International Journal of Epidemiology, 2024, **53**(1), dyad171
https://doi.org/10.1093/ije/dyad171
Original article

IEA
International Epidemiological Association
OXFORD

Original article

Factors associated with frequency of fruit and vegetable consumption among selected sub-Saharan African populations: evidence from the Cardiovascular H3Africa Innovation Resource Project

Akinkunmi Paul Okekunle ,[1,2] Osahon Jeffery Asowata,[3] Onoja Matthew Akpa,[3,4,5] Adekunle Gregory Fakunle,[1,6] Tinashe Chikowore,[7,8] Shukri F Mohamed ,[9] Reginald Obiako,[10] Morenikeji Komolafe,[11] Godwin O Osaigbovo,[12] Godwin Ogbole,[13] Oyedunni Arulogun,[14] Fred Stephen Sarfo,[15] Kolawole Wahab,[16] Lukman Owolabi,[17] Joshua Akinyemi,[3] Albert Akpalu,[18] Ezinne Uvere,[1] Rufus Akinyemi,[19,20] Carolyn Jenkins,[21] Donna K Arnett,[22] Daniel Lackland,[23] Bruce Ovbiagele,[24,†] Michèle Ramsay ,[8,25,†] and Mayowa Owolabi [1,20,26,27,*,†]; on Behalf of SIREN, AWI-Gen and the H3Africa Consortium

[1]Department of Medicine, College of Medicine, University of Ibadan, Ibadan, Nigeria, [2]Department of Food and Nutrition, Seoul National University, Seoul, Korea, [3]Department of Epidemiology and Medical Statistics, College of Medicine, University of Ibadan, Ibadan, Nigeria, [4]Institute of Cardiovascular Diseases, College of Medicine, University of Ibadan, Ibadan, Nigeria, [5]Division of Epidemiology, Biostatistics and Environmental Health, School of Public Health, University of Memphis, Memphis, TN, USA, [6]Department of Public Health, College of Health Sciences, Osun State University, Osogbo, Nigeria, [7]MRC/Wits Developmental Pathways for Health Research Unit, Department of Paediatrics, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa, [8]Sydney Brenner Institute for Molecular, Bioscience, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa, [9]Health and Well-Being Program, African Population and Health Research Center, Nairobi, Kenya, [10]Department of Medicine, Ahmadu Bello University, Zaria, Nigeria, [11]Department of Medicine, College of Health Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria, [12]Jos University Teaching Hospital, Jos, Nigeria, [13]Department of Radiology, College of Medicine, University of Ibadan, Ibadan, Nigeria, [14]Department of Health Promotion and Education, College of Medicine, University of Ibadan, Ibadan, Nigeria, [15]Department of Medicine, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, [16]Department of Medicine, University of Ilorin Teaching Hospital, Ilorin, Nigeria, [17]Department of Medicine, Aminu Kano Teaching Hospital, Kano, Nigeria, [18]Department of Medicine, University of Ghana Medical School, Accra, Ghana, [19]Neuroscience and Ageing Research Unit, Institute for Advanced Medical Research and Training College of Medicine, University of Ibadan, Ibadan, Nigeria, [20]Center for Genomic and Precision Medicine, College of Medicine, University of Ibadan, Ibadan, Nigeria, [21]Department of Nursing, Medical University of South Carolina, Charleston, SC, USA, [22]Office of the Provost, University of South Carolina, Charleston, SC, USA, [23]Department of Neurology, Medical University of South Carolina, Charleston, SC, USA, [24]Weill Institute for Neurosciences, University of California San Francisco, San Francisco, CA, USA, [25]Division of Human Genetics, National Health Laboratory Service, School of Pathology, University of the Witwatersrand, Johannesburg, South Africa, [26]School of Medicine, Lebanese American University, Beirut, Lebanon and [27]Department of Medicine, University College Hospital, Ibadan, Nigeria

*Corresponding author. Department of Medicine and Center for Genomic and Precision Medicine, College of Medicine, University College Hospital, University of Ibadan, PMB 5017 G.P.O Ibadan, Oyo State, Nigeria. E-mail: mayowaowolabi@yahoo.com

[†]Joint senior authors

Abstract

Background: Frequent fruit and vegetable consumption is considered a promising dietary behaviour that protects health. However, most existing studies about the factors associated with this phenomenon among Africans are based on single-country reports, apart from one meta-regression combining smaller studies. This study harmonized large datasets and assessed factors associated with the frequency of fruit and vegetable consumption in this population.

Methods: Individual-level data on sociodemographics, lifestyle and diet from 20 443 participants across five African countries (Burkina Faso, Ghana, Kenya, South Africa and Nigeria), from the Stroke Investigative Research and Educational Network (SIREN) and Africa Wits-INDEPTH partnership for Genomic Research (AWI-Gen) studies, were harmonized. Total frequency of fruit and vegetable consumption (in portions/week) was classified as 'low' (≤6), 'moderate' (7–14) and 'high' (≥15). Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) of factors associated with the total frequency of fruit and vegetable consumption (using 'low' consumption as the reference) were estimated using multinomial regression models.

Results: Mean age of participants was 54.3 ± 11.8 years, 10 641 (52.1%) were female, and the median (interquartile range) frequency of total fruit and vegetable consumption was 10.0 (4.0, 21.0) portions/week. Participants with a family history of cardiovascular disease [moderate (aOR, 0.92; 95% CI, 0.85, 1.00) and high (aOR, 0.85; 95% CI, 0.78, 0.92)], current smokers [moderate (aOR, 0.83; 95% CI, 0.74, 0.94) and high (aOR, 0.78; 95% CI, 0.69, 0.88)], current alcohol users [moderate (aOR, 0.92; 95% CI, 0.85, 1.00) and high (aOR, 0.82; 95% CI, 0.76, 0.89)] and

Received: 15 February 2023. **Editorial Decision:** 13 October 2023

physically inactive participants [moderate (aOR, 0.85; 95% CI, 0.75, 0.96) and high (aOR, 0.80; 95% CI, 0.70, 0.90)] were less likely to consume fruits and vegetables frequently.

Conclusion: Africans with lifestyle risk factors for cardiovascular disease were less likely to consume fruit and vegetables frequently.

Keywords: Fruits, vegetables, diet, food frequency, lifestyle, behaviour, Africans.

Key Messages

- One-third of Africans in this study consumed less than six portions of vegetables and fruits every week.
- Individuals exposed to lifestyle risk factors for cardiovascular diseases (including smoking, alcohol consumption and physical inactivity) are less likely to consume fruits and vegetables frequently.
- Culturally suitable interventions targeted at immediate and remote factors associated with fruit and vegetable consumption might also help prevent or delay the onset of diet-related cardiovascular disease.

Introduction

Unhealthy diets, which are often characterized by high intake of energy-dense, ultra-processed and sugar-sweetened foods and low intake of plant-based food such as fruits and vegetables, have been identified as a prominent cause of disability and mortality.[1] For example, of the 255 million disability-adjusted life-years (DALYs) and 10.9 million deaths attributable to unhealthy diet worldwide in 2017,[1] low fruit consumption accounted for more than 65 million DALYs and 2 million deaths.[2]

The impact of low fruit and vegetable consumption on cardiovascular disease (CVD) has been documented,[3] and regular fruit and vegetable consumption is recommended as a viable dietary behaviour that protects health, including for the primary prevention of CVD-related disability and mortality.[4] Nevertheless, the uptake of this recommendation remains low and often unmet.[5–8] For example, 80% of adults from low- and middle-income countries consumed far less than the World Health Organization's recommended 400 g/day (≈5 portions/day) of fruits and vegetables between 2005 and 2015.[9]

However, existing studies[7,8,10,11] on the immediate and remote factors affecting dietary choices, particularly among indigenous Africans, are mainly based on single-country analyses, apart from one meta-regression combining smaller studies.[12] Also, these earlier reports are limited by methodological biases, such as low statistical power and cross-cultural comparability among others, in Africa. It is yet to be clearly understood if there are immediate and remote factors associated with the uptake of healthy dietary choices (such as adopting frequent fruit and vegetable consumption) among indigenous Africans. Such understanding is crucial for prioritizing interventions and designing policy recommendations to promote frequent fruit and vegetable consumption. By extension, such information might support efforts to manage the already high burden of CVD, which accounts for 22.9 million DALYs, 15% of all non-communicable diseases (NCDs), 37% of all NCD-related deaths and 13% of all deaths in sub-Saharan Africa.[13–15]

Discerning immediate and remote factors (sociodemographic, lifestyle and cardiometabolic) associated with frequent fruit and vegetable consumption will offer unique insights and approaches, to guide intervention and implementation studies to promote the uptake of fruit and vegetable consumption as a viable dietary strategy for CVD prevention and management among indigenous Africans. Therefore, this pooled cross-sectional analysis of >20 000 participants from five African countries was designed to assess factors associated with the frequency of fruit and vegetable consumption among indigenous Africans.

