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Prevalence, determinants and time trends in cardiovascular health in Sub-Saharan Africa, 2003–2022

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Titre : Prévalence, déterminants et tendances temporelles de la santé cardiovasculaire en Afrique subsaharienne, 2003–2022

Résumé:
Les maladies cardiovasculaires constituent une cause de morbidité et de mortalité en pleine croissance dans la région africaine de l'organisation mondiale de la santé (OMS) en rapport avec la transition épidémiologique lié à un vieillissement de la population, l'occidentalisation des modes de vie et les expositions environementales. En utilisant des données harmonisées provenant des enquêtes STEPS de l'OMS menées entre 2003 et 2022, cette thèse fournit l'évaluation régionale la plus complète à ce jour de trois composantes interconnectées de la santé cardiovasculaire (SCV) : l'indice de masse corporelle (IMC), l'hypertension artérielle et une mesure composite de la SCV fondée sur le score à 7 items Life's Simple 7 (LS7).

À travers 54 enquêtes menées dans 36 pays africains (198 901 adultes), les profils d'IMC révèlent un double fardeau persistant de malnutrition. La prévalence pondérée et standardisée selon l'âge de l'insuffisance pondérale, du surpoids et de l'obésité était respectivement de 11,5 %, 17,8 % et 9,0 % ; et 61,7 % des personnes avaient un poids normal. Les femmes étaient 1,4 fois plus souvent en surpoids et trois fois plus souvent obèses que les hommes. L'âge avancé, un niveau d'instruction plus élevé, l'inactivité physique, une mauvaise alimentation et la résidence urbaine étaient des déterminants importants d'un IMC élevé, tandis que l'insuffisance pondérale demeurait concentrée dans les zones rurales. Les analyses de tendances bayésiennes n'ont révélé aucune amélioration significative de l'IMC entre 2003 et 2022. Cependant, la prévalence de l'obésité d'une part, et celle de l'insuffisance pondérale d'autre part, ont significativement augmenté.

Les analyses de l'hypertension artérielle ont intégré 61 enquêtes provenant de 37 pays (251 761 adultes). La prévalence pondérée et standardisée selon l'âge était élevée (≈29 % chez les femmes ; ≈26 % chez les hommes). Un IMC plus élevé, un âge avancé, le statut de retraité, le tabagisme ancien (chez les femmes uniquement), un niveau d'éducation plus élevé (pour la connaissance du diagnostic uniquement) et une consommation d'alcool plus élevée (pour la connaissance du diagnostic chez les hommes uniquement) étaient des déterminants clés de la prévalence de l'hypertension artérielle et du niveau de connaissance du diagnostic l'hypertension artérielle. À l'inverse, un tabagisme actuel et à une consommation élevée d'alcool étaient associés à une probabilité plus faible de traitement et de contrôle de l'hypertension artérielle. Les résultats liés à l'hypertension artérielle étaient également influencés par des facteurs contextuels (au niveau des pays), notamment l'espérance de vie à la naissance, l'indice de développement de genre, la consommation quotidienne de lipides par habitant, le produit intérieur brut par habitant, la part de l'emploi dans l'agriculture et le degré d'urbanisation. L'analyse des tendances bayesiennes montrent que si la prévalence de l'hypertension artérielle n'a pas évolué, le nombre absolu d'adultes hypertendus a presque doublé sur la période 2003-2022. Elles montrent également que bien que la sensibilisation à l'hypertension se soit nettement améliorée, le traitement et le contrôle sont restés extrêmement faibles, avec de fortes disparités selon le sexe et les pays et les sous-régions.

L’analyse du score de SCV a été réalisée dans 22 pays (73 024 adultes) disposant des données nécessaires à son calcul. Seuls 26 % des adultes présentaient une SCV idéale (au moins 5 métriques au niveau idéal), et moins de 1 % avaient les 7 métriques au niveau idéal. L’alimentation et la pression artérielle étaient les métriques les moins fréquemment au niveau idéal, tandis que le cholestérol et le tabagisme étaient les plus fréquemment au niveau idéal. L’âge avancé, le sexe féminin, un faible niveau d’éducation, la consommation excessive d’alcool et la résidence urbaine étaient associés à une moins bonne SCV. Les analyses de tendances bayésiennes n’ont révélé aucune amélioration significative de la SCV entre 2003 et 2022.

Dans l’ensemble, ces résultats menés à grande échelle dans la population adulte africaine montrent le double fardeau de la malnutrition (sous-nutrition et surpoid/obésité), des niveaux dramatiquement bas de traitement et de contrôle de l’hypertension artérielle. Bien qu’un quart seulement des adultes atteignent une SCV idéale, ce chiffre est deux à trois fois plus élevé par rapport aux données européennes. Au total, nos résultats soulignent l’urgence de stratégies de prévention intégrées, sensibles au genre et adaptées au contexte, d’un renforcement des systèmes de soins primaires et d’une mise en œuvre intensifiée des initiatives Global Hearts de l’OMS en Afrique subsaharienne.

Mots clés : maladies cardiovasculaires ; santé cardiovasculaire ; prévention primordiale; promotion de la santé ; IMC ; hypertension artérielle; Région africaine de l’OMS ; enquêtes populationnelles ; analyse bayésienne des tendances.

Title: Prevalence, determinants and time trends of cardiovascular health in sub-Saharan Africa, 2003–2022

Abstract:
Cardiovascular diseases are an increasing cause of morbidity and mortality in the WHO African region, in connection with the epidemiological transition driven by population aging, lifestyles westernization, and environmental exposures. Using harmonized data from WHO STEPS surveys conducted between 2003 and 2022, this thesis provides the most comprehensive regional assessment to date of three interconnected components of cardiovascular health (CVH): body mass index (BMI), high blood pressure, and a composite measure of CVH based on the 7-item Life's Simple 7 (LS7) score.

Across 54 surveys conducted in 36 countries (198,901 adults), BMI profiles revealed a persistent double burden of malnutrition. The age-standardized and weighted prevalence of underweight, overweight and obesity was 11·5%, 17·8%, and 9·0% respectively; and 61·7% were normo-weighted. Women were 1·4 times more often overweight and three times more often obese than men. Older age, higher educational attainment, physical inactivity, poor diet, and urban residence were key determinants of higher BMI, while underweight remained concentrated in rural areas. Bayesian trend analyses showed no significant improvement in BMI between 2003 and 2022. However, the prevalence of obesity on one hand, and underweight on the other, increased significantly.

The hypertension analyses included 61 surveys from 37 countries (251,761 adults). Age-standardized prevalence was high (≈29% in women; ≈26% in men). Higher BMI, older age, retirement status, former smoking (in women only), higher education (for diagnosis awareness only), and higher alcohol consumption (for diagnosis awareness in men only) were key determinants of hypertension prevalence and diagnosis awareness. Conversely, current smoking and high alcohol consumption were associated with lower likelihood of hypertension treatment and control. Hypertension outcomes were also influenced by contextual (country-level) factors, including life expectancy at birth, gender development index, per-capita daily fat consumption, GDP per capita, share of employment in agriculture, and degree of urbanization. Bayesian trend analyses showed that although hypertension prevalence did not change, the absolute number of hypertensive adults nearly doubled over 2003–2022. Although awareness of hypertension improved markedly, treatment and control remained extremely low over the same period, with large disparities by sex, country, and subregion.

CVH score analysis was conducted in 22 countries (73,024 adults) with the complete data. Only 26% of adults had ideal CVH (at least 5 items at the ideal level), and fewer than 1% had all 7 metrics at the ideal level. Diet and blood pressure were the least frequent ideal metrics, while cholesterol and smoking were the most frequently at ideal levels. Older age, female sex, low educational attainment, excessive alcohol consumption, and urban residence were associated with poorer CVH. Bayesian trend analyses showed no significant improvement in CVH between 2003 and 2022.

Overall, these large-scale results from the adult African population highlight the double burden of malnutrition (undernutrition and overweight/obesity), and dramatically low levels of hypertension treatment and control. Although only one quarter of adults achieved an ideal CVH, this figure is two to three times higher than in Western countries. Altogether, our findings underscore the urgency of integrated, gender-sensitive, context-adapted prevention strategies, strengthened primary care systems, and intensified implementation of the WHO Global Hearts initiatives in sub-Saharan Africa.

Keywords: cardiovascular diseases; cardiovascular health; primordial prevention; health promotion; BMI; hypertension; WHO African region; population-based surveys; Bayesian trend analysis.

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1. Introduction

1.1. Epidemiology of cardiovascular diseases

Cardiovascular disease (CVD) remains the leading cause of death worldwide, accounting for approximately 19.8 million deaths annually.[1–3] Most of which are attributable to modifiable risk factors like an unhealthy diets, lack of physical activity, obesity, tobacco use, and high blood pressure.[4,5]

Despite significant advances in medical treatments and interventions, preventing CVD remains a pressing public health priority, particularly in settings with limitation in health systems to provide care.[2] Central to this effort is health promotion, which emphasizes regular physical activity, balanced nutrition, and effective prevention and control of key risk factors such as high blood pressure, diabetes, dyslipidaemia, and obesity for all.[2,6] The World Health Organization (WHO) has proposed policy and population-level interventions to address the social, economic, and environmental determinants of cardiovascular health. This includes interventions for tobacco control (MPOWER), salt reduction (SHAKE), promotion of healthier diets (REPLACE), increased opportunities for physical activity (BE ACTIVE), and strengthened primary health care systems to support early detection and treatment.[7,8]

Similarly, the European Society of Cardiology and the European Association of Preventive Cardiology recommended policy interventions at the population level in their 2021 guidelines to tackle each of these risk factors (physical inactivity, unhealthy diet, obesity, high blood pressure, high blood sugar, and high cholesterolemia).[9]

Beyond these traditional approaches focused on individual risk factors, cardiovascular prevention has undergone a major conceptual evolution. This shift reflects, on the one hand, a move from a unifactorial perspective toward a more integrated framework based on the concept of cardiovascular health (CVH), and, on the other hand, a transition from primary prevention to primordial prevention, which seeks to prevent the development of risk factors in the first place.

Indeed, major cardiovascular risk factors such as obesity, unhealthy diet, tobacco use, physical inactivity, high blood pressure, elevated cholesterol, and abnormal glucose

levels do not occur in isolation; rather, they interact, cluster, and reinforce one another within complex social, economic, and environmental contexts. Assessing their combined effects through the integrated framework of CVH therefore provides a more comprehensive and clinically relevant representation of cardiovascular risk. This comprehensive approach aligns with the WHO Global Action Plan for NCDs and with Sustainable Development Goal (SDG) 3.4, which calls for a one-third reduction in premature mortality from NCDs by 2030.[10]

In this paradigm shift, the American Heart Association (AHA) played a pivotal role by introducing the concept of an Ideal Cardiovascular Health (ICVH) in 2010 through Life's Simple 7 score.[11–13] The ICVH is composed of seven key metrics including four health behaviour metrics (non-smoking status, maintaining a body mass index (BMI) of less than 25 kg/m², engaging in physical activity at recommended levels, and adhering to a healthy diet that meets criteria based on five essential dietary components), and three health factor metrics such as an untreated total cholesterol level below 200 mg/dL, untreated blood pressure under 120/80 mmHg, and fasting blood glucose below 100 mg/dL (Table 1). Several studies have consistently shown that a greater number of ideal metrics is strongly associated with a substantial lower risk of CVD but also non-CVD such as cancer, dementia, depression and all-cause mortality.[12,14–16]

In 2022, the LS7 score was updated with the publication of the Life's Essential 8 (LE8), which integrates sleep duration as an eight metric and refines the scoring system from a scale of 0–14 to a scale of 0–100 (see Figure 1).

While primordial prevention awareness in the general population as well as health care professional scientific bodies is high in the United States, its adoption remains limited in most countries. The gap is even more pronounced in low and middle-income countries (LMICs), where data on overall CVH remain scarce, particularly in Africa. This lack of evidence underscores the need to better characterize CVH in these settings in order to inform effective, context-specific prevention strategies.

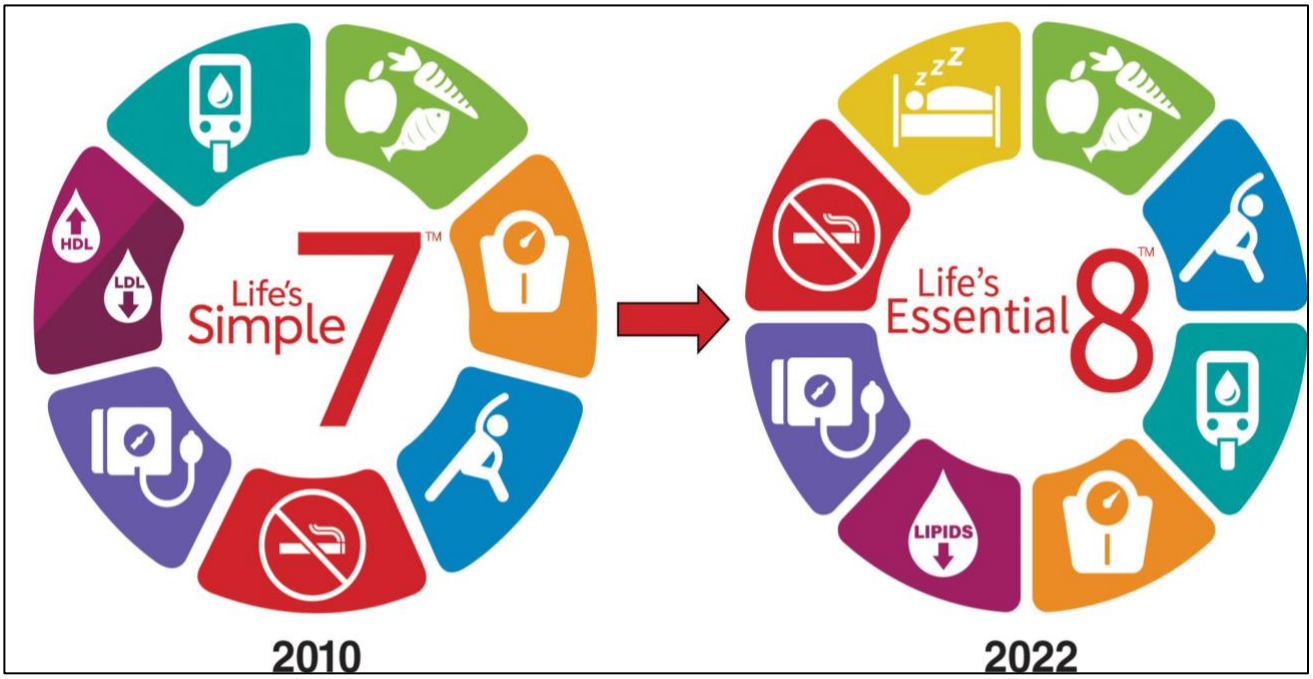


***Figure 1**. Life's simple seven and eight*
(Doi/10.1161/CIR.0000000000001213)

1.2. Epidemiology of cardiovascular diseases in Sub-Saharan Africa

Over three-quarters of CVD deaths in the world, occur in LMICs, where health systems with the least resources are paying the highest price, including those in the Africa countries.[17,18] In sub-Saharan Africa (SSA), the burden of CVDs has been rising rapidly and has now reached epidemic proportions.[17–19] The epidemiologic transition marks the shift from high mortality due to communicable diseases to a growing burden of chronic, noncommunicable diseases (NCD).[20] As populations age and disease patterns change across age groups, health systems must adapt to provide both preventive and long-term care. This "double burden" managing infectious diseases alongside chronic illnesses is well documented in LMICs.[21]

Furthermore, efforts to address CVD and other NCDs are constrained by competing priorities in health and development sectors, such as education, housing, transportation, and security. Without large-scale and coordinated action, the region risks facing a crisis similar to that experienced by Europe and North America in the 1960s, but under even more constrained circumstances.

The epidemiological landscape in SSA is increasingly shaped by a rapid rise in behavioural and metabolic risk factors.[18] Among these, obesity has emerged as a central driver of the cardiovascular disease epidemic,[22–25] reflecting profound shifts in dietary patterns, physical activity, and urban lifestyles. These behavioural risks are strongly patterned by social and environmental determinants, including food insecurity, gender inequality, rapid urbanization, poverty, and limited infrastructure for active transport and recreational physical activity.[26]

At the biological level, hypertension has become the most prevalent and consequential cardiometabolic disorder in the region, closely linked to obesity, poor diet, and physical inactivity.[27,28] Hypertension,[5] alongside dyslipidaemia,[29] and abnormal glucose metabolism,[30] not only represents the cumulative impact of adverse lifestyles but also serves as a sensitive indicator of health system performance. Alarmingly, hypertension control remains critically inadequate across most countries in the SSA region, with fewer than 10% of affected individuals achieving adequate blood pressure control.[27,28] This highlights major shortcomings in screening, long-term treatment, and continuity of care.

Taken together, the clustering of obesity, hypertension, and related metabolic abnormalities translates into markedly poor overall CVH at the population level.[27,28] Addressing this growing cardiovascular burden therefore requires integrated, population-wide strategies that simultaneously target obesity, hypertension, and the broader determinants of cardiovascular health.

Most population-based studies in SSA focused on the distribution of individual risk factors and few of them examined their determinants and even fewer their time trends. [31 32 33].

With regards to BMI, the Non-Communicable Disease Risk Factors Collaboration (NCD-RisC) has regularly and extensively updated the burden of obesity and overweight worldwide including in the WHO African region.[30,34,35] However and despite rigorous statistical methodology, the analysis combined data from multiple sources and study design with heterogeneous data collection methodologies. Furthermore, the prior largest multi-country study on the burden of overweight and obesity in Africa

comprised 24 countries and focused on women only from urban areas.[36] Two prior systematic reviews in Africa addressed the burden of obesity but in clinical samples.[37,38] Finally, the place of contextual factors as potential actionable determinants of obesity in Africa is understudied.

For hypertension, a part of the global status reports[5,39] on hypertension developed by WHO, only 3 studies, including NCD-RisC,[40] SevenCEWA (Seven Communities in East and West Africa)[41] and H3Africa (Human Heredity and Health in Africa) AWI-Gen (Africa WitsINDEPTH Partnership for the Genomic Studies), have examined the distribution of 4 hypertension-related outcomes including the prevalence of hypertension, awareness, treatment and control. Similarly, only 1 study, the SevenCEWA,[41] has assessed the determinants of these 4 outcomes, while the remaining studies usually focused on 1 single hypertension related outcome. Furthermore, although the NCDRisC[40] and the May Measurement Month Initiative (MMM)[42,43] integrated data from >25 African countries, other pooled studies have focused on fewer than 10 countries.[40,44] Understanding time trends in hypertension-related outcomes is crucial for evaluating intervention effectiveness and adapt future interventions. The NCD-RisC[40] has examined the time trend of hypertension prevalence worldwide including Africa, but no studies have further analyzed the time trends of hypertension awareness, treatment, and control.

So far, six studies have reported the prevalence of CVH in the SSA region.[45–50] These correspond to four single-country studies,[46,47,50] including one in people living with HIV.[49] Among the two multi-country studies,[45,48] the largest included only five countries.[45] Only two studies explored the determinants of CVH, and none evaluated its long-term time trend.

Together, these limitations highlight the fragmented nature of the existing evidence on the burden, determinants and time trends of CVD risk factors especially obesity and hypertension but also the CVH score in SSA.

2. Objectives

2.1. General objective

This thesis aims to provide a comprehensive analysis of single CVD risk factors and CVH among adults living in SSA using nationally and regionally representative population-based surveys conducted between 2003 and 2022. We have first focused on two preoccupying components of CVH including malnutrition and hypertension, before examining a more integrated measure represented by the CVH score.

2.1. Specific objectives

The specific objectives are to estimate the prevalence, determinants and time trends of BMI, hypertension-related outcome including awareness, treatment and control, and CVH.

3. Material and Methods

My PhD was conducted using the STEPS data from the WHO African region countries. For the article on hypertension specifically, we were required by the journal to include addional data sources for countries that had not conducted STEPS surveys. We therefore included data source; Demographic and Health Surveys (DHS), to add eight additional countries surveys (see Study Data Sources section).

3.1. Ethical approval

Ethical approval was obtained from relevant institutional review boards in each participating country by primary investigators (PI) while conducting the surveys. Informed consent was secured from all participants. Ethics approval for our study was obtained from the WHO Regional Office for Africa Ethic Review Committee in addition to the data access. Ethics approval code is **AFR/ERC/2023/5.18**.

3.2. Study data sources

We used data from population-based, subnational or national STEPS surveys conducted between 2003 and 2022. Each eligible STEPS dataset was requested from the list of surveys maintained by WHO in the NCD Microdata Repository.

Access to these data was granted, and all datasets are available in the WHO STEPS Survey Repository.[51]

As stated above, the DHS conducted in eight countries were additionally used specifically for the hypertension paper. The DHS are open sourced data and accessible online on demand via official data repositories.[52] Their design and protocols are very similar to those from STEPS, so that we decided not to detail them in the thesis.

3.3. Study population

The study population comprised adults aged 18 to 69 years who participated in the STEPS survey (and in the DHS) in the WHO African region (Figure 2).

