





Factors associated with hypertension among stroke-free indigenous Africans: Findings from the SIREN study

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Abstract

Hypertension is one of the most important risk factors for stroke and cardiovascular diseases (CVD) globally. Understanding risk factors for hypertension among individuals with matching characteristics with stroke patients may inform primordial/

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primary prevention of hypertension and stroke among them. This study identified the risk factors for hypertension among community-dwelling stroke-free population in Ghana and Nigeria. Data for 4267 community-dwelling stroke-free controls subjects in the Stroke Investigative Research and Education Network (SIREN) study in Nigeria and Ghana were used. Participants were comprehensively assessed for sociodemographic, lifestyle and metabolic factors using standard methods. Hypertension was defined as a previous diagnosis by a health professional or use of an anti-hypertensive drug or mean systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg. Logistic regression analysis was used to estimate adjusted odds ratios (aOR) of hypertension and their 95% confidence intervals (CI) at $p < .05$. Overall, 56.7% of the participants were hypertensive with a higher proportion among respondents aged ≥ 60 years (53.0%). Factors including physical inactivity (aOR: 9.09; 95% CI: 4.03 to 20.53, $p < .0001$), diabetes (aOR: 2.70; CI: 1.91 to 3.82, $p < .0001$), being ≥ 60 years (aOR: 2.22; 95% CI: 1.78 to 2.77, $p < .0001$), and family history of CVD (aOR 2.02; CI: 1.59 to 2.56, $p < .0001$) were associated with increased aOR of hypertension. Lifestyle factors were associated with hypertension in the current population of community-dwelling stroke-free controls in west Africa. Community-oriented interventions to address sedentary lifestyles may benefit this population and reduce/prevent hypertension and stroke among them.

1 | INTRODUCTION

Hypertension is increasingly a challenge to public health worldwide and a prime modifiable risk factor for cerebrovascular and cardiovascular events.¹ Recent estimates show that hypertension prevalence increased from 26.4%, (representing nearly one billion people) in 2000² to 31.1% (with data from 135 countries) in 2010.^{3,4} Similarly, recent global blood pressure estimates suggest an increased prevalence among populations from low-income settings including sub-Saharan Africa⁵ with 47.9% prevalence of hypertension.⁶

Aging is a natural and adaptive degenerative phenomenon characterized by alteration in metabolism and changes in body organ(s)⁷ with cumulative susceptibility to degenerative tendencies such as hypertension^{4,8} and adverse significance on virile health.^{7,9} About 7% of the world population are older persons (>60 years)¹⁰ with a projected estimate of one out of every five individuals being over 60 years by 2030.⁸ The rate of hypertension among the older population has been well reported in high-income societies¹¹⁻¹⁴ with little information from populations of African ancestry.

Also, many lifestyle factors have been implicated in the rising burden of hypertension in Africa,^{2,4,15} but reports on the significance of physical inactivity in the epidemiology of hypertension outcomes among Africans are relatively limited. The mechanism and magnitude of the protective effect of achieving at least 30 minutes of moderate-intensity physical activity per day have been established in both laboratory-based research and large longitudinal studies.¹⁶⁻¹⁸ We defined physical inactivity as having a physical activity level of fewer than 30 minutes per day. This recommendation is a reliable

proxy for gauging behavioral susceptibilities to a sedentary lifestyle and poor cardiovascular health.^{17,19}

In addition to cross-country empirical studies,^{6,20} meta-analytical estimates of hypertension in Africa have been reported^{2,3,5,21} and some factors in the general population of Africans have been linked to risk of hypertension.^{2,3,5,8,20,21} However, information about risk factors for hypertension among apparently healthy continental Africans, verified to have matching characteristics with stroke patients, is severely lacking in the literature. Such information in the context of Africa is not only novel but also critical, as increased risk of hypertension in this population is an indication of eventual stroke or vascular events among them.

The present study was designed to assess the factors associated with hypertension status among apparently healthy continental Africans, verified to have matching characteristics with stroke patients. We envisaged that such information may inform and guide the design of interventions for primary prevention of hypertension, and stroke or other vascular events in this important population.

2 | METHODS

2.1 | Data source, extraction, and sample size

The Stroke Investigative Research and Educational Network (SIREN) began in 2014, to assess the burden of stroke in sub-Saharan Africa. It was a multi-center study and recruited

TABLE 1 Sociodemographic, lifestyle, anthropometric, and metabolic characteristics of stroke-free controls according to hypertension status in the SIREN Study