Methods

Study design and population

This study is a secondary analysis of individual-level pooled data of participants from the Cardiovascular H3Africa Innovation Resource (CHAIR) in Africa. The CHAIR was designed to identify the determinants of CVD and offer context-specific interventions for CVD prevention and management among Africans. The principle and design guiding the CHAIR project have been reported elsewhere.[16]

Data source

Participating studies for this current study were the Stroke Investigative Research and Educational Network (SIREN)[17,18] and the Africa Wits-INDEPTH partnership for Genomic Research (AWI-Gen) studies.[19,20] This report includes individual-level data of all 20 443 participants recruited in both studies (SIREN: 8411 and AWI-Gen: 12 032) across five African countries: Burkina Faso, Ghana, Kenya, Nigeria and South Africa. The design of participating studies, harmonization and definitions of variables are detailed in Supplementary Tables S1 and S2 (available as Supplementary data at *IJE* online).

Definition of data variables

Frequency of fruit and vegetable consumption

Food frequency questionnaires were used to collect data on dietary information from participants, including fruit and vegetable consumption.[17,19,21] Participants' detailed information on fruit and vegetable consumption included the number of portions and the frequency of consumption in a typical period (day/week/month) in the prior months. Details of how fruit and vegetable consumption were assessed are summarized in Supplementary Table S2 (available as Supplementary data at *IJE* online). Responses were coded and transformed into frequency of consumption per week. The level of fruit and vegetable consumption of participants in a week was characterized as low, moderate or high based on the tertile distribution of the frequency of fruit consumption, vegetable consumption and total fruit and vegetable consumption. It includes fruit consumption—'low/none' (0 portions), 'moderate' (1–4 portions) or 'high' ($\geq$5 portions)—and vegetable consumption—'low' ($\leq$2 portions), 'moderate' (3–9 portions) or 'high' ($\geq$10 portions). The frequency of fruit and vegetable consumption per week was summed to estimate the total fruit and vegetable consumption and classified as 'low' ($\leq$6 portions), 'moderate' (7–14 portions) or 'high' ($\geq$15 portions).

Sociodemographic characteristics

Country was defined as the location where participants were recruited (Burkina Faso, Ghana, Kenya, Nigeria or South Africa; Supplementary Table S2, available as Supplementary data at *IJE* online). Participants reported their area of residence and were classified as rural or urban, depending on the country-specific national definition of urban and rural areas. The age of participants was reported at recruitment (and classified as <60 years or $\geq$60 years) according to the proposed working definition of an older person in Africa.[22] The biological sex of participants was reported as male or female across studies. Marital status was self-reported and classified as never married, cohabiting/married or separated/divorced/widowed. The highest formal education completed was self-reported across studies, harmonized and classified as none, primary, secondary or tertiary education. Employment status was self-reported and categorized as 'no' (if the participants reported not being in any form of employment) or 'yes'.

Lifestyle characteristics

Current smoking status was reported as 'yes' for the current use of a cigarette or any form of tobacco product (e.g. smoking, chewing tobacco or snuff) in the past 12 months or 'no' for never or former smokers. Current alcohol use was derived from alcohol use habits across studies in the past year and classified as 'yes' for the current use of any form of alcoholic drinks in the previous 12 months or 'no' for never users or former alcohol users[18] (Supplementary Table S2, available as Supplementary data at *IJE* online). Physical inactivity was derived from the information provided on total moderate-vigorous physical activity (MVPA) across studies and classified as 'no' (if MVPA was $\geq$4 h/week) or 'yes' (if MVPA <4 h/week).[23]

Anthropometric measurements, obesity and definitions of NCD risk factors

Body mass index (BMI) is a function of weight (in kilograms) divided by the square of height (in metres), and obesity was defined as BMI $\geq$30 kg/m^2.[24] Participants provided information on their current medication use for diabetes mellitus, dyslipidaemia and hypertension management and whether they had been diagnosed with any of these conditions by a trained physician. Family history of CVD was self-reported as a history of CVD (ischaemic heart disease, hypertension, obesity, dyslipidaemia, stroke, heart failure and cardiac disease) in participants' family lineage to second-degree relatives. Data on fasting glucose and lipid profiles, assessed using standardized methods (derived from blood samples drawn after an $\geq$8-h overnight fast across studies),[25,26] were used to classify participants as having at least one NCD if they met the criteria for defining any of the following conditions: diabetes mellitus,[25] dyslipidaemia[26] and hypertension[27] (Supplementary Table S2, available as Supplementary data at *IJE* online).

Statistical analysis

The median [interquartile range (IQR)] frequency of portions of fruit, vegetables and total fruit and vegetable consumption was compared across country, sex and age groups using the median test. Participant characteristics were compared by categories of fruit and vegetable consumption (stratified by sex and age group) using a one-way analysis of variance and chi-square test for continuous and categorical data, respectively. Characteristics of participants were presented across the distribution of fruit and vegetable consumption frequency using mean [standard deviation (SD)] for continuous data and frequency (percentages) for categorical data. Sociodemographic, lifestyle and cardiometabolic characteristics associated with fruit and vegetable consumption frequency were examined using multinomial regression to estimate the adjusted odds ratio (aOR) and 95% confidence interval (CI). Variables were included in the regression models based on the empirical evidence from our data and understanding of the scientific literature. Covariates in Model 1 included non-modifiable characteristics only: age group (<60 years, $\geq$60 years), sex (female, male) and family history of CVD (no, yes). Model 2 included modifiable sociodemographic characteristics only: area of residence (rural, urban), formal education (none and primary education, secondary education and above), employment (no, yes) and marital status (never married, cohabiting/married/separated/divorced/widowed). Model 3 included lifestyle characteristics only: current smoking status (no, yes), current alcohol use (no, yes) and physical inactivity (no, yes). In Model 4, we included BMI (<30 kg/m^2, $\geq$30 kg/m^2) and having at least one NCD (no, yes) only. The final model included all the covariates mentioned above. Subgroup analyses by sex, age group and country of residence were also carried out. Multivariate imputation by chained equation package in R software was used to impute missing data, and all statistical analyses were performed using IBM SPSS Statistics for Windows, version 25 (IBM, Armonk, NY, USA) and R statistical program (version 3.6.2) at a two-sided $P < 0.05$.

Results

Characteristics of participants

In all, 20 443 individual-level participants were included in this study; mean age was 54.3 ± 11.8 years, 10 641 (52.1%) were female and 6193 (30.3%) reported not having a formal education (Table 1). Also, 2108 (10.3%) were current smokers, 6335 (31.0%) currently used alcohol, the mean BMI was 25.7 ± 6.3 kg/m^2, 4713 (23.1%) were obese and 16 202 (79.3%) had at least one NCD. Details of the country-specific characteristics of participants are in Table 1.

Fruit and vegetable consumption

The median (IQR) frequency of total fruit and vegetable consumption in the overall sample (Table 2) was 10.0 (4.0, 21.0) portions per week; it was 8.0 (3.0, 17.0) in South Africa and 12.0 (6.0, 24.0) in Nigeria. The median (IQR) frequency of portions per week of fruit consumption was 2.0 (0.0, 7.0), and vegetable consumption was 6.0 (4.0, 21.0). The fruit and vegetable consumption levels did not differ by sex and age in this sample. There were 6957 participants (34.0%) who reported consuming at least 15 portions of fruit and vegetables per week, whereas 7089 (34.7%) reported consuming as few as six portions of fruit and vegetables weekly (Table 3). A similar distribution was observed for the frequency of fruit

Table 1. Characteristics of 20 443 participants by country in the SIREN and AWI-Gen studies