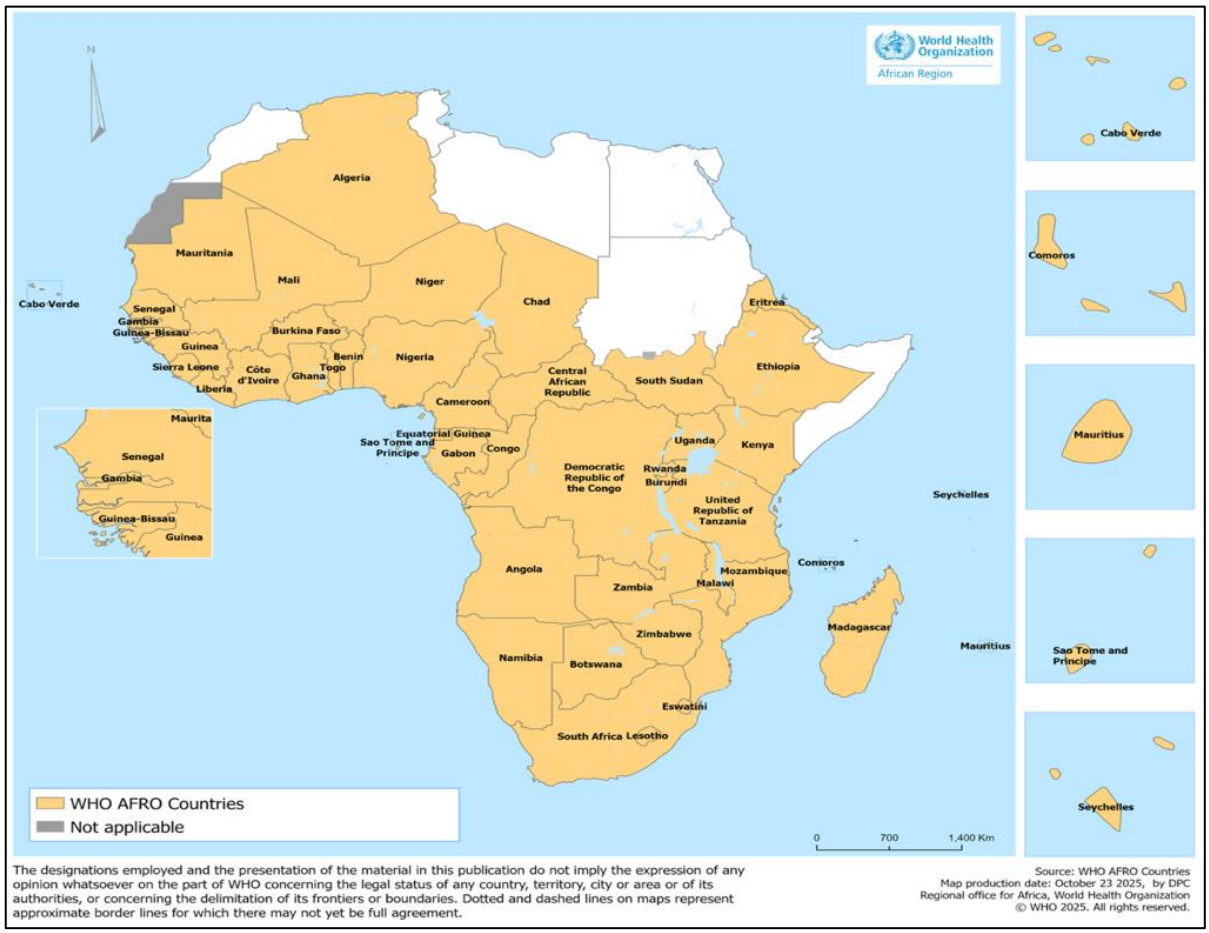


***Figure 2**. Map of the WHO Regional office for Africa countries*

3.4. Study design

The STEPS is a standardized method for collecting, analyzing, and disseminating data on NCDs and their risk factors. It provides countries with a framework to monitor the prevalence of NCDs and track progress towards national and global health goals.
The STEPS implementation leverages a standardized and consistent methodology to ensure robust data collection and analysis across countries.

This comprehensive approach begins with meticulous planning and preparation, including stakeholder engagement with government bodies and health institutions to secure collaboration, training field staff on standardized data collection and ethical procedures, and conducting pilot tests to refine methodologies. During the data collection phase, household surveys gather information from representative samples, with rigorous quality control measures like repeat measurements and cross-checking to guarantee data accuracy. Statistical analysis of the collected data identifies prevalence rates, risk factor correlations, and trends, which are then detailed in comprehensive reports for policymakers, health professionals, and the public.

The STEPS has three main objectives:

- Standardization: To provide a common methodology for countries to collect and compare NCD data.
- Flexibility: To allow countries to use the approach according to their resources and needs.
- Scalability: To enable countries to start with basic data collection and expand as resources allow.

The survey is conducted in three steps, each building on the previous one to provide a comprehensive overview of NCDs and their risk factors: Step 1: A questionnaire-based interview to collect information on demographic characteristics and risk factors for NCDs; Step 2: Physical measurements; and Step 3: Biochemical measurements.

- **Step 1: Questionnaire:**

- Demographic Information: Collects data on age, sex, education, and other sociodemographic variables.
- Behavioural Risk Factors: Includes questions on tobacco use, alcohol consumption, diet, and physical activity, collected in face to face.

- History of Disease: Gathers information on known history of diseases such as hypertension, diabetes, and cardiovascular conditions.

- **Step 2: Physical Measurements:**
- Anthropometric Data: Measures height, weight, and waist circumference to assess obesity and overweight.
- Blood Pressure: Records systolic and diastolic blood pressure to identify hypertension.

- **Step 3: Biochemical Measurements**
- Blood Samples: to measure blood glucose levels and lipid profiles (cholesterol, triglycerides) on fresh samples.
- Urine Samples: May include urine tests for additional markers relevant to NCDs.

In the STEPS survey, sampling weights are calculated to ensure that the data collected are representative of the target population. The sampling weight corrects for unequal probabilities of selection and adjusts for non-response and post-stratification.

3.5. Study outcome

- Body Mass Index (BMI):

BMI is a widely used metric to classify underweight, normal weight, overweight, and obesity in adults. It is calculated by dividing a person's weight in kilograms by the square of their height in meters (kg/m^2). According to WHO, BMI categories are defined as follows:

- Underweight: BMI < 18.5 kg/m^2
- Normal weight: BMI 18.5–24.9 kg/m^2
- Overweight: BMI 25–29.9 kg/m^2
- Obesity: BMI ≥ 30 kg/m^2

- Hypertension related outcomes**:**

Blood pressure was measured by trained field interviewers following the standardized WHO STEPS protocol. Measurements were taken on the right arm of seated participants after at least five minutes of rest, using a validated automated digital blood pressure device with an appropriately sized cuff. Three consecutive readings were obtained at intervals of approximately three minutes, and the mean of the last two readings was used for analysis.

Hypertension was defined as having systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg (or both) or taking medication for hypertension (treatment). We also reported the stage of hypertension according to the Hypertension Practice Guidelines of the International Society of Hypertension:14 normal (<130/85 mmHg), high-normal (130–139/85–89 mmHg), stage 1 hypertension (140–159/90–99 mmHg), and stage 2 hypertension (≥160/100 mmHg).

Undiagnosed hypertension was defined as participants who had a measured SBP ≥140 mmHg and/or DBP ≥90 mmHg during the survey but did not report any previous diagnosis of hypertension by a health professional.

Awareness was defined based on the responses to the following question: " Have you ever been told by a doctor or other health worker that you have raised blood pressure or hypertension?" or "In the past two weeks, have you taken any drugs (medication) for raised blood pressure prescribed by a doctor or other health worker?".

Treatment in STEPS surveys was defined based on the responses to the following two questions: (i) "In the past two weeks, have you taken any drugs (medication) for raised blood pressure prescribed by a doctor or other health worker?" or (ii) "During the past two weeks, have you been treated for raised blood pressure with drugs (medication) prescribed by a doctor or other health worker?" In DHS, treatment was defined based on the response to the following question: "Are you taking medication to control your blood pressure?

Control was defined as having a measured SBP <140 mm Hg and DBP <90 mm Hg among those treated both the STEPS and in DHS.

- Cardiovascular health metrics

We used the AHA LS7 CVH score since information on sleep health was unavailable precluding assessing the Life's Essential 8 score. Table 1 defines the three levels including poor (scored 0), intermediate (scored 1) and ideal (scored 2) of each metric. The Table also provides the categories of the total CVH score (range 0 to 14) following established cut-off in the literature.

***Table 1**. Definition of poor, intermediate, and ideal level for each CVH metric*

Goal/Metric	Poor	Intermediate	Ideal
Smoking	Currently smoking	Former, quit ≤12 month	Never or quit >12 month
Body mass index, kg/m2	>30 kg/m2	25–29.99 kg/m2	<25 kg/m2
Physical activity [b]	None	1–149 min/wk moderate or 1–74 min/wk vigorous or 1–149 min/wk combination	≥150 min/wk moderate or ≥75 min/wk vigorous or ≥150 combination
Healthy diet score	0–1 daily portion of fruits and vegetables	2–3 daily portions of fruits and vegetables	4–5 daily portions of fruits and vegetables
Total cholesterol, mg/dL	≥240 mg/dL	200–239 mg/dL or treated to goal	<200 mg/dL [a]
Blood fasting glucose	≥ 126 mg/dL [a]	100–125 mg/dL [a], or treated to <100 mg/dL	<100 mg/dL, [a]
Blood pressure, mm Hg	≥140/90 mm Hg	120–139/ 80–89 mm Hg or treated to goal	<120/<80 mm Hg (untreated)
Total CVH Score	0–8 Points	9–11 Points	12–14 Points

[a] Untreated values. [b] Physical activity levels were categorized as low, moderate, or high according to WHO recommendations based on total metabolic equivalents (METs) per week.

3.6. Covariates

Behavioural covariates were obtained through interviewer-administered questionnaires using the WHO STEPS core modules. These included tobacco use

(current use of any smoked or smokeless product), alcohol consumption (current drinking in the past 30 days), fruit and vegetable intake, salt-related behaviours (adding salt at the table or frequent consumption of processed foods), and physical activity, assessed at work, transport, and recreation domains using the Global Physical Activity Questionnaire (GPAQ).

All biochemical and physiological measurements were performed by trained health personnel under close field supervision. Regular device calibration, adherence to WHO quality-assurance protocols, and cross-country harmonization of variable definitions ensured comparability of blood pressure, glucose, and cholesterol data across all STEPS surveys used in this thesis.

3.7. Contextual covariates

We incorporated contextual covariates to capture macro-level determinants of cardiovascular risk factors and health outcomes.

They were sourced from globally recognized databases such as the World Bank, United Nations Development Programme (UNDP), and World Health Organization Global Health Observatory and matched to each STEPS survey by country and the nearest available year.

Key contextual covariates comprised gross domestic product (GDP) per capita, which serves as a proxy for national income and economic development; health expenditure per capita, reflecting the level of investment in the health system and healthcare access; and human development index (HDI), a composite measure of average achievement in key dimensions of human development (health, education, standard of living). Additional variables included urbanization (percentage of population living in urban areas) to represent urban-rural social and lifestyle differentials; unemployment rate, as an indicator of economic vulnerability; poverty prevalence (percentage of population below the national poverty line); gender inequality indices (such as the Gender Development Index or Gender Inequality Index) to examine structural gender-based disparities in health; life expectancy at birth, a summary indicator of population

health context; demographic dependency ratio (ratio of non-working to working-age population); and population density, which may proxy for environmental and lifestyle exposures.

These contextual covariates were harmonized, checked for missing data, and interpolated where necessary to align with survey years.

3.8. Statistical analysis methods

The statistical analyses combined descriptive, hierarchical modeling frameworks and spatio-temporal analyses to estimate prevalence, identify associated factors and examine time trends.

The analytical framework was developed after an extensive review of global and regional studies that used similar data sources including WHO STEPS,[51] Global Burden of Disease (GBD),[53] and NCD Risk Factor Collaboration (NCD-RisC) datasets,[54] to evaluate the most suitable statistical techniques for handling multi-country, multi-year, and hierarchically structured data.

Two levels of weighting were applied in the analysis. First, country-specific, age-standardized prevalence estimates were first computed using the complex survey design elements (weights, strata, and primary sampling units) available in each WHO STEPS dataset to ensure nationally representative estimates. Second, these individuals data were then aggregated by countries and survey years using weighted means, where weights corresponded to the size of the population in the corresponding survey year, obtained from the United Nations World Population Prospects.[55]

Because surveys were implemented in different years across countries, each country–year observation was treated as a random realization of the underlying regional distribution. The combined regional estimate thus represents an empirical expectation of the population-weighted mean prevalence, reflecting both demographic influence and inter-country variability. To quantify uncertainty, standard errors and 95% confidence intervals were calculated using Taylor linearization and propagation of variance formulas.[56]

3.8.1. Multilevel Logistic Regression for Associated Factors

To explore the determinants of BMI categories, hypertension-related outcomes, and CVH categories, hierarchical logistic regression models were employed. These models jointly incorporated individual-level covariates (age, sex, education, residence, behavioural risk factors, and biological measures) and contextual covariates (GDP per capita, HDI, health expenditure, and urbanization). Random intercepts for country and year captured unobserved heterogeneity and dependence within clusters.

Odds ratios and 95% confidence intervals were derived for each covariate. Model diagnostics included assessment of residual variance, random-effects distribution, and multicollinearity statistics (variance inflation factors).

3.8.2. Time trends analysis: spatio-Temporal Modeling Approach

To characterize geographic variation and temporal trends in BMI, hypertension, and CVH across SSA, a comprehensive spatio-temporal modeling framework was implemented, comprising sequential steps of data harmonization, aggregation into longitudinal panels, preparation and imputation of contextual covariates, hierarchical and spatio-temporal modeling.

- **Selection of methods*:*** To identify the most relevant and statistically robust spatio-temporal model for these studies, we compared the five leading approaches for spatio-temporal trend estimation: INLA, RStan, Gaussian Processes, Generalized Additive Models, and State-Space Models assessing their strengths, limitations, and suitability for different types of data and analytical objectives (Table 2).

***Table 2**. Comparative Summary of the Five Leading Methods for Spatio-Temporal Trend Estimation*

Method	Main Idea	Strengths	Limitations	Data Size Suitability	Model Flexibility	Uncertainty Quantification	Computation Speed	Best Use Cases	Key Reference
INLA (SPDE-based Bayesian)	Uses Laplace approximation + GMRF/SPDE to perform fast Bayesian inference for spatial & spatio-temporal fields	Extremely fast for large spatial meshes; robust uncertainty estimates; handles missing data naturally; highly interpretable	Less flexible than Stan for non-GMRF models; custom likelihoods limited	Very large spatial datasets(10k–100k points)	Medium–high (within GMRF/SPDE class)	Excellent	Fastest Bayesian	Environmental trends, disease mapping, climate surfaces	Lindgren, Rue & Lindström (2011)
RStan (HMC/NUTS Bayesian)	Full Bayesian hierarchical modeling with Hamiltonian Monte Carlo	Maximum modeling flexibility; can express any spatio-temporal structure; gold standard for scientific inference	Computationally heavy; slow for large spatial meshes; needs careful tuning	Small–medium datasets (hundreds–few thousands locations)	Highest flexibility	Excellent (exact MCMC)	Slow–medium	Custom hierarchical spatio-temporal models	Stan Development Team (2015)

Gaussian Processes (GPs)	Nonparametric covariance-based modeling of space–time smoothness	Highly flexible smooth trends; interpretable kernels; excellent scientific modeling	Cubic scaling; difficult for large datasets unless approximated; kernel choice critical	Small–medium unless sparse GP used	High (via kernels)	Excellent	Slow for large N	Climate, geostatistics, interpolation	Cressie & Wikle (2011)
GAM/GAMM	Penalized spline smoothers for space, time, and interactions	Easy to fit; very interpretable; fast; works with many likelihoods	Not fully Bayesian; can understate uncertainty; limited for complex spatial correlation	Small–large datasets (fast)	Medium	Good (frequentist CIs)	Fast	Applied trend analysis, ecology, health data	Wood (2017)
State-Space / DLM (Kalman filter)	Dynamic latent states for time + spatial extensions	Excellent for temporal trend extraction; handles missing data well; real-time updating	Spatial structure must be simplified; less flexible for non-Gaussian space-time	Medium–large time series	Medium	Good	Very fast for time-dominant problems	Real-time forecasting, monitoring, filtering	Durbin & Koopman (2012)

The INLA approach has been selected as the most appropriate method, as it provides a strong balance of statistical rigor, computational efficiency, and accurate uncertainty quantification for spatio-temporal trend estimation, particularly in studies involving large datasets and complex spatial structures."

- **Data aggregation**

Country-level summary statistics for BMI, hypertension, and CVH were calculated from the harmonized datasets. These data were transformed into a panel structure (country × year) to allow for longitudinal modeling. Each record contained outcome measures, year of data collection, and country-level contextual covariates such as gross domestic product (GDP) per capita, health expenditure per capita, and urbanization level.

- **Contextual covariates preparation**

Contextual covariates were harmonized to match the temporal dimension of the STEPS data. Covariate data were first cleaned, and where values were missing, missing years were linearly interpolated or smoothed using locally weighted regression (LOESS) to ensure temporal continuity. Missing years were linearly interpolated or smoothed using locally weighted regression (LOESS) to ensure temporal continuity.[57,58] All variables were standardized (z-scores) before inclusion in the modeling framework to facilitate convergence and interpretability of regression coefficients.

- **Contextual covariates imputation**

Missing country–year observations in covariates were imputed using the Amelia II multiple imputation algorithm implemented in R.[59] Amelia applies a bootstrapped expectation–maximization (EMB) algorithm to iteratively estimate missing values under a multivariate normal assumption, while preserving both temporal and cross-sectional correlation structures.[58–61] Ten imputed datasets were generated, and estimates were combined following Rubin's rules to incorporate between-imputation variance into the final uncertainty estimates. Model diagnostics included over imputation plots, convergence checks, and comparison of observed vs. imputed distributions to confirm statistical plausibility.[58,61]

- **Spatiotemporal modelling**[60,61]

Due to the uneven temporal distribution of STEPS surveys, missing country–year observations, the spatio-temporal models were fitted to estimate smooth trends in prevalence across space (countries) and time (survey years). These models incorporated spatial random effects to capture geographical correlation between neighboring countries and temporal random effects to model autocorrelation over time. The general model structure can be expressed as:

$$Y_{i,t} = \alpha + \beta X_{i,t} + u_i + v_t + \epsilon_{i,t}$$

where $Y_{i,t}$ represents the prevalence in country *i* at time *t*, $X_{i,t}$ denotes country-level covariates, u_i is the spatial random effect, v_t is the temporal random effect, and $\epsilon_{i,t}$ is the residual error term. This framework allowed estimation of regional and subregional trajectories while accounting for heterogeneity and missingness across space and time. Models were fitted under both frequentist and Bayesian paradigms using Markov Chain Monte Carlo (MCMC) techniques for robustness checks.

The model used a Hierarchical or Multilevel Modeling for Trend Analysis: temporal evolution of BMI, hypertension, and CVH was further examined using hierarchical (multilevel) mixed-effects models that accounted for the nested data structure — individuals nested within countries, and countries observed across years. These models included random intercepts and random slopes for country and year, allowing the baseline prevalence and rate of change to vary across countries. Fixed effects captured the average regional trend, while random components modeled country-specific deviations.

Model adequacy was assessed using intraclass correlation coefficients (ICC) to quantify variance explained at each level, and Akaike (AIC) and Bayesian (BIC) Information Criteria were used to compare model fit. The inclusion of both fixed and random components made it possible to disentangle systematic regional trends from random fluctuations due to data sparsity or country-specific effects.

3.8.3. Common sensitivity analyses

A series of sensitivity analyses were performed to evaluate the robustness and stability of the main findings.

- **Alternative Weighting and Standardization Schemes**

To test the influence of population weighting, regional prevalence was recalculated using unweighted country averages and compared with the population-weighted estimates. Additionally, age-standardization was repeated using alternative reference populations to verify the stability of prevalence estimates.

- **Time trends analysis**

  - **Data Inclusion and Completeness**

Analyses were repeated after restricting the sample to countries with at least two survey rounds to assess the influence of temporal data sparsity on the estimation of regional trends.

  - **Imputation Robustness**

Given the use of multiple imputation with the Amelia II algorithm to address missing country-year data, the stability of imputed values was examined through alternative imputation settings. This included varying the number of imputations (from 5 to 20), adjusting the temporal smoothing parameter, and re-estimating models using only observed data (complete case analysis). Convergence diagnostics and over-imputation plots were reviewed to ensure convergence and confirm that the imputed distributions were statistically coherent with observed data.[60]

  - **Alternative Analytical Frameworks**

Results obtained under the frequentist framework were compared with those generated under Bayesian hierarchical modeling using Markov Chain Monte Carlo (MCMC) estimation to evaluate the consistency of trend direction, uncertainty intervals, and posterior distributions. Additionally, selected analyses were replicated using bootstrapping (1,000 replicates) to assess the stability of point estimates and standard errors under data resampling.

- **Model Specification and Random Effects Structure**

The sensitivity of the hierarchical and spatio-temporal models to structural assumptions was evaluated by modifying the random effects specification. Models were refitted using:

- Random intercepts only (excluding random slopes); Alternative covariance structures (independent, autoregressive AR(1)); and different spatial correlation priors (e.g., intrinsic conditional autoregressive vs. unstructured).
- The consistency of fixed-effect estimates, model fit indices (AIC, BIC, DIC), and posterior predictive checks were used to assess the robustness of the trend and association estimates.

- **Covariate Sensitivity**

To examine the stability of associations, models were re-estimated after excluding highly correlated contextual covariates (e.g., GDP per capita and health expenditure) to assess multicollinearity effects. Variance inflation factors (VIFs) and condition indices were inspected. Sensitivity analyses also tested the effect of including or excluding contextual variables such as urbanization, HDI, or gender development index, as well as behavioural covariates (e.g., diet, physical activity).

3.8.4. Sensitivity Analyses for the analysis of hypertension

First, linear mixed models with random effects for country and survey year were applied to assess the factors associated with SBP and DBP. Second, a more parsimonious model containing commonly available risk factors in DHS and STEPS (Figure 3) including age, education level, smoking status, and work status was conducted. Third, the main models were further and sequentially adjusted for (i) physical activity, which was available in 95% (n=181 444) of the individuals, and then for (ii) diabetes, marital status, and high total cholesterol which were available in 75% (n=148 538), 78% (n=142 219) and 63% (n=119 324) of the population, respectively. Fourth, we addressed the influence of rural-urban status in a subsample of 105 946 participants (55%) in whom the information was available. We described the

distribution of the four hypertension-related outcomes by rural-urban status and repeated the analysis of their determinants further adjusting for the rural-urban status. Lastly, we provided time trends of the four-related hypertension outcomes and of the absolute number of hypertension cases using observed instead of imputed data. These information were available in at least one STEPS survey and/or DHS each year between 2003 and 2022 except 2018.

All statistical analyses were weighted according to the weighting strategy described above, except for the regression analyses, which were performed without applying survey weights. Data cleaning, imputation, and modeling were performed using R (version 4.4.2), with visualization using ggplot2 and sf packages in R.

