means and standard deviation while categorical variables were summarized with proportions and percentages.

The overall prevalence of prediabetes as well as age and sex-specific prevalences were determined. Univariate logistic regression analyses were used to determine the factors associated with prediabetes odds ratios and 95 % CI were also presented. Mean differences and 95 % CI in the mean FBS by patient characteristics were compared using independent *t* test or one-way ANOVA as appropriate.

Results

Characteristics of the adolescents (Table 1)

The mean age of study participants was 14.6 ± 1.54 years and 46.4 % were males, 63.9 % were Christians and above 60 % of both parents had post-secondary education—father (65.3 %) and mother (61.3 %). Majority were of Yoruba ethnic group (81.0 %) and came from small family size, i.e. having less than four children (81.2 %). Two thirds attended private schools.

According to their lifestyle characteristics, about a third reported frequent consumption of fruits (27.2 %), 20.0 % took carbonated soda drinks more than five times a week, 31.0 % reported insufficient physical activity, 39.4 % walked to school daily and 71.8 % walked back from school daily. On average, the weight (52.4 ± 10.1), height (1.72 ± 0.09), SBP (116.6 ± 13), SBP (63.9 ± 13.2) and mean BMI for age (17.6 ± 2.95).

Prevalence of prediabetes (Table 2)

There was one self-reported case of diabetes which was excluded from the analysis. The overall prevalence of prediabetes among the adolescents was 4.0 % 95 % CI (2.2–5.7) with a higher sex-specific rate among males 4.5 % 95 % CI (1.7–7.2) compared to females 3.5 % 95 % CI (1.2–5.8). The prevalence was also higher in the older age category.

Factors associated with prediabetes

Table 3 presents the unadjusted odds ratios and 95 % confidence intervals of factors associated with prediabetes. Females (OR = 0.77; 95 % CI 0.31–1.93; $p = 0.58$), respondents with sufficient physical activity (OR = 0.97: 95 % CI 0.77–9.0: p = 0.96) and those who reported frequent intake of fruits (OR = 0.8; 95 % CI 0.46–3.30 $p = 0.66$) had a reduced risk of having prediabetes.

On the other hand, adolescents attending private schools were more than 2 times more likely to have prediabetes compared with those in public school. (OR = 2.58; 95 % CI 0.77–9.0; $p = 0.15$). Similarly, those who consumed carbonated drinks frequently had 45 % increased risk compared with those who did not (OR = 1.45; 95 % CI 0.51–4.16; $p = 0.48$). Having elevated blood pressure (OR = 2.04; 95 % CI 0.57–7.35; $p = 0.57$) and being overweight or obese (OR = 2.91; 95 % CI 0.38–22.3: $p = 0.30$) were associated with a higher risk of having prediabetes.

Mean differences in fasting blood glucose by adolescent characteristics (Table 4)

The mean blood glucose of the adolescent was 85.3 ± 8.2. Males had significantly higher mean fasting blood glucose (FBG) compared to females with the mean difference of 1.65:95 % CI (0.017–3.14) $p = 0.03$. Pupils who reported frequent ingestion of carbonated drinks compared with those who did not had higher FBS levels–mean difference of −2.42;95 % CI (−4.3; 5.1) $p = 0.01$.

Conversely, those in public school compared with private schools −2.64;95 % CI (−4.2;−1.06) $p = 0.01$; those who

Table 1 Characteristics of adolescents by sociodemographic and lifestyle factors in Ibadan