| Characteristics | All patients (N = 4267) | | | | <60 years (n = 2411) | | | | ≥60 years (n = 1856) | | | |
|-----------------------------|-------------------------|-----------------------------|-------------------------|--------|----------------------|-----------------------------|-------------------------|--------|----------------------|----------------------------|-------------------------|--------|
| | Combined (N = 4267) | Not Hypertensive (n = 1848) | Hypertensive (n = 2419) | p | Combined (N = 2411) | Not Hypertensive (n = 1273) | Hypertensive (n = 1138) | p | Combined (N = 1856) | Not Hypertensive (n = 575) | Hypertensive (n = 1281) | p |
| Sex | | | | | | | | | | | | |
| Female | 2177 (51.0) | 855 (46.3) | 1322 (54.7) | <.0001 | 1278 (53.0) | 613 (48.2) | 665 (58.4) | <.0001 | 889 (48.4) | 242 (42.1) | 657 (51.3) | <.0001 |
| Male | 2090 (49.0) | 993 (53.7) | 1097 (45.3) | | 1133 (47.0) | 660 (51.8) | 473 (41.6) | | 957 (51.6) | 333 (57.9) | 624 (48.7) | |
| Age (years) | 55.9 ± 14.7 | 51.1 ± 15.4 | 59.7 ± 13.0 | <.0001 | 45.5 ± 9.2 | 42.7 ± 9.6 | 48.6 ± 7.6 | <.0001 | 69.5 ± 7.9 | 69.5 ± 7.7 | 69.5 ± 7.9 | .931 |
| <60 years | 2411 (56.5) | 1273 (68.9) | 1138(47.0) | <.0001 | | | | | | | | |
| ≥60 years | 1856(43.5) | 575(31.1) | 1281(53.0) | | | | | | | | | |
| Income | | | | | | | | | | | | |
| ≤\$100/month | 2672 (62.6) | 1176 (63.6) | 1496 (61.8) | .230 | 1430 (59.3) | 774 (60.8) | 656 (57.6) | .115 | 1242 (66.9) | 402 (69.9) | 840 (65.6) | .066 |
| >\$100/month | 1595 (37.4) | 672 (36.4) | 923 (38.2) | | 981 (40.7) | 499 (39.2) | 482 (42.4) | | 614 (33.1) | 173 (30.1) | 441 (34.4) | |
| Education | | | | | | | | | | | | |
| None | 879 (20.6) | 294 (15.9) | 585 (24.2) | <.0001 | 289 (12.0) | 122 (9.6) | 167 (14.7) | <.0001 | 590 (31.8) | 172 (29.9) | 418 (32.6) | .245 |
| ≥Primary | 3388 (79.4) | 1554 (84.1) | 1834 (75.8) | | 2122 (88.0) | 1176 (90.4) | 977 (85.3) | | 1266 (68.2) | 403 (70.1) | 863 (67.4) | |
| Domicile | | | | | | | | | | | | |
| Rural | 1922 (45.0) | 858 (46.4) | 1064 (44.0) | .112 | 1103 (45.7) | 580 (45.6) | 523 (46.0) | .845 | 819 (44.1) | 278 (48.3) | 541 (42.2) | .014 |
| Urban | 2345 (55.0) | 990 (53.6) | 1355 (56.0) | | 1308 (54.3) | 693 (54.4) | 615 (54.0) | | 1037 (55.9) | 297 (51.7) | 740 (57.8) | |
| Physical inactivity | 78 (1.8) | 18 (1.0) | 60 (2.5) | <.0001 | 13 (0.5) | 05 (0.4) | 08 (0.7) | .315 | 65 (3.5) | 13 (2.3) | 52 (4.1) | .062 |
| Tobacco use (Yes) | 265 (6.3) | 89 (4.9) | 176 (7.3) | .001 | 112 (4.7) | 47 (3.7) | 65 (5.7) | .019 | 153 (8.3) | 42 (7.4) | 111 (8.7) | .360 |
| Alcohol use (Yes) | 1080 (25.4) | 412 (22.4) | 671 (27.7) | <.0001 | 568 (23.7) | 273 (21.6) | 295 (26.1) | .010 | 512 (27.7) | 139 (24.3) | 373 (29.2) | .030 |
| Salt Use (Yes) | 1005 (23.8) | 509 (27.8) | 496 (20.7) | <.0001 | 621 (26.0) | 358 (28.3) | 263 (23.5) | .007 | 384 (20.9) | 151 (26.8) | 233 (18.3) | <.0001 |
| Dyslipidemia (Yes) | 2395 (56.1) | 975 (52.8) | 1420 (58.7) | <.0001 | 1311 (54.4) | 667 (50.9) | 644 (56.6) | .039 | 1084 (58.4) | 308 (53.6) | 776 (60.6) | .005 |
| Diabetes (Yes) | 471 (11.0) | 95 (5.1) | 376 (15.5) | <.0001 | 194 (8.0) | 54 (4.2) | 140 (12.3) | <.0001 | 277 (14.9) | 41 (7.1) | 236 (18.4) | <.0001 |
| History of CVD (Yes) | 1070 (25.1) | 379 (20.5) | 691 (28.6) | <.0001 | 700 (29.0) | 302 (23.7) | 398 (35.0) | <.0001 | 370 (19.9) | 77 (13.4) | 293 (22.9) | <.0001 |
| SBP (mmHg) | 135.8 ± 24.2 | 118.0 ± 10.9 | 149.0 ± 23.0 | <.0001 | 130.5 ± 22.6 | 116.9 ± 10.8 | 145.5 ± 22.8 | <.0001 | 142.6 ± 24.5 | 120.7 ± 10.8 | 152.1 ± 22.7 | <.0001 |
| DBP (mmHg) | 82.7 ± 14.3 | 73.4 ± 8.1 | 89.7 ± 14.0 | <.0001 | 82.4 ± 14.1 | 73.9 ± 8.0 | 91.7 ± 13.4 | <.0001 | 83.2 ± 14.6 | 72.3 ± 8.2 | 88.0 ± 14.2 | <.0001 |
| BMI (kg/m ²) | 26.2 ± 5.8 | 25.0 ± 5.3 | 27.2 ± 5.9 | <.0001 | 26.8 ± 5.8 | 25.5 ± 5.3 | 28.3 ± 6.1 | <.0001 | 25.5 ± 5.6 | 23.9 ± 5.1 | 26.2 ± 5.6 | <.0001 |
| ≥30 kg/m ² (Yes) | 911 (22.1) | 256 (14.4) | 655 (27.9) | <.0001 | 583 (25.0) | 203 (16.6) | 380 (34.4) | <.0001 | 328 (18.3) | 53 (9.7) | 275 (22.1) | <.0001 |
| WC (cm) | 89.7 ± 14.5 | 86.7 ± 14.7 | 91.9 ± 14.0 | <.0001 | 89.9 ± 14.6 | 86.8 ± 14.2 | 93.2 ± 14.2 | <.0001 | 89.5 ± 14.5 | 86.5 ± 15.8 | 90.8 ± 13.6 | <.0001 |

(Continues)

TABLE 1 (Continued)

| Characteristics | All patients (N = 4267) | | | <60 years (n = 2411) | | | ≥60 years (n = 1856) | | |
|-----------------|-------------------------|-----------------------------|-------------------------|----------------------|-----------------------------|-------------------------|----------------------|----------------------------|-------------------------|
| | Combined (N = 4267) | Not Hypertensive (n = 1848) | Hypertensive (n = 2419) | Combined (N = 2411) | Not Hypertensive (n = 1273) | Hypertensive (n = 1138) | Combined (N = 1856) | Not Hypertensive (n = 575) | Hypertensive (n = 1281) |
| HDL (mg/dl) | 51.7 ± 17.2 | 50.5 ± 16.4 | 52.5 ± 17.8 | 51.2 ± 16.8 | 50.3 ± 16.0 | 52.2 ± 17.6 | 52.3 ± 17.7 | 51.1 ± 17.2 | 52.9 ± 17.9 |
| LDL (mg/dl) | 118.9 ± 44.6 | 115.1 ± 43.3 | 121.8 ± 45.4 | 116.3 ± 42.4 | 114.1 ± 41.8 | 118.7 ± 43.0 | 122.4 ± 47.2 | 117.4 ± 46.6 | 124.6 ± 47.4 |
| TC (mg/dl) | 192.1 ± 49.1 | 187.3 ± 49.2 | 195.8 ± 48.8 | 188.5 ± 46.9 | 185.1 ± 47.3 | 192.2 ± 46.3 | 197.1 ± 51.6 | 192.4 ± 53.1 | 199.1 ± 50.8 |
| TG (mg/dl) | 103.3 ± 50.4 | 97.7 ± 48.3 | 107.3 ± 51.5 | 101.2 ± 50.6 | 96.7 ± 49.7 | 106.2 ± 51.1 | 105.9 ± 50.1 | 100.2 ± 44.9 | 108.3 ± 52.0 |
| FBG (mg/dl) | 95.0 ± 41.3 | 91.2 ± 40.3 | 97.8 ± 41.8 | 91.8 ± 25.8 | 88.9 ± 21.2 | 95.1 ± 29.9 | 99.1 ± 55.0 | 96.6 ± 66.8 | 100.1 ± 49.6 |

Note: Continuous variables are presented as mean ± standard deviation and compared using the t test; Categorical variables are presented as n(%) and compared using the chi-square test.

Abbreviations: BMI, body mass index; CVD, cardiovascular diseases; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; WC, waist circumference.

population-based adults (≥18 years) as stroke-free controls from different localities in Nigeria and Ghana.²² Controls were adults (≥18 years), matched to stroke patients for age (±5 years), sex, and ethnicity. Further details on the protocol,²² recruitment, validation, and pilot findings of the SIREN study have been reported elsewhere.^{23,24} Ethical approval and informed consent were obtained from respondents before participation in the study. The current report utilized data from the population-based controls comprising of 4408 community-dwelling stroke-free adults (≥18 years) that participated in the SIREN study. We excluded respondents with missing data on sex (n = 14), income status (n = 111), level of education (n = 4), region of residence (n = 2), and hypertension status (n = 10). The final analysis of this report was based on 4267 respondents with complete information on sociodemographic and hypertension status.