4. Results

The flow chart of the three analyses is presented in Figure 3.
For this project, among the 47 countries in the WHO African Region, 38 have conducted at least one STEPS survey, while 9 had not conducted the survey as of the time of our request. We obtained access to surveys from 37 countries available in the STEPS survey repository, though one had missing BMI data. We analysed individual-level data from the remaining 36 countries, combining 54 subnational and national cross-sectional STEPS surveys conducted between 2003 and 2022. The list and description of available STEPS surveys by country is reported in appendix **(Supplementary Table 1).**

For the article on hypertension specifically, after excluding countries without blood pressure measurements, STEPS individual-level data from 37 countries were included in the analysis. Following the request from the journal to increase the coverage of the study, 8 DHS surveys from 6 countries including South Africa, Namibia, Tanzania, Lesotho, Ghana, and Benin that had not conducted STEPS surveys were added.

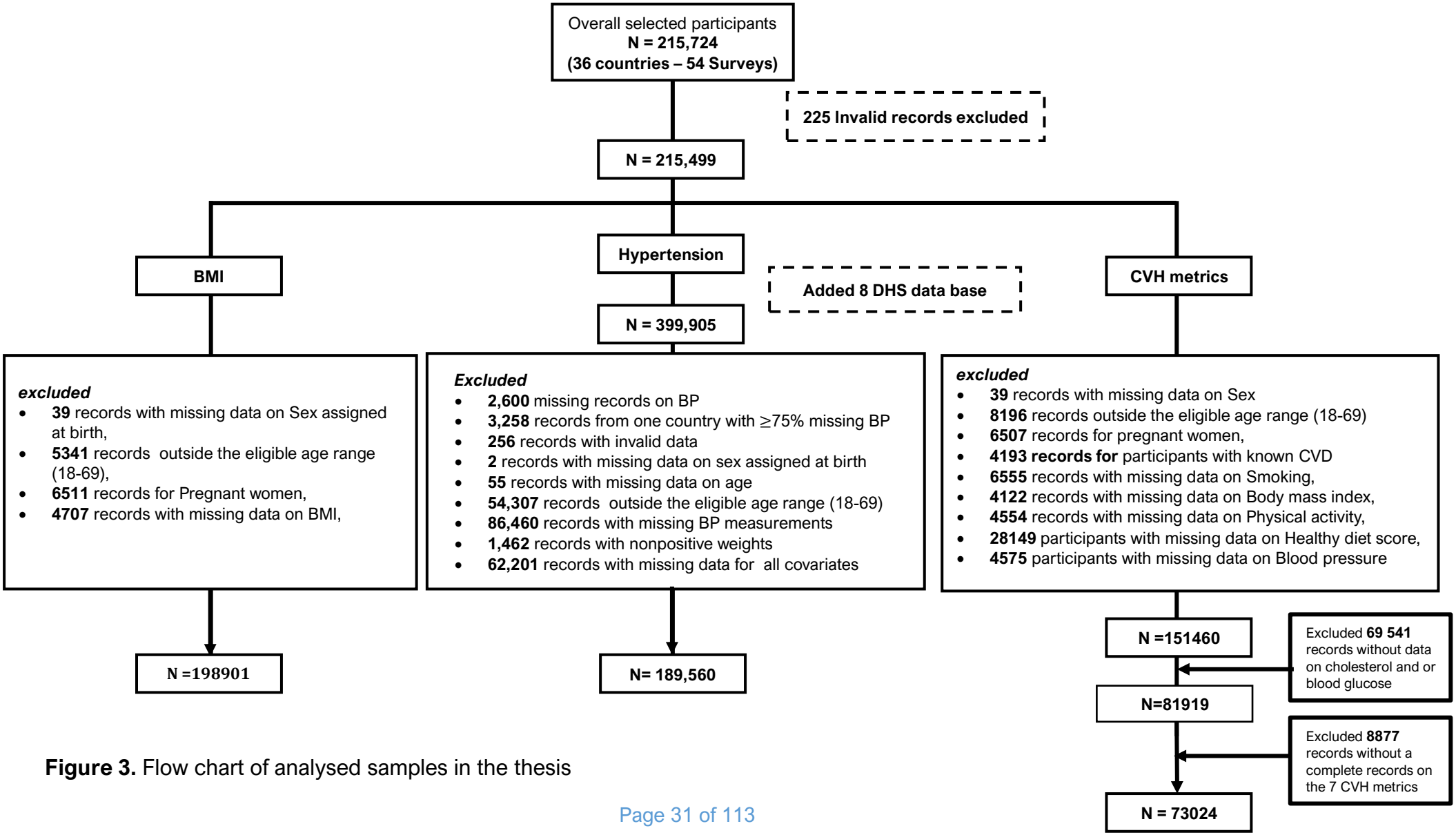


Figure 3. Flow chart of analysed samples in the thesis

4.1. Paper 1: Burden of overweight and obesity

Accepted for publication in BMJ Global Heath (open acces) and presented as oral presentation at the World Congress of Epidemiology September 2024.

We compiled data from 198,901 adult participants (50·3% women) with a mean age of 36·3 ± 12·9 years, representing a population of 156 million from 54 surveys. Of the 36 countries examined, 13 were in West Africa, 9 in East Africa, 5 in Southern Africa, 8 in Central Africa, and 1 in North Africa (Algeria only north African country member of the WHO African Region).

Baseline characteristics

The overall mean BMI was 23·3 ± 2·0 kg/m^2 (standard deviation, SD), 24·23 ± 1·60 in women and 22·11 ± 1·53 in men (p for sex difference <0·001). The age-standardized and weighted prevalence of underweight, overweight and obesity was 11·5%, 17·8%, and 9·0% respectively; and 61·7% were normo-weighted. The corresponding unweighted prevalences are reported in Supplementary Table 2. Women were 1·4 times more often overweight and three times more often obese than men (Figure 4)

The distribution of individual characteristics overall and by BMI categories is reported in Table 3. In addition to the previously noted sex disparities, overweight and obese as compared to normo-weighted were older, more educated, less physically active, had less often optimal diet, were more often never or past smoker, alcohol abstainers, and had higher levels of blood pressure, total cholesterol and blood glycemia.

The distribution of the population characteristics by rural-urban status are reported in Supplementary Table 2. It shows in particular that underweight was overrepresented in rural areas whereas overweight and obesity were overrepresented in urban areas.

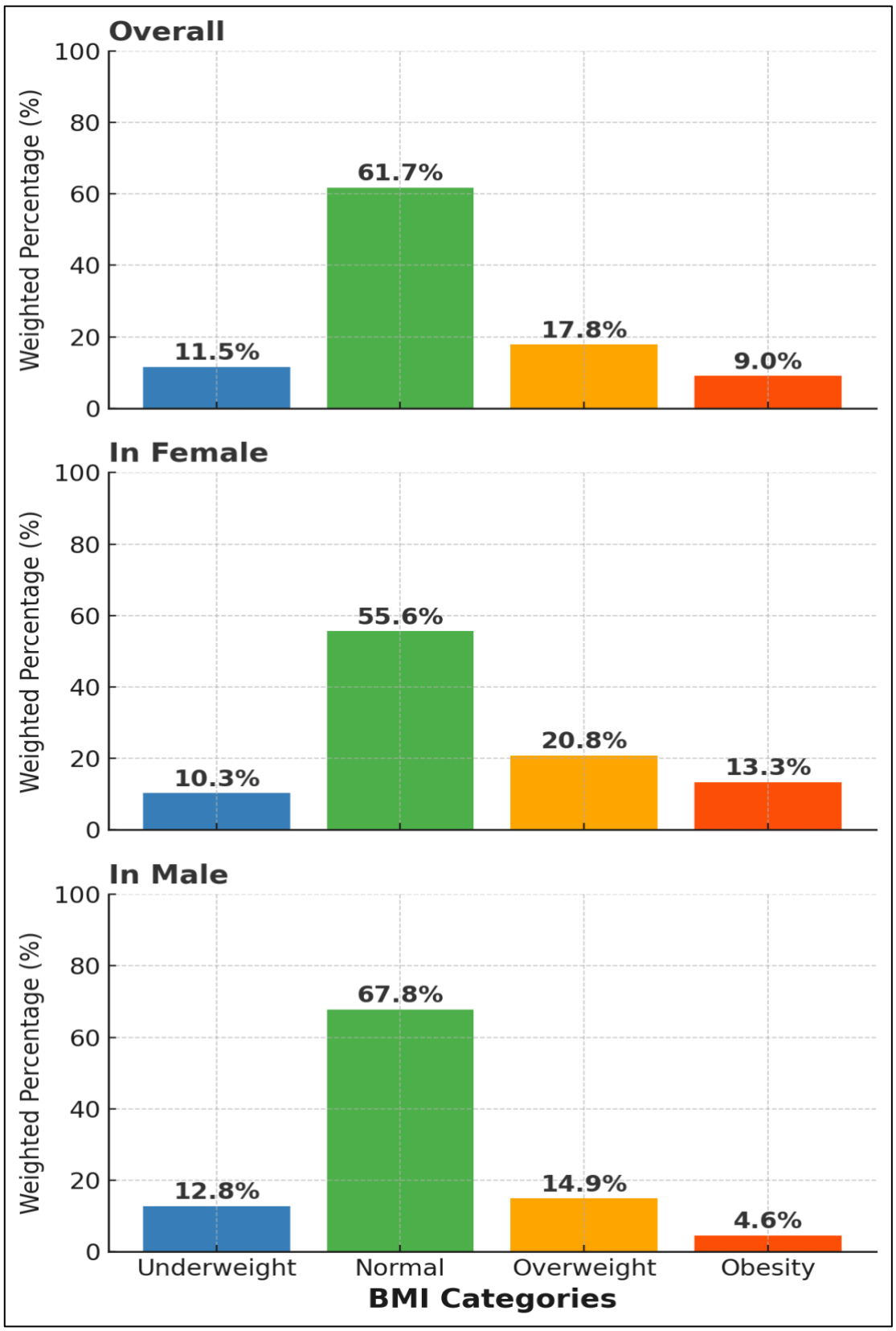


***Figure 4**. Distribution of Prevalence of BMI categories overall and by sex.*

***Table 3**. Characteristics of study participants overall and by BMI categories*

Characteristic		Body Mass Index (kg/m²)				
		Overall, N = 198901 (100%)[1]	**Underweight (< 18·5kg/m²)**, N = 20991 (11·5%)[2]	**Normal (18·5 to 24·9 kg/m²)**, N = 114560 (61·7%)[2]	**Overweight (25 to 29·9 kg/m²)**, N = 40470 (17·8%)[2]	**Obese (>=30kg/m²)**, N = 22 880 (9·0%)[2]
Female Sex	**198 901**	115 811 (50·3%)	11 499 (10·3%)	59 543 (55·6%)	26 319 (20·8%)	18 450 (13·3%)
Age, mean (SD)	**195 633**	36.3 (12.9)	36.0 (13.9)	34.8 (12.6)	38.8 (12.5)	41.3 (12.0)
Level of education	**193 950**					
No education		61 605 (26·7%)	8 581 (16·3%)	36 681 (63·5%)	10 657 (13·4%)	5 686 (6·7%)
Primary education		74 133 (44·4%)	7 301 (11·2%)	43 734 (63·8%)	14 586 (16·8%)	8 512 (8·3%)
Secondary education		45 623 (22·2%)	3 650 (8·3%)	24 969 (58·5%)	10 730 (22·0%)	6 274 (11·2%)
Tertiary education		12 589 (6·6%)	900 (5·6%)	6 369 (50·9%)	3 332 (28·3%)	1 988 (15·2%)
Physical activity	**193 202**					
≥150 min/wk moderate or ≥75 min/wk vigorous or ≥150 combination		75 255 (53·6%)	7 912 (11·6%)	45 742 (64·3%)	14 332 (16·6%)	7 269 (7·5%)
1–149 min/wk moderate or 1–74 min/wk vigorous or 1–149 min/wk combination		28 579 (17·3%)	2 646 (11·1%)	16 228 (58·8%)	6 120 (19·5%)	3 585 (10·6%)
None		89 368 (29·0%)	9 827 (11·8%)	49 277 (58·4%)	18 921 (19·2%)	11 343 (10·6%)

Characteristic		Body Mass Index (kg/m²)				
		Overall, N = 198901 (100%)[1]	**Underweight (< 18·5kg/m²)**, N = 20991 (11·5%)[2]	**Normal (18·5 to 24·9 kg/m²)**, N = 114560 (61·7%)[2]	**Overweight (25 to 29·9 kg/m²)**, N = 40470 (17·8%)[2]	**Obese (>=30kg/m²)**, N = 22 880 (9·0%)[2]
Fruit & vegetable consumption	**165 516**					
4–5 servings per day		87 275 (51·7%)	9 784 (12·8%)	51 112 (63·1%)	17 026 (16·3%)	9 353 (7·9%)
2–3 servings per day		56 844 (37·9%)	4 760 (8·1%)	32 144 (59·6%)	12 593 (21·4%)	7 347 (10·8%)
0–1 serving per day		21 397 (10·4%)	2 036 (7·9%)	11 908 (57·0%)	4 637 (22·0%)	2 816 (13·0%)
Smoking	**192 868**					
Never or quit > 12 m		169 349 (87·4%)	17 046 (11·1%)	95 774 (60·8%)	35 817 (18·5%)	20 712 (9·6%)
Former, quit ≤12 m		1 108 (0·7%)	144 (10·7%)	712 (69·3%)	162 (11·0%)	90 (8·9%)
Current		22 411 (11·9%)	3 094 (14·6%)	14 785 (68·2%)	3 223 (12·9%)	1 309 (4·3%)
Alcohol consumption	**193 404**					
Never or quit > 12 m		113 391 (60·4%)	12 304 (10·8%)	63 704 (58·7%)	23 491 (19·9%)	13 892 (10·6%)
Current drinker		58 878 (27·0%)	5 902 (12·3%)	34 593 (65·5%)	11 988 (15·3%)	6 395 (6·9%)
Heavy episodic drink		21 135(12·5%)	2 342 (13·8%)	13 462 (68·5%)	3 623 (12·7%)	1 708 (5·0%)
Systolic blood pressure (SBP), mmHg	**193 275**	126·4 (31·0)	120·7 (30·7)	125·4 (32·8)	130·2 (25·7)	133·4 (25·8)

Characteristic		Body Mass Index (kg/m^2)				
		Overall, N = 198901 (100%)[1]	**Underweight (< 18·5kg/m^2)**, N = 20991 (11·5%)[2]	**Normal (18·5 to 24·9 kg/m^2)**, N = 114560 (61·7%)[2]	**Overweight (25 to 29·9 kg/m^2)**, N = 40470 (17·8%)[2]	**Obese (>=30kg/m^2)**, N = 22 880 (9·0%)[2]
Fasting blood glucose, mg/dL	**138 056**	80·0 (32·4)	76·4 (29·6)	77·0 (30·2)	86·5 (34·2)	93·1 (40·4)
Blood total cholesterol, mg/dL	**112 328**	136·2 (54·4)	125·8 (48·7)	129·6 (51·2)	152·6 (56·8)	163·3 (61·9)

Mean (SD); [1] Percentage in column (%); [2] Percentage in row. All percentages are weighted; all n are unweighted

Determinants of BMI categories

Factors associated with BMI categories are reported in Table 4. After multivariable analysis, being a female, older age, higher education, physical inactivity, and poor diet, were positively associated with overweight or obesity compared to normal weight, whereas inverse associations were seen with past or current smoking. Strikingly, the odds of being overweight or obese were respectively two times higher (aOR = 2·05 [95% CI: 1·81 - 2·33]) and almost five times higher (aOR = 4·86 [95% CI: 4·08 – 5·84]) in females compared to males. Additionally, those with tertiary education were two times (aOR = 1·90 [95% CI: 1·49 - 2·41]) and three times (aOR = 3·32 [95% CI: 2·45 - 4·50]) more likely to be overweight and obese than the less educated. Furthermore, older age, former and current smoking, were associated with higher odds of underweight, whereas higher education was inversely related to underweight. Factors associated with BMI categories did not differ by sex.

Further adjustment for country-level contextual factors did not change the association of individual risk factors with overweight or obesity as none of the contextual risk factors were significantly related to adverse BMI categories (supplementary Table 3).

Trends analysis

Using the spatio-temporal model, no significant trend in overall mean BMI was noticed (Figure 5), weighted and age standardized mean BMI being 23·25 kg/m^2 ([95% CI: 20·1-26·6]) in 2003 and 23.43 kg/m^2 ([95% CI: 19·3-27·8]) in 2022 (p for trend=0·783). This reflects a significant increase in the overall prevalence of obesity from 15·89% in 2003 to 17·11% in 2022, p for trend < 0·001, (Figure 5) along with a plateau in the prevalence of overweight from 18·01% in 2003 to 18·03% in 2022, p for trend = 0·461.

Trend analysis by sex indicates that the prevalence of obesity increased from 16·01% in 2003 to 17·16% in 2022 in women (p for trend <0·001), and from 05·32% in 2003 to 05·90% in 2022 in men (p for trend <0·001) (Figure 5).

***Table 4**. Factors associated with overweight, and obese status as compared to normal weight*

Predictor	Underweight vs Normal		Overweight vs Normal		Obesity vs Normal	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
	0.09	0.05—0.16	0.1	0.06—0.15	0.01	0.01—0.02
Sex						
Male	1(ref)		1(ref)		1(ref)	
Female	1.25	1.06—1.46	2.07	1.83—2.34	4.92	4.13—5.89
Age groups						
[18;25)	1(ref)		1(ref)		1(ref)	
[25;35)	0.85	0.67—1.08	1.85	1.49—2.29	2.83	2—4.06
[35;45)	0.88	0.68—1.14	2.44	1.96—3.05	5.4	3.82—7.8
[45;55)	1.01	0.76—1.33	2.53	1.99—3.2	6.57	4.62—9.56
[55;69]	1.26	0.96—1.67	2.66	2.07—3.4	6.78	4.72—9.93
Level of education						
No education	1(ref)		1(ref)		1(ref)	
Primary education	0.76	0.64—0.9	1.21	1.05—1.39	1.8	1.49—2.17
Secondary education	0.88	0.7—1.11	1.72	1.45—2.04	2.89	2.33—3.6
Tertiary education	0.94	0.64—1.36	2.07	1.63—2.63	3.77	2.77—5.11
Employment status						
Employee	1(ref)		1(ref)		1(ref)	
Self-employed	1.48	1.12—1.97	0.84	0.71—1.01	0.77	0.61—0.97
Student voluntary	1.82	1.33—2.5	0.59	0.46—0.76	0.52	0.37—0.72
Unemployee / retired	1.53	1.16—2.05	0.77	0.64—0.92	0.73	0.58—0.91
Physical activity						

≥150 min/wk moderate or ≥75 min/wk vigorous or ≥150 combination	1(ref)		1(ref)		1(ref)	
1–149 min/wk moderate or 1–74 min/wk vigorous or 1–149 min/wk combination	1.2	0.97—1.47	1.07	0.91—1.25	1.27	1.04—1.55
None	1.19	0.98—1.44	1.06	0.91—1.23	1.27	1.05—1.54
Fruit & vegetable consumption						
4–5 servings per day	1(ref)		1(ref)		1(ref)	
2–3 servings per day	0.88	0.75—1.03	1.14	1.01—1.28	1.19	1.02—1.37
0–1 serving per day	1.15	0.92—1.44	1.01	0.85—1.2	1.36	1.1—1.68
Smoking						
Never or quit > 12 m	1(ref)		1(ref)		1(ref)	
Former. quit ≤12 m	1.53	0.62—3.4	0.13	0.02—0.52	0.86	0.27—2.3
Current	1.81	1.47—2.22	0.62	0.51—0.77	0.63	0.46—0.84
Alcohol consumption						
Never or quit > 12 m	1(ref)		1(ref)		1(ref)	
Current drinker	0.96	0.8—1.14	1.04	0.91—1.2	1	0.83—1.2
Heavy episodic drink	0.98	0.79—1.21	1.03	0.86—1.23	1.08	0.85—1.37

OR: Odds Ratio, CI = Confidence Interval. Data are in OR (95% CI).
OR and their 95% CI were estimated by hierarchical multinomial mixed-effects regression using normal weight as the reference category and including a random effect on the country and year; they were adjusted for the variables listed in the Table. The analysis was conducted in N=149,404 individuals without missing covariates.

