Epidemiological Investigation of hypertension in The Gambia: Evaluating the burden and management in a nationwide survey

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Declaration

I, Modou Jobe, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed: 

Date: 8th January 2024

Dedication

This PhD thesis is dedicated:

To my adorable parents, the late Mr Jim Binta Jobe and Mrs Ramatoulie Sallah, and to all the Njoben family of Kerr Jarga Jobe in the Jokadou District of The Gambia.

To my special mum, Mrs Ndey Amie Njie of Brikama, West Coast Region, The Gambia.

To the two amazing women of my life, Mrs Sohna Manneh Joof and Mrs Aminata Baldé.

To my wonderful children: Isatou Jobe, Muhammad Jim Jobe, Abubacarr Jobe, and Aminata Jobe.

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I would like to thank my family for their support and understanding especially during periods when I had to be away or secluded at home working on my PhD thesis.

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Abstract

Background

The prevalence of hypertension and other non-communicable diseases has been increasing at an alarming rate in sub-Saharan Africa (SSA) and is disproportionately affected compared to other regions. The Gambia, a low-income and smallest country in mainland Africa, has had only two nationwide surveys on hypertension and related non-communicable diseases (NCDs) in 1996 and 2010 respectively. Issues related to hypertension management such as hypertension care cascade, blood pressure levels by hypertension and treatment status respectively have not been previously evaluated. This thesis investigates the prevalence of hypertension and related NCDs and their associated risk factors and evaluates gaps in the management of hypertension in The Gambia.

Methods

The data for this PhD was collected as part of a nationally representative survey of adults aged 35 years or more. Socio-demographic and economic information, self-reported personal and family health history, as well as information on smoking and alcohol consumption were collected and used in the analysis for this thesis. Relevant anthropometric data such as height, weight, capillary blood glucose and blood pressure were also collected. Analyses were weighted according to the population distribution of the 2013 Gambia Population and Housing Census and weighted to account for sex, age, and cluster size.

Results

The thesis documented very high prevalence rates of hypertension, diabetes, obesity and multimorbidity in Gambian adults. The prevalence rates for all conditions were

strongly related to age. There was also very low performance of the cascade of care for hypertension characterised by high proportion of undiagnosed cases, low rates of treatments and very low proportion of those receiving treatment achieving desired blood pressure targets. The thesis also demonstrated that regardless of treatment status, blood pressure levels were high among all individuals with hypertension. Finally, in the investigation of the association between BMI and blood pressure, there was as expected, a positive association. However, there were sex differences in this association with a steeper rise in systolic blood pressure with BMI observed in men and a more gradual increase in women.

Conclusion

The research findings have broad implications for policy and public health interventions against NCDs. Its calls for a comprehensive multisectoral strategy to reduce the prevalence of NCDs. This includes programmes on health and nutrition education, policies to improve quality of food supply as well as on transportation and environmental design. Better population screening approaches for hypertension to identify undiagnosed cases of hypertension, increasing treatment allocation to reach untreated cases should be devised and implemented. Finally current treatment guidelines should be revisited and strategies to improve treatment adherence reinforced.

List of abbreviations

BMI	body mass index
DALYs	disability-adjusted life years
GBoS	Gambia Bureau of Statistics
GNEHS	Gambia National Eye Survey
HMOD	hypertension-mediated organ damage
IHD	ischaemic heart disease
LMIC	low- and middle-income countries
NCD	non-communicable diseases
PSC	Prospective Studies Collaboration
SSA	sub-Saharan Africa
STEP	STEPwise approach to NCD risk factor
WHO	World Health Organisation

CHAPTER ONE: AIM, OBJECTIVES, THESIS DESIGN AND STRUCTURE, AND PHD ASSOCIATED PUBLICATIONS AND OTHERS

This chapter describes the aim and objectives of the thesis, as well as its design and structure, and the publications and manuscripts under review associated with the PhD work. It also includes other publications that I contributed to during the tenure of my PhD.

1.1 Aim

The aim of this PhD is to shed light on key aspects of the prevalence of hypertension and other major chronic non-communicable diseases (NCDs) and their determinants and evaluate gaps in the management of hypertension in The Gambia.

1.2 Objectives

The objectives of this thesis are to:

1. Assess the prevalence of hypertension and other NCDs and their determinants in a nationally representative sample of adults aged 35 years or more in The Gambia.
2. To appraise the continuum of care for hypertension in The Gambia using the cascade of care framework.
3. To evaluate blood pressure levels of adults aged 35 years or more in different population groups according to their position in the hypertension care cascade.

4. To examine the association between body mass index (BMI) and blood pressure in adult Gambians.

1.3 Design of the thesis

This thesis is based on a NCD survey which was embedded into the nationally representative 2019 Gambia National Eye Health Survey (GNEHS) (1). The data collected in this survey primarily included information on eye health, but also included a significant component on NCDs. I oversaw the planning, design, and implementation as well as led the data interpretation, analysis and drafting of all manuscripts related to the NCD component of the survey.

