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Study protocol

Sugar-Sweetened Beverages Consumption among Adolescents in Nigeria (SURRENDER): Research Plan and Procedures of Mixed-Method Survey

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Summary: Sugar-sweetened beverage (SSB) consumption has been estimated to be the highest in sub-Saharan Africa, with a significant impact on the increasing burden of diet-related non-communicable diseases among adolescents. This manuscript highlights the research plan and procedures for SSB consumption among adolescents in Nigeria (SURRENDER), a survey designed to assess the magnitude and patterns of sweetened beverages (SSB) consumption with its associated factors and the potential association with cardiometabolic risk factors, including obesity, high blood pressure and elevated blood sugar, among in-school adolescents in Nigeria. The SURRENDER study surveyed in-school adolescents (males and females, aged 10–19 years) from secondary schools across three main cities: Abuja, Ikeja, and Ibadan, Nigeria. Participant enrollment, including questionnaire administration, physical examination and blood specimen collection, started in 2023, using the World Health Organization's STEPS Instrument for Chronic Disease Risk Factor Surveillance for data collection. Data were collected on sociodemographics, parent and family characteristics, lifestyle factors, food access and dietary diversity, SSB consumption, physical and sedentary activity, school environment, anthropometric measurements (including weight in kilograms, height and mid-upper arm circumference in centimetres) and blood pressure assessment (including systolic and diastolic blood pressure and pulse rate) and blood glucose measurements by trained personnel in keeping with standing protocol, procedures and tools. A total of 1,699 (females – 58.6%) were recruited (29.4% - Abuja, 29.4% - Ikeja and 41.1% - Ibadan) with a 74.9% response rate and focused group discussions are underway to understand the etiological basis for perceptions, attitudes, and environmental drivers of dietary SSB consumption among adolescents. The SURRENDER would be promising, as it would provide evidence-based and innovative data that would ultimately inform the design of public health guidelines, advisories, and policy initiatives to support strong adolescent health in Nigeria and can be extrapolated for guidance in other African countries.

Keywords: *SURRENDER; Adolescent health; Obesity; Hypertension; Diabetes; Chronic diseases; Africa.*

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INTRODUCTION

Sugar-sweetened beverages (SSB), defined as carbonated or non-carbonated drinks containing added sugars, have become the primary source of added sugar in many diets (Malik *et al*., 2006). There has been a significant increase in consumption levels, especially among teenagers and young adults, as well as notable increases in low- and middle-income countries (LMIC) (Lara-Castor *et al*., 2023). SSB consumption provides trifling nutritional benefits, promoting less satiety than healthier diets, large volume consumption, and reduced intake of balanced diet (Popkin and Hawkes, 2016). All these factors have been linked to increased energy intake and a significant contribution to weight gain (Malik *et al*., 2006) and diet-related non-communicable diseases (NCDs) (Malik *et al*., 2010), with solid evidence suggesting causal etiologies for cardiometabolic diseases worldwide (Malik and Hu, 2022).

Several reports have documented SSB consumption trends and influences on cardiometabolic risk factors from different world regions. For example, the Global Dietary Database reported a mean global SSB intake of 2.7 servings (equivalent to 8 oz, or 248 grams) per week among adults worldwide (Lara-Castor *et al*., 2023). Similarly, the Centre for Disease Control of the United States (US) revealed that SSBs are the foremost source of added sugars in the

American diet, with five in every ten adults drinking SSB daily and an average of 145 calories per day attributable to SSB between 2011 and 2014 (Rosinger *et al*., 2017a). The situation is no different in Europe, where 12% of men and 7% of women consume sugar-sweetened soft drinks daily (Eurostat, 2021). Despite the enormous stakes and the potential public health risk portended by SSB, minimal studies are available on the trend and consumption of SSB in LMICs, especially in sub-Saharan Africa (SSA).