Characteristic	Prediabetes		Total
	Yes (19)	No (457)	
Sociodemographic factors			
Age group			
10–14	9 (3.8)	229 (96.2)	238 (50.3)
15–19	10 (4.3)	225 (95.7)	235 (49.7)
Sex			
Male	10 (4.5)	211 (96.5)	221 (46.4)
Female	9 (3.5)	246 (96.5)	255 (53.6)
Fathers' education			
Secondary and below	7 (4.8)	140 (95.2)	147 (34.6)
Post-secondary	10 (3.6)	268 (96.4)	278 (65.4)
Mothers' education			
Secondary and below	5 (2.9)	166 (97.1)	171 (38.7)
Post-secondary	11 (4.1)	260 (95.9)	271 (61.3)
Religion			
Christians	11 (3.6)	292 (96.4)	303 (63.9)
Non-Christians	8 (4.7)	163 (95.3)	171 (36.1)
Ethnicity			
Yorubas	15 (3.9)	369 (96.1)	384 (81.2)
Non-Yorubas	4 (4.5)	85 (96.5)	89 (18.5)
Number of Siblings			
<4	14 (4.1)	329 (95.9)	362 (74.5)
≥4	4 (3.3)	116 (96.7)	124 (25.5)
School type			
Public	3 (2.0)	149 (98.0)	152 (31.9)
Private	16 (4.9)	308 (95.1)	354 (68.1)
Lifestyle characteristics (diet and physical activity)			
Frequent fruits and vegetables			
>5 days per week	6 (4.72)	121 (95.2)	127 (27.2)
≤5 days per week	13 (3.83)	326 (96.1)	339 (72.8)
Frequent carbonated drinks			
>5 days per week	5 (5.5)	86 (94.5)	91 (20.0)
≤5 days per week	14 (3.8)	351 (96.2)	365 (80.0)
Physical Activity			
Insufficient	6 (4.1)	142 (95.9)	148 (31.0)
Sufficient	13 (4.0)	315 (96.0)	328 (69.0)
Walked to school daily			
Yes	5 (2.7)	181 (97.3)	186 (39.4)
No	14 (4.9)	274 (95.1)	288 (60.6)
Walked from school daily			
Yes	14 (3.80)	354 (96.2)	368 (71.8)
No	5 (4.8)	100 (95.2	105 (22.2)
Cardiometabolic parameters			
Weight (kg)	51.6 ± 7.8	52.3 ± 10.2	52.4 ± 10.1
Height (m)	1.69 ± 0.09	1.72 ± 0.10	1.72 ± 0.09
SBP	118.7 ± 10.8	116.6 ± 10.5	116.6 ± 13
DBP	65.6 ± 9.8	64.1 ± 13.2	63.9 ± 13.2
BMI	17.9 ± 2.06	17.6 ± 3.00	17.6 ± 2.95

Table 2 Prevalence and 95 % confidence intervals of prediabetes among Nigerian adolescents by age and sex

	Total	Prediabetes (%)	Normal (%)
All	476	4.0 (2.2–5.7)	96 (94.2–97.7)
Age			
10–14	473	3.8 (1.3–6.2)	96.2 (93.7–98.7)
15–19		4.3 (1.7–6.8)	95.6 (93.1–98.3)
Sex			
Male	476	4.5 (1.7–7.2)	95.4 (92.7–98.2)
Female		3.5 (1.2–5.8)	96.4 (94.1–98.7)

walked back to their homes after school every day −2.07:95 % CI (−3.55; − 0.59) $p = 0.01$ also had a significantly lower FBG.

Discussion

Diabetes mellitus and prediabetes have become an emerging public health problem among children and adolescents in developed and now in developing countries [6, 7]. Although we set out to investigate diabetes among in-school adolescents, the occurrence of diabetes was negligible (0.2 %) among the study population; hence, we investigated the prevalence and risk factors of prediabetes and the FBG pattern among in-school adolescents in Ibadan. An earlier attempt to investigate diabetes mellitus and prediabetes among secondary school students in Nigeria was conducted by Bassey and her co-workers [19] in Port-Harcourt in which students were screened using urine glucose. The prevalence of glycosuria in their study was 0.7 % which was likely to be an underestimate because of its low sensitivity. FBG is the preferred method of screening for DM which was used in our study [22]. To our knowledge, this study is likely the first to determine the prevalence of prediabetes and its risk factors among adolescents in south western, Nigeria using FBG. In spite of the fact that the traditional risk factors associated with abnormal glucose metabolism have been described, within-country studies are crucial for locally targeted public health interventions. This is because recent evidence shows that there are significant within- and across-country variations in both social and behavioural determinants of prediabetes and diabetes justifying the need for locally generated data to inform policy and interventions [23, 24].