1.4 Structure of the thesis

The thesis is written in research style format and comprises 8 chapters. It includes 4 independent research papers each respectively addressing specific objectives listed for the PhD. Two of the research papers have undergone peer-review and have been published, one is presently undergoing peer-review process and the other is being finalised to be submitted for peer-review. Although the manuscripts are independent research papers, the methods section covering the study population, data collection procedures and type of data collected, are similarly described across papers.

The contents of each of the subsequent chapters are briefly outlined below:

Chapter 2 describes background and rationale for the PhD. The chapter reviews the literature on hypertension relevant to the thesis in sub-Saharan Africa in particular.

Chapter 3 describes the methods and data collection procedures of the 2019 Gambia National Eye Health Survey which forms the basis for this PhD.

Chapter 4, published in Lancet Global Health, describes the epidemiology of hypertension in The Gambia and assesses the variation of its prevalence by sex, location and other socio-demographic characteristics. Given hypertension is related to other NCDs and risk factors, the chapter also examines the prevalence of diabetes, obesity, multimorbidity and related risk factors (smoking and alcohol consumption).

Chapter 5, published in eClinicalMedicine, evaluates the hypertension cascade of care performance for hypertension in The Gambia. This chapter informs about the continuum of care and identifies areas in the care cascade where health resources should be most effectively targeted.

Chapter 6, under review at Journal of Clinical Hypertension, further evaluates the blood pressure levels among individuals with hypertension according to the hypertension cascade of care performance. It examines blood pressure levels in normotensive individuals and in three groups of individuals with hypertension as follows: i) self-reported hypertension and not receiving treatment (untreated); ii) self-reported hypertension and receiving treatment (treated); and iii) individuals not aware of their hypertension status (unaware).

Chapter 7, to be submitted to Global Health journal, investigates the association between BMI and blood pressure and assesses whether this differs by sex and other sociodemographic factors.

Using evidence generated in the above chapters, **Chapter 8** discusses the key findings from the thesis and outlines suggested policy, practice and research approaches to addressing them.

1.5 Research papers associated with this PhD

i) Paper on prevalence of NCDs and related risk factors

Jobe M, Mactaggart I, Bell S, Kim MJ, Hydara A, Bascaran C, Njai M, Badjie O, Perel P, Prentice AM, Burton MJ. Prevalence of hypertension, diabetes, obesity, multimorbidity, and related risk factors among adult Gambians: a cross-sectional nationwide study. Lancet Glob Health 2024; 12: e55-65

ii) Paper on evaluating the hypertension care cascade in The Gambia

Jobe M, Mactaggart I, Hydara A, Kim MJ, Bell S, Badjie O, Bittaye M, Perel P, Prentice AM, Burton MJ. Evaluating the hypertension care cascade in middle-aged and older adults in The Gambia: findings from a nationwide survey. EClinicalMedicine. 2023;64:102226

iii) Paper on blood pressure levels according to hypertension care cascade

Jobe M, Mactaggart I, Hydara A, Kim MJ, Bell S, Kotanmi GB, Badjie O, Prentice AM, Burton MJ. Blood pressure and the hypertension care cascade in The Gambia: findings from a nationwide survey. Under review at Journal of Clinical Hypertension

iv) Paper on association between BMI and blood pressure

Jobe M, Mactaggart I, Hydara A, Kotanmi BG, Bell S, Perel P, Burton MJB, Prentice AM. Sex differences in the association between body mass and blood pressure in adult Gambians: Findings from a nationwide survey. To be submitted to Global Heart.

1.6 Other papers published during the tenure of my PhD

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Book chapter

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CHAPTER TWO: BACKGROUND AND LITERATURE REVIEW

2.1 A brief historical perspective on hypertension

Hypertension is one of the best studied diseases in clinical medicine. Most of our current understanding about hypertension came about in the last few decades. In the early 20th century, hypertension was regarded as a natural part of the ageing process or a compensatory phenomenon that must not be treated (2). Around 1910, insurance companies in the United States recognised an increased risk of death in those with a high blood pressure, and were often refusing lifetime insurance policies from people with a high blood pressure (3)(4). By 1925, hypertension was linked to an increased risk of cardiovascular disease and death in a report by the Actuarial Society of America (5). Despite these, medical opinion was against treatment of hypertension apart from in malignant cases.

As stated by John H Hay, Professor of Medicine at University of Liverpool in 1931:

"*The greatest danger to a man with high blood pressure lies in its discovery, because then some fool is certain to try and reduce it*" (6).

This was echoed by Dr Paul Dudley White, a US cardiologist who in 1937 wrote: *"Hypertension may be an important compensatory mechanism which should not be tampered with, even were it certain that we could control it"* (7).