In addition, the excessive consumption of refined sugars, especially from SSB, promotes neurobehavioral alterations (Burger, 2017; Jacques *et al*., 2019) that interrupt the encephalon reward network by impairing food signalling systems, leading to obsessive consumption (Falbe *et al*., 2019) or satiety manipulation (Shearrer *et al*., 2016), with a significant impact on obesity and NCD manifestations (Audain *et al*., 2019; Yin *et al*., 2021; Malik and Hu, 2022). Consequently, it is worthwhile to discern the pattern of SSB consumption among adolescents in SSA as a potential resource for designing appropriate interventions. Furthermore, the SSB consumption trend among adolescents has been documented to be on the increase among adolescents globally, in Europe (Eurostat, 2021; Chatelan *et al*., 2023), Australia (Clifton *et al*., 2011), and the US (Rosinger *et al*., 2017b) with little information on this phenomenon, especially among adolescents from SSA. A similar effort in Burkina Faso and Kenya recently demonstrated that half of 3759 women of reproductive age reported SSB consumption without articulating relevant information for adolescents (Semagn *et al*., 2023). Similarly, a nationally representative study of 74,055 in-school adolescents aged 12 to 15 years from eighteen predominantly LMIC fell short of evidence on the trend of SSB consumption in SSA (Smith *et al*., 2024). Nigeria, which is the most populous black nation worldwide, is not exempted from this issue, as data on SSB consumption and the associated factors are scarce, thereby making it tedious to support healthcare systems in SSA with critical information in addressing nutrition policy and public health practice to improve its preparedness in addressing the snowballing burden of NCDs (Gouda *et al*., 2019).

Furthermore, recent global estimates suggest that populations from SSA currently experience the most significant increase in SSB consumption (Lara-Castor *et al*., 2023). However, there is limited information on the proximal and distal factors associated with SSB consumption, particularly among adolescents. Studies aimed at identifying the magnitude and characteristics associated with SSB consumption among adolescents would be a worthwhile investment, providing vital information to help adolescents transition into healthy adulthood and contribute to the development of a healthy workforce. This information is critical for preventing the potential negative impact of SSB consumption not only in adolescents but also in later adulthood. The food environment is crucial in informing dietary behaviour (Kelly *et al*., 2019), especially for younger populations, including adolescents, who are vulnerable to advertising and marketing pressures that could manipulate their dietary choices (Harris and Graff, 2011) to naively inform dietary lifestyle practices that could potentially lead to adverse health outcomes that could impair functionality and promote disability in later adulthood. To this effect, the necessity of assessing the significance of SSB consumption, its associated factors and its impact on cardiometabolic health outcomes among adolescents cannot be overemphasized in strengthening stakeholders' efforts (such as government, donor agencies, and public health practitioners, among others) in improving health system quality service delivery for the struggling healthcare systems in SSA which simultaneously grapples under the dual burden of infectious and NCDs.

Additionally, the Sugar-Sweetened Beverage Consumption among Adolescents in Nigeria (SURRENDER) study is a home-grown research effort for in-school adolescents, primarily aimed at achieving three main goals. First, to examine the trends and factors associated with SSB consumption. Second, to determine the potential association of SSB with the prevalence of cardiometabolic risk factors, including obesity, high blood pressure, and high blood glucose. Third, to quantify the magnitude of cardiometabolic risk factors, offer information and promote evidence-based public health guidelines, advisories, and policy initiatives that support adolescent health.

MATERIALS AND METHODS

Project Organization: Study investigators for the SURRENDER study were professionals with diverse educational backgrounds (in medicine, medical laboratory science, pharmaceutical science, biostatistics, and nutrition) and research training in epidemiology, maternal, child, and adolescent health. The study also employed research assistants, volunteer interviewers, and data clerks who were fluent in English and specific local languages to facilitate smooth communication with the participants and minimize language barriers. Additionally, the technical staff reviewed data collection, entry, and administration for consistency and accuracy. All research staff were accountable to the study investigators across study sites, and the principal investigator coordinated the study's administration.

Study Design: The SURRENDER study was a multicenter, cross-sectional study that collected data among in-school adolescents from private and public schools across three major cities in Nigeria: Abuja, Ikeja, and Ibadan, using predefined inclusion and exclusion criteria. The Ethics Review Committee approved the study across study sites. In Abuja, the National Health Research Ethics Committee of Nigeria, located at the Federal Ministry of Health, Abuja, Nigeria, approved the study (Approval number: NHREC/01/01/2007-02/05/2023). In Ikeja, the Institutional Review Board of the National Institute of Medical Research, Lagos State, Nigeria, approved the study (Project number: IRB/23/017). In Ibadan, the Research Ethics Review Committee of the Ministry of Health, Oyo State Government, Nigeria, approved the study (NREC Assigned number: NHREC/OYOSHRIEC/10/11/22). All interviews and data sampling were conducted during school hours after permission from the school principal. Informed consent was obtained prior to participation, following receipt of a signed explanatory note and informed consent that was shared with parents or guardians to explain the study's purpose and assent from eligible in-school adolescents.