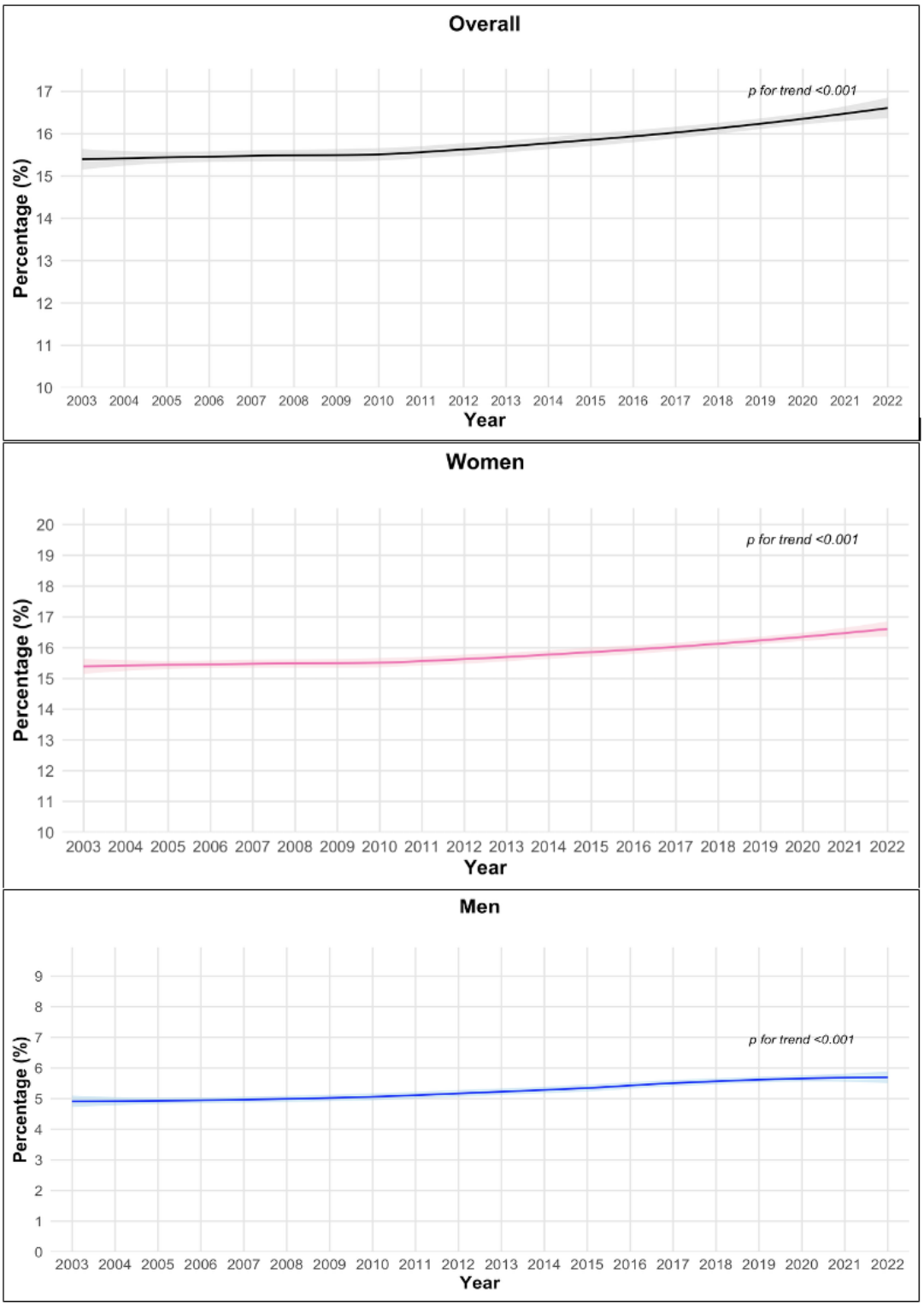


Figure 5. *Trend in age-standardised prevalence of Obesity overall and by sex from 2003 – 2022*

Imputed data for all the 47 countries in the WHO African region

4.2. Paper 2: Burden of hypertension

Published in JACC 1st December 2025 (open access), and presented as oral presentation at the World Congress of Epidemiology in South African September 2024.

The study population included 251,761 participants (59.5% females; mean age: 37.1 ± 12.3 years in females and 38.6 ± 12.6 years in males), representing 148 million adults in the AFRO from 37 countries. Out of the 37 countries analyzed, 19 had data from 2 or more surveys representing 75% of the study sample. There were 12 countries (representing 32.4% of the total) from West Africa, 12 (32.4%) from Eastern Africa, 7 (18.9%) from Central Africa, 5 (13.5%) from Southern Africa, and 1 country (2.7%, Algeria) from North Africa (Figure 3).

The baseline characteristics

The age-standardized mean SBP and DBP were 123.9 mmHg (95% CI: 123.4–124.5 mmHg) and 79.0 mmHg (95% CI: 78.6–79.3 mmHg) in females, and 126.5 mmHg (95% CI: 125.8–127.3 mmHg) and 78.2 mmHg (95% CI: 77.7–78.7 mmHg) in males, respectively (Figure 6).

The distribution of participant characteristics by hypertension status in females and males is presented in Table 5. Among females, those with hypertension were more frequently overweight or obese, physically inactive, unemployed, students, or unpaid workers, divorced, separated, or widowed, less likely to smoke or consume alcohol, and had lower educational attainment. In contrast, hypertensive males were more often underweight, employed, single, more physically active, more likely to smoke and consume alcohol, and had higher education levels.

The prevalence estimates of hypertension status, awareness, treatment, and control are shown in Figure 6. Females had a higher age-standardized prevalence of hypertension than males: 28.9% (95% CI: 27.6–30.2%) vs. 26.1% (95% CI: 24.5–27.7%) (p for sex difference = 0.001). The proportion of undiagnosed hypertension was also higher among females than males: 25.0% (95% CI: 23.9–26.0%) vs. 22.4% (95% CI: 21.1–23.7%) (p for sex difference = 0.003).

Similarly, among participants with hypertension, awareness (62.4% [95% CI: 58.5–66.3%] vs. 50.5% [95% CI: 44.5–56.4%]; p < 0.001), treatment rates (15.0% [95% CI: 13.1–16.9%] vs. 8.4% [95% CI: 6.7–10.2%]; p < 0.001), and control rates (7.3% [95% CI: 5.8–8.8%] vs. 3.7% [95% CI: 2.4–4.9%]; p < 0.001) were consistently higher in females compared with males.

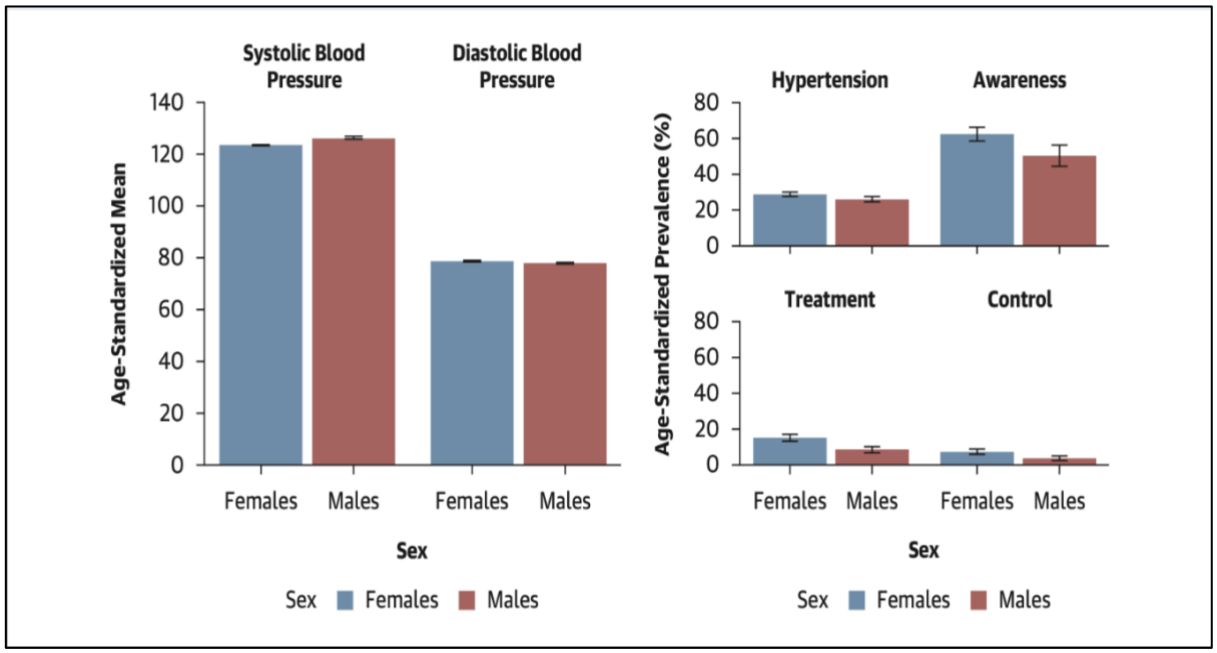


Figure 6. Sex-stratified age-standardized mean blood pressure levels and sex-stratified age-standardized prevalence of hypertension, awareness, treatment, control.

***Table 5**.Characteristics of participants by sex according to hypertension status*

	Overall population	Females: n=149 518 (50.5)		P-value[c]	Males: n=102 243 (49.5)		P-value[c]
		Hypertension	No hypertension		Hypertension	No hypertension	
Number of participants[a]	251 761 (100.0)	43 240 (25.9)	106 287 (74.1)		29 666 (24.3)	72 577 (75.7)	
Age (years); Mean (95% CI)	35.2 (35.2-35.3)	42.1 (42.0-42.2)	32.6 (32.5-32.8)	<.0001	40.9 (40.8-41.1)	33.6 (33.5-33.7)	<.0001
Age group				<.0001			<.0001
18-24	33 340 (22.0)	2118 (10.1)	18 638 (25.3)		1619 (12.8)	10 965 (25.9)	
25-34	80 223 (32.2)	8573 (22.6)	41 312 (37.3)		6045 (24.7)	24 293 (32.9)	
35-44	64 086 (21.8)	11 265 (23.4)	26 752 (21.2)		7228 (22.4)	18 841 (21.6)	
45-54	42 376 (13.5)	10 827 (22.0)	12 895 (10.5)		7166 (18.6)	11 488 (12)	
55-69	31 736 (10.4)	10 457 (21.9)	6681 (5.7)		7608 (21.5)	6990 (7.5)	
Body mass index (kg/m2)[b]				<.0001			<.0001
<18.5	20 817 (12.6)	2559 (7.6)	9553 (12.7)		2026 (8.5)	6679 (15.5)	
18.5–24.99	122 975 (63.4)	16 542 (47.3)	54 899 (61.9)		14 117 (62.7)	37 417 (70.7)	
25–29.99	45 323 (16.2)	10 968 (23.8)	21 109 (17.5)		5760 (20.4)	7486 (11.0)	
≥30	26 146 (7.8)	10 971 (21.3)	11 235 (7.9)		2180 (8.4)	1760 (2.8)	
Physical activity[b]				<.0001			0.0016
None	29 589 (15.6)	6953 (19.4)	13225 (18.2)		3455 (13.3)	5956 (12.2)	
1 to 149 min/week moderate or 1 to 74 min/week vigorous or 1 to 149 min/week combination	46 590 (21.4)	10 526 (28.3)	21 421 (26.0)		5063 (17.9)	9580 (15.7)	
≥150 min/week moderate or ≥75 min/week vigorous or ≥150 combination	119 380 (63.0)	19 163 (52.3)	45 304 (55.8)		16 162 (68.8)	38 751 (72.1)	
Smoking				<.0001			<.0001
Never or quit >12 months	209 797 (85.5)	37 818 (93.3)	98 568 (96.0)		21 049 (74.2)	52 362 (75.8)	
Former, quit ≤12 months	3601 (1.8)	694 (1.5)	728 (0.7)		741 (3.9)	1438 (2.3)	
Current	33 053 (12.8)	3433 (5.2)	5340 (3.4)		6836 (22.0)	17 444 (21.9)	

Alcohol intake[b]				0.6841			0.0244
Never or quit >12 months	122 102 (68.4)	25161 (77.3)	54 838 (76.8)		12 394 (58.3)	29 709 (60.3)	
Current	49 834 (11.6)	7980 (11.8)	20768 (12.1)		5735 (10.9)	15351 (11.3)	
Heavy episodic drink	33169 (19.9)	3753 (10.8)	7560 (11.1)		7241 (30.8)	14615 (28.4)	
Highest level of education				<.0001			0.0014
No formal schooling/<primary school/primary school	162 423 (73.3)	30 308 (79.3)	71 098 (76.3)		17 125 (68.6)	43 892 (69.8)	
Secondary school	54 774 (16.1)	8170 (12.0)	22 905 (14.6)		6836 (17.5)	16 863 (18.6)	
High school	16 451 (3.6)	1951 (2.8)	5932 (3.1)		2609 (4.5)	5959 (4.1)	
University+	10 888 (7.0)	1317 (5.9)	3492 (6.0)		2032 (9.5)	4047 (7.5)	
Work status				<.0001			<.0001
Employed	45 950 (14.1)	6572 (9.6)	16 449 (8.6)		7566 (23.0)	15 363 (18.4)	
Self-employed	67 722 (33.5)	10 629 (29.2)	24 153 (28.4)		9728 (40.2)	23 212 (38.1)	
Farmer/Manual worker	26 582 (0.6)	2128 (1.1)	9343 (0.6)		2912 (0.9)	12 199 (0.4)	
Unemployed	27 078 (9.9)	5204 (11.8)	13 519 (11.0)		2392 (8.1)	5963 (8.8)	
Student/Non-paid	61 621 (40.0)	14 082 (46.4)	34 273 (50.9)		3189 (22.1)	10 077 (32.7)	
Retired	3647 (1.5)	776 (1.6)	381 (0.3)		1586 (5.3)	904 (1.3)	
Others	3481 (0.2)	622 (0.2)	1586 (0.2)		325 (0.3)	948 (0.3)	
Marital status[b]				<.0001			<.0001
Single	39 811 (21.9)	4492 (9.8)	15 838 (18.0)		4009 (18.6)	15 472 (31.1)	
Married/cohabiting	132 246 (68.8)	20 854 (68.9)	57 449 (70.0)		16 014 (76.5)	37 929 (65.2)	
Divorced/Separated/Widowed	23 673 (9.2)	7607 (21.3)	11 273 (12.0)		1600 (4.8)	3193 (3.7)	
Diabetes[b]				<.0001			<.0001
High total cholesterol (>190 mg/dL)[b]	164 864 (95.5)	28 203 (89.8)	70 492 (97.3)		18 816 (91.7)	47 353 (97)	

SBP: systolic blood pressure. DBP: diastolic blood pressure. CI: confidence interval. Survey weights were incorporated into the estimates of all percentages. Categorical variables were described as column percentages. [a]Variables were described as row percentages. [b]For body mass index (BMI), alcohol use, physical activity, marital status, diabetes, and total cholesterol, information was available in 85% (n=215 261 individuals), 84% (n=211 860), 78% (n=195 559), 78% (n=195 730), 74% (n=187 168) and 50% (n=125 212) of the population, respectively. In all DHS data, BMI was available among females only. [c]P-value of Chi-Square Rao-Scott test for categorical variables and Weighted t-test for continuous variables.

Factors Associated with Hypertension status

In both males and females, older age, overweight or obesity, and retired status were associated with higher odds of hypertension. Conversely, being underweight or employed as a farmer or manual worker was linked to lower odds of hypertension.

Among females, former smoking was associated with higher odds of hypertension, while among males, alcohol consumption was positively associated. In contrast, being a student, unpaid worker, or unemployed was associated with lower odds of hypertension in males (Figure 7).

Factors Associated with Hypertension Awareness

In both males and females, older age, overweight or obesity, higher educational attainment (high school or above), and retired status were positively associated with awareness of hypertension. Among females, former smoking and achieving education beyond the primary level were associated with higher odds of awareness, whereas being a farmer or manual worker was linked to lower odds. Among males, current smoking, self-employment, student/unpaid work, unemployment, and alcohol consumption were all associated with lower odds of awareness (Figure 7).

Factors Associated with Hypertension Treatment

In both males and females, older age, overweight or obesity, education beyond the primary level, and retired status were associated with higher odds of receiving hypertension treatment. Conversely, current smoking and alcohol consumption were associated with lower odds of treatment. Among females, underweight status was also linked to reduced odds of treatment, while among males, being self-employed or a student/unpaid worker was associated with lower treatment rates (Figure 7).

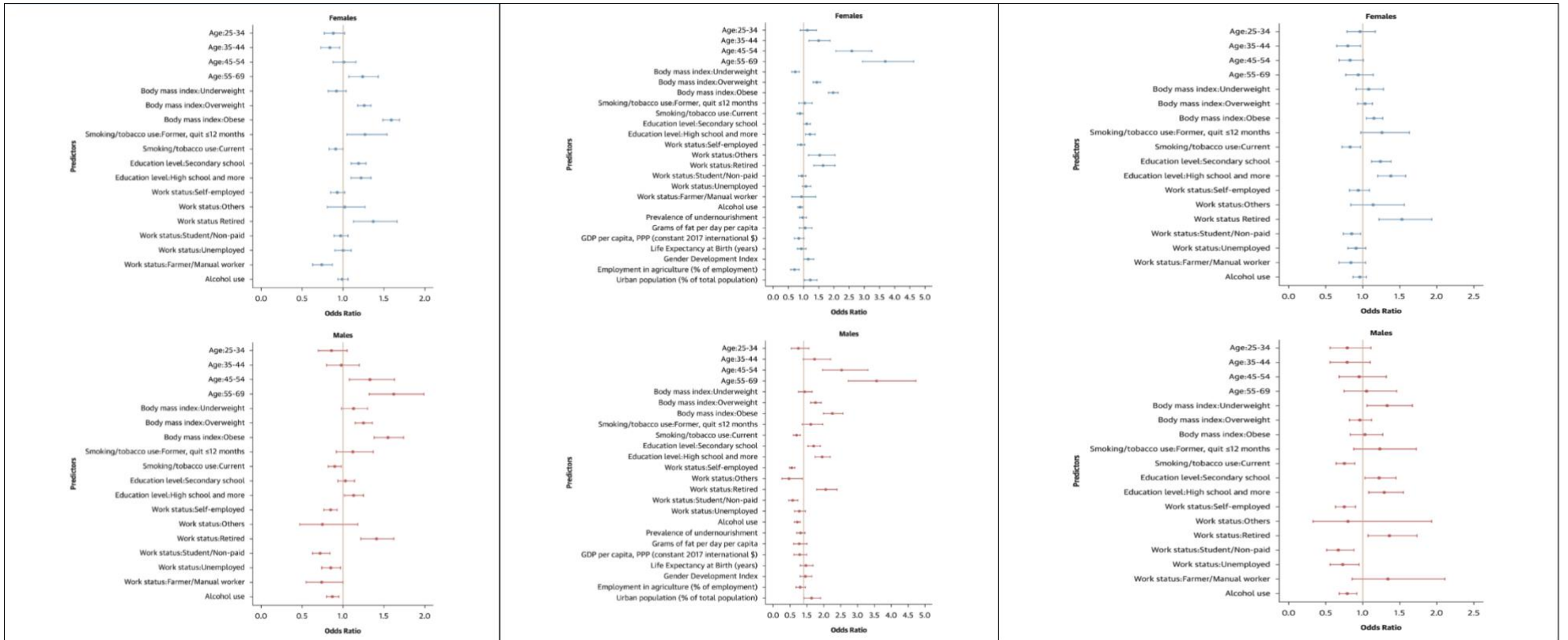
Factors Associated with Hypertension Control

Attaining education beyond the primary level and being retired were associated with higher odds of hypertension control in both sexes. Conversely, current smoking and being a student or unpaid worker were linked to lower odds of control.

Among females, obesity was positively associated with hypertension control, while among males, underweight status was linked to higher odds of control. In contrast,

self-employment, student/unpaid work, unemployment, and alcohol consumption were associated with lower odds of hypertension control (Figure 7).
Random effects for survey year were statistically significant in all models ($p < 0.0001$).

Further adjustment for country-level contextual factors, Hypertension-related outcomes were also influenced by contextual (country-level) factors including life expectancy at birth, Gender Development Index, grams of fat per day per capita, Gross Domestic Product per capita, employment in agriculture, and urbanization. (Supplementary Figure 1)



ORs and their 95% CIs were estimated via logistic regression analyses with random effects for country and survey year. The analysis was conducted among hypertensive individuals only. Dots represent adjusted ORs and horizontal lines their 95% CIs for each predictor. An OR >1 indicates a positive association (increased odds of hypertension treatment), and an OR <1 indicates a negative association (reduced odds).

Figure 7. *Determinants of Hypertension Awarness, Treatment, and Control: Sex-Stratified Multivariable Hierarchical Analysis*

Time trends in hypertension related outcomes

The prevalence of hypertension remained stable, from 32.0% in 2003 to 31.4% in 2022 in females (p for trend=0.597) and from 31.0% in 2003 to 30.2% in 2022 in males (p for trend=0.525) (Figure 8). However, during the same period, the absolute number of individuals with hypertension almost doubled from 123 (95% CI: 115–132) to 199 (185–213) million females and from 118 (110–126) to 191 (178–204) million males (Supplementary Figure 3). Hypertension awareness rates nearly doubled in both sexes, from 40.0% to 72.8% in females (p for trend<0.001) and from 26.9% to 59.3% in males (p for trend<0.001) (Figure 8). Treatment rates increased from 14.4% to 22.0% for females (p for trend<0.001) and from 9.2% to 14.7% for males (p for trend<0.001) (Figure 8). Control rates remained critically low, from 9.6% to 11.2% in females (p for trend<0.001) and from 5.7% to 7.1% in males (p for trend=0.004) (Figure 8).

Over the same time period, age-standardized mean SBP declined from 128.6 mmHg to 124.4 mmHg among females (p for trend < 0.001) and from 130.1 mmHg to 125.6 mmHg among males (p for trend < 0.001).

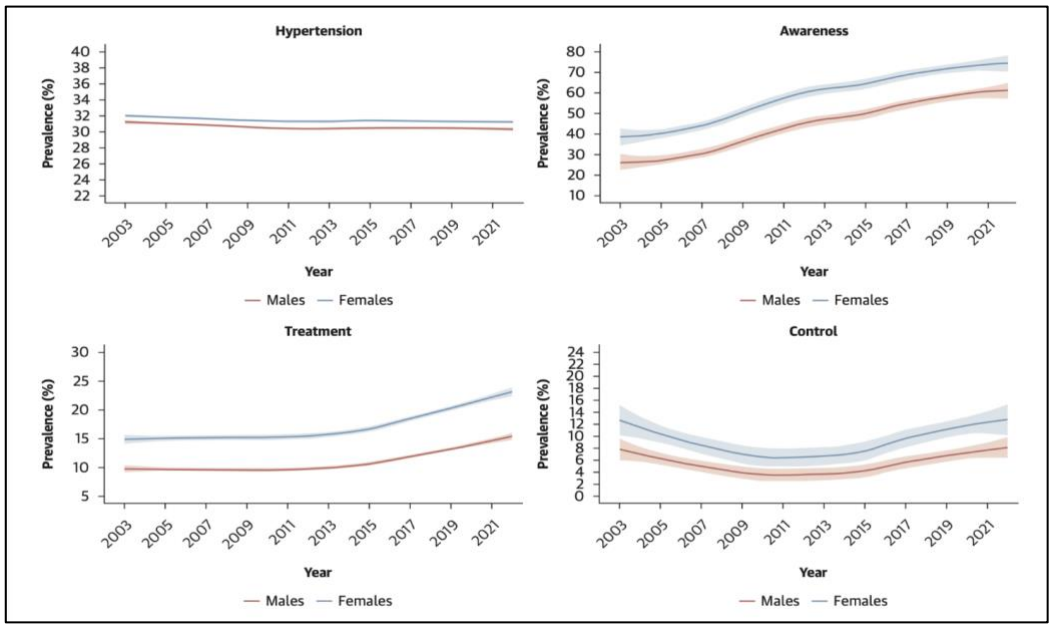


***Figure 8**. Sex-stratified trend in age-standardized prevalence of hypertension-related outcomes from 2003–2022*

4.3. Paper 3: Cardiovascular health

Piblished in JAMA Cardiology (open access) and presented as oral presentation at the 2025 joint European Society of cardiodiology (ESC) congress and world congress of cardiology in August 2025 in Madrid.