Characteristic	All countries (n=20 443)	Burkina Faso (n=2097)	Ghana (n=4533)	Kenya (n=2003)	Nigeria (n=5894)	South Africa (n=5916)
Sociodemographic characteristics						
Area of residence						
Rural	9312 (45.6)	2097 (100.0)	2172 (47.9)	0 (0.0)	1158 (19.6)	3885 (65.7)
Urban	11 131 (54.4)	0 (0.0)	2361 (52.1)	2003 (100.0)	4736 (80.4)	2031 (34.3)
Age (years), mean ± SD	54.3 ± 11.8	49.8±5.8	55.7±12.7	48.8±5.8	57.6±14.7	53.8±9.8
<60	14 701 (71.9)	2017 (96.2)	3206 (70.7)	1904 (95.1)	3046 (51.7)	4528 (76.5)
≥60	5742 (28.1)	80 (3.8)	1327 (29.3)	99 (4.9)	2848 (48.3)	1388 (23.5)
Sex						
Male	9802 (47.9)	1056 (50.4)	2284 (50.4)	922 (46.0)	3037 (51.5)	2503 (42.3)
Female	10 641 (52.1)	1041 (49.6)	2249 (49.6)	1081 (54.0)	2857 (48.5)	3413 (57.7)
Marital status						
Never married	1350 (6.6)	18 (0.9)	185 (4.1)	85 (4.2)	242 (4.1)	820 (13.9)
Cohabiting/married	14 287 (69.9)	1833 (87.4)	3085 (68.1)	1332 (66.5)	4732 (80.3)	3305 (55.8)
Separated/divorced/widowed	4806 (23.5)	246 (11.7)	1263 (27.8)	586 (29.3)	920 (15.6)	1791 (30.3)
Educational status						
None	6193 (30.3)	1731 (82.6)	1868 (41.2)	154 (7.7)	1250 (21.2)	1190 (20.1)
Primary	5892 (28.8)	242 (11.5)	1028 (22.7)	1151 (57.5)	1225 (20.8)	2246 (38.0)
Secondary	5455 (26.7)	105 (5.0)	1070 (23.6)	672 (33.5)	1446 (24.5)	2162 (36.5)
Tertiary	2903 (14.2)	19 (0.9)	567 (12.5)	26 (1.3)	1973 (33.5)	318 (5.4)
Employment status						
No	6606 (32.3)	24 (1.1)	1450 (32.0)	121 (6.0)	1641 (27.8)	3370 (57.0)
Yes	13 837 (67.7)	2073 (98.9)	3083 (68.0)	1882 (94.0)	4253 (72.2)	2546 (43.0)
Lifestyle characteristics						
Current smoking (yes)	2108 (10.3)	143 (6.8)	483 (10.7)	244 (12.2)	128 (2.2)	1110 (18.8)
Current alcohol use (yes)	6335 (31.0)	1334 (63.6)	1923 (42.4)	372 (18.6)	597 (10.1)	2109 (35.6)
Physical inactivity (yes)	1625 (7.9)	341 (16.3)	384 (8.5)	26 (1.3)	131 (2.2)	743 (12.6)
Anthropometry and history of NCDs						
BMI, mean ± SD	25.7±6.3	20.9±3.4	24.6±5.7	25.4±3.7	26.0±5.4	27.9±7.3
BMI ≥30 kg/m^2	4713 (23.1)	43 (2.1)	805 (17.8)	439 (21.9)	1217 (20.6)	2209 (37.3)
Family history of CVD (yes)	5093 (24.9)	349 (16.6)	941 (20.8)	529 (26.4)	978 (16.6)	2296 (38.8)
Have at least one NCD (yes)	16 202 (79.3)	1374 (65.5)	3550 (78.3)	1466 (73.2)	5068 (86.0)	4744 (80.2)
Diabetes mellitus (yes)	2467 (12.1)	56 (2.7)	697 (15.4)	122 (6.1)	1306 (22.2)	286 (4.8)
Dyslipidaemia (yes)	12 033 (58.9)	1206 (57.5)	2789 (61.5)	1279 (63.9)	3253 (55.2)	3506 (59.3)
Hypertension (yes)	10 764 (52.7)	345 (16.5)	2405 (53.1)	543 (27.1)	4256 (72.2)	3215 (54.3)

Categorical variables are presented as n (%), and continuous data as mean±SD.
AWI-Gen, Africa Wits-INDEPTH partnership for Genomic Research; BMI, body mass index; CVD, cardiovascular disease; NCD, non-communicable disease; SD, standard deviation; SIREN, Stroke Investigative Research and Educational Network.

consumption (Supplementary Table S3, available as Supplementary data at *IJE* online) and vegetable consumption (Supplementary Table S4, available as Supplementary data at *IJE* online). Country-specific stratification of participants' characteristics (Supplementary Tables S5–S9, available as Supplementary data at *IJE* online) showed a similar trend, as at least a quarter of participants in each country reported a low frequency of total fruit and vegetable consumption: 720 (34.3%) in Burkina Faso, 1616 (35.6%) in Ghana, 767 (38.2%) in Kenya, 1528 (25.9%) in Nigeria and 2457 (41.5%) in South Africa.

Characteristics of participants by the distribution of fruit and vegetable consumption

Country-wise, the number of participants with a high total frequency of fruit and vegetable consumption was 2404 (34.5%) in Nigeria, 1706 (24.5%) in South Africa, 1458 (21.0%) in Ghana, 764 (11.0%) in Burkina Faso and 625 (9.0%) in Kenya (Table 3). The number of female participants within each level of total frequency of fruit and vegetable consumption was 3721 (52.5%), 3389 (53.0%) and 3531 (50.8%) for low, moderate and high, respectively. The prevalence of smoking was 9.3% ($n=644$) among participants who reported a high total frequency of fruit and vegetable consumption, and 9.6% ($n=614$) and 12.0% $n=850$) among those who reported moderate and low total frequency of fruit and vegetable consumption, respectively. A similar trend was observed for current alcohol use, physical inactivity, obesity and family history of CVD. The results trended similarly after stratifying participants' characteristics by level of fruit consumption (Supplementary Table S3, available as Supplementary data at *IJE* online) or vegetable consumption (Supplementary Table S4, available as Supplementary data at *IJE* online). The country-stratified distribution of participants' characteristics by frequency of fruit, vegetable or total fruit and vegetable consumption mirrored findings in the overall sample (Supplementary Tables S5–S9, available as Supplementary data at *IJE* online).

Factors associated with fruit and vegetable consumption

The aOR and 95% CI from the multinomial regression models (using low consumption as a reference) are presented in Table 4. In Model 1, male participants more than female participants (moderate (aOR, 0.97; 95% CI, 0.91, 1.04) and high (aOR, 1.07; 95% CI, 1.00, 1.14)) had higher odds of having high total fruit and vegetable consumption, but a family history of CVD (moderate (aOR, 0.93; 95% CI, 0.86, 1.00) and high (aOR, 0.81; 95% CI, 0.75, 0.88)) was associated with lower odds of high frequency of total fruit and vegetable consumption.

Table 2. Frequency of fruit and vegetable consumption in portions/week in SIREN and AWI-Gen studies

	All participants		Sex				Age group			
			Female		Male		<60 years		≥60 years	
Country	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
Fruit consumption										
Burkina Faso	2.0	0.0, 7.0	2.0	1.0, 7.0	3.0	0.0, 14.0	2.0	0.0, 7.0	2.0	0.0, 12.0
Ghana	2.0	0.0, 6.0	2.0	0.0, 6.0	2.0	0.0, 6.0	2.0	0.0, 6.0	2.0	0.0, 6.0
Kenya	2.0	0.0, 7.0	2.0	0.0, 7.0	2.0	0.0, 7.0	2.0	0.0, 7.0	2.0	0.0, 7.0
Nigeria	2.0	0.0, 6.0	2.0	0.0, 7.0	2.0	0.0, 6.0	2.0	0.0, 6.0	2.0	0.0, 6.0
South Africa	2.0	0.0, 7.0	2.0	0.0, 6.0	2.0	0.0, 7.0	2.0	0.0, 7.0	2.0	0.0, 6.0
Overall	**2.0**	**0.0, 7.0**	**2.0**	**0.0, 7.0**	**2.0**	**0.0, 7.0**	**2.0**	**0.0, 7.0**	**2.0**	**0.0, 6.0**
Vegetable consumption										
Burkina Faso	6.0	1.0, 14.0	4.0	1.0, 9.0	7.0	2.0, 28.0	6.0	1.0, 14.0	6.0	2.0, 12.0
Ghana	6.0	2.0, 12.0	6.0	2.0, 12.0	6.0	2.0, 14.0	6.0	2.0, 12.0	6.0	2.0, 14.0
Kenya	5.0	1.0, 12.0	5.0	1.0, 14.0	5.0	1.0, 12.0	5.0	1.0, 12.0	6.0	2.0, 12.0
Nigeria	7.0	4.0, 16.0	7.0	4.0, 16.0	7.0	4.0, 16.0	7.0	4.0, 16.0	7.0	3.0, 16.0
South Africa	4.0	1.0, 12.0	4.0	1.0, 12.0	4.0	1.0, 10.0	4.0	1.0, 12.0	4.0	1.0, 12.0
Overall	**6.0**	**4.0, 21.0**	**6.0**	**2.0, 14.0**	**6.0**	**2.0, 14.0**	**6.0**	**2.0, 14.0**	**6.0**	**2.0, 14.0**
Total fruit and vegetable consumption										
Burkina Faso	10.0	4.0, 27.0	8.0	3.0, 16.0	12.0	6.0, 35.0	10.0	4.0, 27.0	9.0	6.0, 21.0
Ghana	9.0	4.0, 18.0	9.0	4.0, 18.0	9.0	4.0, 18.0	9.0	4.0, 18.0	10.0	4.0, 18.0
Kenya	9.0	4.0, 19.0	9.0	4.0, 19.5	8.0	4.0, 18.2	9.0	4.0, 19.0	9.0	3.0, 16.0
Nigeria	12.0	6.0, 24.0	12.0	6.0, 23.0	12.0	6.0, 24.0	12.0	6.0, 24.0	12.0	6.0, 24.0
South Africa	8.0	3.0, 17.0	8.0	3.0, 17.5	8.0	3.0, 16.0	8.0	3.0, 16.0	8.0	3.0, 18.0
Overall	**10.0**	**4.0, 21.0**	**10.0**	**4.0, 20.0**	**10.0**	**4.0, 21.0**	**9.0**	**4.0, 21.0**	**10.0**	**5.0, 21.0**