Specific Aims and Hypotheses: The SURRENDER study has three main aims and underlying hypotheses. First, the

trends and factors associated with SSB consumption among in-school adolescents will be explored. Second, to determine the potential association of SSB consumption with the prevalence of cardiometabolic risk factors, including obesity, high blood pressure and high blood glucose among in-school adolescents. Third, to quantify the magnitude of cardiometabolic risk factors and the qualitative and quantitative contributions of sociodemographic factors, lifestyle habits, and sedentary behaviors in a sample of in-school adolescents in Nigeria. The critical premise guiding these aims hypothesizes that the distribution of the risk factors, including SSB consumption, will likely modify the undercurrents and magnitude of cardiometabolic risk factors among in-school adolescents from diverse backgrounds in Nigeria. We hypothesize that differences in the SBB consumption trends and risk factors may explain changes in cardiometabolic risk factors among in-school adolescents in Nigeria. The central idea behind this objective is to obtain reliable phenotypic data, including SSB consumption, to assess cardiometabolic risk factors among in-school adolescents in Nigeria. Additionally, chronic exposure to these risk factors may alter the vasculature, influencing the assessment of the magnitude and burden of cardiometabolic risk factors among in-school adolescents.

The cross-sectional recruitment of in-school adolescents (including males and females) from diverse school settings in Abuja, Ikeja, and Ibadan, Nigeria, has been completed (Fig. 1). Furthermore, focus group discussions and key informant interviews were conducted to clarify the knowledge, perception, and beliefs of in-school adolescents about voluntary participation in research, SSB consumption, cardiometabolic risk, with potential traditional risk factors. The premise for these objectives stems from the need to promote viable research for designing evidence-based public health interventions, guidelines, advisories, and policy initiatives for promoting strong cardiometabolic health among adolescents.

Study Location: Enrollment and data collection for this study took place across three study sites (Figure 1), including Abuja, Ikeja, and Ibadan, Nigeria, due to the rich multicultural diversity and diverse demographic and socioeconomic backgrounds representative of Nigeria's multi-ethnic and multicultural populace.

Abuja – FCT: The FCT – Abuja is the eighth most populous city in Nigeria, located on longitude 6° 45" and 7° 45" East of the Greenwich Meridian and latitude 8°35′ and 9° 25′ North of the equator, with a land area of about 8,000km^2, managed across six (6) area councils with a total population of 776,298 according to the 2005 population census (Ola Balogun and Balogun, 2001; National Population Commission, 2006). The Abuja Municipal Area Council was purposively selected for this study, as it serves as the administrative and commercial hub of the FCT in Abuja. Furthermore, thirteen (four private and nine public) schools were randomly selected from the entire sample frame of three hundred and seven (307) registered secondary schools in the Abuja municipal area council for participant recruitment.