Data from 215 499 individuals free of CVD from 36 countries were compiled (Supplement Table 1). Of these, 47 955 individuals had missing data on at least 1 behavioral metric or BP metric. Among the remaining 151 460 individuals, 78 446 had incomplete or unmeasured data on blood glycemia and total cholesterol. Therefore, the final study population comprised 73 024 individuals (mean [SD] age, 35.4 [12.9] years; 49 505 female [49.4%]; 23 519 male [50.6%]) representing a population of 95 million adults across 22 countries and 25 surveys. From the 22 countries examined, 8 were West African, 6 were Eastern African, 5 were Southern African, 2 were Central African, and 1 was Northern African (Algeria). Prevalence of CVH Status and Metrics

The baseline characteristics

As shown in Figure 9, and in Table 6, the weighted prevalence of ideal (CVH score 12-14), intermediate (CVH score 9-11), and poor CVH (CVH score 0-8) were 26.2% (95% CI, 25.7%-28.0%), 57.9% (95% CI, 54.8%-59.0%), and 15.9% (95% CI, 15.1%-17.0%), respectively. Although there were no sex differences, age disparities were noted so that the prevalence of ideal CVH decreased with age while the opposite was seen for poor CVH. As shown in Supplementary Figure 3, 33.7% (95% CI, 33.0%-34.0%), 15.3% (95% CI, 15.0%-15.4%), and 1.3% (95% CI, 0.8%-1.6%) had achieved, respectively, 5, 6, and 7 ideal CVH metrics, respectively. Total cholesterol was the most frequent ideal metric (90.9%; 95% CI, 83.2%-94.8%), whereas healthy diet (10.8%; 95% CI, 7.9%-11.4%) was the least frequent ideal metric. Of note, only 36.1% (95% CI, 34.5%-37.9%) had achieved an optimal BP. Compared with males, females had more often an ideal level for smoking (93.8% vs 79.1%) and BP (47.9% vs 32.5%), whereas the opposite was seen for BMI (64.0% vs 79.4%) and physical activity (68.1% vs 79.4%) (Figure 9) & (Supplementary Figure 3).

Table 6. *Participant characteristics by Cardiovascular Health LS7 score categories*

Characteristics	Overall, N = 73,024	Cardiovascular Health categories, (%)		
		Ideal, (LS7 score 12–14), N = 15,820 (26.2)	**Intermediate, (LS7 score 9–11),** N = 41,627 (57.9)	**Poor, (LS7 score 0-8),** N = 15,577 (15.9)
Sex, (%)				
Females	49,505 (49.4)	9,071 (48.4%)	24,851 (48.8%)	9,871 (53.1%)
Males	23,519 (50.6)	6,749 (51.6%)	16,776 (51.2%)	5,706 (46.9%)
Age groups, years, (%)				
[18,30)	21,626 (29.6)	6,789 (54.8%)	12,741 (40.6%)	2,096 (19.7%)
[30,45)	27,688 (37.9)	5,834 (30.7%)	16,349 (36.2%)	5,505 (37.3%)
[45,60)	17,049 (23.3)	2,452 (11.3%)	9,104 (17.4%)	5,493 (29.9%)
[60,69]	6,661 (9.1)	745 (3.2%)	3,433 (5.8%)	2,483 (13.1%)
Level of education, (%)				
No education	21,469 (29.4)	4,171 (17.7%)	12,470 (21.8%)	4,828 (23.5%)
Primary education	31,671 (43.4)	7,026 (49.3%)	18,018 (47.5%)	6,627 (46.2%)
Secondary education	15,671 (21.5)	3,593 (23.9%)	8,794 (23.6%)	3,284 (22.8%)
Tertiary education	4,213 (5.8)	1,030 (9.2%)	2,345 (7.1%)	838 (7.6%)

Characteristics	Overall, N = 73,024	Cardiovascular Health categories, (%)		
		Ideal, (LS7 score **12–14**), N = 15,820 (26.2)	Intermediate, (LS7 score **9–11**), N = 41,627 (57.9)	Poor, (LS7 score **0-8**), N = 15,577 (15.9)
Marital Status, (%)				
Divorced/Separated/Widowed	9,569 (13.1)	1,604 (7.5%)	5,218 (8.6%)	2,747 (12.0%)
Married/Cohabitating	49,174 (67.3)	10,221 (61.1%)	28,162 (67.2%)	10,791 (74.9%)
Single	14,281 (19.6)	3,995 (31.4%)	8,247 (24.1%)	2,039 (13.1%)

All percentages are weighted and are calculated in column; all n are Unweighted, Mean (SD);

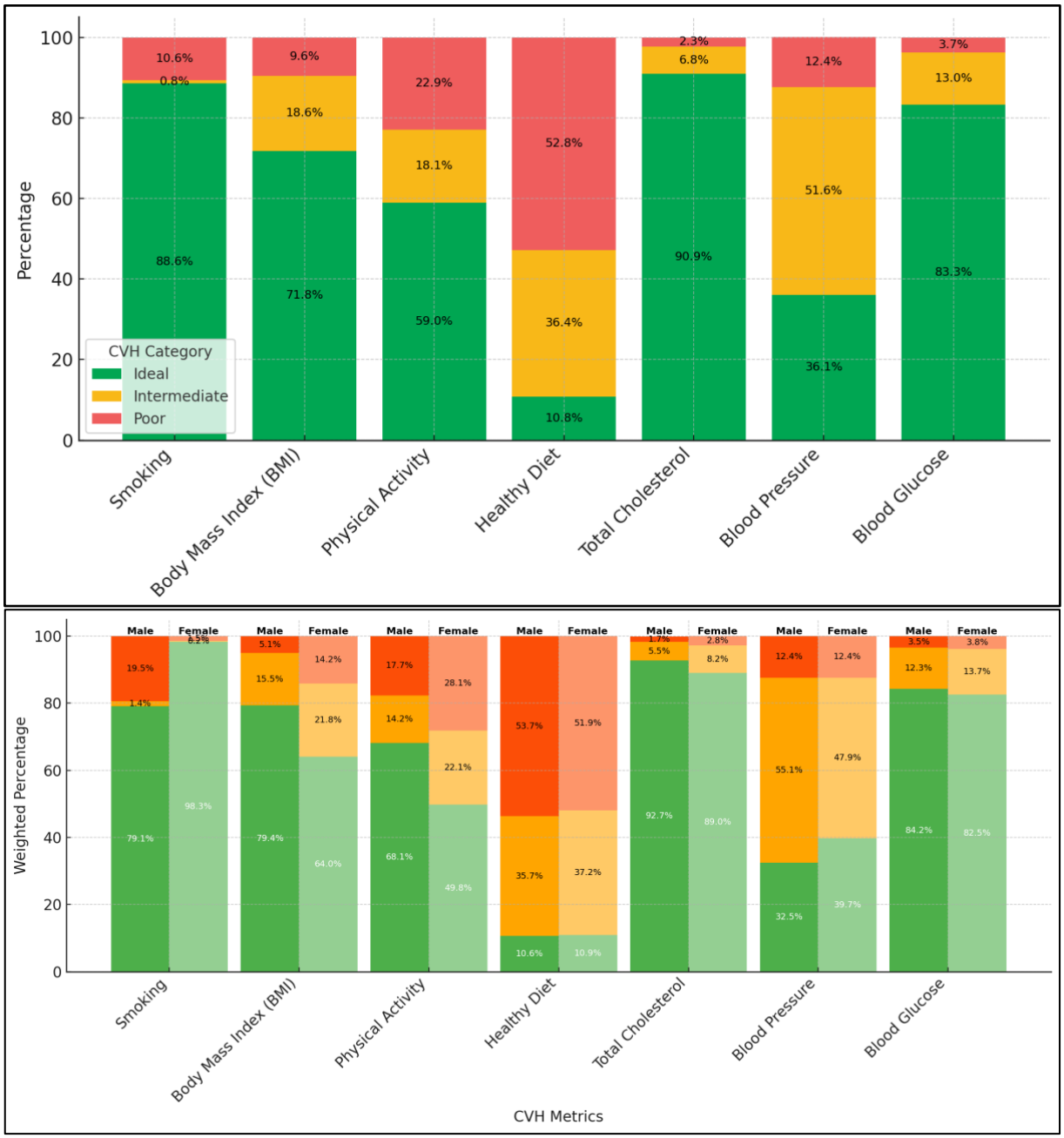


Figure 9. *Prevalence of individual Life's simple 7 cardiovascular health metric overall and by sex*

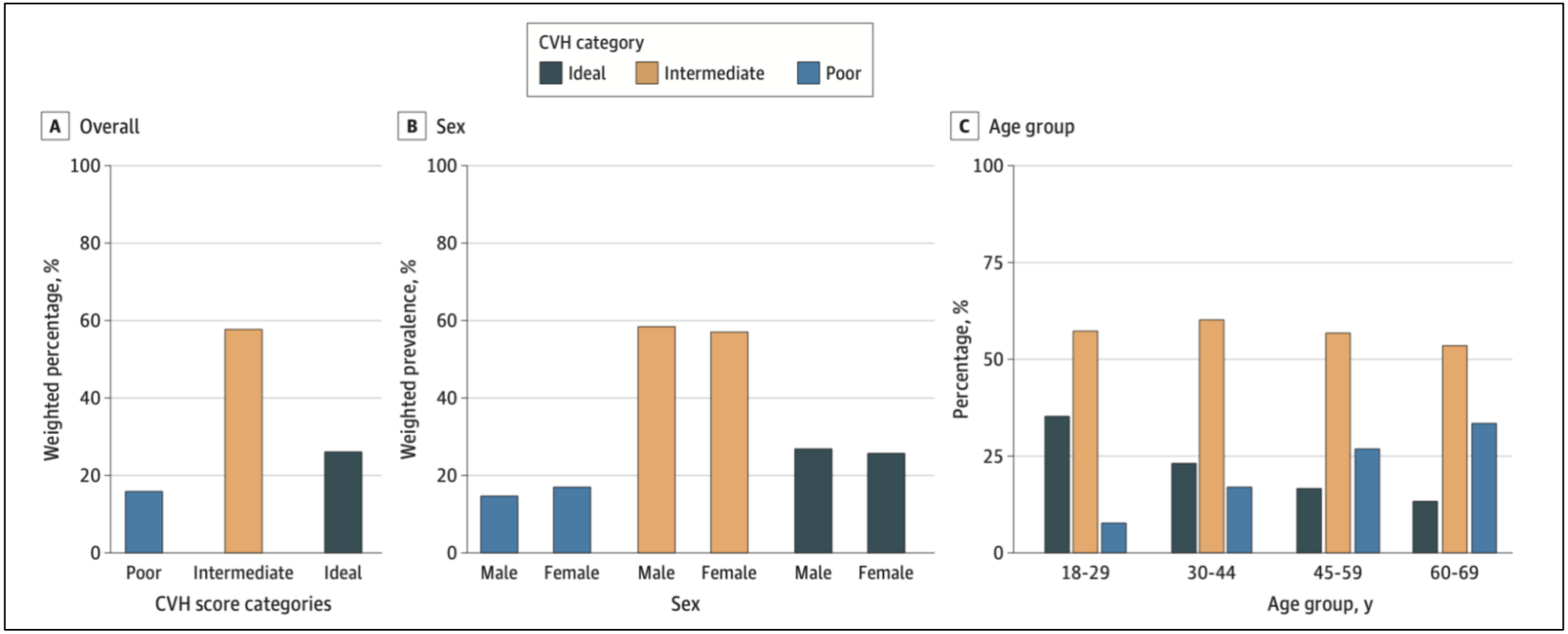


Figure 10. *Distribution of Life's Simple 7 Cardiovascular Health (CVH) Score Categories*

Factors Associated with CVH Status

As shown in Table 7, in multivariable analysis, older age, being a female, and heavy episodic alcohol consumption were each associated with a lower likelihood of achieving an intermediate or an ideal compared with a poor CVH score category. Additionally, lower educational attainment was significantly associated with reduced odds of achieving an ideal CVH score. These findings were consistent when considering the CVH score and in males and females.

Further adjustment for country-level contextual factors did not change the association with individual risk factors. In this latest analysis, country-level contextual factors including higher mean years of schooling (β = 0.24; 95% CI, 0.17-0.32), higher education percentage (β = 0.01; 95% CI, 0-0.02); higher prevalence of undernourishment (β = 3.14; 95% CI, 0.63-5.65), and employment in agriculture (β = 0.02; 95% CI, 0-0.04) were positively associated with higher CVH score, whereas the opposite was found for food production index (β = –0.04; 95% CI, −0.06 to –0.02) and indicators of urbanization.

Table 7. *Factors associated with intermediate and Ideal compared to Poor Cardiovascular Health status*

Predictor	Intermediate vs Poor		Ideal vs Poor	
	OR	95% CI	OR	95%CI
Sex				
Males	1.00		1.00	
Females	0.77	0.67 - 0.89	0.80	0.64 - 0.92
Age groups				
[18,25)	1.00		1.00	
[25,35)	0.48	0.34 - 0.64	0.36	0.25 - 0.50
[35,45)	0.30	0.21 - 0.41	0.17	0.12 - 0.24
[45,55)	0.18	0.13 - 0.25	0.09	0.06 - 0.12
[55,69]	0.14	0.10 - 0.20	0.06	0.04 - 0.09
Level of education				
Tertiary education	1.00		1.00	
Secondary education	0.82	0.60 - 1.10	0.51	0.35 - 0.75
Primary education	0.90	0.68 - 1.20	0.68	0.47 - 0.97
No education	0.97	0.71 - 1.32	0.63	0.43 - 0.92
Marital Situation				
Married/Cohabitating	1.00		1.00	
Divorced/Separated/Widowed	1.03	0.85 - 1.25	0.95	0.74 - 1.24
Single	1.08	0.89 - 1.34	1.19	0.93 - 1.52
Alcohol consumption				
Never or quit > 12 m	1.00		1.00	
Current user	0.96	0.82 - 1.23	0.92	0.75 - 1.13
Heavy episodic drink	0.72	0.60 - 0.88	0.51	0.39 - 0.67

OR: Odds Ratio, CI = Confidence Interval. ORs and their 95% CI were estimated by hierarchical multinomial mixed-effects regression using Poor cardiovascular health score category as reference and including a random effect on the country and year; they were adjusted for the variables listed in the Table.

Time Trends of Mean CVH Score and CVH Score Categories

As shown in Figure 10, there was no significant trend in the prevalence of the ideal CVH score category which ranged from 23.6% to 28.3% between 2003 and 2022. Similarly, the prevalence of poor CVH fluctuated between 18.4% and 21.7%, and those in the intermediate category consistently remained the majority, ranging from 50% to 58%. Trends were highly consistent in males and females. Similarly, the mean (SD) overall CVH score fluctuated between 7.2 (0.7) in 2003 and 7.5 (0.6) in 2022 with no statistically significant trend (p = 0.22).

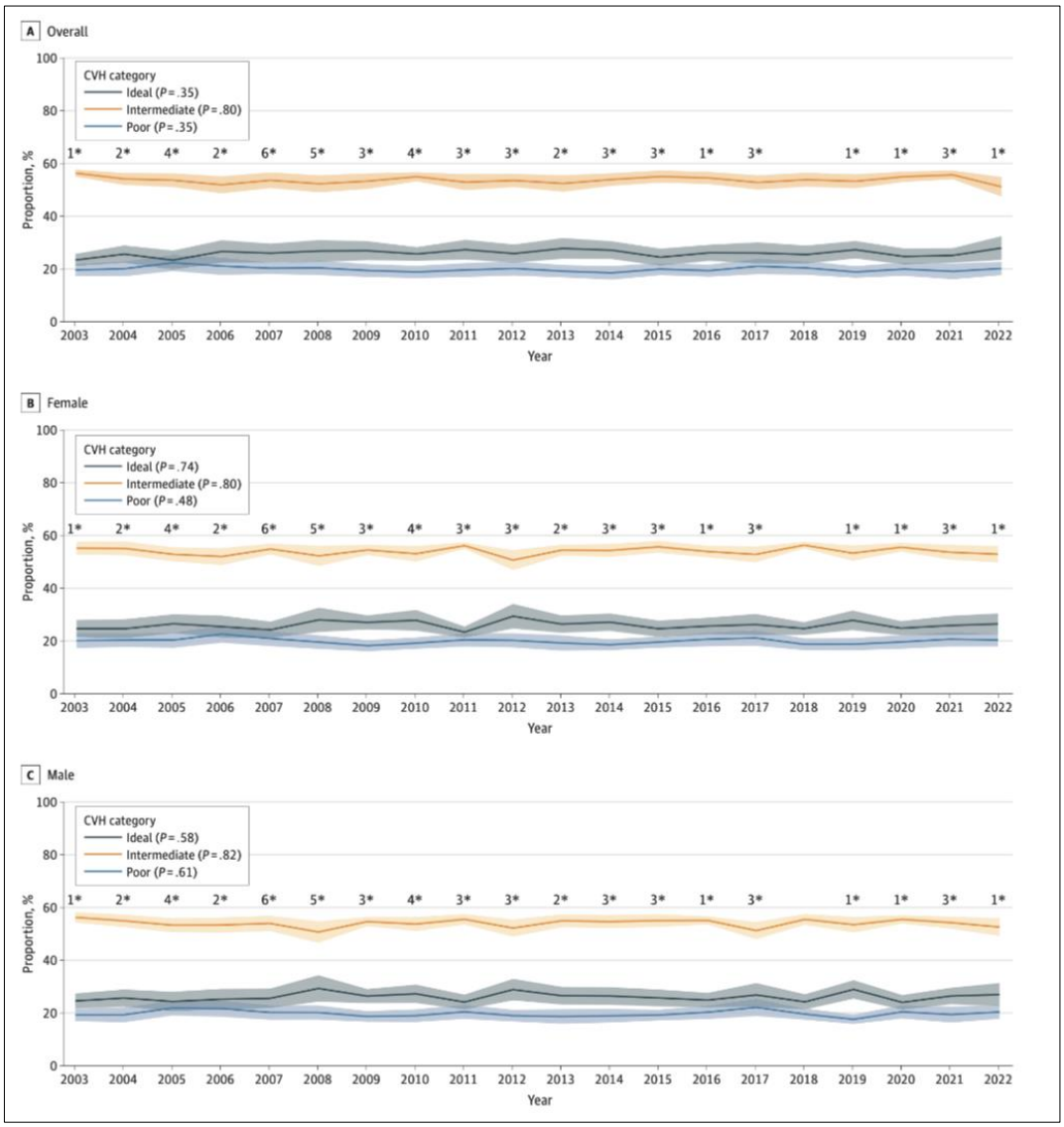


Figure 11. *Time Trend Between 2003 and 2022 of Life's Simple 7 Cardiovascular Health (CVH) Score Categories*

5. Discussion

5.1. Strengths and limitations

Strengths

This doctoral work represents one of the largest and most comprehensive multi-country analyses of cardiovascular risk factors conducted to date in the WHO African Region. Drawing upon data from over 60 nationally or subnationally representative surveys across 37 countries, it integrates evidence on the burden of obesity/overweight, hypertension, and CVH within a unified analytical framework.

The use of standardized data collection instruments, primarily through the WHO STEPS and the DHS, enhances comparability across countries and permit to provide robust and harmonized indicators across diverse populations. The combination of individual-level data with country-level contextual indicators offers a multidimensional understanding of the determinants of cardiovascular risk factors, and allow to identify different levels of interventions. Moreover, the assessment of time trends in BMI, hypertension and CVH, permitted to indirectly evaluate past or ongoing preventive programmes and to make some projections.

Limitations

Despite these strengths, several limitations should be acknowledged.

First, data coverage was incomplete: the analyses included up to 37 of the 47 WHO African Region Member States, with key countries such as South Africa (which has among the highest obesity prevalence) not represented due to lack of available data. Consequently, findings may not fully capture the diversity of the region or be generalizable to the entire African continent.

Second, the studies relied exclusively on cross-sectional survey data, preventing from assessing longitudinal change of exposures over time among the same individuals, and making causal inference between risk factors and expoures. The lack of event follow-up also precluded to evaluate the clinical consequences of the examined exposures.

Third, several measurement limitations apply.

- Blood pressure was measured at a single visit (three readings during one occasion), which may overestimate hypertension prevalence compared with 24-hour ambulatory monitoring.[62]
- BMI, while widely used and standardized, captures overall adiposity but not fat distribution or abdominal obesity, which may have distinct cardiometabolic implications.[63,64]
- Diet was based only on self-reported fruit and vegetable intake, potentially misclassifying adherence to healthy diets as they did not account for total energy intake, nutrient quality, or validated dietary indices. Similarly, diet-related deficiencies and undernutrition, key issues in low-resource settings, were not captured.[65,66]

Fourth, residual confounding cannot be excluded. Additional determinants—such as household income or expenditure, healthcare access, mental health, socioeconomic deprivation, and environmental exposures—were not measured or available at the time of analysis.

Fifth, the surveys focused on adults aged 18–69 years, thereby excluding children, adolescents, and older adults.

Sixth, the time-trend analysis involved modeled estimates for missing countries and years, introducing potential uncertainty, although consistency between observed and modeled data supports the robustness of findings.

Seventh, for the hypertension analysis, definitions of awareness and treatment relied on a two-week recall period, which may underestimate chronic treatment in contexts with irregular medication access.

Eighth, the CVH analysis could not rely on the most recently score, the AHA Life's Essential 8 (LE8) construct, since metrics such as sleep health and HbA1c were not available in STEPS. [67]

Finally, the entire analytical process represented a statistically demanding and technically complex exercise, given the scale, heterogeneity, and temporal imbalance of the datasets. Harmonizing two decades of survey data, managing missingness across multiple countries, and fitting spatio-temporal and multilevel models required iterative validation, sensitivity testing, and deep statistical expertise. Despite these challenges, we used a methodological approach that ensures rigorous analytical framework, robust, reproducible, and policy-relevant estimates of cardiovascular risk and health indicators across the WHO African Region.