AWI-Gen, Africa Wits-INDEPTH partnership for Genomic Research; IQR, interquartile range; SIREN, Stroke Investigative Research and Educational Network.

In Model 2, participants residing in urban areas [moderate (aOR, 1.25; 95% CI, 1.17, 1.37) and high (aOR, 1.11; 95% CI, 1.04, 1.21)] had higher odds of high total fruit and vegetable consumption compared with rural residents. Similarly, participants who were cohabiting/married/separated/divorced/widowed [moderate (aOR, 1.21; 95% CI, 1.06, 1.23) and high (aOR, 1.15; 95% CI, 1.13, 1.31)] had higher odds of high total fruit and vegetable consumption compared with those who had never been married. In contrast, those with at least secondary school education [moderate (aOR, 0.90; 95% CI, 0.81, 0.96) and high (aOR, 0.88; 95% CI, 0.79, 0.93)] had lower odds of high total fruit and vegetable consumption compared with those with lower forms of formal education. In Model 3, current smokers [moderate (aOR, 0.81; 95% CI, 0.72, 0.92) and high (aOR, 0.80; 95% CI, 0.71, 0.90)] compared with non-smokers were at lower odds of high total fruit and vegetable consumption. Similarly, current alcohol users compared with non-alcohol users [moderate (aOR, 0.90; 95% CI, 0.83, 0.98) and high (aOR, 0.87; 95% CI, 0.80, 0.94)] were at lower odds of high total fruit and vegetable consumption. The case was not different for physically inactive participants [moderate (aOR, 0.82; 95% CI, 0.73, 0.93) and high (aOR, 0.79; 95% CI, 0.70, 0.89)].

The trends remained in the final model (when all variables were included in a single multinomial regression model; Figure 1). For example, male participants more than female participants [moderate (aOR, 1.03; 95% CI, 0.96, 1.12) and high (aOR, 1.16; 95% CI, 1.08, 1.25)] had higher odds of high total fruit and vegetable consumption, but participants with a family history of CVD [moderate (aOR, 0.92; 95% CI, 0.85, 1.00) and high (aOR, 0.85; 95% CI, 0.78, 0.92)] had lower odds of high total fruit and vegetable consumption. Similarly, current smokers, current alcohol users and physically inactive participants had low odds of high total fruit and vegetable consumption.

Age, BMI and having at least one NCD were not associated with total fruit and vegetable consumption in the final model. Even though similar trends were observed for the frequency of fruit consumption only (Figure 2; and Supplementary Table S10, available as Supplementary data at *IJE* online) or vegetable consumption only (Figure 3; and Supplementary Table S11, available as Supplementary data at *IJE* online), urban residents [moderate (aOR, 0.88; 95% CI, 0.82, 0.96) and high (aOR, 0.79; 95% CI, 0.73, 0.86)] had lower odds of high fruit consumption compared with rural residents. Also, participants with at least one NCD [moderate (aOR, 0.97; 95% CI, 0.89, 1.06) and high (aOR, 0.87; 95% CI, 0.80, 0.96)] compared with those without an NCD had lower odds of high fruit consumption. Similarly, stratified adjusted models by sex (Supplementary Tables S12 and S13, available as Supplementary data at *IJE* online), age groups (Supplementary Tables S14 and S15, available as Supplementary data at *IJE* online) and country (Supplementary Tables S16–S20, available as Supplementary data at *IJE* online) showed similar observations with trivial differences.

Discussion

This study characterized factors associated with the frequency of fruit and vegetable consumption, and found that about two out of every five Africans in this sample reported a very low frequency of total fruit and vegetable consumption (i.e. less than seven portions per week). Also, vast variations exist in fruit and vegetable consumption frequency across sociodemographic and lifestyle differentials. Given the widely reported significance of fruit and vegetable consumption in the primary prevention of NCDs, our findings are promising

Table 3. Characteristics of 20 443 participants by frequency of total fruit and vegetable consumption in the SIREN and AWI-Gen studies

Characteristic	Total fruit and vegetable consumption (portions/week)			
	Low (≤6) (*n*=7089)	Moderate (7–14) (*n*=6397)	High (≥15) (*n*=6957)	*P*
Sociodemographic characteristics				
Country				
Burkina Faso	720 (10.2)	613 (9.6)	764 (11.0)	
Ghana	1616 (22.8)	1459 (22.8)	1458 (21.0)	<0.0001
Kenya	767 (10.8)	611 (9.6)	625 (9.0)	
Nigeria	1529 (21.6)	1961 (30.7)	2404 (34.5)	
South Africa	2457 (34.6)	1753 (27.3)	1706 (24.5)	
Area of residence				
Rural	3377 (47.6)	2739 (42.8)	3196 (45.9)	<0.0001
Urban	3712 (52.4)	3658 (57.2)	3761 (54.1)	
Age (years), mean ± SD	54.1±11.2	54.5±11.7	54.6±12.4	<0.0001
<60	5266 (74.3)	4544 (71.0)	4891 (70.3)	<0.0001
≥60	1823 (25.7)	1853 (29.0)	2066 (29.7)	
Sex				
Male	3368 (47.5)	3008 (47.0)	3426 (49.2)	0.024
Female	3721 (52.5)	3389 (53.0)	3531 (50.8)	
Marital status				
Never married	526 (7.4)	387 (6.0)	437 (6.3)	<0.0001
Cohabiting/married	4789 (67.6)	4505 (70.4)	4993 (71.8)	
Separated/divorced/widowed	1774 (25.0)	1505 (23.5)	1527 (21.9)	
Educational status				
None	2100 (29.6)	1905 (29.8)	2188 (31.5)	<0.0001
Primary	2095 (29.6)	1865 (29.2)	1932 (27.8)	
Secondary	1991 (28.1)	1666 (26.0)	1798 (25.8)	
Tertiary	903 (12.7)	961 (15.0)	1039 (14.9)	
Employment status				
No	2378 (33.5)	2049 (32.0)	2179 (31.3)	0.016
Yes	4711 (66.5)	4348 (68.0)	4778 (68.7)	
Lifestyle characteristics				
Current smoking (yes)	850 (12.0)	614 (9.6)	644 (9.3)	<0.0001
Current alcohol use (yes)	2369 (33.4)	1932 (30.2)	2034 (29.2)	<0.0001
Physical inactivity (yes)	637 (9.0)	484 (7.6)	504 (7.2)	<0.0001
Anthropometry and history of NCDs				
BMI, mean ± SD	25.7±6.4	25.8±6.4	25.6±6.3	0.079
BMI ≥30kg/m^2	1661 (23.4)	1537 (24.0)	1515 (21.8)	0.006
Family history of CVD (yes)	1895 (26.7)	1611 (25.2)	1587 (22.8)	<0.0001
Have at least one NCD (yes)	5608 (79.1)	5142 (80.4)	5452 (78.4)	0.015
Diabetes mellitus (yes)	790 (11.1)	826 (12.9)	851 (12.2)	0.006
Dyslipidaemia (yes)	4230 (59.7)	3793 (59.3)	4010 (57.6)	0.035
Hypertension (yes)	3642 (51.4)	3473 (54.3)	3649 (52.5)	0.003

Categorical variables are presented as *n* (%), and continuous data as mean±SD.
AWI-Gen, Africa Wits-INDEPTH partnership for Genomic Research; BMI, body mass index; CVD, cardiovascular disease; NCD, non-communicable disease; SD, standard deviation; SIREN, Stroke Investigative Research and Educational Network.

for designing nutrition education to promote fruit and vegetable consumption among indigenous Africans.