2.2 | Data collection procedures

In-person interviews and physical examinations were conducted by trained medical personnel to extract information on demographics, lifestyle, history of diseases, and metabolic parameters of respondents who gave duly informed consent for participation in the study. The recruitment of participants and the data collection strategies have been reported previously.^{22,23} Sociodemographic information assessed were age (in years), sex (men/women), domicile (rural or urban), highest education completed, average monthly income etc. Also, respondents reported the average number of hours of physical activities per day (including working and leisure times) and were classified as physically inactive if they were not involved in a moderate or strenuous exercise of ≥4 hours/week as reported by O'Donnell et al²⁵ Tobacco use was defined as whether the respondent used any form of tobacco products, 12 months before the study or in a lifetime. Alcohol use was defined as habitual use of any form of alcoholic drink(s) in a respondent's lifetime and/or in the last 12 months preceding the study. Participants were also requested to provide information on adding salt to food after cooking (at the table, just before or while eating).

2.3 | Definition of phenotypes

2.3.1 | Definition of hypertension (the outcome variable)

Systolic and diastolic blood pressures were assessed three-times (while the participants were at a resting state) by trained medical experts using, and the mean of the last two measurements was computed as the blood pressure for each participant. Hypertension was defined as mean SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg or previous hypertension diagnosis by a health professional or use of anti-hypertensive/blood pressure-lowering drugs according to the American Heart Association guidelines.²⁶

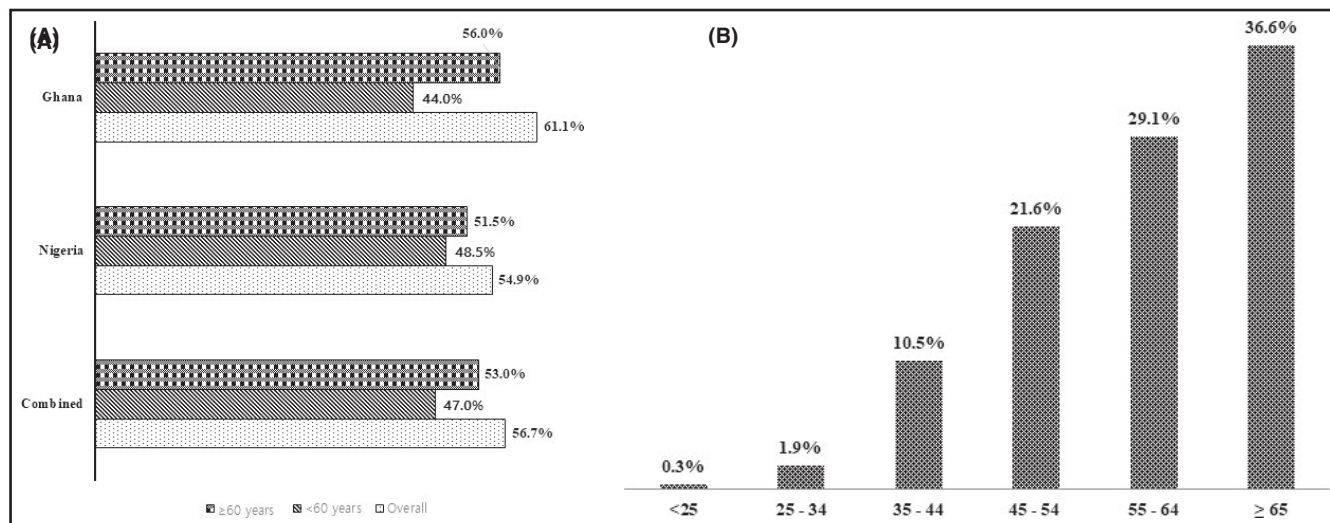


FIGURE 1 In-country (A) and age-specific (B) prevalence of hypertension among stroke-free subject in the SIREN study

2.3.2 | Definition of hypertension risk factors (Independent variables)

Fasting blood samples were taken after an overnight fast of at least 8-12 hours to evaluate fasting blood glucose and lipid profile; high-density lipoprotein (HDL), low-density lipoprotein (LDL), total cholesterol (TC), and triglycerides (TG). Dyslipidemia was defined as HDL \leq 40 mg/dl or LDL \geq 100 mg/dl or TC \geq 200 mg/dl or TG \geq 150 mg/dl using the National Cholesterol Education Program Adult Treatment Panel III guidelines.²⁷ Diabetes was defined as a self-reported prior diagnosis by a medical expert, or HbA1c $>$ 6.5%, or a fasting blood glucose \geq 126 mg/dl or the use of glucose-lowering drugs. Also, family history of cardiovascular diseases was established where respondents reported any known family history of cardiovascular diseases (CVD).²³ Waist circumference—WC (cm), height (cm), and weight (kg) were determined using standard protocols.²⁸ Body mass index (BMI) was calculated as weight (kg) divided by square of height (m^2) using WHO guidelines.²⁹

2.4 | Statistical analysis

The distribution of categorical and continuous data was presented using percentages and mean \pm standard deviation (SD), respectively. Demographic and lifestyle characteristics were compared between hypertensive and non-hypertensive groups using chi-squared test or independent sample t-test for categorical or continuous variables, respectively. Multiple logistic regression was used to estimate the adjusted odds ratio (aOR) and 95% confidence interval (95% CI) of hypertension for all risk factors. To investigate age-specific and in-country factors associated with hypertension, participants characteristics were stratified by subgroups defined by age (older adult, ≥ 60 years and young adults, 18-60 years),

based on WHO proposed working definition for older persons³⁰ and by country (Nigeria and Ghana). All statistical analyses were carried out at two-sided $p < .05$ using SPSS for Windows (version 22; IBM Corporation).

3 | RESULTS

3.1 | Characteristics of respondents

Overall, 51.0% were women, mean age was 55.9 ± 14.7 years, 43.5% were ≥ 60 years, 55.0% resided in urban areas, 1.8% were physically inactive, 6.3% used tobacco, and 25.4% use alcohol (Table 1). Besides, mean SBP was 135.8 ± 24.2 mmHg and 22.1% were obese. The trend appeared similar among respondents < 60 years. Among respondents ≥ 60 years, 51.6% were men, 3.5% were physically inactive, 8.3% on tobacco, 27.7% on alcohol, and 18.3% were obese. In the Nigerian sample (Table S1), 57.4% were < 60 years, 55.8% resided in rural households, 0.7% were physically inactive, 4.9% used tobacco, and 26.5% added salt to already prepared meals at the table. Among older adults (≥ 60 years) of Nigerian descent, 53.4% were men, 1.7% were physically inactive, 6.2% used tobacco, 20.8% were alcoholics, 52.3% had dyslipidemia, and 13.5% were diabetics. In the Ghanaian sample (Table S2), 51.6% were men, 4.4% were physically inactive, 9.4% used tobacco, and 43.4% habitually used alcohol. Among patients ≥ 60 years from Ghana, 47.4% were men, 19.8% reside in rural areas, 7.3% were physically inactive, 43.1% used alcohol, 72.2% had dyslipidemia, 18.2% were diabetics, and 26.9% were obese.