Table 3 Risk factors of prediabetes Adolescents (crude odds ratios and 95 % confidence intervals)

Factors	Unadjusted odds ratios	95 % confidence intervals	*p* value
Age			
10–14	1.00	-	0.79
15–19	1.13	(0.44–2.84)	
Sex			
Male	1.00	-	0.58
Female	0.77	(0.31–1.93)	
School type	2.58	(0.77–9.0)	1.49
Private	1.00	-	
Public			
Physical activity			
Insufficient	1.00	-	0.96
Sufficient	0.97	(0.77–9.0)	
Frequent fruits and vegetables			
Yes	1.00	-	
No	1.24	(0.46–3.30)	0.66
Frequent carbonated drinks			
Yes	1.45	(0.51–4.16)	0.48
No	1.00	-	
BMI status			
Underweight	1.00	-	
Normal	2.26	(0.51–4.16)	0.57
Overweight	2.91	(0.38–22.3)	0.30
Blood pressure			
Normal	1.00	-	0.57
Elevated	2.04	(0.57–7.35)	

Table 4 Mean differences and 95 % confidence intervals of fasting blood glucose of adolescent characteristics

	Total	Mean FBS ± SD	Mean difference and 95 % CI	*p* value
All	476	85.3 ± 8.2 95%CI (84.6–86.1)		
Sex				
Male	476	86.2 ± 7.9	1.65 (0.17–3.14)	0.03
Female		84.6 ± 8.5		
Age				
10–14	473	85.4 ± 8.6	−0.047 (−1.45;1.54)	0.95
15–19		85.3 ± 8.0		
School type				
Public	473	83.5 ± 8.2	−2.64 (−4.2; −1.06)	0.01
Private		86.2 ± 8.2		
Physical activity				
Insufficient	476	84.9 ± 8.7	−0.68 (−2.29; 0.92)	0.40
Sufficient		85.5 ± 8.1		
Daily walk to School				
Yes	474	84.4 ± 7.3	−1.35 (−2.87; −0.17)	0.08
No		85.8 ± 8.8		
Daily walk from school				
Yes	470	84.4 ± 8.1	−2.07 (−3.55;-0.59)	0.006
No		86.5 ± 8.3		
Frequent fruits and vegetables				
>5 days per week	466	85.3 ± 8.7	−0.24 (−1.94; 1.45)	0.78
≤5 days per week		85.5 ± 8.1		
Frequent carbonated drinks				
>5 days per week	456	87.4 ± 8.3	−2.42 (−4.3; 5.1)	0.01
≤5 days per week		85.0 ± 8.1		
Skip breakfast				
Never skips	463	84.7 ± 8.6	1.29 (−0.23; −2.8)	0.096
skips		86.0 ± 8.0		
DM in first-degree relatives				
Yes	443	88.2 ± 9.8	2.83 (−1.28;6.96)	0.18
No		85.3 ± 8.2		
BMI				
Normal	463	85.6 ± 7.4		0.89
Overweight		86 ± 6.2		(F = 0.11)
Underweight		85.3 ± 8.6		
Blood pressure				
Normal	460	84.9 ± 7.8		0.167
Prehypertension		86.4 ± 8.4		(F = 1.8)
Hypertension		84.5 ± 10.9		

The overall prevalence of prediabetes was 4.0 % 95 % CI (2.2–5.7) with a higher occurrence among males compared to females. Expectedly, studies from developed countries have reported higher prevalence of diabetes and impaired blood glucose compared to developing countries [6, 25]. In the USA, Li and his colleagues [6] using the data of the National Health and Nutrition Examination Survey 2005–2006, estimated a national prevalence of prediabetes as 16 % among the US adolescents. Earlier studies which investigated prediabetes were restricted to obese adolescents because of their increased risk for prediabetes. Shina et al. in the New England Journal [9] reported a 21 % prevalence of impaired glucose tolerance among adolescents attending an obesity clinic in the USA. Generally, there is a paucity of data on prediabetes among adolescents although studies have begun to emerge even in developing countries. For example, an Indian study that estimated the prevalence of prediabetes among school-going children, reported a prevalence of 3.7 % which is similar to our finding [12].