In the late 1960s, the Veteran Affairs Cooperative Study which compared a combination of antihypertensives (thiazide diuretic and reserpine and hydralazine) against placebo in hypertensive individuals, was the first trial to provide evidence on the benefits of blood pressure lowering medication on mortality (8). This was followed by other classical studies such as the Multiple Risk Factor Intervention Trial (MRFIT)

(9), the Prospective Studies Collaboration (PSC) (10) and the CArdiovascular research using LInked Bespoke studies and Electronic health Records (CALIBER) (11). These studies and several others, most notably the Framingham Heart Study (12), conducted over the past decades have shaped our understanding of hypertension as a major risk factor for cardiovascular disease and death. Table 1 provides examples of some major clinical trials conducted on the effect of lowering blood pressure on cardiovascular disease and death.

Table 1: Examples of major clinical trials on hypertension over the past several decades

Study	**Publication year**	**Study population and intervention**	**Summary of findings**
VA Cooperative Study (8)	1967	- Study population: male hypertensives with diastolic blood pressure of 115-129mmHg. - Hydrochlorothiazide plus reserpine plus hydralazine hydrochloride versus placebo	Benefit of treatment in reducing cardiovascular events
US Public Health Service Cooperative Study: treatment of mild hypertension (13)	1977	- Study population: patients with diastolic blood pressures between 90 and 115 mm Hg - Combination of a diuretic and *Rauwolfia serpentina* versus placebo	- Higher reduction in diastolic blood pressure in treatment group - No difference in major endpoints of deaths, myocardial infarction, coronary artery disease and stroke
Oslo study (14)	1980	- Study population: symptom-free men, aged 40-49 years with systolic blood pressures between 150 and 179 mmHg and diastolic blood pressure below 110 mmHg - Randomised to drug hydrocholrothiazide +/-	No effect on major or total 5-year cardiovascular morbidity or mortality in drug-treated vs untreated men with “mild” hypertension

		methyldopa or proporanolol. Other arm was not given placebo	
Multiple risk factor intervention trial (9)	1982	- Study population: high-risk men aged 35 to 57 years - Randomised to special intervention program (treatment for hypertension, counselling for cigarette smoking, and dietary advice for lowering blood cholesterol levels) versus usual sources of health care in the community	No difference in total mortality over a 7-year period between groups
Medical Research Council (MRC) Trial of Treatment of Mild Hypertension (15)	1985	- Study population: Men and women aged 35-64 years with diastolic blood pressure 90 to 109 mmHg - randomised to bendrofluazide or propranolol or placebo tablets	Reduction in stroke and all cardiovascular events, but not coronary events or mortality, in actively treated patients vs placebo-treated patients
Swedish Trial in Old Patients With Hypertension (STOP-Hypertension) (16)	1991	- Study population: hypertensive men and women aged 70-84 years - Compare beta-blockers (either atenolol, pindolol or metoprolol +/- amiloride or hydrochlorothiazide) versus placebo	Active drug treatment reduced cardiovascular morbidity and mortality vs placebo-treated patients
Hypertension Optimal Treatment (HOT) Study (17)	1998	Study population: Men and women in 26 countries between 50 and 80 years of age - Felodipine plus additional treatment as per protocol versus placebo	Reduction in cardiovascular risk in treated group with little further reduction of with lowering systolic blood pressure beyond 130–140 mm Hg and diastolic blood pressure beyond 80–85 mm Hg
Heart Outcomes Prevention Evaluation (HOPE) study (18)	2000	- Study population: high-risk patients aged 55 years or older) with evidence of vascular disease or diabetes plus one other cardiovascular risk factor - Ramipril versus placebo	Ramipril significantly reduces risk of death, myocardial infarction, and stroke

Antihypertensive and Lipid-Lowering Treatment to Prevent Heat Attack Trial (ALLHAT) (19)	2002	- Study population: participants aged 55 years or older with hypertension and at least 1 other coronary heart disease risk factor - Chlorthalidone versus amlodipine versus lisinopril for planned follow-up of approximately 4 to 8 years.	Thiazide-type diuretics (chlorthalidone) are superior in preventing 1 or more major forms of cardiovascular disease
Action to Control Cardiovascular Risk in Diabetes (ACCORD) (20)	2010	- Study population: Participants with type 2 diabetes - Intensive therapy, targeting a systolic pressure of less than 120 mm Hg, or standard therapy, targeting a systolic pressure of less than 140 mm Hg	Targeting intensive blood pressure therapy did not reduce the rate of a composite outcome of fatal and nonfatal major cardiovascular events