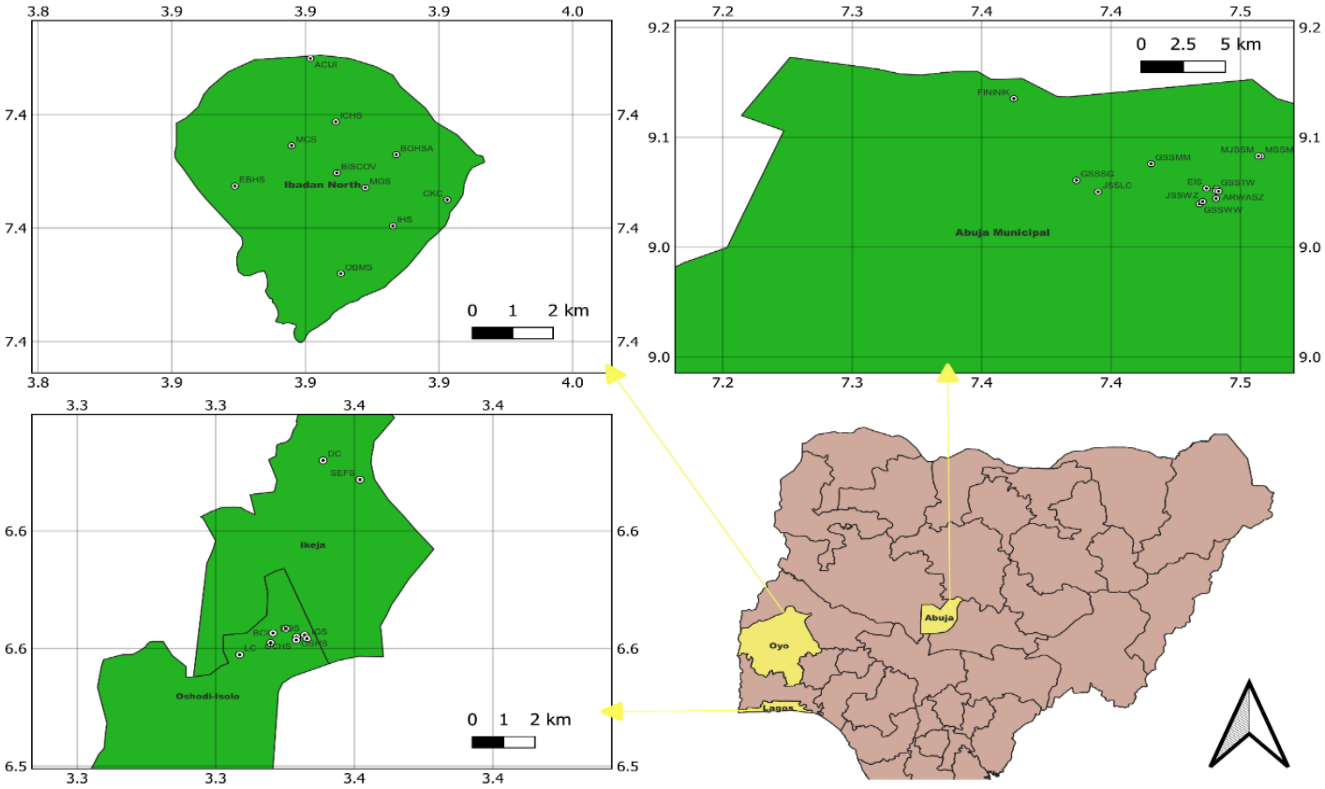

Figure 1:
Sampling locations for the SURRENDER study in Abuja, Ikeja and Ibadan, Nigeria

Ikeja – Lagos State: Lagos is the core economic hub of Nigeria, located on longitude 2° 42′–4° 20′ East of the Greenwich Meridian and latitude 6° 22′–6° 42′ North of the equator, with an enormously diverse population of about 8,048,430 according to the 2006 census and administratively governed across twenty (20) local government areas – LGA (YO Balogun *et al*., 1999; National Population Commission, 2006). Oshodi-Isolo LGA was purposively selected from the sampling frame of LGAs in Lagos, Nigeria, based on its administrative significance and the diversity of its population, which provides wide-ranging information on socioeconomic, demographic, and health outcomes. Ten (10 – five private and five public) schools were randomly selected from the entire sample frame of one hundred and six (106) registered secondary schools in Oshodi-Isolo LGA for participant recruitment. Furthermore, two schools declined to participate, and two additional schools were purposively selected from Ikeja LGA next to Oshodi-Isolo LGA.

Ibadan – Oyo State: Ibadan is one of the largest metropolitan cities in Nigeria, located at longitude 3°5′ East of the Greenwich Meridian and latitude 7°2′ North of the equator, with eleven (11) local governments (Okekunle *et al*., 2015) and a population well-known for its unique accretion of people from diverse socioeconomic and cultural backgrounds representative of the Nigerian population (Fabiyi, 2004). The Ibadan North LGA was purposively selected from the sampling frame of LGAs in Oyo State, Nigeria, given that it harbours the highest number of educational institutions and is currently the central hub of commercial activities in Ibadan, Nigeria. Also, ten (10 – five private and five public) schools were randomly selected from the entire sample frame of one hundred and eight (108) registered secondary schools in Ibadan North LGA for participant recruitment.

Sample size estimation and power validation: The sample size was estimated per study site using 80% power and a two-sided 95% confidence level. With a 24.2% prevalence of daily SSB consumption among adolescents from Sagamu, Nigeria (Sholeye *et al*., 2018), a 50% R-squared, and a 10% non-response rate, a minimum sample size of n = 463 (approximated to 480) per study site was needed to detect an odds ratio ≥1.50 for SSB association with cardiometabolic risk factors in the study being guided by a technique by the World Health Organization (Lwanga *et al*., 1991). The sample size was proportionately assigned to the selected schools based on the projected in-school adolescent population.

Sampling Technique: The eligible participants for this study were in-school adolescents selected from public and private secondary schools across study sites through multistage sampling techniques. The schools were randomly selected from a sampling frame of private and public schools in each study site, specifically from a selected LGA or area council. In-school adolescents were recruited from a total of thirty-three secondary schools, including ten (four private and nine public) in Abuja, ten (five private and five public) in Ikeja, and ten (five private and five public) in Ibadan, Nigeria.