The risk factors of prediabetes investigated in this study were sex, physical activity level, diet which was assessed by the consumption of fruits and vegetables and regular intake of carbonated drinks, BMI status and blood pressure. Notably, none of these risk factors was found to be statistically significant. Likewise, the Indian researchers also did not observe any statistically significant association with major risk factors of diabetes (18). However, this does not preclude the clinical or public health relevance of the findings. The awareness of the relevant risk factors of prediabetes, a reversible condition, for a particular population is crucial for implementing necessary interventions. Gilles et al. [26] in a systematic review that evaluated interventions to delay or prevent T2DM in individuals with prediabetes, noted that lifestyle and drug interventions reduced the rate of progression to T2DM in persons with impaired glucose tolerance. Moreover, lifestyle interventions like weight reduction was as effective as drug treatment [26].

The rise in the occurrence of T2DM and its precursor prediabetes in the paediatric age group has been strongly linked to childhood obesity epidemic in the developed countries. Earlier studies were conducted among obese children who were most at risk [27]. In this study, there was a graduated increase in the odds of having prediabetes from normal (OR = 2.26) and overweight/obese (OR = 2.91) compared with those who were underweight. Researchers have noted that severe obesity has a prominent role in the pathogenesis of T2DM in children and adolescents [15, 28]. Ordinarily, the pathophysiology of DM which leads to abnormalities in glucose metabolism is underlined by changes in the sensitivity and secretion of insulin which changes are increased with obesity. From a practical standpoint, intervention that promote lifestyle changes like healthy diet and physical activity are also crucial in the control of T2DM and prediabetes.

Healthy diet, though a very broad concept, was measured by the frequent consumption of fruits and vegetables in this study, and one in every four adolescents reported the frequent consumption of fruits and vegetables; the practise led to a 20 % reduction in the risk of prediabetes. Carter et al. [28] in a study carried out to investigate the independent effects of intake of fruit and vegetables on incidence of type 2 diabetes reported that the greater intake of green leafy vegetables was associated with a 14 % reduction in risk of type 2 diabetes.

On the other hand, the frequent ingestion of carbonated drinks (CD) was associated with a higher likelihood of having prediabetes (OR = 1.45) and a higher fasting blood glucose levels on average compared with those who took these drinks less frequently. Carbonated drinks commonly called soft drinks or glucose-sweetened beverages are consumed all over the world but probably more commonly among children and adolescents. In our study, 20 % of the adolescents reported a regular consumption of these drinks, a proportion much lower compared to what obtains in the developed world. Harnack et al. [29] reported that 70% of adolescents in the UK consumes soft drinks on a regular basis. Carbonated drinks have high glycaemic index and are energy dense because they have a high content of free glucose, and a regular consumption will result in a positive energy balance. Recently, carbonated drinks have been implicated in a number of health conditions, namely obesity- and weight-related issues (importantly, obesity epidemic among children in the developed countries), tooth decay and osteoporosis. Mozaffarri and her colleagues [30] from the Harvard School of Public Health using data from the 2010 Global Disease burden estimated that 180,000 deaths annually are attributed to the regular consumption of glucose-sweetened beverages which deaths were linked to diabetes, cardiovascular diseases and cancers. Very few studies have investigated their association with diabetes or prediabetes in children or adolescents [31, 32]. WHO recommends that free glucoses should not be more than 10 % of daily energy intake [33]. James et al. [27] in their clustered randomized controlled trial aimed at reducing the consumption of carbonated drinks among 644 children aged 7–11 years in six primary schools in South England reported that school based educational programmes that discouraged CD led to the reduction in overweight and obesity among school children for that year. The implication of this is that the school can provide an effective platform for the control of the risk factors.