3.2 | Prevalence of hypertension

Overall, 56.7% of the entire population were hypertensive (Figure 1A). The prevalence was lower ($p < .0001$) among

TABLE 2 In-country comparison of sociodemographic, lifestyle, anthropometric, and metabolic characteristics of hypertensive among stroke-free controls stratified by age in the SIREN Study

| | Hypertensives only | | | | | |
|-----------------------------|------------------------|------------------------|--------|------------------------|------------------------|--------|
| | Nigerian (N = 1651) | | | Ghanaian (N = 764) | | |
| | <60 years (n = 800) | ≥60 years (n = 851) | p | <60 years (n = 336) | ≥60 years (n = 428) | p |
| Sex | | | | | | |
| Female | 492 (61.5) | 415 (48.8) | <.0001 | 171 (50.9) | 241 (56.3) | .136 |
| Male | 308 (38.5) | 436 (51.2) | | 165 (49.1) | 187 (43.7) | |
| Age (years) | 47.8 ± 7.7 | 68.8 ± 7.7 | <.0001 | 50.4 ± 6.8 | 71.0 ± 8.2 | <.0001 |
| Income | | | | | | |
| ≤\$100/month | 480 (60.0) | 565 (66.4) | .007 | 174 (51.8) | 274 (64.0) | .001 |
| >\$100/month | 320 (40.0) | 286 (33.6) | | 162 (48.2) | 154 (36.0) | |
| Education | | | | | | |
| None | 135 (16.9) | 282 (33.1) | <.0001 | 31 (9.2) | 135 (31.5) | <.0001 |
| ≥Primary education | 665 (83.1) | 569 (66.9) | | 305 (90.8) | 293 (68.5) | |
| Domicile | | | | | | |
| Rural | 456 (57.0) | 464 (54.5) | .311 | 65 (19.3) | 77 (18.0) | .633 |
| Urban | 344 (43.0) | 387 (45.5) | | 271 (80.7) | 351 (82.0) | |
| Physical inactivity | 00 (0.0) | 16 (1.9) | <.0001 | 08 (2.4) | 35 (8.2) | .001 |
| Tobacco use (Yes) | 42 (5.3) | 61 (7.2) | .106 | 23 (6.9) | 50 (11.7) | .025 |
| Alcohol use (Yes) | 145 (18.2) | 192 (22.2) | .028 | 150 (44.8) | 181 (42.4) | .509 |
| Salt Use (Yes) | 203 (25.8) | 192 (22.7) | .147 | 58 (17.5) | 41 (9.6) | .002 |
| Dyslipidemia (Yes) | 394 (49.2) | 452 (53.1) | .116 | 249 (74.1) | 323 (75.5) | .667 |
| Diabetes (Yes) | 91 (11.4) | 145 (17.0) | .001 | 48 (14.3) | 91 (21.3) | .013 |
| History of CVD (Yes) | 227 (28.4) | 157 (18.4) | <.0001 | 169 (50.3) | 136 (31.8) | <.0001 |
| SBP (mmHg) | 143.8 ± 22.9 | 151.8 ± 23.3 | <.0001 | 149.7 ± 21.9 | 152.9 ± 21.3 | .048 |
| DBP (mmHg) | 91.9 ± 13.3 | 89.4 ± 14.4 | <.0001 | 91.2 ± 13.7 | 85.4 ± 13.4 | <.0001 |
| BMI (kg/m ²) | 27.8 ± 6.0 | 25.6 ± 5.4 | <.0001 | 29.3 ± 6.2 | 27.5 ± 5.9 | <.0001 |
| ≥30 kg/m ² (Yes) | 245 (31.4) | 152 (18.2) | <.0001 | 134 (41.5) | 123 (30.3) | .002 |
| WC (cm) | 94.0 ± 14.2 | 90.8 ± 13.7 | <.0001 | 91.4 ± 14.0 | 90.7 ± 13.5 | .533 |
| HDL (mg/dl) | 50.9 ± 17.7 | 51.9 ± 18.4 | .362 | 55.0 ± 17.2 | 54.7 ± 16.9 | .801 |
| LDL (mg/dl) | 108.2 ± 34.9 | 114.7 ± 44.6 | .003 | 141.3 ± 49.7 | 140.9 ± 47.0 | .912 |
| TG (mg/dl) | 180.5 ± 39.7 | 188.4 ± 49.6 | .001 | 217.3 ± 49.4 | 216.8 ± 48.0 | .887 |
| TG (mg/dl) | 103.8 ± 46.8 | 107.7 ± 45.9 | .123 | 111.1 ± 58.6 | 109.7 ± 60.8 | .749 |
| FBG (mg/dl) | 94.7 ± 27.5 | 102.2 ± 59.3 | .013 | 95.7 ± 33.1 | 97.2 ± 32.3 | .552 |

Abbreviations: BMI, body mass index; CVD, cardiovascular diseases; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides; WC, waist circumference.

respondents <60 years (47.0%) compared with respondents ≥60 years (53.0%). Stratification by country revealed a similar trend between Nigeria and Ghana but the burden of hypertension in the controls was significantly higher ($p < .0001$) in the Ghanaian sample (61.1%) than among Nigerians (54.9%). Stratifying hypertension prevalence by age-group (Figure 1B), showed a progressive increase in the prevalence of hypertension among controls (from 0.3% among participants aged <25 years to 36.6% among older adults, aged ≥65 years).

3.3 | Country-specific and age-specific comparison of hypertensives

A country-specific comparison of hypertensives (Table S3) revealed hypertensives from the Ghanaian sample (61.8 ± 12.7 years) were significantly older than their Nigerian counterpart (58.6 ± 13.0 years). Also, the proportion of hypertensives with high-income (>\$100/month) was significantly higher among Ghanaians (41.4%) compared with Nigerians (36.7%), and proportion of hypertensives with some

TABLE 3 Independent association of sociodemographic, lifestyle, anthropometric, and metabolic factors with hypertension among stroke-free controls in the SIREN study