The low fruit and vegetable consumption level observed in this study is similar to that reported among Tanzanians (less than two portions daily)[11] and the 36% prevalence of inadequate fruit and vegetable consumption among adolescents from seven countries in East and Southern Africa.[28] However, our observation slightly differed from that seen among Nigerians (about two portions daily)[10] and among Africans (about three portions daily) in the Prospective Urban Rural Epidemiology study in low- and middle-income countries (LMICs).[29] Similarly, we observed country-specific differences in the median frequency of total fruit and vegetable consumption, particularly with vegetable consumption. Besides diverse food cultures, accessibility, affordability and environmental barriers for fruit and vegetable production across countries,[12] the reasons for these differences are multifaceted. This observation is generally aligned to the perpetually prevalent low fruit and vegetable consumption in LMICs,[6] drawing attention to the enormous deficit in the uptake of a promising health-protecting behaviour, and perhaps offering a clue into the significance of suboptimal dietary exposure in the escalating burden of CVD, particularly among indigenous Africans.

In this study, men were more likely to consume fruit and vegetables frequently. This observation was similar to those in other reports[7,30] but differed from other reports from Asia, Europe and South America.[31–34] Why men (compared with women) in this sample were more likely to consume fruit and vegetables frequently is unclear. However, the multifactorial influence of a wide range of culturally sensitive socio-cultural factors accounts for the varied lifestyle, typically leading to differences in food habits between men and women. Also, urban dwellers and married participants were more likely to consume fruits and vegetables frequently. A similar observation has been reported in some studies[30,32,35]

Table 4. Adjusted odd ratios and 95% confidence interval of factors associated with levels of frequency of total fruit and vegetable consumption in portions/week based on multinomial logistic regression

Characteristic	Total fruit and vegetable consumption (portions/week)					
	Low (≤6)	Moderate (7–14)	High (≥15)	Low (≤6)	Moderate (7–14)	High (≥15)
Sociodemographic characteristics and family history of CVD						
Non-modifiable factors		**Model 1**			**Full model**	
Age (≥60 years) (reference: <60 years)	1.00	1.00 (0.99, 1.00)	1.00 (1.00, 1.00)	1.00	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)
Sex (male) (reference: female)	1.00	0.97 (0.91, 1.04)	1.07 (1.00, 1.14)	1.00	1.03 (0.96, 1.12)	1.16 (1.08, 1.25)
Family history of CVD (yes) (reference: no)	1.00	0.93 (0.86, 1.00)	0.81 (0.75, 0.88)	1.00	0.92 (0.85, 1.00)	0.85 (0.78, 0.92)
Modifiable factors		**Model 2**				
Residence (urban) (reference: rural)	1.00	1.25 (1.17, 1.37)	1.11 (1.04, 1.21)	1.00	1.22 (1.13, 1.32)	1.07 (1.00, 1.16)
Education (secondary education and above) (reference: none and primary education)	1.00	0.90 (0.81, 0.96)	0.88 (0.79, 0.93)	1.00	0.90 (0.83, 0.99)	0.88 (0.81, 0.96)
Employment (yes) (reference: no)	1.00	1.02 (0.94, 1.09)	1.08 (0.98, 1.14)	1.00	1.02 (0.95, 1.11)	1.07 (1.00, 1.16)
Marital status (cohabiting/married/ separated/divorced/widowed) (reference: never married)	1.00	1.21 (1.06, 1.23)	1.15 (1.13, 1.31)	1.00	1.16 (1.01, 1.33)	1.08 (0.94, 1.24)
Lifestyle characteristics		**Model 3**				
Current smoking (yes) (reference: no)	1.00	0.81 (0.72, 0.92)	0.80 (0.71, 0.90)	1.00	0.83 (0.74, 0.94)	0.78 (0.69, 0.88)
Current alcohol (yes) (reference: no)	1.00	0.90 (0.83, 0.98)	0.87 (0.80, 0.94)	1.00	0.92 (0.85, 1.00)	0.82 (0.76, 0.89)
Physical inactivity (yes) (reference: no)	1.00	0.82 (0.73, 0.93)	0.79 (0.70, 0.89)	1.00	0.85 (0.75, 0.96)	0.80 (0.70, 0.90)
Anthropometry and the presence of NCDs		**Model 4**				
BMI (≥30 kg/m^2) (reference: <30 kg/m^2)	1.00	1.02 (0.94, 1.10)	0.91 (0.84, 0.98)	1.00	1.01 (0.93, 1.10)	0.95 (0.87, 1.03)
NCD (yes) (reference: no)	1.00	1.07 (0.99, 1.17)	0.96 (0.89, 1.05)	1.00	1.02 (0.94, 1.12)	0.93 (0.86, 1.01)

All variables were included in the full model.
Model 1 included age group (<60 years, ≥60 years), sex (female, male) and family history of CVD (no, yes) only.
Model 2 included area of residence (rural, urban), formal education (none and primary education, secondary education and above), employment (no, yes) and marital status (single/separated/divorced/widowed, cohabiting/married) only.
Model 3 included current smoking status (no, yes), alcohol use (no, yes) and physical inactivity (no, yes) only.
Model 4 included BMI (<30 kg/m^2, ≥30kg/m^2) and NCD (no, yes) only.
CVD, cardiovascular diseases; BMI, body mass index; NCD, non-communicable diseases.

but contradicted in others.[12,31] There are complexities to these differences, with some possible explanations. First, urban residents are generally from higher economic stratum households[35] with higher educational status, better health literacy and higher disposable income and purchasing power than rural residents. In this study, more than 50% of participants from rural areas had no formal education. Another study with findings similar to ours demonstrated that >90% of those with formal education were from urban areas, and >70% of those with primary education or without formal education were from rural areas.[30] Second, we hypothesize that urban participants might consume more starchy vegetables than non-starchy vegetables (which are more accessible and cheaper), compared with rural participants. A meta-analysis demonstrated this phenomenon.[12] In that study, the rural-urban differential in vegetable consumption was more substantial among rural residents after adjusting for starchy vegetable intakes.

Contrary to previous reports,[30–33,35] we found that participants with higher education (compared with those with no or lower education) were less likely to consume fruit and vegetables frequently. Uneducated individuals tend to live in rural areas with closer access to fruits and vegetables than their educated counterparts, who predominantly reside in urban cities where the cost of fruits and vegetables is high relative to poor income and purchasing power resources. Society-wide poor awareness (independent of educational status even in urban settings) of the significance of fruit and vegetable consumption,[6] and physical barriers associated with fruit and vegetable accessibility among educated individuals[36] among others in this setting, is a probable rationale for the opposite observation in this sample. Also, this sample's uneven country-specific distribution of educational status might have accounted for this difference.

Furthermore, in concordance with previous observations,[37,38] we found that participants who reported a family history of CVD, current smokers, current alcohol users and physically inactive participants were less likely to consume fruit and vegetables frequently. These factors are generally deleterious risk factors for NCDs. With this observation, it might be necessary for future nutrition education and interventions designed to promote healthy dietary habits to consider integrated intervention approaches complementary to healthy lifestyle habits, such as increased physical activity and alcohol and smoking cessation.