5.2. Burden of overweight and obesity

The analysis of 54 nationally/regionally representative and cross-sectional STEPS surveys from 2003 to 2022 across 36 countries from the WHO Africa region reveals three main findings. Almost 30% (i.e 26%) were overweight or obese with females being much more affected than males. Furthermore, the 20 years trend analysis is revealing a significant increase in obesity and underweight rates, and a plateau for overweight. This underscores the double burden of malnutrition in the region. Strikingly, the most educated were more likely to have overweight or obesity than the less educated.

The NCD-RisC has provided regular data on BMI worldwide both in children and in adults.[68,69,70,71] In the latest analysis, the prevalence of obesity in 2022 ranged from less than 20% (Rwanda) up to 50% (South Africa) in African adult women and from 10% (Sierra Leone) to 30% (Central African Republic) in adult men, respectively.[71] By combining hundreds of data sources, these studies were by far the most extensive and exhaustive. Despite rigorous statistical approaches, the use of multiple and unharmonized data sources may however raise some concerns. Furthermore, six multi-country studies using data from Demographic and Health Surveys have examined these questions specifically in Africa.[72–77] In the largest study comprising 24 studies, in 2014, the prevalence of overweight ranged from 23.1% (Zambia) to 44% (Egypt) and that of obesity from 11.5% (Zambia) to 39.2% (Egypt) respectively.[78] However, this study focused on females aged 15 to 49 years and living in urban areas only.

The lower rates of overweight and obesity reported here, respectively 18.1% and 9.2% have at least 2 explanations. Firstly, these rates reflect the situation of the WHO Africa region only and not of the entire African continent. In particular, data from Northern Africa which at the exception of Algeria are not part of the WHO Africa region, and data from South Africa, which is part of the WHO Africa region, were not available, although these are places were overweight and obesity rates are the most explosive. Also, the reliance on one sole data source (STEPs surveys) and the use of standardized data collection and measures needs to be considered.

In contrast to patterns observed in the Global North—where men often show similar or higher prevalence of overweight and obesity, and higher education is related to lower risk of overweight;[79,80]—the current study revealed higher prevalence rates in women and in the most educated likely reflecting contextual differences in lifestyle, socioeconomic transitions, and cultural perceptions of body size. The substantial sex disparities in the prevalence of overweight and obesity is consistent with the results of previous studies in Africa.[38,81–83] This can be attributed to socio-cultural norms that often prioritize larger body sizes for women, influencing their dietary habits and physical activity levels.[84–86] Additionally, economic and healthcare-related factors, such as limited access to health prevention services including nutrition education—may further widen these gaps. Educational attainment could also play a role; however, it varies across settings and should be interpreted within each country's specific context.[85] Similarly, previous studies conducted in LMICs and in Africa have reported inverse association between higher education and overweight and obesity.[38,68,77,78,81,87]

In LMICs, higher education correlates with elevated socioeconomic status and access to Western diets and sedentary lifestyles, contributing to higher obesity rates. Furthermore, the correlation between education and overweight/obesity is influenced by multiple factors, fluctuates over time, and is intricately linked to evolving dietary patterns across different countries.[88] Additionally, the less educated are likely to engage in manual labor thus increasing physical activity coupled with undernutrition, which limits weight gain. Taken together, these findings underscore the need for targeted public health interventions that consider the unique socio-cultural and

economic contexts affecting women in the WHO African Region. Also, the results raise that education and awareness campaigns should not solely target individuals with lower education levels, as those with higher education may also require information and support.

Studies in the in sub-Saharan Africa have shown clear rural-urban differences in BMI distribution , with underweight more common in rural areas, and overweight and obesity more prevalent in urban populations.[91–96] Our findings reflect this pattern both in unadjusted and multivariable analysis. This is consistent with the ongoing nutrition transition in urban settings with increased intake of processed, energy-dense foods, driven by higher income and food access in urban settings.[91,94,96,97] Differences in economic development and urbanization also shape food environments and lifestyle patterns across the WHO African region.[91,98]

The present study further underscores the dual burden of malnutrition in the African region, showing significant increase trends in both obesity and underweight. Interestingly, in their latest analysis, the NCD-RisC reports a significant increasing trend in prevalence of obesity from 1990 to 2022 worldwide,[35] and the largest increases were seen in several sub-saharan African countries. Furthermore, there were several sub-saharan African countries where the underweight prevalence was above 10% in women in 1990 and that did not show any detectable decreasing trend.[35] This is in contrast with what is seen in most of the remaining countries. This further underscores the critical need for interventions in sub-Saharan Africa that address both obesity and undernutrition. Contrary to the present study, the NCD Risk Factor Collaboration (NCD-RisC) reported a significant increase in mean BMI in Africa between 1980 and 2014, from 21.0 to 23.0 kg/m² in males and from 21.9 to 24.9 kg/m² in females, respectively.[30] One possible reason for this apparent discrepancy is that the earlier and longer period (1980–2014) in the NCD-RisC analysis may have captured the earlier stages of the nutrition transition. Interestingly, the mean levels of BMI in our study are consistent with the mean levels of BMI achieved in the late period of the NCD risk evaluation. Furthermore, the projections made by the 2025 World Obesity Federation Atlas indicating that the number of adults with Class II obesity (BMI $\geq$ 35) is expected to increase by over 200% between 2010 and 2030 (from 11.8 million

to 37.2 million) in Africa is consistent with the results of our trend analysis on the prevalence of obesity.[99]

The WHO is intensifying its efforts to address the rising burden of obesity by focusing on highly cost-effective Best Buy interventions.[100,101] These include advocating for the taxation of sugar-sweetened beverages, reducing the intake of harmful fats through initiatives like the REPLACE Trans Fat program, and promoting policies to limit the harmful marketing of unhealthy foods and beverages, particularly to children.[102] Additionally, WHO's Global Action Plan for the Prevention and Control of NCDs and the Global Strategy on Diet, Physical Activity, and Health emphasize creating environments that support healthy diets and physical activity.[103] Our findings indicate that these efforts should be tailored according to sex and gender, but also according to the socio-economic background. Moreover, incorporating primordial prevention, focusing on preventing the emergence of risk factors such as poor diet and physical inactivity could serve as a key complementary strategy.[12,104]

5.3. Burden of Hypertension

This analysis on the burden of hypertension in 250 000 African adults from 37 countries of the AFRO region revealed three main findings. First, hypertension affects one in three adult females and one in four adult males. Among people diagnosed with hypertension, more than half were aware of their condition, but only 15% of females and 8% of males were treated, and only 7% of females and 4% of males had controlled hypertension. Second, hypertension-related outcomes were influenced by both individual and contextual (country-level) risk factors. Third, while the 20-year trend analysis from 2003 to 2022 suggests a slight decrease in hypertension prevalence, the absolute number of hypertension-diagnosis nearly doubled over the same period from 123 to 199 million in females and 118 to 191 million in males.

With 61 national and subnational surveys in 37 countries, this is by far the largest and most comprehensive study addressing the prevalence, associated factors and time-trend of hypertension, awareness, treatment and control in the African region. Compared to the (May Month Measurement (MMM) study and the NCD-RisC study, the largest multicountry nationwide studies in Africa with 25 countries so far, the age-

standardized prevalence of hypertension (29% in females and 26% in males) in the present study is similar to the 26% age-standardized prevalence reported in the MMM study in both sexes,[105] but lower than the latest (i.e., 2019) analysis of the NCD-RisC study, reporting prevalence rates of 48% in females and 34% in males in SSA.[106] Of note however, study participants were older in NCD-RisC compared to the STEPS surveys and DHS (30–79 compared to 18–69 years or 15–59 years). Strikingly, the doubling of the absolute number of individuals affected by hypertension from 2003 to 2022 to reach 199 million females and 191 million males in 2022 contrasts with the steady trend in the hypertension prevalence over the same period, a finding consistent with the trends reported in the NCD-RisC from 1999 to 2019.[106,107] This rise is likely driven by factors such as urbanization and related behavioral changes (i.e. dietary changes and physical inactivity), increased screening and diagnosis.[108,109] This also likely due to the co-existence of an ageing population, the habitual provider of hypertension cases, and an important growth of the young population, an additional provider of hypertension cases in Africa.[106,110] Altogether, this doubling of hypertension cases is compensated by the growing population explaining the apparent stable prevalence of hypertension rates over time.

The age-standardized hypertension awareness rates in the present study (62% in females and 51% in males) were consistent with the SevenCEWA study,[111] but were higher than those from the MMM study.[112] However, awareness was solely based on the use of antihypertensive medications in the MMM study, while knowledge of having raised blood pressure was additionally considered in the current study. The almost doubling prevalence rates of awareness between 2003 and 2022—from 40% to 73% in females and 27% to 59% in males—in the present study is likely reflecting expanded screening like MMM initiatives that promote the importance of regular blood pressure monitoring,[112] the growing implementation of community-based programs,[113–115] broader efforts to integrate hypertension management into primary health care systems,[116] and WHO PEN's integration into primary care across the region.[117]

The high level of hypertension awareness and its significant increased trend contrasts with the dramatically low level of both treatment and control of hypertension globally and over time. The reported age-standardized hypertension treatment rates (15% in

hypertensive females and 8% in hypertensive males) and the even lower rates of age-standardized hypertension control (7% in hypertensive females and 4% in hypertensive males) are considerably lower than those reported in the NCD-RisC,[106] MMM,[112] SevenCEWA,[111] and the H3Africa AWI-Gen,[118] where treatment rates ranged from 18 to 50% and control rates from 12 to 22%. The MMM study relies on voluntary participation, attracting individuals who are likely already more aware of their health status. The other two studies included older populations than the participants in the present study, the current study clearly showing that older age is a strong risk factor for hypertension treatment and control. We may have underestimated treatment rates given that treatment was evaluated using a 2 weeks-time window. In the African context with limited treatment affordability, such time window is probably too short and restrictive to reliably identify untreated patients. Furthermore, the control rates might differ according to adherence to treatment but such information was unavailable in STEPS surveys and DHS. A recent systematic review indicates a level of adherence to antihypertensive treatment of 34% in Africa,[119] a finding corroborating the results of a clinical study in 12 SSA countries reporting that two thirds of hypertensive patients followed in specialized clinics had poor to medium adherence to antihypertensive treatment.[120] Interestingly, studies conducted in hypertensive patients attending hypertension clinics in SSA have reported uncontrolled rates of hypertension of 77.4%.[121] Altogether, these low rates of hypertension treatment and control echo the systemic barriers such as limited access to healthcare services, affordability and the availability of quality medications,[122–125] along with the use of traditional treatments.[132] Specifically, the SEVEN study[127] showed that up to 16% of cardiovascular drugs in SSA, particularly calcium channel blockers, are of poor quality, with rates reaching 50% in informal street markets. Furthermore, the EIGHT study[124] highlighted that many patients with severe hypertension are still treated with monotherapy, possibly reflecting gaps in guideline adherence, clinical inertia, and socioeconomic constraints, and control remains suboptimal even with combination therapy. While challenging, comprehensive strategies that include enhancing primary healthcare capacity, strengthening pharmaceutical regulatory systems to combat counterfeit and substandard medicines, promoting generic drugs, implementing financial support mechanisms, such as subsidies or insurance schemes, and promoting community-

based interventions to support long-term management of hypertension are urgently needed.

We noted striking sex differences in hypertension awareness, treatment, and control rates in favour of females compared to males. Studies have shown that females more than males regularly interact with health care professionals to access birth control, child health and for gynecological health, which may increase opportunities for blood pressure diagnosis and hypertension awarness.[128–130] Gender-related factors may also operate through differences in health-seeking behaviors,[119–121] gender norms,[131] exposure to lifestyle risk factors, differing perceptions of disease risk and personal vulnerability,[132] thereby influencing detection, treatment, and control of hypertension. However, more studies are needed to explain sex and gender difference in the burden of hypertension in Africa.

This is the first African multicountries study connecting contextual factors with the burden of hypertension. They are completing the role played by lifestyle and socio-economic risk factors at the individual level shown here and in the SevenCEWA.[111] Higher rates of awareness, treatment and control were found in urban regions-countries, countries with higher life expectancy at birth and Gender Development Index values, and according to fat consumption per capita. This is likely reflecting more developed healthcare infrastructure, greater equity in access to health services, and increased health literacy, which tend to be more favorable in urbanized and socioeconomically advantaged settings.[133–135] Urban areas often have a denser distribution of health facilities and trained personnel, facilitating regular screening and follow-up, while higher GDI scores may indicate reduced gender-based disparities in health-seeking behavior, improving detection and management for both sexes. Similarly, longer life expectancy often indicates more developed health systems and stronger infrastructure for managing chronic diseases. Altogether, these results suggest that tackling hypertension in the African region requires multicomponent and multilevels interventions targeting both the individuals but also their contexts of living.

The findings of the present study have implications. The doubling in the number of hypertension cases over 20 years coupled with the extremely low treatment and control rates are of major concerns and threaten the capacities of already fragile

healthcare systems in the region. Recent initiatives like the ACHIEVE initiative[133] led by 34 African experts and supported by organizations like the WHO, the World Hypertension League, and Resolve to Save Lives, have been proposed but not yet implemented, to enhance the prevention, treatment, and control of hypertension in Africa through comprehensive strategies, including public education, evidence-based guidelines, and the WHO's HEARTS program for improving cardiovascular health and reducing the burden of heart disease at primary healthcare level. In this context, and on the long-term, implementing primordial prevention strategies, aiming at preventing the development of risk factors in the first place may be a complimentary but crucial preventative strategy.[137–139] Accordingly, higher CVH scores have been associated with lower risk of hypertension onset in other populations[139–142] but such data are lacking in the African context. Finally, the consistent observed associations of hypertension ouctomes with markers of social and health system development highlight actionable levers for policy such as investing in urbanization and equitable health access, promoting gender equity, and strengthening public health education to improve hypertension outcomes across diverse African contexts.

5.4. Status of CVH

This analysis of CVH in 73,024 individuals from 25 WHO STEPS surveys in 22 SSA countries representing 95 million adults aged 18 to 69 years, reveals three main findings. First, one in four adults in the region achieved an ideal CVH as estimated by a CVH score of 12-14. Second, females were less likely than males to achieve higher CVH. Third, over the past 20 years, there were no statistically significant trend in the weighted prevalence of ideal, intermediate or poor CVH, overall and in each sex.

So far only six studies have examined the distribution of CVH in Africa,[45–50] including four single-country studies and two multi-country studies. The largest study included 15,356 adults from five countries (Ghana, Gambia, Mali, Botswana, and Guinea) and reported that 14.3% of the adults had 5 optimal metrics. However, this study used the STEPS-HEART index, a 5-item index including smoking, hypertension, diabetes, obesity/overweight, and daily consumption of fruits and vegetables as a proxy for CVH.[45] The second multicounty study (H3Africa AWI-Gen), included 9011 participants

from four countries (Burkina Faso, Ghana, Kenya, and South Africa). In that study, one third of the population had an ideal CVH with high disparities across countries from 11.3% in South Africa to 50.6% in Ghana.[48] The 26.2% of ideal CVH reported in the present study is consistent with the estimate from the H3Africa AWI-Gen study. Our study however includes CVH data from 22 countries across 25 representative surveys.

The distribution pattern of CVH in the SSA in the present study is substantially different from what is observed in western countries. For instance, the prevalence of ideal CVH (score 12-14) is much higher (26.2% vs. 6.8%) whereas that of poor CVH (score 0-7) is much lower (15.9% vs. 41.2%) as compared to data from the MESA cohort, one of the most ethnically diverse cohort in the US; the distribution of intermediate CVH (score 8-11) is more consistent between the continents (57.9% vs.52%).[143] Similarly, except BP, the prevalence of ideal level for each LS7 metric is higher than what has been reported in the 2022 AHA heart and stroke statistics including the latest distribution of LS7 components.[144] These disparities may be attributed to the younger age in the African population, with mean age was 35.4 ± 12.9 years. Despite rapid urbanization and western lifestyle shift, professions with higher levels of physical activity, particularly in rural areas, remained frequent, and many African communities continue to adhere to traditional diets rich in whole grains, fruits, and vegetables.[145] Strikingly and despite the younger age of the African population as compared to western settings, ideal BP was achieved by only 36% of the adults in the present study compared to the 90% in most western countries. This aligns with the challenges in BP awareness, access to care, and medications in Africa.[146–148]

Only two prior studies have addressed the determinants of adults CVH in the Africa region, the STEPS-Heart study index in Botswana, Gambia, Ghana, Guinea, and Mali,[45] and a Beninese study.[46] Consistently with these two studies (and with prior evidence in western countries) older age and lower education were associated with lower odds of intermediate or ideal CVH in the present study. A striking result was that females were less likely than males to achieve a better CVH in multivariable analysis. This is at variance from prior studies in western countries. This might be partly due to significant sex difference in the distribution of some behavioural metrics, the prevalence of poor BMI and poor physical activity being systematically higher in females compared to

males in the current study. Furthermore, the proportion of participants with no education was twice more frequent in females compared to males. Similar sex disparities in CVH have been reported in the STEPS-Heart index study,[45] but not in the Beninese study.[46] However the latter was a single country study, and the covariates of the multivariable analysis were not the same as in our study. The study further adds to prior evidence the contribution of country-level contextual factors to the CVH level in Africa, showing the positive influence of education and the negative effect of urbanization. The positive association between higher national prevalence of undernourishment and higher CVH should not be interpreted as a health benefit of undernourishment but rather might reflect reduced exposure to overnutrition-related risk factors such as obesity and metabolic syndrome. Higher GDP was unrelated to higher CVH but significant association could have emerged with more comprehensive index such as the Sociodemographic Index developed by the Global Burden of Disease, but this index was not available at the time of the analysis. In exploratory analysis, the higher prevalence of ideal CVH in the rural compared to the urban settings likely reflects lifestyle differences, as urbanization is often linked to reduced physical activity and unhealthy diets. Accounting for urban slums could have brought even more contrasts,[149] unfortunately, urban slum classification was not available in the STEPS surveys used.

To our best knowledge, this is the first time trend analysis of CVH over 20 years in the African region. This analysis did not observe significant trend in CVH score categories between 2003 to 2022. Two single country studies that evaluated CVH prevalence at two time points only. A Malawian study showed significant difference in the CVH status measured in 2009 and in 2017, the prevalence of ideal CVH being respectively 9.4% and 33.3%, and that of poor CVH being 7.6% and 0.5%.[47] In the Beninese study however, opposite differences were reported, the prevalence of ideal CVH being 33.5% in 2008 and 15.5% in 2015, while the prevalence of poor CVH was 1% and 8.5% at the same dates.[46] Still and despite the robustness of spatio-temporel model, the reliance on modeled estimates for unavailable CVH data at specific years and in specific countries may have introduced uncertainties that do not completely capture the real-world variability.

Since 2016, several initiatives proposed by WHO under Global Hearts Initiative that aims at improving heart health by targeting both individual and contextual factors includes packages like MPOWER for tobacco control, SHAKE for salt reduction, HEARTS for strengthening CVD management in primary health care, REPLACE to eliminate industrially-produced trans fats, and ACTIVE to promote physical activity.[150] The relatively young age of the African population may also contribute to a more favourable CVH profile. However, the CVH plateau over the past years observed in the present study may either suggest a lack of implementation and/or adherence to these initiatives; or that these efforts should be prioritized or adapted to some segments of the population including females and adults with lower education in whom the prevalence of low CVH was the highest, respectively. Furthermore, this analysis suggests that improving CVH through primordial prevention could be an impactful preventative strategy in the SSA. This raises the challenging issues to strengthen, scale up and sustain the above preventive programs across the region, starting early in life given the rise in obesity in young populations in the region.[151]

5.5. Public health and policy implications

This doctoral work provides critical insights into the epidemiological landscape of cardiovascular health and two of its components represented by obesity and hypertension across 37 countries of the WHO African Region. Together, these findings underscore an urgent need for multisectoral, integrated, and context-specific policy responses to address the escalating burden of cardiovascular diseases (CVDs) and their risk factors.

(a) Addressing the Double Burden of Malnutrition

The simultaneous increase in both obesity and underweight prevalence reflects the ongoing double burden of malnutrition in the African region. Policy responses must therefore be dual-purpose addressing overnutrition while continuing to tackle undernutrition. This includes:

- Integrating nutrition and physical activity promotion into school curricula and workplace health programmes;

- Regulating the marketing and pricing of ultra-processed and sugar-sweetened foods and beverages through fiscal and legislative measures;
- Strengthening food systems to ensure availability and affordability of fresh, minimally processed foods; and
- Enhancing surveillance systems to monitor both undernutrition and obesity using harmonized WHO standards.

National multisectoral action plans should engage agriculture, education, urban planning, and trade sectors to create food environments that favor healthy dietary choices.

(b) Strengthening Hypertension Control and Health System Capacity

The extremely low hypertension treatment and control rates (below 10%) reveal major gaps in health system capacity, affordability, and access to quality medications. To reverse these trends, countries should:

- Integrate hypertension screening and management into primary health care (PHC) using standardized treatment protocols aligned with the WHO HEARTS technical package;
- Expand community-based screening programmes, supported by task-shifting to nurses, pharmacists, and community health workers;
- Ensure reliable medicine supply chains, promote affordable generic drugs, and strengthen pharmaceutical regulatory systems to combat counterfeit medicines;
- Implement financing reforms, such as health insurance schemes and subsidies for essential NCD drugs; and
- Develop digital and mobile health tools to support follow-up, adherence, and patient education.

These system-level reforms should be accompanied by training of health professionals and investment in data systems to monitor treatment coverage and control outcomes.

(c) Strengthening Primordial and Primary Prevention

The evidence of rising obesity rates, the doubling of hypertension cases and the persistently low CVH scores, over the past two decades highlights the need to prioritize primordial prevention—preventing the development of risk factors in the first place. Policies should promote healthy environments that facilitate healthy diets, physical activity, and reduced tobacco and alcohol use. National governments, in alignment with WHO's Global Hearts Initiative and NCD Best Buys, should scale up evidence-based interventions such as:

- MPOWER for tobacco control,
- SHAKE for salt reduction,
- REPLACE for eliminating trans fats,
- ACTIVE for promoting physical activity, and
- HEARTS for strengthening CVD prevention and management in primary care.

Embedding these packages into national NCD strategies can help reduce risk factor exposure early in life, slow the growth of obesity and improve population-level CVH.