| Factors | Combined | | | Nigeria | | | Ghana | | |
|------------------------------|------------------------------------|-------------------------------------|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|------------------------------------|
| | All | <60 years | ≥60 years | All | <60 years | ≥60 years | All | <60 years | ≥60 years |
| | | | | | | | | | |
| Sex (Male) | 0.66 (0.53, 0.83) [†] | 0.60 (0.45, 0.81) [†] | 0.85 (0.59, 1.23) | 0.68 (0.52, 0.89) ^{**} | 0.57 (0.40, 0.80) [†] | 0.92 (0.60, 1.41) | 0.59 (0.37, 0.93) [*] | 0.64 (0.35, 1.16) | 0.56 (0.25, 1.23) |
| Age (≥60 years) | 2.22 (1.78, 2.77) [†] | ^a | ^a | 1.93 (1.48, 2.50) [†] | ^a | ^a | 3.03 (1.93, 4.76) [†] | ^a | ^a |
| Education (≥Primary) | 0.88 (0.66, 1.16) | 0.75 (0.48, 1.18) | 0.88 (0.60, 1.28) | 0.76 (0.55, 1.06) | 0.63 (0.38, 1.05) | 0.76 (0.48, 1.21) | 1.48 (0.82, 2.67) | 1.95 (0.64, 5.88) | 1.35 (0.62, 2.91) |
| Domicile (Urban) | 0.72 (0.58, 0.89) ^{**} | 0.59 (0.44, 0.78) [†] | 0.98 (0.70, 1.37) | 0.78 (0.61, 1.01) [*] | 0.64 (0.46, 0.90) ^{**} | 1.06 (0.70, 1.60) | 0.74 (0.44, 1.23) | 0.71 (0.34, 1.45) | 0.74 (0.35, 1.54) |
| Physical inactivity | 9.09 (4.03, 20.53) [†] | 8.32 (1.84, 37.54) ^{**} | 8.42 (3.16, 22.43) [†] | 11.34 (2.40, 53.60) ^{**} | ^a | 10.02 (2.10, 47.81) ^{**} | 8.51 (3.04, 23.77) [†] | 13.74 (2.65, 71.31) ^{**} | 4.86 (1.30, 18.10) [*] |
| Tobacco use | 1.38 (0.90, 2.11) | 1.99 (1.11, 3.57) [*] | 0.91 (0.48, 1.70) | 1.91 (1.07, 3.42) [*] | 2.39 (1.11, 5.14) [*] | 1.42 (0.58, 3.47) | 0.93 (0.48, 1.79) | 1.30 (0.50, 3.36) | 0.76 (0.30, 1.96) |
| Alcohol use | 0.99 (0.77, 1.28) | 0.83 (0.61, 1.13) | 1.29 (0.86, 1.93) | 1.08 (0.77, 1.51) | 0.95 (0.60, 1.49) | 1.31 (0.78, 2.21) | 1.06 (0.69, 1.63) | 0.92 (0.53, 1.60) | 1.30 (0.63, 2.65) |
| Salt use | 0.69 (0.54, 0.88) ^{**} | 0.83 (0.61, 1.13) | 0.43 (0.29, 0.64) [†] | 0.76 (0.57, 1.01) | 0.80 (0.55, 1.16) | 0.52 (0.32, 0.83) [*] | 0.49 (0.30, 0.80) ^{**} | 0.74 (0.40, 1.37) | 0.24 (0.10, 0.55) [†] |
| Dyslipidemia | 1.21 (0.99, 1.48) | 1.11 (0.85, 1.45) | 1.27 (0.91, 1.76) | 1.13 (0.89, 1.44) | 1.05 (0.77, 1.44) | 1.18 (0.80, 1.76) | 1.58 (1.05, 2.38) [*] | 1.62 (0.91, 2.79) | 1.62 (0.84, 3.13) |
| Diabetes | 2.70 (1.91, 3.82) [†] | 3.35 (2.06, 5.47) [†] | 2.13 (1.29, 3.52) ^{**} | 2.56 (1.67, 3.91) [†] | 3.08 (1.69, 5.58) [†] | 2.06 (1.10, 3.85) [*] | 3.04 (1.64, 5.64) [†] | 3.49 (1.43, 8.48) ^{**} | 2.58 (1.05, 6.33) [*] |
| Family history of CVD | 2.02 (1.59, 2.56) [†] | 2.34 (1.74, 3.15) [†] | 1.69 (1.11, 2.59) [*] | 2.35 (1.73, 3.19) [†] | 2.83 (1.94, 4.11) [†] | 1.76 (1.02, 3.03) [*] | 1.49 (0.98, 2.26) | 1.61 (0.95, 2.73) | 1.45 (0.69, 3.03) |
| SBP | 1.09 (1.09, 1.10) [†] | 1.08 (1.07, 1.10) [†] | 1.11 (1.10, 1.13) [†] | 1.09 (1.08, 1.10) [†] | 1.08 (1.06, 1.09) [†] | 1.12 (1.10, 1.14) [†] | 1.11 (1.09, 1.13) [†] | 1.11 (1.08, 1.13) [†] | 1.11 (1.08, 1.14) [†] |
| DBP | 1.11 (1.09, 1.12) [†] | 1.13 (1.11, 1.15) [†] | 1.08 (1.06, 1.10) [†] | 1.12 (1.10, 1.14) [†] | 1.15 (1.12, 1.17) [†] | 1.09 (1.07, 1.12) [†] | 1.07 (1.05, 1.10) [†] | 1.09 (1.06, 1.13) [†] | 1.06 (1.02, 1.10) ^{**} |
| BMI (≥30 kg/m ²) | 1.30 (0.98, 1.73) | 1.15 (0.80, 1.65) | 1.68 (1.02, 2.77) [*] | 1.48 (1.04, 2.10) [*] | 1.31 (0.84, 2.02) | 2.08 (1.11, 3.91) ^{**} | 1.13 (0.67, 1.93) | 1.30 (0.66, 2.55) | 1.04 (0.43, 2.52) |
| Waist circumference (cm) | 1.01 (1.00, 1.02) [†] | 1.01 (1.00, 1.02) ^{**} | 1.01 (1.00, 1.03) ^{**} | 1.01 (1.00, 1.02) [†] | 1.01 (0.99, 1.02) | 1.01 (0.99, 1.02) | 1.02 (1.00, 1.04) ^{**} | 1.01 (0.99, 1.03) | 1.03 (1.00, 1.06) |

Abbreviations: BMI, body mass index; CVD, cardiovascular diseases; DBP, diastolic blood pressure; SBP, systolic blood pressure.

^aThe variable was constant for the selected cases and was exempted from the analysis.^{*}*p* < .05.^{**}*p* < .01.[†]*p* < .0001.

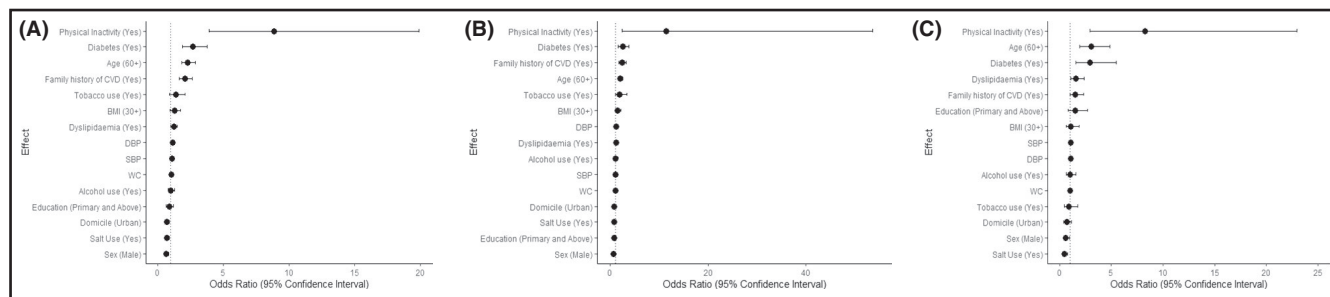


FIGURE 2 Adjusted odds and 95% CI of factors associated with hypertension in the overall population (A), Nigerian sample (B), and Ghanaian sample (C)

education was significantly higher among Ghanaian sample (78.3%) than the Nigerian sample (74.7%). Also, the prevalence of physical inactivity was significantly higher among hypertensive from Ghana (5.6%) compared with those from Nigeria (1.0%). Tobacco and alcohol use were more rampant among Ghanaians sample (9.6% and 49.6% respectively) than Nigerians (6.3% and 20.5% respectively). Also, the prevalence of dyslipidemia among those with hypertension was significantly higher in the Ghanaian (74.9%) compared with the Nigerian sample (51.2%). Similarly, the prevalence of diabetes was higher among hypertensive from the Ghanaian sample (18.2%) compared with the Nigerian sample (14.3%) and obesity appears more prevalent in the Ghanaian sample (35.3%) than in the Nigerian sample (24.6%).

Stratifying hypertensives by age-group (Table S3), we found, the prevalence of high-income earning was higher among hypertensives <60 years (42.4%) compared with those ≥60 years (34.4%), and physical inactivity was rampant among hypertensive ≥60 years (4.1%) compared with those <60 years (0.7%). Also, tobacco use was rampant among hypertensive adults ≥60 years (8.7%) compared with those <60 years (5.7%), but the prevalence of salt use was higher among hypertensives <60 years (23.5%) compared with those ≥60 years (18.3%). History of CVD was more prevalent among hypertensives <60 years (35.0%) compared with those ≥60 years (22.9%). In the same vein, obesity prevalence was higher among hypertensives <60 years (34.4%) compared with those ≥60 years (22.1%).