Causal inferences cannot be interpreted for factors associated with fruit and vegetable consumption in this study, and there was no information on fruit juices. Fruit and vegetable consumption information was based only on the frequency of portions and not portion size estimates. Neither the SIREN nor AWI-Gen study collected data on the type of fruit or vegetable or portion size estimates. Moreover, quantitative estimation and harmonizing of portion sizes were unfeasible because standard portion sizes differ widely across countries. An underestimation of the variability of participants' characteristics in the regression model is likely, given the binary presentation of participants' characteristics (e.g. 'no' or 'yes' for current smoking and physical inactivity). However, this approach was necessary to simplify these characteristics for statistical analysis, results presentation and ease of

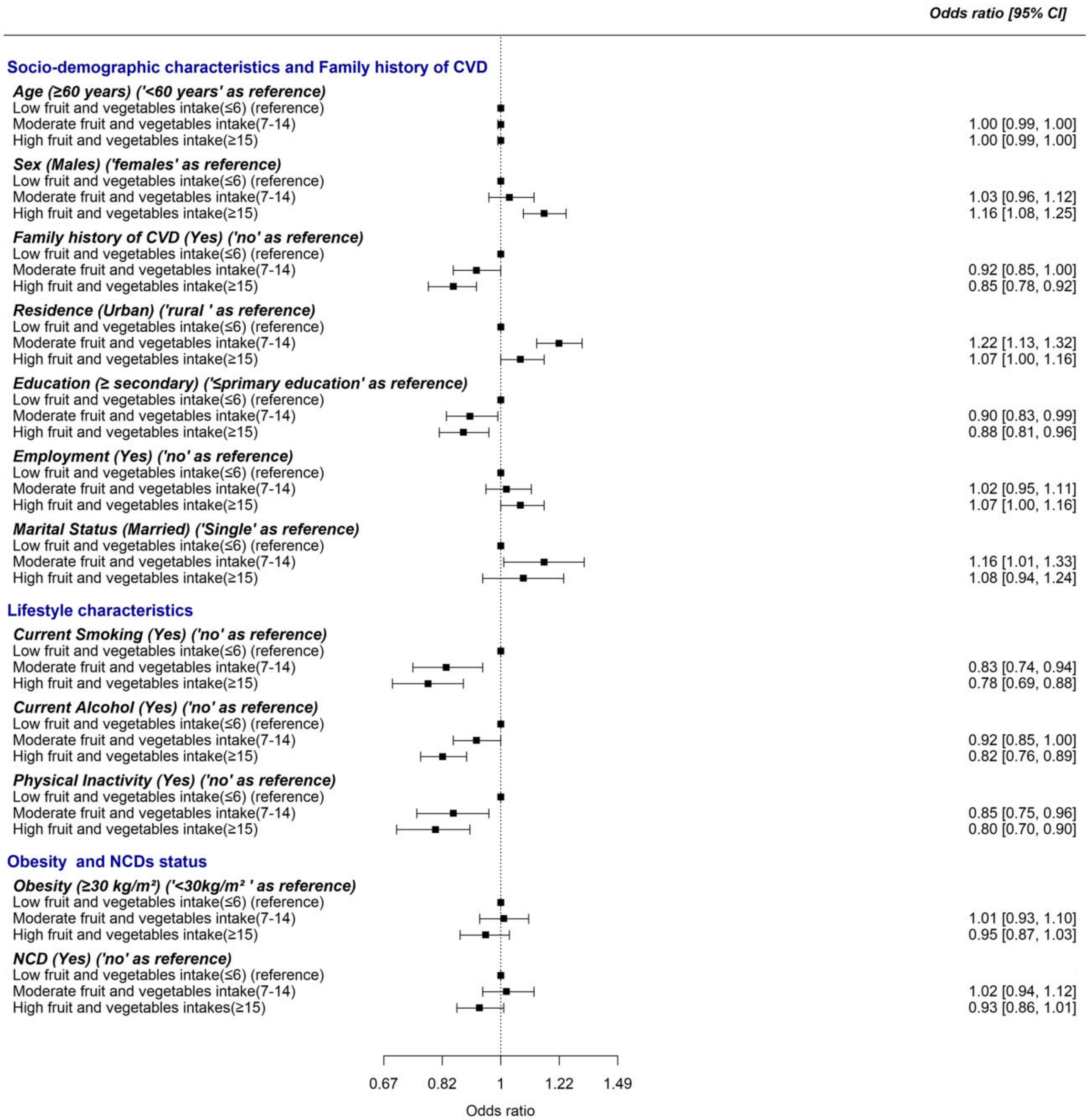

Figure 1. Forest plots of odds ratio and 95% confidence intervals (CIs) of factors associated with the total frequency of fruit and vegetable consumption in the SIREN and AWI-Gen studies. All variables were included in a single model. AWI-Gen, Africa Wits-INDEPTH partnership for Genomic Research; CVD, cardiovascular disease; NCD, non-communicable disease; SIREN, Stroke Investigative Research and Educational Network

interpretation. Also, participants' overall food and dietary exposure was unaccounted for in the multivariable-adjusted analyses. Fruits and vegetables are not consumed independently of other diets. Evaluating the overall dietary exposures of a population, though multifaceted, is critical and quite informative in nutrition epidemiology. The food frequency information was specifically articulated for this population and was not validated. Validation studies are essential for data consistency but somewhat costly and time-dependent. The participating studies pioneered the synoptic investigation of dietary determinants of CVD in Africa and were not primarily designed to comprehensively assess overall dietary exposure. This study is currently the most extensive single dataset to examine the significance of multiple factors in fruit and vegetable consumption and to document the co-occurrence of deleterious CVD-related lifestyle factors (such as smoking, alcohol use and physical inactivity) concerning lower fruit and vegetable consumption, particularly among indigenous Africans. The large sample size, strong statistical power and multifactor assessment of variables in the regression models were additional strengths.

Our findings support the design of culturally suitable educational interventions for promoting habitual and adequate fruit and vegetable consumption. This will contribute to reducing the burden of NCDs, thereby improving the health of Africans in line with the African Union 2063 agenda.[39]

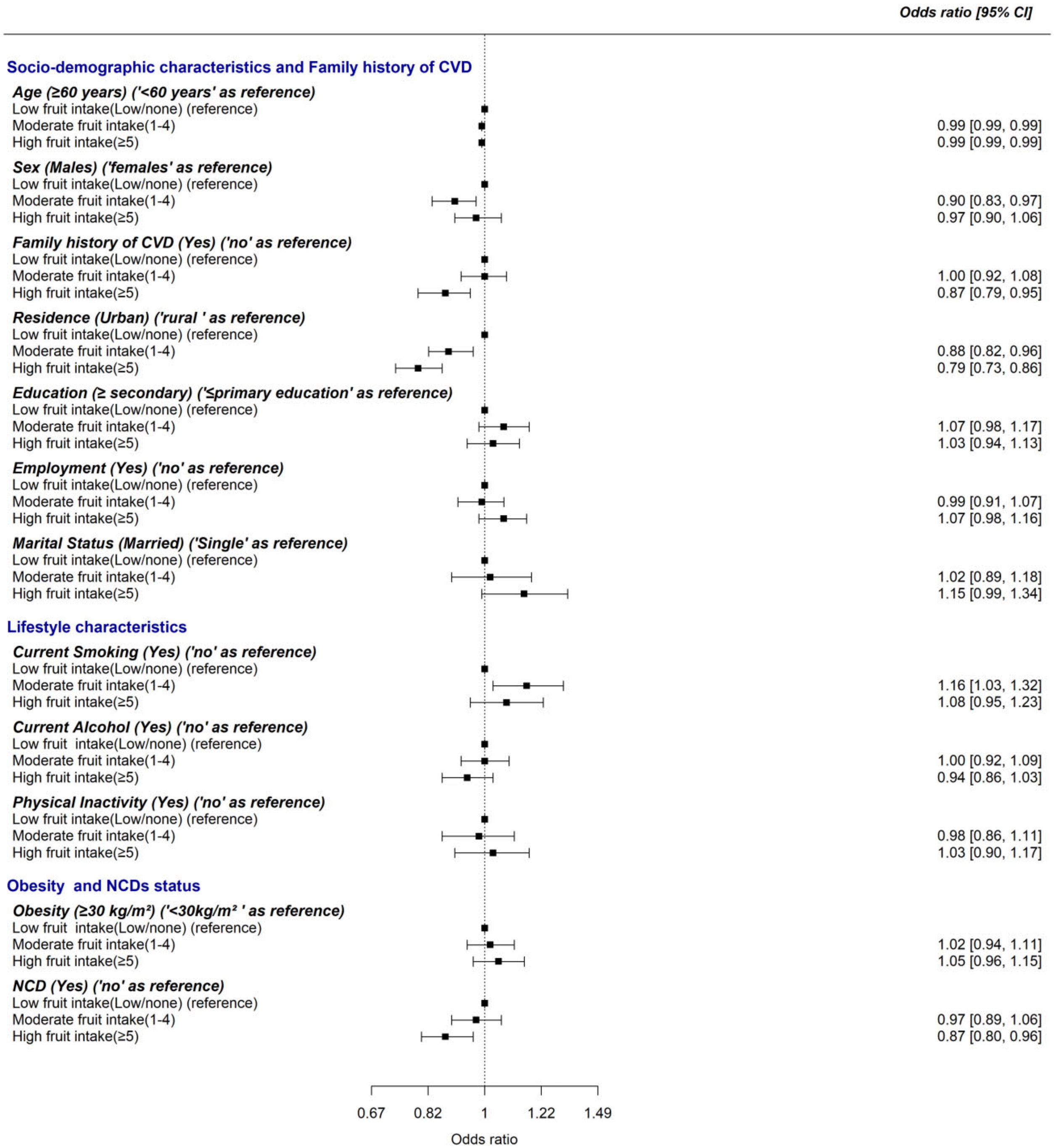

Figure 2. Forest plots of odds ratio and 95% confidence intervals (CIs) of factors associated with the frequency of fruit consumption only in the SIREN and AWI-Gen studies. All variables were included in a single model. AWI-Gen, Africa Wits-INDEPTH partnership for Genomic Research; CVD, cardiovascular disease; NCD, non-communicable disease; SIREN, Stroke Investigative Research and Educational Network

Conclusion

This study found that Africans in this sample generally consumed fruit and vegetables less frequently than populations from other geographical regions, and those who reported harmful lifestyle NCD risk factors were less likely to consume fruit and vegetables frequently.