2.2 Definition

Epidemiological data shows a continuous positive relationship between blood pressure and adverse cardiovascular outcomes such as stroke and coronary artery disease from a systolic blood pressure of 115 mmHg or more, or a diastolic blood pressure of 75 mmHg or more (21). The PSC was a large meta-analysis of 61 prospective cohort studies between 1950 and 1990, using data on 100000 deaths among 1 million participants (10). The PSC study reported that a 20-mmHg reduction in blood pressure was associated with a reduction in cardiovascular risk in all age groups irrespective of baseline blood pressure. In the age group with the largest number of fatal events (70–79 years), there was a hazard ratio (HR) of 0.60 for ischaemic heart disease mortality (95% confidence interval [CI], 0.58–0.61) and a HR of 0.50 (95% CI, 0.48–0.52) for stroke mortality for a 20mmHg reduction in blood pressure. These reductions were modestly different in men and women. Whilst the

proportional risk reductions for ischaemic heart disease were slightly greater in women, they were similar for both sexes for stroke mortality (10).

It should therefore be noted that the dichotomy between normotension and hypertension is artificial, arbitrary, evolving, and mainly used for pragmatic reasons to simplify diagnosis and treatment decisions (22). The most widely used threshold for defining hypertension at present is an office systolic blood pressure measurement of 140 mmHg or more, or a diastolic blood pressure of 90 mmHg or more. According to data from clinical trials, the benefits of treatment at this threshold unequivocally outweigh the risk of no treatment. Other thresholds exist for defining hypertension depending on the blood pressure evaluation method used. This for instance, is a mean systolic blood pressure of ≥135 mmHg and/or a mean diastolic blood pressure of ≥85mmHg using home blood pressure measurement. For 24-hour ambulatory blood pressure measurement on the other hand, the threshold is a mean systolic blood pressure of ≥130mmHg and/or 80mmHg (23)(24).

2.3 Prevalence of hypertension

Hypertension, defined as a systolic blood pressure of 140 mmHg or more, or diastolic blood pressure of 90 mmHg or more is one of the leading causes of disease burden globally. It affects over 1.39 billion people globally, more than 75% of whom (1.04 billion people) live in low- and middle-income countries (LMICs) (25)(26). Hypertension is the leading underlying cause of death worldwide, causing an estimated 10 million annual deaths (27).

The prevalence of hypertension has been increasing globally apart from in a few isolated populations. These are mainly in so-called “salt-free”, largely isolated societies, who were found to have significantly lower blood pressure levels according to the INTERSALT studies. The mean systolic and diastolic blood pressure levels in these societies [Yanomamo and Xingu Indians of Brazil, Luo tribe in rural Kenya and the Asaro tribe in Papua New Guinea] were 103mmHg and 63mmHg respectively. In other INTERSALT centres i.e., “non salt-free” centres, these were respectively 120mmHg and 74mmHg (28).

Hypertension is generally present in all countries and societies, although at varying prevalence rates principally determined by the lifestyle and environmental factors adopted by respective populations (29). The prevalence of hypertension is expected to continue to rise with population ageing, increasing sedentarism, increasing body weight and adoption of unhealthy diets. Globally, hypertension is expected to affect 1.5 billion individuals by 2025, which is an increase of 15-25% from current estimates (30).

Whilst the age-standardised prevalence of hypertension decreased by 2.6% in high-income countries between 2000 and 2010, this increased by 7.7% in LMICs (31). Furthermore, out of 8.5 million deaths attributable to hypertension in 2015, 88% occurred in LMICs (32). Sub-Saharan Africa (SSA) is disproportionately affected compared to other low and middle income regions (33). There has been a steady increase in the number of people with hypertension in the region. This has increased from 54.6 million in 1990 to 92.3 million in 2000 (70% rise) and 130.2 million in 2010 (41% increase from 2000). It is projected to further affect 216.8 million (66% from

2010) by the year 2030 if appropriate measures are not taken (34). Already in the region, hypertension imposes significant direct and indirect economic costs to individual patients, their families and to national economies (35)(36)(37).

According to the Global Burden of Disease Study, ischaemic heart disease was the second leading cause of death in 2019 in The Gambia. Ischaemic heart disease, of which high blood pressure is the main risk factor, increased its contribution to the country's disability-adjusted life years (DALYs) lost by 34.8% between 2009 and 2019 (38). The nationwide prevalence of hypertension in those aged 15 years or more was 24.1% in 1996 (39), and was found to be 29.1% in adults aged 24-64 years according to the 2010 WHO STEP survey (40). These surveys were a useful contribution to a basic understanding of the hypertension burden in The Gambia. However, they lacked data on many important issues, including the causes behind the unexpected higher prevalence in rural compared to urban settlements found in the WHO STEP survey, the clustering of comorbidities, the hypertension cascade of care, and the association between adiposity and blood pressure, among others.