In our study, attending a private school was positively associated with prediabetes (OR = 2.58) they also had a higher levels of fasting blood glucose on average compared with adolescents who attended public schools. The plausible explanation for this difference is the variation in their socioeconomic status. In our study, the pupils who attended private secondary schools belonged to a higher socioeconomic class compared to those that attended public schools because a greater proportion of their parents had higher levels of education, had higher paying jobs (civil servants or professional), lived in privately owned apartment, had washing machines and personal cars compared to the children that attended public schools (data not shown). Due to their higher socioeconomic status these children indulge in lifestyles that increase their risk of prediabetes. Importantly sedentary behaviour like being driven to school unlike students in public schools students who do not have the luxury but instead have to walk to and from school. They have access to motorised equipment such as washing machine and spend their leisure time sitting and watching television and playing video games. Several studies have shown that the prevalence of the metabolic syndrome significantly increases with high socioeconomic status in both developing and developed countries [34–36]. Similarly, a cross-sectional study conducted among 693 high school students in Vietnam (Nguyen et al. [37]), reported a positive association between metabolic syndrome and high socioeconomic status. These students came from wealthy families and were reportedly less physically active because their parents usually provide them with “modern” life, which included recreational facilities such as televisions, computers, an undue reliance on automated household devices like washing machines and the availability of domestic servants, all of which reduced the level of physical activity. Besides, wealthier families are more likely to be able to provide abundant food including energy-dense foods and drinks [37].

Our study had certain limitations, the most important being the low yield of the study outcome among the study population, meaning that a larger sample is required to more accurately examine the relationship between the risk factors of prediabetes among Nigerian in-school adolescents. For the same reason, multivariate analysis could not be done to adjust for co-variates and confounders; hence, the unadjusted odds ratios presented might have underestimated or overestimated the strength of association. Also, the use of a cross section study design precluded the examination of causal relationships. Even though a number of risk factors were explored, they were not exhaustive; for example, the history of gestational diabetes in their mothers and their birth weight were not investigated. Lastly, the self-reported information on dietary intake and physical activity were likely to have been subject to some bias.

But more importantly, our study has important policy implications for the prevention and control of prediabetes and diabetes among adolescents within the formal school setting. The World Health Organization promotes school health programmes as a strategic means to prevent health risk in school-based children particularly the prevention of the factors that lead to premature death, disease and disability. Diabetes being a preventable and chronic debilitating illness is associatedwith life-threatening complications, which have worse outcomes when they begin early. Therefore, our study can inform public health interventions like creating awareness on diabetes, influencing the built environment and promoting physical activities etc.

In conclusion, the prevalence of prediabetes among the study population was low and the sex-specific prevalence rate was higher among males compared to females. Notably, the determinants that drive the occurrence of prediabetes like insufficient physical activity and frequent consumption of carbonated drinks were prevalent among the study population. Pupils attending private schools on average had higher fasting blood glucose levels than those in public schools. Implying that apart from the individual characteristics of the pupils who attend private schools, further research needs to explore the built environment of secondary schools especially private schools and how they can be adjusted to prevent non-communicable diseases among adolescents.

Compliance with ethical standards

Funding This study was self-sponsored, i.e.no form of external funding was received for this study which was conducted by OA under the supervision of IA and OY, in partial fulfilment of the award of a Master's degree in Epidemiology at the College of Medicine University of Ibadan.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standard All procedures performed in the study were approved by the Oyo State Ethical Review Committee of the Oyo State Ministry of Health. Permission to carry out the study was obtained from the Oyo State Ministry of Education and the authorities of each of the selected school. Informed consent was obtained from the parents/guardian while the study participants gave their assent before data collection commenced.

Authors' contributions Conception of research idea was conducted by OA, IA, OJ. OA and IA designed the study. AO conducted the study under the supervision of IA and OY. OA and IA analysed the data and wrote the draught of the manuscript. IA, OJ and OY reviewed and critically revised the manuscript. All authors read and approved the final manuscript. IA finalised the manuscript.

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