In-country assessment of sociodemographic, lifestyle, anthropometric, and metabolic characteristics of hypertensives according to age-group is presented in Table 2. In the Nigerian sample of hypertensives, high incoming earning was more prevalent among those <60 years (40.0%) than those ≥60 years (33.6%), but the prevalence of alcohol use was higher among those ≥60 years (22.2%) compared with those <60 years (18.2%). Also, diabetes was prevalent among hypertensives ≥60 years (17.0%) compared with those <60 years (11.4%), but a family history of CVD was more prominent among those <60 years (28.4%) than those ≥60 years (18.4%). Also, the prevalence of obesity was higher among hypertensive <60 years (31.4%) compared with those ≥60 years (18.2%). Furthermore, findings from the Ghanaian sample (Table 2) were similar to the observation in the Nigerian sample, but the prevalence of salt use was significantly higher among hypertensives <60 years (17.5%) compared with those ≥60 years (9.6%).

3.4 | Factors associated with hypertension

Overall (Table 1) prevalence of hypertension was significantly higher among women (54.7%) than men (45.3%), and among older adults (53.0%) compared with young adults (47.0%). Also, hypertension prevalence was among urban residents (56.0) compared with rural dwellers (44.0%). Prevalence of physical inactivity was significantly higher among hypertensives (2.5%) compared with non-hypertensives (1.0%). Similarly, tobacco use was prevalent among hypertensives (7.3%) compared with non-hypertensives (4.9%) and prevalence of alcohol use was significantly higher among hypertensives (27.7%) compared with non-hypertensives (22.4%). Also, a higher proportion of hypertensives (58.7%) compared with non-hypertensives (52.8%) had dyslipidemia and hypertensives (27.9%) were likely to present a higher obesity prevalence than non-hypertensives (14.4%).

The findings were slightly attenuated but largely remained unchanged after stratifying by age groups. However, the region of residence and physical inactivity were unrelated to hypertension among patients <60 years. Similarly, age, education, and tobacco use differed insignificantly by hypertension status among patients ≥60 years. Furthermore, findings from the Nigerian sample (Table S1) were similar to the combined population. While the region of residence was unrelated to hypertension risk, hypertension significantly prevalent among high-income earners—>\$100/month (57.8%) compared with low-income earners—<\$100/month (53.3%). Similarly, findings from the Ghanaian sample inclined with the results of the combined sample (Table S2).

3.5 | Odds of hypertension

In the combined population (Table 3, Figure 2A), men (aOR: 0.66; CI: 0.53 to 0.83, $p < .0001$) compared with women and urban residents (aOR: 0.72; CI: 0.58 to 0.89, $p < .01$) compared with rural residents were less likely to be at risk of hypertension. Older age (≥60 years) was independently associated with increased odds of (aOR: 2.22; CI: 1.78 to 2.77, $p < .0001$) of hypertension. The adjusted odds of hypertension was nine times higher among physically inactive respondents (aOR: 9.09; CI: 4.03 to 20.53, $p < .0001$) compared with those who reported some forms of physical activities. Diabetes (aOR: 2.70; CI: 1.91 to 3.82, $p < .0001$), family history of CVD (aOR: 2.02; CI:

1.59 to 2.56, $p < .0001$), and higher WC (aOR: 1.01; CI: 1.00 to 1.02, $p < .0001$) were also more independently associated with hypertension in the sample studied. Also, age-stratification of the results presented different magnitudes of risk but largely similar findings as in the overall population (Figure S1).

Findings from the Nigerian sample (Table 3, Figure 2B) trended similarly with the overall population, but, adjusted odds of hypertension was eleven times higher among physically inactive patients (aOR: 11.34; CI: 2.40 to 53.60, $p < .01$) compared with those who reported some forms of physical activities. Also, tobacco use (aOR: 1.91; CI: 1.07 to 3.42, $p < .05$) and being obese (aOR: 1.48; CI: 1.04 to 2.10, $p < .01$) were independently associated with hypertension in the Nigerian sample. Furthermore, odds relationship from the Ghanaian sample (Figure 2C, Table 3) was not far different from the findings in the combined population, but odds of hypertension was unrelated with residence (aOR: 0.74 CI: 0.44 to 1.23, $p > .05$). Additionally, physical inactivity (aOR: 8.51; CI: 3.04 to 23.77, $p < .0001$) and having dyslipidemia (aOR: 1.58; CI: 1.05 to 2.38, $p < .05$) were independently related with hypertension in the Ghanaian sample.

4 | DISCUSSION

In the current study, we present a piece of evidence on the burden, pattern and risk factors of hypertension among stroke-free community-dwelling adults within West African (Nigeria and Ghana). We reported in-country and age-specific factors deserving attention for the intervention or management of hypertension in this group and related population in low and middle-income countries (LMIC). The current population is not only unique but also crucial as many of the stroke-free control may eventually develop stroke if adequate attention is not given to the drivers of hypertension among them.²³

In our report, over fifty percent of stroke-free controls were hypertensives. This finding is comparable to previous reports^{6,31-34} where hypertension prevalence among stroke-free subject has been documented. Two distinct multi-center reports, Paolo et al³² and Aigner et al,³³ found 67% and 23.2% of stroke-free controls in their cohorts to be hypertensive. Earlier, the interstroke study³¹ (conducted across 22 countries worldwide) found 32% of stroke-controls in the study to be hypertensive. Also, a similar report on the epidemiology of hypertension among apparently healthy populations in LMIC revealed a hypertension prevalence of 42.4% and 46.0% in Ghana and South Africa, respectively.³⁵ Most hypertension cases (particularly in low resource environment as ours) are often presented for management and treatment post-onset of cardiovascular events given the underperformance of community-based primary health care services, compounded by the inability to afford health care cost and the poor service delivery.³⁶⁻⁴⁰ Thus, the high burden of hypertension reported in the present study is likely to depict the situation in this population.

We found that physical inactivity is the leading risk factors for hypertension, with aggravated odds of hypertension among older adults in Nigeria (but not Ghana). This collaborates with previous

reports^{11,12,41,42} and reviews,⁴³⁻⁴⁷ where regular physical activity was reported to significantly reduce the risk of hypertension and CVD. Indeed, physical inactivity is a major risk factor for CVD,⁴⁸ incident stroke among Ghanaian hypertensives⁴⁹ and the fourth leading risk factor of all global deaths.⁵¹ Also, physical inactivity was reported to account for more deaths than smoking only in 2012,⁴¹ with an increasingly compelling cost implication on individual healthcare spending.⁵¹

The pathophysiology of physical inactivity and hypertension risk has been previously described as being plausible via multifactorial bio-contrivances primarily hinged on compromised endothelial competences.^{43,52,53} Increased physical activity can strengthen endothelial function for improved baroreflex sensitivities and also downregulate sympathetic or renin-angiotensin architecture activity to promote effective blood pressure regulation.⁴³ Also, effective physical activity plausibly avert hypertension by reducing body fat to improve cardiac output and lessen oxidative stress.⁵³ Other risk factors of hypertension (identified in this report) consistent with observations(s) from previously published studies^{13,35,54-56} include being female,⁵⁶ older age,³⁵ low educational level, tobacco use, alcohol consumption, history of CVD,⁴ elevated WC, and obesity^{35,55,56} among others. These allude to the importance of vibrant evidence-driven, context-specific and health care system tactics to promote healthy behaviours in the community management of hypertension. On one hand, our findings validate the appositeness of community-based approaches and environmentally responsive designs to promote physical activity for the management of not only hypertension but other hypertension-dependent CVD events, particularly among older populations. On the other hand, the significance of pharmacological interventions in the management of blood pressure cannot be underestimated. There is no question that lifestyle modification is important and can be guided by the data obtained in the present study but rapid BP reduction may be critical in some situations such as stroke. Pharmacologic intervention must be initiated from the outset and intensified when needed once hypertension is diagnosed in such situations.^{57,58}