Abuja – Federal Capital Territory: In Abuja, the Abuja Municipal Area Council was purposively selected for this study, and thirteen (four private and nine public) schools were randomly selected from the sampling frame of registered secondary schools (13/307; 4.2%) in the area council, intending to recruit nine hundred and thirty-nine (939) participants each across selected private schools and public schools. In the third step at each selected school, eligible adolescents were proportionately selected from a sampling frame of adolescents by class (excluding those in the examination class at junior and senior secondary schools). The first participant per class was randomly selected, and subsequent participants were selected using the kth term based on the sampling frame to ensure the sampling of seventy-two (72) participants per school.

Ikeja – Lagos State: Oshodi-Isolo LGA was purposively selected in Ikeja, and eight (four private and four public) and an additional two (from Ikeja LGA) schools were randomly selected from the sampling frame of registered secondary schools (10/106; 9.4%) in the LGA, intending to recruit three hundred (300) participants each across all private schools and public schools selected. In the third step at each selected school, eligible adolescents were proportionately selected from a sampling frame of adolescents by class (excluding those in the examination class at junior and senior secondary schools). The first participant per class was randomly selected, and subsequent participants were selected using the kth term based on the sampling frame to ensure that sixty (60) adolescents were sampled per school, achieving a total of five hundred eighty (580) participants.

Ibadan – Oyo State: Ibadan North LGA was purposively selected in Ibadan, and ten (five private and five public) schools were randomly selected from the sampling frame of registered secondary schools (10/108; 9.3%) in the LGA. In the third step at each selected school, eligible adolescents were proportionately selected from a sampling frame of adolescents by class (excluding those in the examination class at junior and senior secondary schools). The first participant per class was randomly selected, and subsequent participants were selected using the k^{th} term based on the sampling frame to ensure that seventy-five (75) adolescents were sampled per school, thereby achieving a sampling target of seven hundred and fifty (750) participants.

Inclusion and Exclusion Criteria: Participants were selected from in-school adolescents (aged ≥10 years) enrolled in one of the schools chosen at the time of the study will be/were recruited. To participate in the study, in-school adolescents must be between 10 and 19 years old on their last birthday, enrolled in the school for at least the last six months preceding the survey, and apparently healthy with signed informed consent from their parents or guardians before participating. In-school adolescents were excluded from the study based on the following criteria: being over 19 years old, being unhealthy, currently preparing for or taking a test or examination, lacking informed consent from a parent or guardian, and declining interest in the study.

Recruitment: Participant recruitment began with a detailed presentation of the study's aims to the school principals, who granted access to allow participants to indicate their interest

in the study. An eligible in-school adolescent who indicated interest and assented to participate was provided with informed consent, signed by the parent or guardian, approving their participation. Participants without signed informed consent from the parent or guardian were not allowed to participate in the survey.

Data Collection: Data collection consists of three parts: completing the questionnaire, taking physical measurements (including anthropometric and blood pressure assessments), and conducting biochemical assessments (Table 1). Trained research personnel guided in-school adolescents in filling out the questionnaire privately, with the opportunity to withdraw from the recruitment at any time without suffering any harm or consequences. Furthermore, physical examinations, including anthropometric measurements and blood pressure checks, were conducted following standard protocol, and blood draws were performed by a trained phlebotomist.

Table 1
Overview Variables and Measurements in the SURRENDER study

Date/Information	Variable or instrument for data collection	Study sites		
		Abuja	Ikeja	Ibadan
Survey Information	Questionnaire			
	School name	○	○	○
	Area of Residence	○	○	○
	Type of Residence	○	○	○
	Parental consent	○	○	○
Demographic Characteristics	Questionnaire			
	Sex	○	○	○
	Date of birth	○	○	○
	Age	○	○	○
	Type of school	○	○	○
	Current School Class	○	○	○
Family Characteristics	Questionnaires			
	Living with who?	○	○	○
	Parents' marital status	○	○	○
	Number of siblings	○	○	○
	Household size	○	○	○
Parents' Demographic Characteristics	Questionnaires			
	Father's characteristics	○	○	○
	Mother's characteristics	○	○	○
School Environment	Questionnaires			
	Presence of convenience stores, including snacks and soft drinks stores within school premises	○	○	○
	Presence of sporting or recreational facilities within the school premises	○	○	○
Nutrition Knowledge of SSB	Knowledge Questionnaire			
	SSBs are high in sugars	○	○	○
	High levels of SSB consumption contribute to dental caries/tooth decay	○	○	○
	High levels of SSB consumption contribute to overweight.	○	○	○
	High levels of SSB consumption contribute to diabetes.	○	○	○
SSB Beverage Consumption Pattern	Adapted Beverage Intake Questionnaire (BEVQ)	○	○	○
Physical Activity	Physical Activity Questionnaire for Older Children and Adolescents	○	○	○
Screen Time Assessment	Questionnaires	○	○	○
Dietary Diversity	Dietary Diversity Scale	○	○	○
Anthropometric measurements	Weighing Scale and Stadiometer			
	Weight (kg)	○	○	○
	Height (cm)	○	○	○
	Mid-upper arm Circumference (cm)	○	○	○
	Waist circumference (cm)	○	○	○
Blood pressure measurements	Electronic Blood Pressure			
	Systolic blood pressure (mmHg)	×	○	×
	Diastolic blood pressure (mmHg)	×	○	×
	Pulse (beats/minutes)	×	○	×
Blood Glucose measurements	Blood Glucometer			
	Blood Glucose (*m*mol/*l*)	○	×	×
	Family History of Diabetes Mellitus	○	×	×