(d) Reducing Gender and Socioeconomic Inequities

Findings from all three analyses consistently show pronounced sex and education disparities in obesity, hypertension, and CVH. Women were disproportionately affected by obesity and had poorer overall CVH, while men were less likely to be aware of or treated for hypertension. Education often considered a protective determinant was paradoxically associated with higher obesity rates, suggesting complex social and cultural dynamics.

Policymakers should integrate gender- and equity-sensitive approaches into NCD prevention and management strategies. This includes:

- Targeted health education and behaviour change programmes tailored to both women and men, acknowledging gender norms that shape health behaviours;
- Ensuring equal access to prevention, diagnosis, and treatment services, including reproductive health platforms as entry points for NCD screening; and

- Addressing social determinants of health, such as poverty, education, and urbanization, through intersectoral collaboration.

(e) Leveraging Education and Urbanization for Health Promotion

At the contextual level, higher mean years of schooling and better Gender Development Index (GDI) were associated with more favorable hypertension and CVH outcomes. Education is thus a powerful lever for improving cardiovascular health literacy and promoting healthy lifestyles. Ministries of Education and Health should collaborate to:

- Introduce health literacy and NCD prevention modules in national education curricula;
- Promote healthy school environments with nutritious meals and physical activity programmes; and
- Encourage community and workplace-based education on CVD prevention.
- Given the rapid urbanization in Africa, urban planning policies must also prioritize health-promoting infrastructures—including safe public spaces for physical activity, improved public transportation, and access to healthy foods—to mitigate the adverse effects of urban lifestyle transitions.

(f) Strengthening Surveillance, Research, and Policy Accountability

The lack of longitudinal data and reliance on cross-sectional surveys highlight an urgent need to strengthen surveillance systems for NCD risk factors. Countries should:

- Institutionalize regular STEPS surveys with sustainable funding mechanisms;
- Establish hypertension and CVH registries for continuous monitoring; and
- Promote implementation research to evaluate the effectiveness of ongoing prevention and management programmes.

At the regional level, collaboration through the African Union, WHO AFRO, and national ministries should aim to develop shared NCD data platforms to track progress toward the Sustainable Development Goal (SDG) 3.4 target of reducing premature mortality from NCDs by one-third by 2030.

(g) Investing in Multisectoral Action and Political Commitment

Achieving meaningful progress against CVDs in Africa requires strong political leadership and sustained financing. Governments should align national NCD strategies with broader development frameworks and ensure domestic resource allocation for CVD prevention and care. Regional economic communities (e.g., ECOWAS, SADC, EAC) can play a pivotal role in harmonizing policies on food regulation, medication quality, and health workforce development.

Global partners, including WHO, World Bank, and international donors, should support African countries through technical assistance, policy advocacy, and catalytic funding to scale up effective interventions.

6. Conclusions

This doctoral work provides one of the most comprehensive multi-country assessments of two preoccupying risk factors including malnutrition and hypertension, and cardiovascular health in general, across the WHO African Region. Drawing on data from over 60 nationally and subnationally representative surveys across 37 countries, these analyses collectively offer an unprecedented situational overview of the region's cardiovascular health landscape.

Findings confirm the high and rising prevalence of overweight and obesity, especially in women and paradoxically in more educated people. Concurrently, the thesis shows that the burden of hypertension remains substantial, especially regarding the persistently and dramatically low levels of treatment and control over the past two decades, representing silent killers for already fragile health systems. Finally, the thesis provides one of the largest analysis of CVH per se in the African region.

Together, these findings provide a robust empirical foundation for evidence-based policy and programme development to mitigate the burden of CVD risk factors and subsequently combat CVDs in the WHO African Region. Strengthening national health systems, integrating NCD prevention into primary care, and scaling up community-based interventions are essential to curb the growing CVD risk factors and diseases

epidemic. Future prospective studies are needed to quantify the impact of tackling malnutrition, hypertension-related ouctomes and improving CVH score on reducing CVD morbidity and mortality, and to monitor progress toward achieving Sustainable Development Goal 3.4—reducing premature deaths from noncommunicable diseases by one-third by 2030.

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7. **Appendice**

7.5. Supplemental Tables

Supplementary Table 1: Characteristics of individual WHO STEP survey in the African region by country and by year from 2003 to 2022

	Country	**WHO AFRO Sub-region**	**Year of survey**	**Rural, urban or both**	**Country income level**	**Sample size**
1	Algeria	North Africa	2003	Both	Lower_Middle	4047
2	Algeria	North Africa	2016	Urban	Upper_Middle	6628
3	Benin	West Africa	2007	Both	Low	2522
4	Benin	West Africa	2008	Both	Low	6795
5	Benin	West Africa	2015	Rural	Low	4847
6	Botswana	South Africa	2007	Rural	Upper_Middle	3820
7	Botswana	South Africa	2014	Both	Upper_Middle	3738
8	Burkina Faso	West Africa	2013	Rural	Low	4475
9	Cabo Verde	West Africa	2007	Rural	Lower_Middle	1724
10	Cabo Verde	West Africa	2020	Rural	Lower_Middle	4458
11	Cameroon	Central Africa	2003	Urban	Low	8019
12	Central African Republic	Central Africa	2010	Both	Low	3812

13	Central African Republic	Central Africa	2017	Both	Low	3268
14	Chad	Central Africa	2008	Urban	Low	1840
15	Comoros	East Africa	2011	Rural	Low	5042
16	Congo	Central Africa	2004	Urban	Low	1967
17	Côte d'Ivoire	West Africa	2005	Both	Low	4169
18	Democratic Republic of the Congo	Central Africa	2005	Urban	Low	1658
19	Eritrea	East Africa	2004	Both	Low	2067
20	Eritrea	East Africa	2010	Both	Low	5653
21	Eswatini	South Africa	2007	Both	Lower_Middle	1259
22	Eswatini	South Africa	2014	Both	Lower_Middle	2835
23	Ethiopia	East Africa	2006	Both	Low	3952
24	Ethiopia	East Africa	2015	Rural	Low	8749
25	Gabon	Central Africa	2009	Urban	Upper_Middle	2455
26	Gambia	West Africa	2010	Urban	Low	3529
27	Ghana	West Africa	2006	Urban	Low	2479
28	Guinea	West Africa	2009	Both	Low	2164

29	Kenya	East Africa	2015	Rural	Lower_Middle	4266
30	Lesotho	South Africa	2012	Both	Lower_Middle	2170
31	Liberia	West Africa	2011	Both	Low	2269
32	Liberia	West Africa	2022	Both	Low	3892
33	Madagascar	East Africa	2005	Both	Low	5068
34	Malawi	South Africa	2009	Rural	Low	4844
35	Malawi	South Africa	2017	Rural	Low	4012
36	Mali	West Africa	2007	Urban	Low	2243
37	Mali	West Africa	2013	Both	Low	1759
38	Mauritania	West Africa	2006	Urban	Low	2283
39	Mozambique	Central Africa	2005	Both	Low	2960
40	Niger	West Africa	2007	Both	Low	2487
41	Niger	West Africa	2021	Both	Low	5329
42	Rwanda	East Africa	2012	Both	Low	6482
43	Rwanda	East Africa	2021	Rural	Low	5509
44	Sao Tome and Principe	Central Africa	2008	Both	Lower_Middle	2286

45	Sao Tome and Principe	Central Africa	2019	Urban	Lower_Middle	2291
46	Seychelles	East Africa	2004	Both	Upper_Middle	1255
47	Sierra Leone	West Africa	2008	Rural	Low	4525
48	Togo	West Africa	2010	Both	Low	3858
49	Togo	West Africa	2021	Both	Low	3750
50	Uganda	East Africa	2014	Urban	Low	3682
51	United Republic of Tanzania	East Africa	2011	Urban	Low	2525
52	United Republic of Tanzania	East Africa	2012	Rural	Low	5402
53	Zambia	South Africa	2008	Urban	Low	1779
54	Zambia	South Africa	2017	Rural	Lower_Middle	4004

Supplementary Table 2. Characteristics of study participants overall and by Urban and Rural Residence

Characteristics	Overall, N = 111577 (100%)[1]	Rural, N = 55523 (61%)[1]	Urban, N = 56054 (38,7%)[1]
Body Mass Index			
Normal	63 598 (61,1%)	35 591 (67,9%)	28 007 (50,3%)
Underweight	10 051 (11,5%)	6 183 (14,0%)	3 868 (7,5%)
Overweight	24 140 (18,2%)	9 523 (12,9%)	14 617 (26,6%)
Obesity	13 788 (9,3%)	4 226 (5,3%)	9 562 (15,6%)
Sex			
Women	65 326 (49,1%)	31 885 (47,5%)	33 441 (51,7%)
Men	46 251 (50,9%)	23 638 (52,5%)	22 613 (48,3%)
Age groups			
[18,25)	12 192 (20,0%)	5 001 (19,9%)	7 191 (20,3%)
[25,35)	36 317 (32,1%)	18 081 (32,5%)	18 236 (31,6%)
[35,45)	27 777 (22,4%)	14 293 (22,8%)	13 484 (21,7%)
[45,55)	19 384 (14,3%)	9 904 (13,9%)	9 480 (15,0%)
[55,69]	15 907 (11,1%)	8 244 (11,0%)	7 663 (11,3%)

Characteristics	Overall, N = 111577 (100%)[1]	Rural, N = 55523 (61%)[1]	Urban, N = 56054 (38,7%)[1]
Level of education			
No education	31 683 (24,2%)	20 576 (30,9%)	11 107 (13,6%)
Primary education	42 795 (45,1%)	22 014 (48,7%)	20 781 (39,5%)
Secondary education	28 515 (23,5%)	10 387 (16,9%)	18 128 (33,9%)
Tertiary education	8 035 (7,2%)	2 318 (3,5%)	5 717 (13,0%)
Marital Situation			
Single	17 142 (23,6%)	6 270 (18,1%)	10 872 (32,6%)
Married/Cohabitating	54 098 (67,1%)	34 283 (72,3%)	19 815 (58,4%)
Divorced/Separated/Widowed	10 656 (9,4%)	6 597 (9,6%)	4 059 (9,0%)
Missing observations	11 124 786	5 656 764	5 468 022
Employment status			
Employee	19 322 (18,2%)	8 588 (13,7%)	10 734 (25,7%)
Self-employed	37 373 (28,9%)	22 796 (30,3%)	14 577 (26,5%)
Student/voluntary	11 525 (19,0%)	6 804 (23,5%)	4 721 (11,4%)
Unemployed/retired	34 478 (34,0%)	17 019 (32,5%)	17 459 (36,4%)

Characteristics	Overall, N = 111577 (100%)[1]	Rural, N = 55523 (61%)[1]	Urban, N = 56054 (38,7%)[1]
Physical activities			
≥150 min/wk moderate or ≥75 min/wk vigorous or ≥150 combination	43 389 (55,5%)	22 555 (56,9%)	20 834 (53,3%)
1–149 min/wk moderate or 1–74 min/wk vigorous or 1–149 min/wk combination	17 200 (18,3%)	7 321 (17,4%)	9 879 (19,8%)
None	47 638 (26,2%)	24 003 (25,8%)	23 635 (26,9%)
Fruit & vegetable consumption			
4–5 Components	45 953 (50,9%)	25 584 (53,7%)	20 369 (46,7%)
2–3 Components	32 719 (38,9%)	17 403 (36,8%)	15 316 (42,1%)
0–1 Component	10 214 (10,2%)	4 980 (9,5%)	5 234 (11,2%)
Smoking			
Never or quit > 12 m	94 981 (88,0%)	48 780 (88,9%)	46 201 (86,6%)
Former, quit ≤12 m	708 (0,8%)	338 (0,7%)	370 (0,9%)
Current	11 787 (11,2%)	6 210 (10,5%)	5 577 (12,4%)
Missing observations	1 526 488	124 955	1 401 533
Alcohol consumption			
Never or quit > 12 m	64 266 (62,0%)	34 999 (59,9%)	29 267 (65,5%)

Characteristics	Overall, N = 111577 (100%)[1]	Rural, N = 55523 (61%)[1]	Urban, N = 56054 (38,7%)[1]
Current user	31 715 (25,5%)	14 285 (26,2%)	17 430 (24,3%)
Heavy episodic drink	10 495 (12,5%)	6 231 (13,9%)	4 264 (10,3%)
BP classification, mmHg			
Normal BP	61 960 (61,4%)	31 660 (62,1%)	30 300 (60,3%)
High-normal BP	20 316 (19,4%)	10 768 (19,2%)	9 548 (19,6%)
Grade 1 hypertension	14 452 (12,6%)	7 415 (12,6%)	7 037 (12,6%)
Grade 2 hypertension	9 843 (6,6%)	4 598 (6,1%)	5 245 (7,4%)
Systolic blood pressure (SBP), mmHg	**124,7 (18,5)**	**124,1 (18,3)**	**125,5 (18,7)**
Fasting blood glucose, mg/dl	**84,3 (28,2)**	**81,0 (24,3)**	**89,9 (33,1)**
Blood total cholesterol, mg/dl	**142,9 (45,7)**	**136,2 (36,5)**	**154,8 (56,5)**

[1] n (unweighted) (%); Mean (SD)

Supplementary Table 3: Factors associated with overweight, and obese status as compared to normal weight including contextual factors

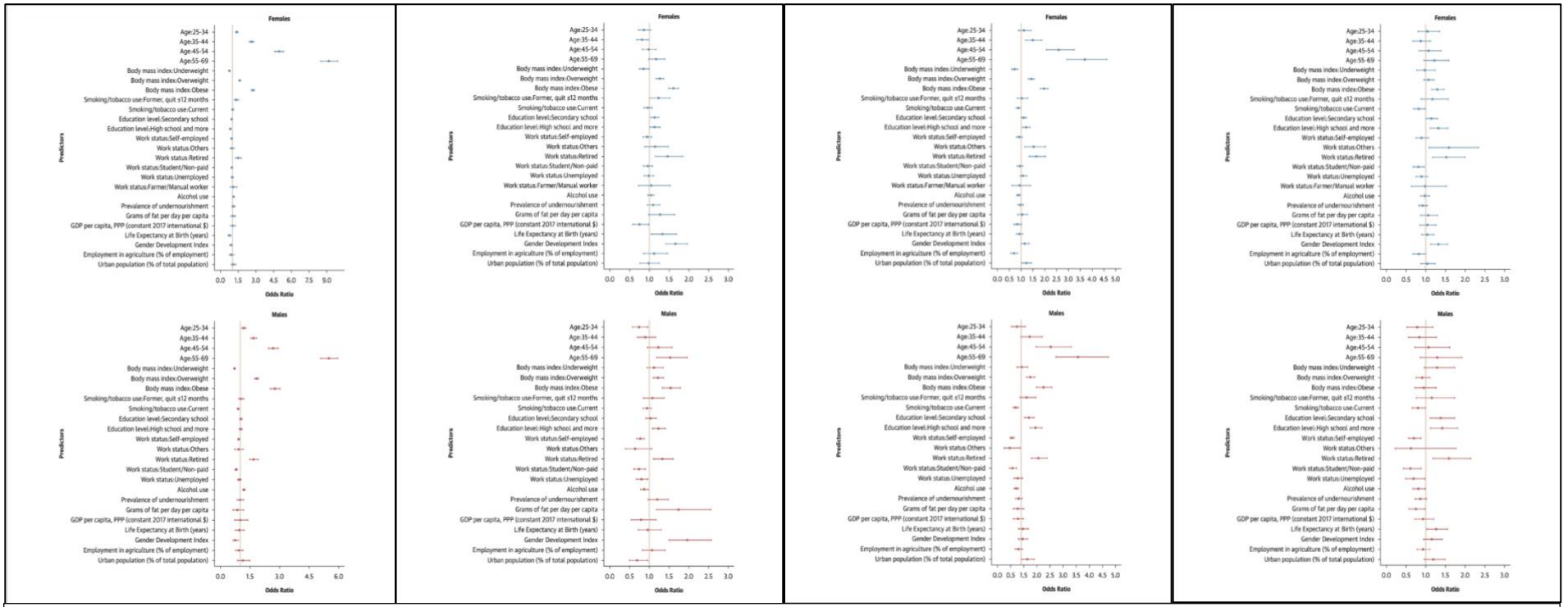
	Underweight			Overweight			Obesity		
Variable	**OR**	**CI_lower**	**CI_upper**	**OR**	**CI_lower**	**CI_upper**	**OR**	**CI_lower**	**CI_upper**
Sex									
Women	1(ref)			1(ref)			1(ref)		
Men	1.04	0.94	1.15	0.52	0.48	0.56	0.21	0.19	0.24
Age Groups									
[18,25)	1(ref)			1(ref)			1(ref)		
[25,35)	0.74	0.70	0.79	1.93	1.82	2.04	2.96	2.70	3.24
[35,45)	0.80	0.75	0.86	2.74	2.60	2.91	6.03	5.51	6.59
[45,55)	0.98	0.92	1.06	3.10	2.92	3.29	7.92	7.20	8.69
[55,69]	1.16	1.08	1.24	3.04	2.86	3.24	7.51	6.82	8.28
Level of Education									
No education	1(ref)			1(ref)			1(ref)		
Primary education	0.82	0.78	0.85	1.33	1.28	1.38	1.65	1.58	1.73
Secondary education	0.76	0.72	0.81	1.72	1.65	1.80	2.38	2.25	2.51
Tertiary education	0.68	0.62	0.75	2.10	1.97	2.22	3.09	2.87	3.34
Employment status									

	Underweight			Overweight			Obesity		
Variable	**OR**	**CI_lower**	**CI_upper**	**OR**	**CI_lower**	**CI_upper**	**OR**	**CI_lower**	**CI_upper**
Employee									
Self-employed	1.48	1.12	1.97	0.88	0.73	1.05	0.82	0.65	1.03
Student voluntary	1.79	1.31	2.47	0.62	0.48	0.8	0.55	0.39	0.78
Employee	1.53	1.15	2.04	0.78	0.65	0.94	0.75	0.59	0.94
Physical activity									
≥150 min/wk moderate or ≥75 min/wk vigorous or ≥150 combination	1(ref)			1(ref)			1(ref)		
1–149 min/wk moderate or 1–74 min/wk vigorous or 1–149 min/wk combination	1.05	0.99	1.11	1.08	1.04	1.13	1.22	1.15	1.29
None	1.13	1.07	1.18	1.10	1.06	1.15	1.32	1.26	1.39
Fruit & vegetable consumption									
4–5 servings per day	1(ref)			1(ref)			1(ref)		
2–3 servings per day	0.93	0.89	0.97	1.13	1.08	1.17	1.13	1.08	1.17
0–1 serving per day	0.95	0.89	1.01	1.17	1.11	1.24	1.17	1.11	1.24
Life Expectancy at Birth (years)	1.01	0.99	1.03	0.99	0.98	1.01	0.98	0.96	1.01
Mean Years of Schooling (years)	1.05	1.02	1.09	1.02	0.99	1.05	0.98	0.95	1.02
Gender Development Index	0.38	0.05	2.55	9.7	1.64	62.43	10.02	0.49	214.34
Grams of fat per day per capita	0.99	0.98	1.00	1.01	0.99	1.02	1.01	0.99	1.023

	Underweight			Overweight			Obesity		
Variable	**OR**	**CI_lower**	**CI_upper**	**OR**	**CI_lower**	**CI_upper**	**OR**	**CI_lower**	**CI_upper**
Prevalence of undernourishment	2.28	0.60	8.10	7.14	1.83	28.90	111.09	11.26	1296.61
Employment in agriculture (% of employment)	1.06	0.81	1.40	0.95	0.76	1.17	1.15	0.82	1.59
Urban population (% of total population)	0.61	0.21	2.06	1.92	0.59	5.66	2.27	0.36	15.09
GDP per capita, PPP (constant 2017 international $)	1.20	0.97	1.50	0.88	0.66	1.14	1.55	0.97	2.43
Food production index (2014-2016 = 100)	0.99	0.99	1.00	0.99	0.98	1.00	1.00	0.99	1.01

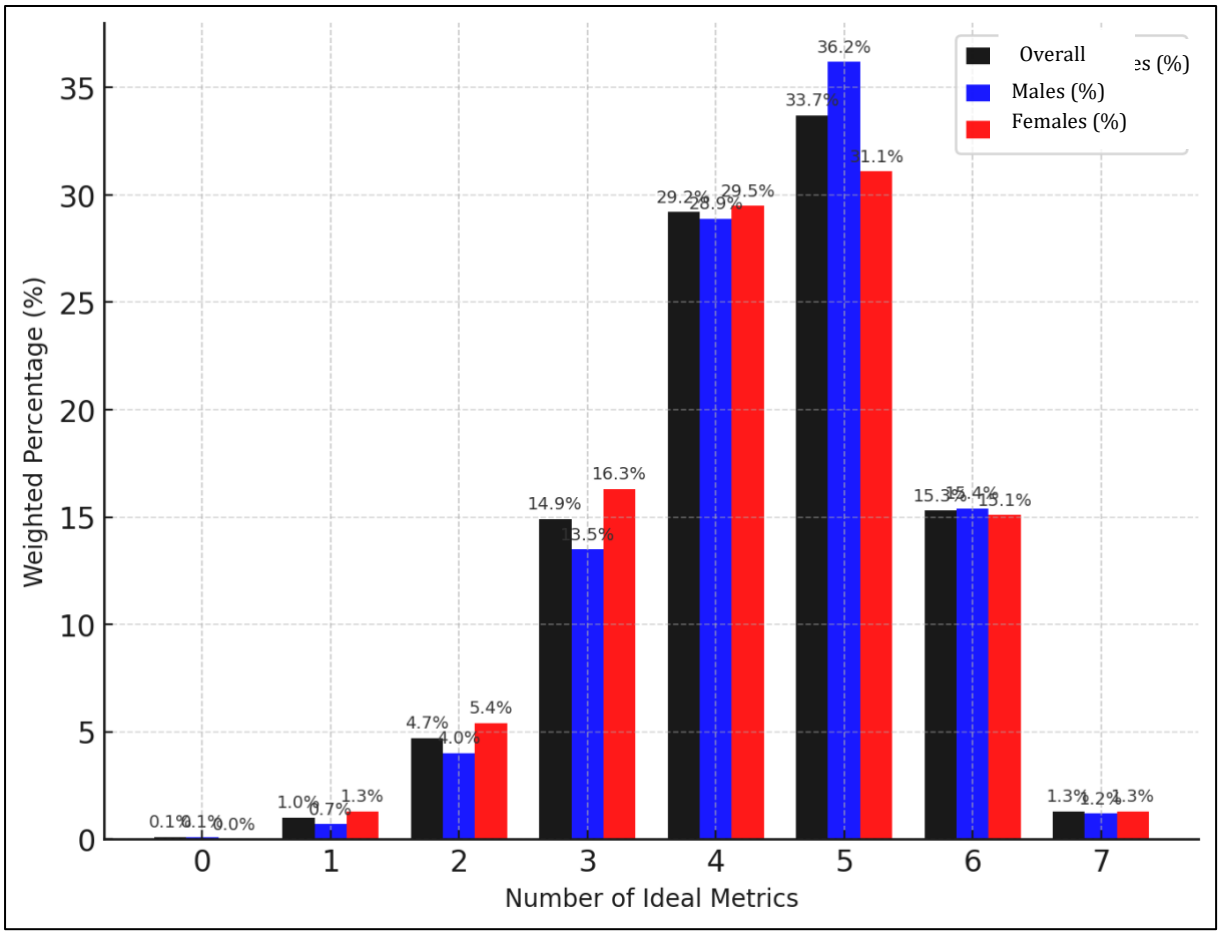
OR: Odds Ratio, CI = Confidence Interval. Data are in OR (95% CI).
OR and their 95% CI were estimated hierarchical multinomial mixed-effects regression using normal weight as the reference category and including a random effect on the country and years; they were adjusted for the variables listed in the Table.