2.4 Hypertension prevalence in men and women

Observational data shows that blood pressure is a sexually dimorphic trait with significant differences observed in men and women. Men are generally known to have a higher blood pressure than women, although this varies by age and location (41). In the United States Heart and Stroke Statistics 2021 update, the prevalence of hypertension in adults over 20 years was 51.7% in males and 42.8% in females (42). Awareness of hypertension status also differ between sexes. In the Canadian Health Measures Survey between 2007 and 2017, there was a lower level of awareness,

treatment and control by 13%, 17% and 23.1% respectively among women relative to men. An opposite pattern was observed in the Asian continent. In the China Hypertension Survey, awareness (51.9% vs 42.5%), treatment (46.6% vs 35.6%) and control rates (17.7% vs 13.2%) were higher among females compared to males (43). As in the Chinese study, similar observations were found in a cross-sectional study in Bangladesh (44). In a Sierra Leonean study however, awareness and treatment rates were higher in women, but control rates did not differ by sex (45).

2.5 Hypertension cascade of care

The retention and loss of patients with hypertension across the different stages of care has been reported in various settings and is vital in assessing healthcare performance. Data reported from 1.1 million participants living in 44 LMICs show an overall hypertension prevalence of 17.5%, among whom 39.2% were aware of their diagnosis, 29.9% had received treatment, and only 10.3% of these had their blood pressure adequately controlled (35). In SSA however, control rates were found to be less than 5% of patients in nearly two-thirds of countries (46)(47). The control rates were reported to be 4% in The Gambia according to data from the 2010 WHO STEP survey (40). According to Mills et al, high-income countries have approximately double the awareness (67.0% versus 37.9%) and treatment (55.6% versus 29.0%) rates and four times the control rates among patients with hypertension (28.4% versus 7.7%) compared to LMICs (31).

2.6 Population blood pressure levels

Although the cascade of care is a useful metric for assessing healthcare performance, it is limited in giving insights into blood pressure levels. Some studies have reported

that blood pressure levels are not always lower in individuals receiving blood pressure lowering treatment. A study of older persons (aged 60-69 years) in the United Kingdom found significantly higher blood pressure levels amongst individuals receiving treatment compared to those not receiving treatment (48). In Peru however, those unaware of their hypertension (previously undiagnosed) had the highest blood pressure levels [151.3mmHg (95% CI: 150.9-151.7)], followed by those receiving treatment [141.2 mmHg (95% CI: 140.4- 141.9)] (49). This emphasises that favourable outcomes are achieved through quality care, both drug and lifestyle, in patients receiving treatment.

Analysis of data from multiple countries over a 20-year period shows contrasting trends in countries according to income level. The data shows that blood pressure levels have declined in high-income and in some middle-income countries. These levels have increased or at best stagnated in low income and some middle-income countries (29). These trends in respective countries are influenced by several nutritional, behavioural and environmental factors throughout the life course. Specifically these include diet (50)(51), adiposity (52), smoking (53), physical inactivity (54), psychosocial stress (55) and availability and use of blood pressure lowering medication (56). Factors favouring higher blood pressure levels are lower in high income countries. Higher income countries have year-round availability of fruits compared to low-income countries where availability is highly seasonal and unaffordable in most cases (57). Furthermore blood pressure lowering medication and better health systems are more present in high income settings (58).

2.7 Adiposity and blood pressure

The association between BMI and blood pressure is well established. As a result, weight loss has been shown to be associated with reduction in blood pressure levels and weight gain vice versa, therefore suggesting a causal association (59)(60). Weight loss has become an integral part of hypertension management and a major recommendation in treatment guidelines (61)(62). A 10kg reduction in weight has been shown to reduce systolic blood pressure by 5-20mmHg (63)(64). The prevalence of overweight and obesity has been increasing in SSA, and this increase is higher among women compared to men. There is evidence to suggest there are sex-differences in the cardiovascular manifestations in men and women, which is delayed in women (65)(41). Further, blood pressure levels are observed to progress more rapidly in women (66). Despite these differences, treatment approaches are similar in men and women. The association between adiposity and blood pressure has been not well described in SSA. A greater understanding of the association between BMI and blood pressure could have important clinical and public health implications.

2.8 Hypertension as a cardiovascular risk factor

As reviewed above, hypertension is the commonest modifiable and one of the strongest risk factors for cardiovascular disease. It significantly increases the risk of cardiovascular diseases, including coronary heart disease, congestive heart failure, ischemic and haemorrhagic stroke, renal failure, and peripheral arterial disease (24). Hypertension commonly coexists with other cardiovascular disease risk factors such as diabetes mellitus, dysplipidaemia and obesity. Depending on the number of concomitant risk factors, the risk of cardiovascular disease increases by up to 30-fold at any blood pressure level (67).