Ethics approval

The SIREN and AWI-Gen are multicentre studies, and the institutional review board (IRB) approved the study at all sites. The overall coordinating IRB for the SIREN study was the University of Ibadan/University College Hospital Ibadan, Nigeria (approval number: UI/EC/13/0105). The overall coordinating IRB for the AWI-Gen Study was the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (Wits), South Africa (approval no: M121029). Details of the IRB and the approval numbers for all participating sites in the SIREN and AWI-Gen studies are in Supplementary Table S21 (available as Supplementary data at *IJE* online). Individual participants gave informed consent by signing or thumb-printing on an informed consent form in the language they understood.

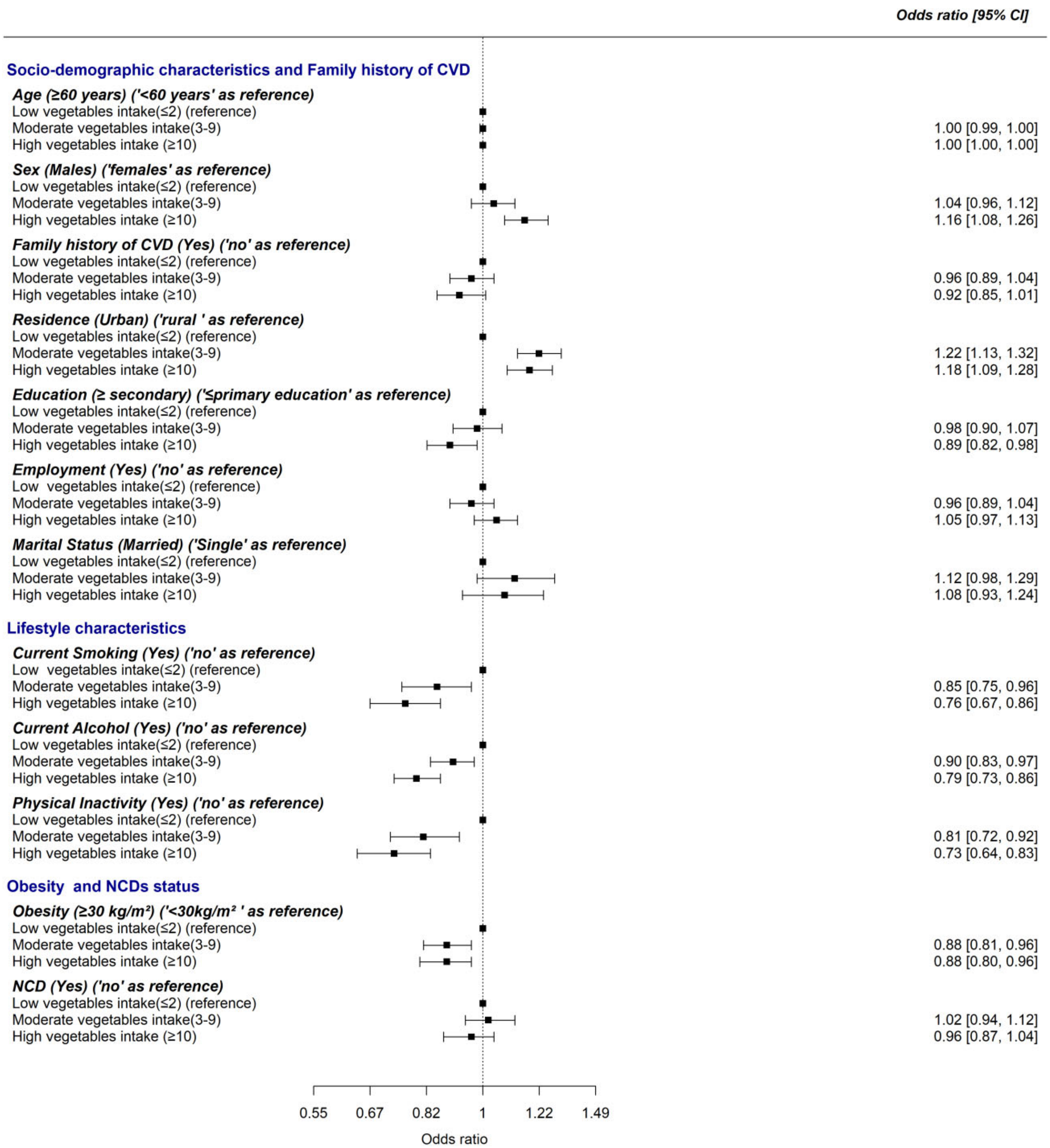

Figure 3. Forest plots of odds ratio and 95% confidence intervals (CIs) of factors associated with the frequency of vegetable consumption only in the SIREN and AWI-Gen studies. All variables were included in a single model. AWI-Gen, Africa Wits-INDEPTH partnership for Genomic Research; CVD, cardiovascular disease; NCD, non-communicable disease; SIREN, Stroke Investigative Research and Educational Network

Data availability

Individual participant data that underlie the results reported in this article (text, tables, figures and appendices) have been de-identified. The joint dataset is available upon reasonable request. A proposal to access the data should be directed to the senior authors, Professor Mayowa Owolabi (SIREN PI: mayowaowolabi@yahoo.com) and Professor Michele Ramsay (AWI-Gen PI). Data requesters will need to sign a data access agreement. The AWI-Gen phenotype data are available on request to the H3Africa Data and Biospecimen Access Committee (EGA accession number—EGAD00001006425).

Supplementary data

Supplementary data are available at *IJE* online.

Author contributions

A.P.O. designed the study. A.P.O., O.J.A., OMA, M.R. and M.O. directed the study's implementation. A.P.O., O.J.A. and O.M.A. designed and executed the analytical strategy. A. P.O. wrote the first draft. O.J.A., O.M.A., A.F., T.C., S.F.M., R.O., M.K., G.O.O., G.O., O.A., F.S., K.W., L.O., J.A., A. A., E.U., R.A., C.J., D.K.A., D.L., B.O., M.R. and M.O.

contributed to the Introduction, Methods and Discussion sections of the text and interpretation of data for the work. O. M.A., C.J., D.K.A., D.L., B.O., M.R. and M.O. critically revised the manuscript for important intellectual content. All authors gave final approval and agreed to be accountable for all aspects of the work, ensuring integrity and accuracy.

Funding

The National Institutes of Health grants supported the study; SIREN (U54HG007479), SIBS Genomics (R01NS107900), SIBS Gen Gen (R01NS107900-02S1), ARISES (R01NS115944-01), H3Africa CVD Supplement (3U24HG009780-03S5), CaNVAS (1R01NS114045-01), Sub-Saharan Africa Conference on Stroke (1R13NS115395-01A1), Training Africans to Lead and Execute Neurological Trials and Studies (D43TW012030) and Growing Data-science Research in Africa to Stimulate Progress (1UE5HL172183-01), AWI-Gen (U54HG006938) and its supplements, as part of the H3Africa Consortium, with additional funding from the Department of Science and Technology, South Africa (DST/CON 0056/2014). A.P.O. was supported by the Brain Pool Fellowship of the National Research Foundation of Korea (2020H1D3A1A04081265). O.J.A. is a recipient of the SIGHPC Computational and Data Science Fellowship in the USA. The funders had no role in the study design, data collection and analysis, decision to publish or preparation of the manuscript.

Acknowledgements

We thank the volunteers and staff of the participating studies across several sites for their dedication and commitment.

Conflict of interest

None declared.