The effect size of selected risk factors (being woman, older age, low educational level, tobacco use, alcohol consumption, dyslipidemia, diabetes, history of CVD, elevated blood pressure, elevated WC, obesity, and elevated lipid profile but not adherence to high salt use) was aggravated among older populations in this study. Accumulative effects of modifiable risk factors such as tobacco use and alcohol consumption can promote mitochondrial dysfunction, redox, and endothelial imbalances leading to early aging features which in turn predispose to cardiovascular events.⁹ For example, age-related impairment of vascular structure and function^{59,60} (as a result of phenotypic modifications in cell morphology⁶¹) can lead to arterial stiffness (a major predictor of vascular impedance) and consequently alter the pulsatile release of blood from the heart thereby raising the aortic systolic blood pressure.⁹ Primary prevention strategies (particularly behavioral change communication) targeted at these modifiable risks are likely to promote healthy behaviors in the entire life-course. This is likely to significantly decelerate the impact of aging-motivated pathology in the vasculature and heart.

Our study has some limitations, given its cross-sectional design, a causative inference cannot be made but our findings are worth mentioning. Confounding factors such as selection and recall biases are likely in most epidemiological studies including ours. The present hypertension prevalence may not be generalizable to the population since these patients were specifically matched to stroke cases. However, hypertension prevalence is not the primary goal of this study. It is worth mentioning that hypertension is at epidemiological thresholds in Africa accounting for the highest prevalence of 46% compared to other regions of the world.⁶² Nevertheless, all control data in the SIREN study were collected using validated instruments and in relevant situations, responses were verified by physicians. Overall, the data presented in the current report offer context-specific targets for community-based intervention for blood pressure and hypertension management, not only in the African but also in other LMIC outside of Africa. Aside from the need for awareness, detection, and control, mitigating effect(s) of the constellations of other metabolic risks such as diabetes and dyslipidemia is a promising multifactorial approach for managing the burden of hypertension in this population.

5 | CONCLUSION

Physical inactivity is associated with hypertension in this population of community-dwelling stroke-free controls in the SIREN study. Community-oriented interventions to address sedentary lifestyles may benefit this population and reduce the risk of hypertension and the probability of stroke among this cohort of Africans.

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CONFLICT OF INTEREST

There is no conflict of interest or disclosure(s).

AUTHOR CONTRIBUTIONS

Each of the listed authors (OMA, APO, BO, FSS, ROA, AA, KWW, MK, RO, LFO, GO, BF, AF, CMA, COA, DAH, LO, AA, OO, DL, EOU, MMF, OJA, OA, MA, TO, ISY, AO, BC, and MOO on behalf of the SIREN study as part of the H3Africa consortium) meet the criteria for "Authorship" in accordance with the ICMJE recommendations as outlined below: (1) Substantial contributions to the conception or design of the work; (2) Drafting the work or revising it critically for important intellectual content; (3) Final approval of the version to be published; (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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REFERENCES

- Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2015;385(9963):117–171.
- Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysis of worldwide data. *The Lancet*. 2005;365(9455):217–223.
- Mills KT, Bundy JD, Kelly TN, et al. Global disparities of hypertension prevalence and control. *Circulation*. 2016;134(6):441–450.
- Benjamin EJ, Virani SS, Callaway CW, et al. Heart disease and stroke statistics-2018 update: a report from the American Heart Association. *Circulation*. 2018;137(12):e67–e492.
- Collaboration NCDRF. Worldwide trends in blood pressure from 1975 to 2015: a pooled analysis of 1479 population-based measurement studies with 19.1 million participants. *Lancet (London, England)*. 2017;389(10064):37–55.
- Akpa OM, Made F, Ojo A, et al. Regional patterns and association between obesity and hypertension in Africa. *Hypertension*. 2020;75(5):1167–1178.
- Wyss-Coray T. Ageing, neurodegeneration and brain rejuvenation. *Nature*. 2016;539(7628):180–186.
- Heidenreich PA, Trogon JG, Khavjou OA, et al. Forecasting the future of cardiovascular disease in the United States. *Circulation*. 2011;123(8):933–944.
- Costantino S, Paneni F, Cosentino F. Ageing, metabolism and cardiovascular disease. *J Physiol*. 2016;594(8):2061–2073.
- Goulding M, Rogers M, Smith S. Trends in aging—United States and worldwide. *MMWR Morbidity Mortality Weekly Rep*. 2003;52(6):101–104, 106.
- Grøntved A, Koivula RW, Johansson I, et al. Bicycling to work and primordial prevention of cardiovascular risk: a cohort study among Swedish men and women. *J Am Heart Assoc*. 2016;5(11):e004413.
- Chiu M, Rezai M-R, Maclagan LC, et al. Moving to a highly walkable neighborhood and incidence of hypertension: a propensity-score matched cohort study. *Environ Health Perspect*. 2016;124(6):754–760.
- Bromfield SG, Bowling CB, Tanner RM, et al. Trends in hypertension prevalence, awareness, treatment, and control among US adults 80 years and older, 1988–2010. *J Clin Hyperten*. 2014;16(4):270–276.
- Dregan A, Ravindrarajah R, Hazra N, Hamada S, Jackson SHD, Gulliford MC. Longitudinal trends in hypertension management and mortality among octogenarians. *Hypertension*. 2016;68(1):97–105.
- Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APHA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*. 2018;138(17):e426–e483.
- Bull F. Defining physical inactivity. *Lancet*. 2003;361(9353):258–259.
- Antero Kesaniemi Y, Danforth E, Jensen MD, Kopelman PG, Lefebvre P, Reeder BA. Dose-response issues concerning physical activity and health: an evidence-based symposium. *Med Sci Sports Exerc*. 2001;33(6):S351–S358.
- Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: a recommendation from the centers for disease control and prevention and the American College of Sports Medicine. *JAMA*. 1995;273(5):402–407.
- Bull FC, Armstrong TP, Dixon T, Ham S, Neiman A, Pratt M. Chapter 10: physical inactivity. In: Ezzati M, Lopez AD, Rodgers AA, Murray CJL, eds. *Comparative quantification of health risks : global and regional burden of disease attributable to selected major risk*. Geneva, Switzerland: World Health Organization; 2004.