Treatment guidelines therefore incorporate the concept of risk stratification when recommending pharmacotherapy in patients with hypertension - particularly in individuals with BP >140/90 and <160/100 mmHg. The International Society of Hypertension guidelines recommends pharmacotherapy as essential for this group only when they are estimated as high cardiovascular disease risk (68) - supported by recent literature suggesting less compelling evidence to treat individuals with mildly raised blood pressure in SSA (69). The risk estimation can be done through risk scores. This approach however has several limitations in SSA: first, these risk scores are based on the presence or absence of some cardiovascular risk factors such as dyslipidaemia and smoking for which the prevalence might be low in some parts of SSA especially in rural areas (70)(71)(72). Second, compared to high-income countries, most studies conducted in SSA show a substantial burden of hypertension in younger age groups and current risk scores that give a strong weighting to age will invariably classify these individuals at low risk. Third, current risk scores do not consider region-specific factors in SSA such as co-existing chronic communicable disease such as HIV and malaria or exposure to environmental factors (for example indoor air pollution) (73)(74)(75). Finally, most risk scores have been developed in high-income countries and remain unvalidated in rural settings in SSA. Another recommended way to estimate risk is based on the presence of subclinical changes of the brain, heart, eyes, or kidneys. These hypertension-mediated organ damage (HMOD) changes can be detected through electrocardiograms and echocardiograms (left ventricular hypertrophy), fundoscopy (retinopathy), or laboratory tests (renal disease) (22)(76). Patients with HMOD are at high risk of clinical events and therefore all guidelines recommend starting treatment when these changes are detected; in addition, measuring HMOD could be useful to follow-up patients, to titrate treatment

and for early detection of complications (left ventricular dysfunction through echocardiogram). Unfortunately, even if HMOD has been reported to be more prevalent in sub-Saharan African populations, and complications, such as heart failure, are also more frequent and fatal (77). HMOD assessment is not routinely done in SSA because of lack of resources.

2.9 Mechanisms of hypertension

The mechanism of hypertension is multifactorial and complex, involving many organ systems and the interaction of multiple pathways. I will briefly describe the factors involved in the regulation of arterial blood pressure which is vital to understanding the pathogenesis of hypertension.

2.9.1 Determinants of blood pressure

Blood pressure is determined by the product of cardiac output and total peripheral vascular resistance. As shown in Figure 1, cardiac output is determined by stroke volume and heart rate. The stroke volume is related to factors such as ventricular compliance, myocardial contractility, filling pressure and so on. The heart rate on the other hand is largely related to sympathetic and parasympathetic regulation. The peripheral resistance is related to functional and anatomical functions of small arteries and arterioles, and dependent on sympathetic and humoral factors as well as local autoregulation.

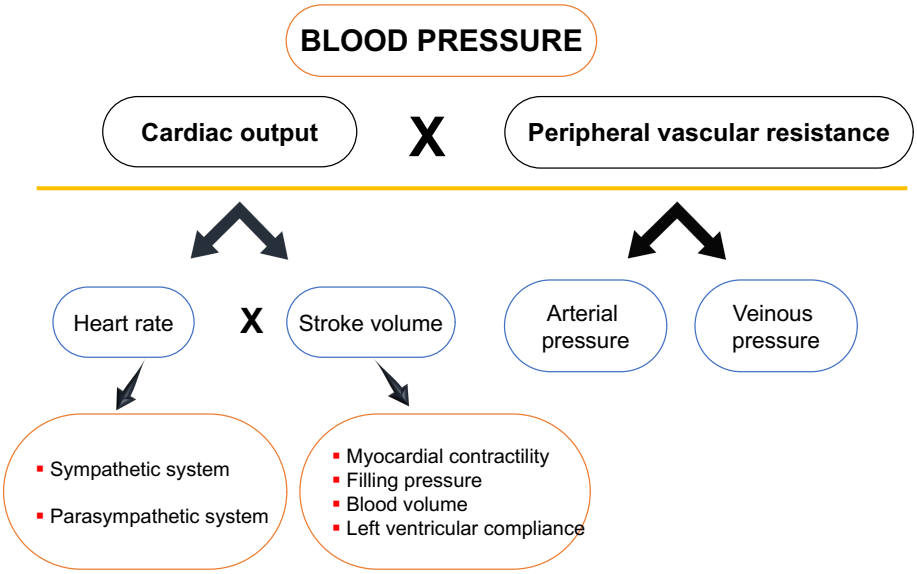

Figure 1: Determinants of blood pressure

2.9.2 Blood pressure regulation

Blood pressure is regulated by various mechanisms, some of which are short-term and others long-term. These regulation systems are briefly described below:

Short-term mechanisms

This is principally maintained by baroreceptors and chemoreceptors, which both function as part of an afferent system. These receptors are located in the aortic arch and carotid sinus (Figure 2). The baroreceptors respond to an increase or decrease in pressure or stretch or an acute reduction in blood volume such as blood loss. The chemoreceptors are sensitive and respond to low partial pressure of oxygen, decreased pH or an elevated partial pressure of carbon dioxide. The system exhibits features of feedback regulation. First it conveys information describing the current blood pressure level, permitting the central evaluators to compare current blood

pressure with the desirable set-point. In elevated blood pressure, the baroreceptors are activated sending signals to the nucleus tractus solitarius in the brainstem through the vagus and glossopharyngeal nerves. This in turn activates the parasympathetic nervous system resulting in reduction in blood pressure through vasodilatation and reducing heart rate. On the other hand, when baroreceptors detect a reduction in blood pressure below the set-point, they send signals to the nucleus tractus solitarius which will deactivate the parasympathetic nervous system and activate the sympathetic pathway. Consequently, there is an increase in the heart rate, cardiac output and constriction of vessels and elevation of blood pressure (78)(79)(80)(81).

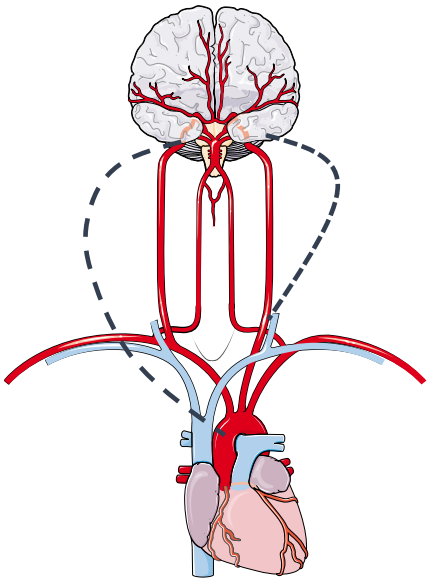

Figure 2: Illustration of receptors for short-term blood pressure regulation located at carotid bifurcation and aortic arch, transmitting signals to the nucleus tractus solitarius

Long-term mechanisms

The principal form of long-term regulation is via the renin-angiotensin-aldosterone system (Figure 3). The system can be activated when there is a loss of blood volume, such as in haemorrhage or dehydration, by a decrease in the filtrate sodium chloride

(NaCl) concentration or a decreased filtrate flow rate that will stimulate the macula densa to signal the juxtaglomerular cells to release renin (82).

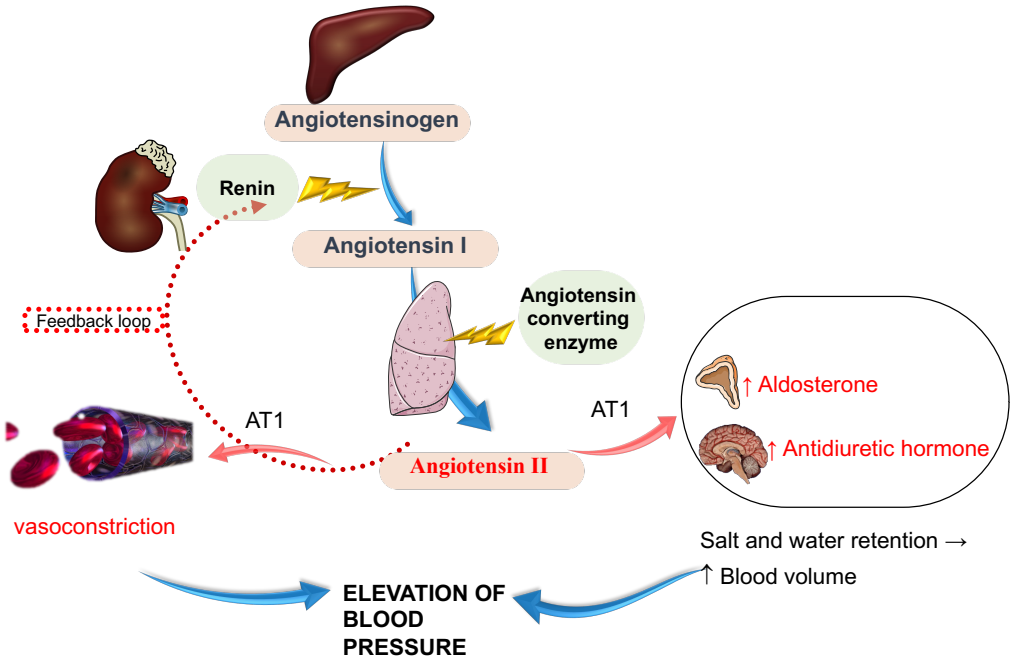

Figure 3: Long term regulation by the renin-angiotensin-aldosterone system

When renal blood flow is reduced, juxtaglomerular cells in the kidneys convert the precursor prorenin (already present in the blood) into renin and secrete it directly into the circulation. Plasma renin then carries out the conversion of angiotensinogen, released by the liver, to a decapeptide called angiotensin I. Angiotensin I is subsequently converted to angiotensin II (an octapeptide) by the angiotensin-converting enzyme (ACE) found on the surface of vascular endothelial cells, predominantly those of the lungs. Angiotensin II which has a short life in circulation of about 1 to 2 minutes, is a potent vasoconstrictor and has numerous other functions including stimulating the release of aldosterone, and antidiuretic hormones among others (80)(81). The renin-angiotensin-aldosterone system, once activated exerts

various effects on the blood vessels, brain, heart, kidneys and adrenal glands (Figure 4).