SSB: Sugar-Sweetened Beverages

○: The information was collected at the study site.

×: The information was not collected at the study site.

Questionnaire: Standard pretested questionnaires were self-administered by participants under the guidance of trained personnel to collect information on sociodemographic, socioeconomic, family and parent characteristics. Furthermore, using standardized instruments, participants provided information on nutrition knowledge, school environment, physical activity (Kowalski *et al*., 2004), screen time, and diversity (Food and Technical Assistance (FANTA) III, 2006).

Anthropometric measurements: First, non-stretchable tape was applied to measure participants' mid-upper arm circumference (MUAC), height, and waist circumference to the nearest 0.1 cm. The MUAC was measured at the midpoint between the tip of the shoulder and the elbow tip (olecranon process and the acromium) of the right upper arm (World Health Organization, 2007). Height was measured while participants stood using a stadiometer (wall height chart). Waist circumference was measured at the midpoint, between the lower border of the rib cage and the iliac crest. Also, the weight of participants was taken while participants were in school uniform without wearing shoes using a digital body weighing scale using Gromy (model: PS-2003A, Gromy Scale Co., Ltd) (Scale, 2008) in Abuja, CAMRY (model: EB9015, Camry Electronic Ltd) (SCALES, 2023) in Ikeja and OMRON (model: HN289) (Healthcare, 2024b) in Ibadan. All anthropometric measurements were taken twice by trained personnel, following the standard protocol (WHO, 2020).

Blood pressure measurements: In keeping with standard protocol (Unger *et al*., 2020), participants' blood pressure, including systolic, diastolic, and pulse rates, were measured three times in a sitting position at a 5-minute interval while they were in a resting position using the blood pressure monitors (OMRON M1 Basic, model: HEM-7121J-AF) (Healthcare, 2024a).

Fasting Blood sample collection: A trained phlebotomist used a blood glucometer (Accu-Chek Active, Model GU, Roche Diabetes Care Middle East FZCO) (Roche, 2024) to check participants' blood glucose levels. The participant's index finger was pricked with a needle at the tip. The second or third drop of blood was carefully placed on the green field of the glucometers' strips. The blood glucose results in mmol/L, as displayed on the digital blood glucometer, were recorded according to the standard protocol (S. Karon *et al*., 2008; Singh *et al*., 2019; Roche, 2024).

Focused Group Discussion: In discerning the etiological basis for perceptions, attitudes, and environmental drivers of dietary SSB consumption among adolescents, the study plans to conduct focused group discussions (FGD) in at least two schools (preferably with the highest response rate in private and public schools) per study site using non-probability sampling methods (Hennink and Leavy, 2014). The study investigators would develop an FGD protocol to gather information from participants with sound knowledge of SSB consumption among adolescents through open discussions. Each FGD session will last approximately 60-90 minutes and will be conducted in a neutral, calm and safe environment to ensure autonomy of thought, impartiality and honesty in the discussion by trained personnel using probing questions to elicit accurate information on the aims and study questions. All conversations will be recorded using an audio recorder, transcribed and independently examined before analysis to guarantee accurate transcription of responses. The transcribed data will be analysed using both thematic and content analysis to identify central themes and patterns. All identified themes will then be interpreted and discussed in the context of the study's aims and research questions. All qualitative coding and analysis would be carried out using the Atlas—ti Web version (ATLAS.ti Scientific Software Development GmbH., 2023).