20. Twagirumukiza M, De Bacquer D, Kips JG, de Backer G, Stichele RV, Van Bortel LM. Current and projected prevalence of arterial hypertension in sub-Saharan Africa by sex, age and habitat: an estimate from population studies. *J Hypertens*. 2011;29(7):1243-1252.
21. Sarki AM, Nduka CU, Stranges S, Kandala N-B, Uthman OA. Prevalence of hypertension in low- and middle-income Countries: a systematic review and meta-analysis. *Medicine (Baltimore)*. 2015;94(50):e1959.
22. Akpalu A, Sarfo FS, Ovbiagele B, et al. Phenotyping stroke in Sub-Saharan Africa: Stroke Investigative Research and Education Network (SIREN) phenomics protocol. *Neuroepidemiology*. 2015;45(2):73-82.
23. Owolabi MO, Sarfo F, Akinyemi R, et al. Dominant modifiable risk factors for stroke in Ghana and Nigeria (SIREN): a case-control study. *Lancet Global Health*. 2018;6(4):e436-e446.
24. Akpalu A, Gebregziabher M, Ovbiagele B, et al. Differential impact of risk factors on stroke occurrence among men versus women in West Africa. *Stroke*. 2019;50(4):820-827.
25. O'Donnell MJ, Xavier D, Liu L, et al. Risk factors for ischaemic and intracerebral haemorrhagic stroke in 22 countries (the INTERSTROKE study): a case-control study. *The Lancet*. 2010;376(9735):112-123.
26. Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure. *Hypertension*. 2003;42(6):1206-1252.
27. Expert Panel on Detection E, Treatment of High Blood Cholesterol in A. Executive summary of the Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). *JAMA*. 2001;285(19):2486-2497.
28. Sarfo FS, Ovbiagele B, Gebregziabher M, et al. Stroke among young West Africans. *Stroke*. 2018;49(5):1116-1122.
29. WHO. Obesity and overweight: Fact sheet. <http://www.who.int/mediacentre/factsheets/fs311/en/>. Published 2017. Accessed 28-Nov 2017, 2017.
30. WHO. Proposed working definition of an older person in Africa for the MDS Project. https://www.who.int/healthinfo/survey/agein_gdefolder/en/. Published 2002. Accessed 21.08.2020, 2020.
31. O'Donnell M, Xavier D, Diener C, et al. Rationale and design of INTERSTROKE: a global case-control study of risk factors for stroke. *Neuroepidemiology*. 2010;35(1):36-44.
32. Colombo PC, Mehra MR, Goldstein DJ, et al. Comprehensive analysis of stroke in the long-term cohort of the MOMENTUM 3 study. *Circulation*. 2019;139(2):155-168.
33. Aigner A, Grittner U, Rolfs A, Norrving B, Siegerink B, Busch MA. Contribution of established stroke risk factors to the burden of stroke in young adults. *Stroke*. 2017;48(7):1744-1751.
34. Ajayi I, Sowemimo I, Akpa O, Ossai N. Prevalence of hypertension and associated factors among residents of Ibadan-North Local Government Area of Nigeria. *Nigerian J Cardiol*. 2016;13(1):67-75.
35. Gebreselassie KZ, Padyab M. Epidemiology of hypertension stages in two countries in Sub-Sahara Africa: factors associated with hypertension stages. *Int J Hypertension*. 2015;2015:e959256.
36. Moore BM, Alex-Hart BA, George IO. Utilization of health care services by pregnant mothers during delivery: a community based study in Nigeria. *East Afr J Public Health*. 2011;8(1):49-51.
37. Katung PY. Socio-economic factors responsible for poor utilisation of the primary health care services in a rural community in Nigeria. *Nigerian J Med*. 2001;10(1):28-29.
38. Dassah E, Aldersey HM, McColl MA, Davison C. 'When I don't have money to buy the drugs, I just manage'.-Exploring the lived experience of persons with physical disabilities in accessing primary health care services in rural Ghana. *Soc Sci Med*. 2018;214:83-90.
39. Novignon J, Nonvignon J. Improving primary health care facility performance in Ghana: efficiency analysis and fiscal space implications. *BMC Health Services Res*. 2017;17(1):399.
40. Cappuccio FP, Miller MA. Cardiovascular disease and hypertension in sub-Saharan Africa: burden, risk and interventions. *Intern Emerg Med*. 2016;11(3):299-305.
41. Wen CP, Wu X. Stressing harms of physical inactivity to promote exercise. *Lancet*. 2012;380(9838):192-193.
42. Diaz KM, Booth JN 3rd, Seals SR, et al. Physical activity and incident hypertension in African Americans: the Jackson Heart Study. *Hypertension (Dallas, Tex : 1979)*. 2017;69(3):421-427.
43. Diaz KM, Shimbo D. Physical activity and the prevention of hypertension. *Curr Hypertens Rep*. 2013;15(6):659-668.
44. Liu X, Zhang D, Liu Y, et al. Dose-response association between physical activity and incident hypertension. *Hypertension*. 2017;69(5):813-820.
45. Börjesson M, Onerup A, Lundqvist S, Dahlöf B. Physical activity and exercise lower blood pressure in individuals with hypertension: narrative review of 27 RCTs. *Br J Sports Med*. 2016;50(6):356-361.
46. Bosu WK, Reilly ST, Aheto JMK, Zucchelli E. Hypertension in older adults in Africa: a systematic review and meta-analysis. *PLoS One*. 2019;14(4):e0214934.
47. Bosu WK, Aheto JMK, Zucchelli E, Reilly ST. Determinants of systemic hypertension in older adults in Africa: a systematic review. *BMC Cardiovasc Disord*. 2019;19(1):173.
48. Artinian NT, Fletcher GF, Mozaffarian D, et al. Interventions to promote physical activity and dietary lifestyle changes for cardiovascular risk factor reduction in adults. *Circulation*. 2010;122(4):406-441.
49. Sarfo FS, Mobula LM, Plange-Rhule J, Ansong D, Ofori-Adjei D. Incident stroke among Ghanaians with hypertension and diabetes: a multicenter, prospective cohort study. *J Neurol Sci*. 2018;395:17-24.
50. Mortality GBD, Causes of Death C. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet (London, England)*. 2015;385(9963):117-171.
51. Ding D, Lawson KD, Kolbe-Alexander TL, et al. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet*. 2016;388(10051):1311-1324.
52. Chase NL, Sui X, Lee D-C, Blair SN. The Association of cardiorespiratory fitness and physical activity with incidence of hypertension in men. *Am J Hypertens*. 2009;22(4):417-424.
53. Hu G, Barengo NC, Tuomilehto J, Lakka TA, Nissinen A, Jousilahti P. Relationship of physical activity and body mass index to the risk of hypertension: a prospective study in Finland. *Hypertension*. 2004;43(1):25-30.
54. Tu K, Chen Z, Lipscombe LL. Prevalence and incidence of hypertension from 1995 to 2005: a population-based study. *Can Med Assoc J*. 2008;178(11):1429-1435.
55. Guwatudde D, Nankya-Mutyoba J, Kalyesubula R, et al. The burden of hypertension in sub-Saharan Africa: a four-country cross sectional study. *BMC Public Health*. 2015;15:1211.
56. Liu X, Liu C, Schenck H, Yi X, Wang H, Shi X. The risk factors of 9-year follow-up on hypertension in middle-aged people in Tujia-Nationality settlement of China. *J Hum Hypertens*. 2017;31(12):838-842.
57. Organization WH. Cardiovascular disease: HEARTS Technical Package. WHO. https://www.who.int/cardiovascular_diseases/hearts/en/. Published 2020. Accessed 31.10.2020, 2020.
58. Patel P, Ordunez P, DiPette D, et al. Improved blood pressure control to reduce cardiovascular disease morbidity and mortality: the standardized hypertension treatment and prevention project. *J Clin Hypertens*. 2016;18(12):1284-1294.
59. Kovacic JC, Moreno P, Hachinski V, Nabel EG, Fuster V. Cellular senescence, vascular disease, and aging. *Circulation*. 2011;123(15):1650-1660.
60. Safar ME. Arterial aging—hemodynamic changes and therapeutic options. *Nat Rev Cardiol*. 2010;7(8):442-449.

61. Sawabe M. Vascular aging: From molecular mechanism to clinical significance. *Geriatr Gerontol Int*. 2010;10(s1):S213-S220.
62. Yoruk A, Boulos PK, Bisognano JD. The state of hypertension in Sub-Saharan Africa: review and commentary. *Am J Hypertens*. 2017;31(4):387-388.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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