7.6. Supplemental Figures

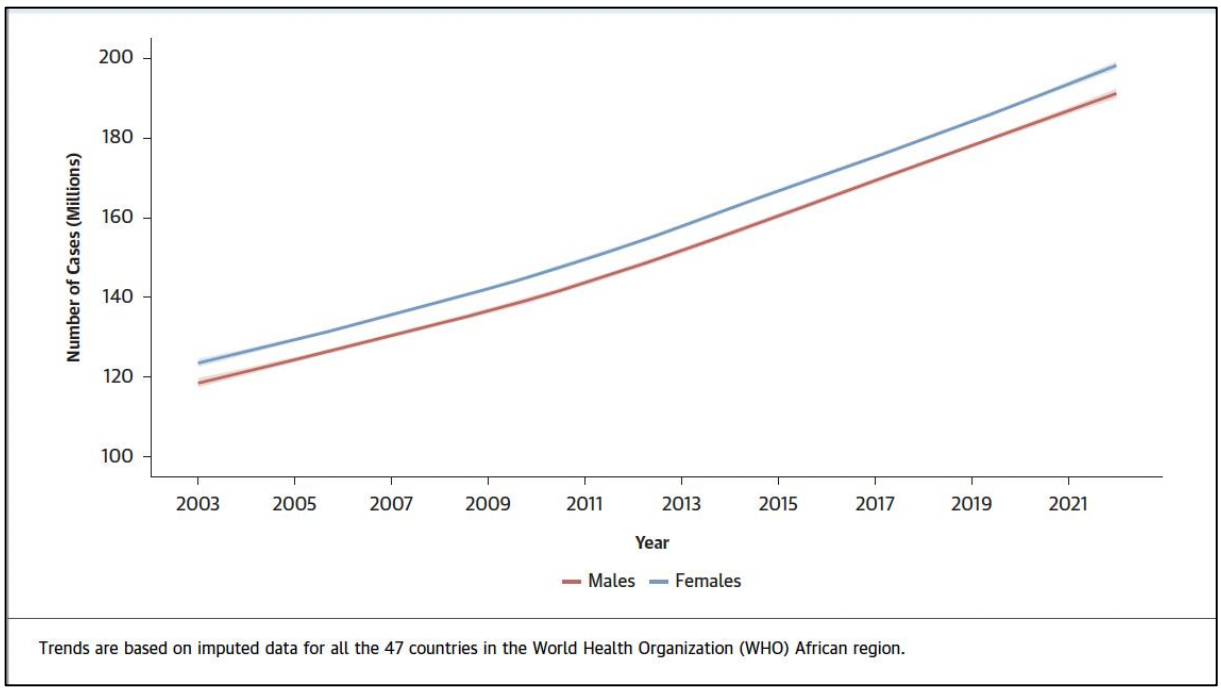


ORs and their 95% CIs were estimated via logistic regression analyses with random effects for country and survey year. The analysis was conducted among hypertensive individuals only. Dots represent adjusted ORs and horizontal lines their 95% CIs for each predictor. An OR >1 indicates a positive association (increased odds of hypertension treatment), and an OR <1 indicates a negative association (reduced odds). Adjusted on contextual factors

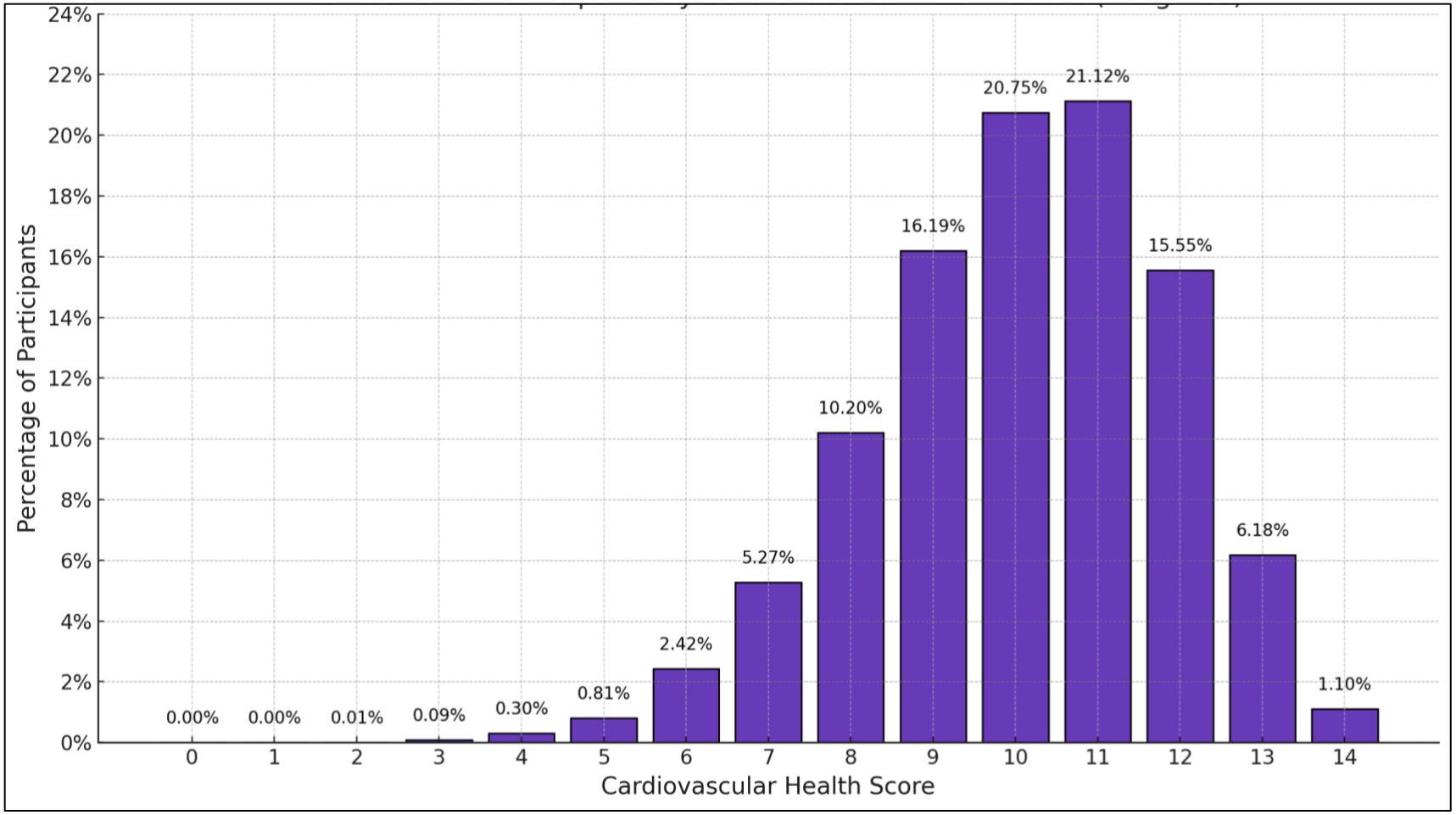
Supplementary Figure 1. Determinants of Hypertension Awarness, Treatment, and Control: Sex-Stratified Multivariable Hierarchical Analysis adjusted for contextual factors



Supplementary Figure 2. Weighted proportion of the number of ideal CVH metrics overall and by sex



Supplementary Figure 3. Sex-stratified trend in the absolute number of hypertensive individuals from 2003 to 2022



Supplementary Figure 4. Distribution of Life's simple 7 cardiovascular health score after multiple imputation of missing glycemia and total cholesterol

8. Scientific Publications

8.5. **Agboyibor KM,** Nambiema A, Golestani A, Okeibunor JC, Diallo c, Jouven J, Dangou JM, Farzadfar F, Empana JP. Prevalence, time-trends, and associated factors and time-trends of adult overweight and obesity in 36 countries in the WHO African region from 2003 to 2022: a study of 54 WHO STEPS surveys representing 156 million adults. Accepted for publication in the BMJ Global Health.

8.6. Nambiema A, **Agboyibor KM,** Dangou JM, Antignac M, Diallo CB, Okeibunor JC, Jouven X, Farzadfar F, Empana JP; African STEPS Group. Prevalence, Awareness, and Treatment of Hypertension in 37 African Countries: Trends From 2003 to 2022. J Am Coll Cardiol. 2025 Dec 9;86(23):2263-2288. doi: 10.1016/j.jacc.2025.09.1600. PMID: 41338838; PMCID: PMC12675140.

8.7. **Agboyibor KM,** Nambiema A, Gbeasor F, Barengo N, Okeibunor JC, Jouven X, Dangou JM, Farzadfar F, Empana JP. Prevalence, Determinants, and Time Trends of Cardiovascular Health in the WHO African Region. JAMA Cardiol. 2025 Nov 1;10(11):1166-1174. doi: 10.1001/jamacardio.2025.3377. PMID: 40884299; PMCID: PMC12398769.

9. Complementary Doctoral Activities

During the course of this PhD, several complementary activities were undertaken to strengthen scientific, teaching, and professional competencies beyond the core research work. These experiences contributed to the dissemination of findings, knowledge transfer, and personal development as a global health researcher.

9.1. Scientific Dissemination

- *Annual Doctoral School Meeting (Saint-Malo, February)*: Participated in the annual doctoral school seminar, where I presented a poster and engaged in discussions on postdoctoral opportunities, ongoing research projects, and keynote lectures from leading scientists.

- *Keynote Speech* – Mauritius Biannual Congress of Obesity and Diabetes (January 2024): Delivered an invited keynote address titled “The Burden of Obesity and Diabetes in Africa and WHO Recommendations.”

- *Oral Presentation* – World Congress of Epidemiology (Cape Town, September 2024): Presented “Prevalence, Time-Trends, and Associated Factors of Adult Overweight and Obesity in 36 Countries in the WHO African Region, 2003–2022,” based on data from 54 WHO STEPS surveys representing over 156 million adults.

- *Oral Presentation* – ESC Congress / World Congress of Cardiology (Madrid, August 2025): Presented “Cardiovascular Health Metrics in the WHO African Region, 2003–2022.”

9.2. Publications and Research Outputs:

- *Contributed and co-author the a manuscript*: “World Health Organization’s Guidance for Tracking Noncommunicable Diseases Toward Sustainable Development Goal 3.4” (published in EClinicalMedicine).
- *Co-author* of “Tackling the (Un)Affordability of Medicines for Cardiometabolic Risk Factors Worldwide: A Call to Action” (published in the BMJ Global Health).
- *Co-author* of “NT-proBNP as a Prognostic Indicator for Decompensated Heart Failure in the Elderly Population” (published in the African Journal of Medical Sciences).
- Lead contributor to the development of the WHO Global Report on Hypertension 2025, published in September 2025.

9.3. Teaching and Mentorship

- Invited lecturer at the Circle U European alliance Summer school 2024 in Louvain Belgium: ***Noncommunicable diseases prevention and control policies***

- Invited Lecturer – Florida International University (August 2025): Delivered a guest lecture titled "***Chronic Diseases: Tackling the Global Burden of Chronic Conditions***" for Master of Public Health students in Epidemiology and Biostatistics.

9.4. Professional Engagement

- World Hypertension League (WHL): Active member of the WHL Council, contributing to advocacy and scientific initiatives for global hypertension prevention and control.

- WHO HEARTS Technical Package: Supported the implementation of hypertension control services through the WHO HEARTS initiative in 11 countries, focusing on primary care strengthening and program evaluation.

9.5. Training and Skills Development

- *Facing the Challenges of Public Health Research in Low- and Middle-Income Countries* – École des Hautes Études en Santé Publique (EHESP)

- 15th Jean-Gérard Guillet Day: Vaccination of High-Risk Populations and COVID-19 Updates – CIC Cochin–Institut Pasteur (IP)

- *Fundamentals for Implementing a Hypertension Program* (MOOC) – Johns Hopkins University

- *Diabetes Epidemiology: Introduction to Basic Concepts and Principles* – International Diabetes Federation (IDF)

- *Health Financing and Strengthening of Health Systems Toward Universal Health Coverage* – Institut des Hautes Études du Développement Durable (IHEDD)

- *Efficiency of Health Interventions in Resource-Limited Settings* – IHEDD

- *Core Components of Strategies to Strengthen Health Systems and Enhance Their Resilience* – IHEDD

- *Research Ethics* – Programme d'Appui à la Gestion de l'Environnement (PAGE)

- *Environmental Crises: Role and Positioning of Research* – Labo 1.5

- *Data Science and Machine Learning for Research: An Introduction* – Doctoral Training Department, Université de Paris

- *Python: An Introduction to Programming for Research* – Doctoral Training Department, Université Paris Cité

- *Master degree in Cardiology*. University of Birmingham

These complementary activities enriched the research objectives of this thesis and contributed to developing advanced expertise in epidemiologic methods, scientific communication, and academic collaboration within the field of global cardiovascular health.

10. More detailed summary in French

Les maladies cardiovasculaires représentent une menace de santé publique en pleine expansion dans la Région africaine de l'OMS, où les transitions démographiques, nutritionnelles et épidémiologiques redéfinissent l'état de santé des populations. Bien que les analyses mondiales aient mis en évidence la montée des risques cardiométaboliques, les données spécifiques à la région, utilisant des mesures harmonisées et un échantillonnage cohérent de la population, restent limitées. Cette thèse rassemble la compilation de données standardisées la plus complète à ce jour sur trois piliers interconnectés de la santé cardiovasculaire (SCV), l'indice de masse corporelle (IMC), l'hypertension artérielle et une mesure composite de la SCV en s'appuyant sur les enquêtes STEPS de l'OMS menées entre 2003 et 2022. En analysant la prévalence, les déterminants et les tendances temporelles de ces

domaines, ce travail fournit une évaluation situationnelle essentielle pour orienter la prévention et les politiques en Afrique subsaharienne.

IMC : prevalence, déterminants et tendances temporelles

Le surpoids et l'obésité sont des contributeurs majeurs à l'augmentation de la charge des maladies non transmissibles (MNT), notamment les maladies cardiovasculaires, le diabète et les troubles musculosquelettiques. Dans les contextes à revenu faible ou intermédiaire, comme ceux de la Région africaine de l'OMS, le rythme de la « transition nutritionnelle », caractérisée par un passage des régimes traditionnels à des aliments transformés riches en énergie, associé à une diminution de l'activité physique s'accélère. La région fait face à un double fardeau complexe, où la sous-nutrition persistante coexiste avec un surpoids et une obésité croissants. Bien que des analyses multinationales comme celles du NCD-RisC aient décrit des tendances mondiales, elles reposent sur des sources hétérogènes et manquent souvent d'informations contextuelles. Des analyses spécifiques à la région, utilisant des données standardisées, sont donc essentielles.

Cette thèse s'appuie sur 54 enquêtes STEPS menées dans 36 pays (198 901 adultes âgés de 18 à 69 ans), fournissant des mesures harmonisées de la taille, du poids, des facteurs de mode de vie et des caractéristiques sociodémographiques. Toutes les analyses ont tenu compte du plan d'échantillonnage complexe et ont été standardisées selon l'âge. L'IMC a été catégorisé en insuffisance pondérale (<18,5 kg/m²), poids normal (18,5–24,9), surpoids (25–29,9) et obésité (≥30). Les tendances temporelles ont été estimées au moyen d'un modèle spatio-temporel bayésien permettant l'inclusion de pays sans données pour certaines périodes, en utilisant des covariables contextuelles telles que le PIB par habitant, l'urbanisation, l'indice de production alimentaire et la sous-nutrition.

L'IMC moyen était de 23,3 kg/m², avec d'importantes différences selon le sexe : 24,23 kg/m² chez les femmes contre 22,11 kg/m² chez les hommes. Le surpoids et l'obésité étaient plus fréquents chez les femmes (20,8 % et 13,3 %) que chez les hommes (14,9 % et 4,6 %), reflétant des influences comportementales, socioéconomiques et

socioculturelles. Malgré les inquiétudes concernant une hausse de l'IMC, la moyenne est restée stable entre 2003 et 2022. Toutefois, la prévalence de l'obésité a augmenté (15,89 % à 17,11 %) et l'insuffisance pondérale a également progressé (12,07 % à 12,76 %). Cette polarisation vers les extrêmes de la distribution de l'IMC illustre un double fardeau persistant.

Les analyses multivariées ont mis en évidence des associations fortes entre le sexe, l'âge, l'éducation, l'activité physique, l'alimentation, le tabagisme et les catégories d'IMC. Le surpoids et l'obésité étaient concentrés en milieu urbain, tandis que l'insuffisance pondérale était plus fréquente en zone rurale. Ces résultats soulignent l'hétérogénéité nutritionnelle et économique, l'influence des normes culturelles et la nécessité de stratégies de prévention adaptées au contexte et au sexe.

Hypertension : prévalence, sensibilisation, traitement, contrôle et tendances

L'hypertension est le principal facteur de risque modifiable des MCV, des maladies rénales chroniques et de la mortalité prématurée. La Région africaine de l'OMS présente la prévalence ajustée sur l'âge la plus élevée au monde, alors que les données robustes à l'échelle régionale sont rares. Les études antérieures se sont limitées à des pays isolés ou à des sous-régions et n'ont pas étudié simultanément les tendances à long terme de la prévalence, de la sensibilisation, du traitement et du contrôle.

Cette thèse rassemble les données les plus complètes à ce jour sur l'hypertension en Afrique, en combinant 61 enquêtes STEPS et DHS menées dans 37 pays (251 761 adultes). Toutes utilisaient des méthodes standardisées de mesure de la pression artérielle et d'échantillonnage.

La prévalence de l'hypertension était élevée : 28,9 % chez les femmes et 26,1 % chez les hommes. La majorité des cas n'étaient pas diagnostiqués (25,0 % chez les femmes ; 22,4 % chez les hommes). La sensibilisation était plus élevée chez les femmes (62,4 % contre 50,5 %), mais ne se traduisait pas par un traitement ou un contrôle adéquats. Seuls 15,0 % des femmes hypertendues et 8,4 % des hommes recevaient un traitement. Le contrôle était très faible : 7,3 % chez les femmes et 3,7 % chez les hommes. Les tendances temporelles ont montré une prévalence stable de 2003 à

2022, mais une explosion du nombre absolu de cas : de 241 millions à 390 millions, due à la croissance démographique et au vieillissement.

Les déterminants incluaient l'âge avancé, un IMC plus élevé, la retraite, l'éducation (favorisant la sensibilisation et le traitement), tandis que le tabagisme, la consommation excessive d'alcool et les emplois agricoles ou informels étaient associés à de plus mauvais résultats. Les facteurs contextuels ; espérance de vie, indice de développement du genre, disponibilité en graisses alimentaires, PIB par habitant et urbanisation, contribuaient également aux écarts observés.

SCV : Life's Simple 7, prévalence, déterminants et tendances

Pour intégrer les facteurs de risque comportementaux et biologiques, la SCV a été évaluée via les Life's Simple 7 (LS7). L'analyse repose sur 25 enquêtes STEPS dans 22 pays (73 024 adultes), représentant environ 95 millions de personnes. Les scores LS7 (0–14) ont été classés en CVH idéale, intermédiaire ou médiocre.

Au niveau régional, 26,2 % des adultes avaient une SCV idéale, 57,9 % une CVH intermédiaire et 15,9 % une SCV médiocre. Très peu de participants (≈1 %) atteignaient un score idéal pour les sept métriques. Le cholestérol total était souvent idéal (>90 %), tandis que le régime alimentaire était la métrique la plus faible (~11 % atteignant le seuil idéal). Seul un tiers avait une tension artérielle idéale. Les femmes fumaient moins et avaient une tension artérielle plus favorable, mais présentaient une obésité plus élevée et une activité physique moindre.

L'âge avancé, le sexe féminin, une éducation faible, la consommation excessive d'alcool et la résidence urbaine étaient associés à une moindre SCV. Les tendances sur 20 ans n'ont montré aucune amélioration significative, avec des scores LS7 moyens stables (7,2–7,5). Ces résultats reflètent la stagnation observée pour l'IMC et l'hypertension malgré les initiatives mondiales de l'OMS (MPOWER, SHAKE, HEARTS, REPLACE, ACTIVE).

Conclusion

Cette thèse fournit l'évaluation la plus complète à ce jour de l'IMC, de l'hypertension et de la SCV composite en Afrique subsaharienne. Les résultats mettent en évidence un double fardeau nutritionnel persistant, une hypertension largement non contrôlée et une stagnation globale de la santé cardiovasculaire. Les disparités entre les sexes, les gradients socioéconomiques et les déterminants structurels façonnent l'ensemble des risques cardiovasculaires. Ces conclusions soulignent l'urgence d'adopter des stratégies intégrées, sensibles au genre et adaptées au contexte, de renforcer les systèmes de soins primaires et d'intensifier la mise en œuvre des initiatives Global Hearts de l'OMS pour prévenir une aggravation de la charge des