Participant feedback and referral: Generally, health education, including nutrition advisories and information on healthy lifestyles, was provided to all participants. However, parents of participants with arbitrarily high blood pressure or glucose levels were counselled and advised to check with trained physicians for appropriate check-ups, medical diagnoses and intervention.

Quality control, Data management and Statistical analysis: A detailed review of data collection, procedures and methods was conducted to ensure consistency of data collection across study sites. Additionally, thorough data cleaning techniques were employed to ensure the high-quality analysis of data and to guarantee the reliability of the data and its findings. First, all questionnaires were in English, and trained personnel were available to translate them into the most common site-specific language and to assist participants who had a limited understanding of the English language. Second, all questionnaire questions were reviewed with participants on-site to clarify any incongruity in responses before data entry using IBM SPSS Statistics for Windows, version 25 (IBM Corporation, Armonk, NY USA). All questionnaires were stored in a safe lock accessible to the site and principal investigator after data entry. Additionally, multiple imputation procedures are planned to address data missingness, taking into account the missing data apparatus, functionality, and selection of confounders in accordance with data management principles reported elsewhere (VanderWeele, 2019). Data analysis will commence using suitable statistical methods, including suitable bivariate and multivariate statistical techniques contingent on the outcome variable of the hypothesis being tested. All statistical analyses will be performed using IBM SPSS Statistics for Windows, version 25 (IBM Corporation, Armonk, NY USA) and R statistical program (version 3.6.2) at P-value < 0.05.

RESULTS

Overall, the response rate for participants in the study was 74.9%, with rates of 53.2% in Abuja, 86.2% in Ikeja, and 93.2% in Ibadan.

A total of 1,699 in-school adolescents (29.4% from Abuja, 29.4% from Ikeja and 41.1% from Ibadan) representing 58.9% females. The distribution of response rate to each variable and instrument includes ≥97.2% for demographic information, ≥98.4% for household characteristics, and ≥99.2% for family and parent characteristics. Furthermore, the response rates for other scales and instruments, such as nutrition knowledge

(100.0%), school environment (≥98.6%), physical activity (≥96.6%), and screen time (≥67.9%), were also moderately high, as detailed in Table 2.

Sugar-sweetened beverages (SSB) were self-reported by participants, with an overall response rate for SSB was ≥ 84.0%. Physical activity had an overall response rate of at least 96.8%. The overall response rate for anthropometric measures was at least 99.4%. The response rates for blood pressure and glucose measurements were 99.2% and 100.0%, respectively, as this information was primarily assessed in Ikeja and Abuja. Details of the response rate are in Table 2.

Table 2
Response rate, n (%) of critical items and variables in the SURRENDER study

Instruments/Scale /Variable	Total		Abuja		Ikeja		Ibadan	
	Frequency (n)	% Response rate	Frequency (n)	% Response rate	Frequency (n)	% Response rate	Frequency (n)	% Response rate
Participant recruitment	1699	74.9%	500	53.2%	500	86.2%	699	93.2%
Questionnaires								
Survey Information	1332 – 1699	≥ 78.4	500	100.0	268 – 500	≥ 53.6	564 – 699	≥ 80.7
Demographic Characteristics	1652 – 1699	≥ 97.2	500	100.0	465 – 500	≥ 93.0	687 – 699	≥ 98.0
Household Characteristics	1672 – 1695	98.4 – 99.8	500	100.0	483 – 494	96.6 – 98.8	685 – 697	≥ 98.0
Parents' Demographic Characteristics								
Father's characteristics	1686 – 1699	≥ 99.2	500	100.0	497 – 500	≥ 99.4	692 – 699	≥ 99.6
Mother's characteristics	1685 – 1699	≥ 99.2	500	100.0	494 – 497	≥ 98.8	691 – 699	≥ 98.4
School Environment	1675 – 1684	≥ 98.6	500	100.0	486 – 490	≥ 97.2	689 – 694	≥ 98.6
Nutrition Knowledge of SSB	1699	100.0	500	100.0	500	100.0	699	100.0
SSB Beverage Consumption	1427 – 1699	≥ 84.0	500	100.0	205 – 500	≥ 41.1	592 – 699	≥ 84.7
Physical Activity	1644 – 1675	96.8 – 98.6	500	100.0	468 – 500	≥ 93.6	676 – 699	≥ 96.7
Screen Time Assessment	1154 – 1562	67.9 – 91.9	285 – 471	57.0 – 94.2	376 – 462	75.2 – 92.4	493 – 629	70.5 – 90.0
Dietary Diversity Scale	1690 – 1699	≥ 99.5	491 – 500	≥ 98.2	500	100.0	699	100.0
Anthropometric measurements								
Weight (kg)	1690	99.5	500	100.0	500	100.0	690	98.7
Height (cm)	1689	99.4	500	100.0	499	99.8	690	98.7
Mid-upper arm Circumference (cm)	1683	99.1	500	100.0	494	98.8	689	98.6
Waist circumference (cm)	1679	98.8	500	100.0	493	98.6	686	98.1
Blood pressure measurements								
Systolic blood pressure (mmHg)	496	99.2	0	0.0	496	99.2	0	0.0
Diastolic blood pressure (mmHg)	496	99.2	0	0.0	496	99.2	0	0.0
Pulse (beats/minutes)	314	62.8	0	0.0	314	62.8	0	0.0
Blood Glucose								
Blood Glucose (*m*mol/*l*)	500	100.0	500	100.0	0	0.0	0	0.0
Family History of Diabetes Mellitus	500	100.0	500	100.0	0	0.0	0	0.0