References

1. Stanaway JD, Afshin A, Gakidou E *et al.* Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018;**392**:1923–94.
2. Afshin A, Sur PJ, Fay KA *et al.* Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2019;**393**:1958–72.
3. Zheng P, Afshin A, Biryukov S *et al.* The Burden of Proof studies: assessing the evidence of risk. *Nat Med* 2022;**28**:2038–44.
4. World Health Organization; Nutrition Unit. *Fruit and Vegetable Promotion Initiative: A Meeting Report, 25–27/08/03*. Geneva: World Health Organization, 2003.
5. Kalmpourtzidou A, Eilander A, Talsma EF. Global vegetable intake and supply compared to recommendations: a systematic review. *Nutrients* 2020;**12**:1558.
6. De Filippo A, Meldrum G, Samuel F *et al.* Barrier analysis for adequate daily fruit and vegetable consumption among low-income residents of Hanoi, Vietnam and Ibadan, Nigeria. *Glob Food Sec* 2021;**31**:100586.
7. Peltzer K, Phaswana-Mafuya N. Fruit and vegetable intake and associated factors in older adults in South Africa. *Glob Health Action* 2012;**5**:1–8.
8. Tachi K, Tetteh J, Yawson AE, Agyei-Nkansah A, Archampong T. Alcohol consumption and fruits and vegetable intake among older adults in Ghana: a cross-sectional survey based on WHO-SAGE Wave 2 data. *BMJ Nutr Prev Health* 2020;**3**:220–28.
9. Frank SM, Webster J, McKenzie B *et al.* Consumption of fruits and vegetables among individuals 15 years and older in 28 low- and middle-income countries. *J Nutr* 2019;**149**:1252–59.
10. Raaijmakers I, Snoek H, Maziya-Dixon B, Achterbosch T. Drivers of vegetable consumption in urban Nigeria: food choice motives, knowledge, and self-efficacy. *Sustainability* 2018;**10**:4771.
11. Msambichaka B, Eze IC, Abdul R *et al.* Insufficient fruit and vegetable intake in a low- and middle-income setting: a population-based survey in semi-Urban Tanzania. *Nutrients* 2018;**10**:222.
12. Mensah DO, Nunes AR, Bockarie T, Lillywhite R, Oyebode O. Meat, fruit, and vegetable consumption in Sub-Saharan Africa: a systematic review and meta-regression analysis. *Nutr Rev* 2020;**79**:651–92.
13. Yuyun MF, Sliwa K, Kengne AP, Mocumbi AO, Bukhman G. Cardiovascular diseases in Sub-Saharan Africa compared to high-income countries: an epidemiological perspective. *Glob Heart* 2020;**15**:15.
14. Roth GA, Mensah GA, Johnson CO *et al.*; GBD-NHLBI-JACC Global Burden of Cardiovascular Diseases Writing Group. Global burden of cardiovascular diseases and risk factors, 1990–2019. *J Am Coll Cardiol* 2020;**76**:2982–3021.
15. Gouda HN, Charlson F, Sorsdahl K *et al.* Burden of non-communicable diseases in Sub-Saharan Africa, 1990–2017: results from the Global Burden of Disease Study 2017. *Lancet Glob Health* 2019;**7**:e1375–87.
16. Owolabi MO, Akpa OM, Made F *et al.*; as members of the CVD Working Group of the H3Africa Consortium. Data resource profile: Cardiovascular H3Africa Innovation Resource (CHAIR). *Int J Epidemiol* 2018;**48**:366–67g.
17. Akpalu A, Sarfo FS, Ovbiagele B *et al.*; SIREN as part of the H3Africa Consortium. Phenotyping stroke in Sub-Saharan Africa: Stroke Investigative Research and Education Network (SIREN) Phenomics Protocol. *Neuroepidemiology* 2015;**45**:73–82.
18. Owolabi MO, Sarfo F, Akinyemi R *et al.*; as part of H3Africa Consortium. Dominant modifiable risk factors for stroke in Ghana and Nigeria (SIREN): a case-control study. *The Lancet Global Health* 2018;**6**:e436–46.
19. Ramsay M, Crowther N, Tambo E *et al.* H3Africa AWI-Gen Collaborative Centre: a resource to study the interplay between genomic and environmental risk factors for cardiometabolic diseases in four Sub-Saharan African countries. *Glob Health Epidemiol Genom* 2016;**1**:e20.
20. Ali SA, Soo C, Agongo G *et al.* Genomic and environmental risk factors for cardiometabolic diseases in Africa: methods used for Phase 1 of the AWI-Gen population cross-sectional study. *Glob Health Action* 2018;**11**:1507133.
21. Okekunle AP, Asowata O, Akpa OM *et al.* Dietary patterns associated with stroke among West Africans: a case–control study. *Int J Stroke* 2023;**18**:193–200.
22. Kowal P, Dowd J. *Definition of an Older Person. Proposed Working Definition of an Older Person in Africa for the MDS Project*. Geneva: World Health Organization, 2001.
23. Akpa OM, Okekunle AP, Ovbiagele B *et al.*; SIREN Study as part of the H3Africa Consortium. Factors associated with hypertension among stroke-free indigenous Africans: findings from the SIREN study. *J Clin Hypertens (Greenwich)* 2021;**23**:773–84.
24. World Health Organization. *Obesity and overweight: Fact sheet*. 2017. http://www.who.int/mediacentre/factsheets/fs311/en/ (28 November 2023, date last accessed).
25. Alberti KG, Zimmet P, Shaw J. International Diabetes Federation: a consensus on Type 2 diabetes prevention. *Diabet Med* 2007;**24**:451–63.
26. Expert Panel on Detection Evaluation, Treatment of High Blood Cholesterol in Adults. 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**:2486–97.
27. Chobanian AV, Bakris GL, Black HR *et al.*; National High Blood Pressure Education Program Coordinating Committee. Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. *Hypertension* 2003; **42**:1206–52.
28. Peltzer K, Pengpid S. Fruits and vegetables consumption and associated factors among in-school adolescents in seven African countries. *Int J Public Health* 2010;**55**:669–78.
29. Miller V, Mente A, Dehghan M *et al.*; Prospective Urban Rural Epidemiology (PURE) Study Investigators. Fruit, vegetable, and legume intake, and cardiovascular disease and deaths in 18 countries (PURE): a prospective cohort study. *Lancet* 2017;**390**:2037–49.
30. Amini M, Najafi F, Kazemi Karyani A, Pasdar Y, Samadi M, Moradinazar M. Does socioeconomic status affect fruit and vegetable intake? Evidence from a cross-sectional analysis of the RaNCD Cohort. *Int J Fruit Sci* 2021;**21**:779–90.
31. Li YC, Jiang B, Zhang M *et al.* Vegetable and fruit consumption among Chinese adults and associated factors: a nationally representative study of 170,847 adults. *Biomed Environ Sci* 2017; **30**:863–74.
32. Hernández-Vásquez A, Visconti Lopez FJ, Vargas-Fernández R. Socio-economic inequalities in the consumption of fruits and vegetables in Peru between 2014 and 2019. *Public Health Nutr***25**:1–11.
33. Stea TH, Nordheim O, Bere E, Stornes P, Eikemo TA. Fruit and vegetable consumption in Europe according to gender, educational attainment and regional affiliation—a cross-sectional study in 21 European countries. *PLoS One* 2020;**15**:e0232521.
34. Peltzer K, Pengpid S. Fruits and vegetables consumption and associated factors among in-school adolescents in five southeast Asian countries. *Int J Environ Res Public Health* 2012;**9**:3575–87.
35. Ball K, Lamb KE, Costa C *et al.* Neighbourhood socioeconomic disadvantage and fruit and vegetable consumption: a seven countries comparison. *Int J Behav Nutr Phys Act* 2015;**12**:68.
36. Assari S, Lankarani MM. Educational attainment promotes fruit and vegetable intake for whites but not blacks. *J (Basel)* 2018;**1**:29–41.
37. Pengpid S, Vonglokham M, Kounnavong S, Sychareun V, Peltzer K. The prevalence and social determinants of fruit and vegetable consumption and its associations with noncommunicable diseases risk factors among adults in Laos. *Asia Pac J Public Health* 2019; **31**:157–66.
38. Peltzer K, Pengpid S. Correlates of healthy fruit and vegetable diet in students in low, middle and high income countries. *Int J Public Health* 2015;**60**:79–90.
39. African Union Commission. *Agenda 2063: The AFRICA We Want*. Addis Ababa, Ethiopia: African Union Commission; 2015.