SURRENDER: **Su**ga**r**-Sweetened Bever**a**g**e**s Co**n**sumption among A**d**ol**e**scents in Nige**r**ia; SSB: Sugar-sweetened beverages

DISCUSSION

Higher SSB consumption has been linked with poor cardiometabolic health (Lara-Castor *et al*., 2023), and the case for the impact of SSB on cardiometabolic health among adolescents in higher-income settings (Clifton *et al*., 2011; Rosinger *et al*., 2017b; Chatelan *et al*., 2023) has been well documented, with little information on adolescents from low- and middle-income countries like Nigeria. This lack of viable information is a considerable setback for understanding the magnitude and potential drivers of SSB consumption, with poor insights into the likely underlying impact on the cardiometabolic well-being and related complications to help deploy fiscal resources to support preventative interventions and clinical management of the increasingly elusive burden and implications of SSB consumption among adolescents in low- and middle-income countries.

The SURRENDER study will deliver relevant and critical information on SSB consumption and its impact on cardiometabolic risk factors, including obesity, high blood pressure and elevated blood sugar, among in-school adolescents. Similarly, it will provide unique insights into the proximal and distal drivers of cardiometabolic health among adolescents, thereby offering opportunities to draw informed conclusions about the magnitude of SSB consumption and its impact on the cardiometabolic well-being of adolescents. These findings will support healthcare providers and health policy stakeholders with information vital for guiding the distribution of resources and efforts to improve cardiometabolic health among adolescents in Nigeria and, by extension, in low and middle-income countries.

There are some limitations in the design, execution and preliminary findings. First, this is a cross-sectional study, and causal associations cannot be inferred from the results. However, the study is potentially promising, providing critical information to guide fiscal budgeting for addressing adolescent health, especially in a low and middle-income country like Nigeria, where budgetary provision for health is meagre and consideration for adolescent health is non-existent. Secondly, misclassification bias is likely, especially with self-reported information on some sections of the instruments for data collection. Still, the meticulous efforts to thoroughly review all questionnaires to resolve all incongruities minimized this bias. Although the statistical threshold for participant recruitment was met at all study sites, the non-response rate in Abuja was very low, primarily due to the inability of parents and guardians to sign consent forms for potential participants in the study.

Thirdly, the adapted BEVQ used to assess dietary exposure was limited to SSB consumption only and has yet to be validated. Validation studies are necessary to ensure the reflection of long-term diet exposure and the reliability of the information collected. However, this might not significantly impact the study's findings because adolescents typically exhibit good memory and are able to provide accurate information during their growth spurt. Similarly, study findings are promising to discern the overall consumption of dietary and lifestyle exposures in the pathophysiology of adolescent health outcomes. In addition, this study holds promise for extending the frontiers of understanding adolescent health in low- and middle-income countries, thereby complementing the global literature on adolescents with sound information and well-informed science worldwide.

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Authors' contributions

IAA and APO were the principal investigators and conceptualized the study; AMO, SIO and MHB were study investigators; SAO was responsible for training study investigators and oversight of the data collection at the study sites; SAO and APO supervised the data acquisition; DKD and APO managed the qualitative methodology for the study, IJO, SAO and OJA were the data managers and responsible for data curation; IJO, SAO, and APO drafted the manuscript; APO and IAA critically revised the manuscript for important intellectual content. All authors read, contributed to the interpretation, approved the final version to be published and agreed to be accountable for the work.

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