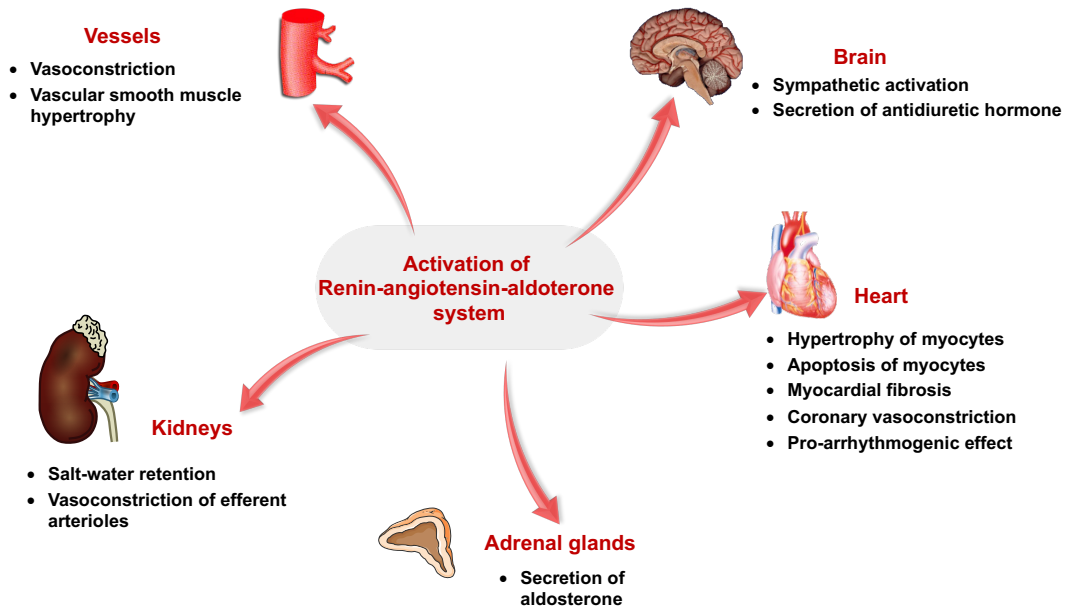

Figure 4: Effects of activation of renin-angiotensin-aldosterone system

2.9.3 Autoregulation of blood pressure

Most tissues have the ability to ensure that there is a constant blood flow to maintain their specific needs, despite changes in perfusion pressure. The degree of autoregulation varies from organ to organ with the brain, heart and kidneys showing excellent autoregulation whilst the skeletal muscles have moderate autoregulation. Without autoregulation, vital organs will not be adequately perfused such as in cases of acute hypotension or in narrowing of blood vessels. When there is a fall of blood pressure or perfusion, resistance decreases as small arteries and arterioles dilate hence increasing blood flow to vital organs. Similarly, blood pressure is maintained through interaction between cardiac output and total peripheral resistance to ensure

that blood pressure is as tightly maintained as possible. In acute reduction of blood pressure, arteriolar constriction occurs as well as venular constriction to redistribute peripheral volume to the central circulation to elevate blood pressure (83).

2.9.4 Variability of blood pressure and its determinants

This refers to the continuous and dynamic fluctuations of blood pressure in individuals throughout their lives. It is a complex phenomenon which is not fully understood. Blood pressure variability should be considered in evaluating blood pressure levels especially in cross-sectional studies and in spot clinic measurements (84)(78). Blood pressure variability has both behavioural and genetic determinants.

Behavioural factors include cigarette smoking which, due to its nicotine content, potentially leads to transient elevation of blood pressure (85). Alcohol consumption can result in high blood pressure variability depending on quantity consumed (86). Similarly caffeine, especially in diet sodas, is known to steeply raise blood pressure levels (87). Other behavioural factors are physical inactivity (88) and dietary habits (high salt diet, low potassium diets, etc) (88), which lead to blood pressure variability in the short-term and may lead to the development of hypertension in the long term.

Although approximately 50% of blood pressure variability is heritable, the associated genetic variations identified explain only a fraction (2-3%) of this variability (89) leading to the hypothesis that epigenetic mechanisms may at least in part explain the “missing heritability” (90). High blood pressure variability is thought to confer cardiovascular risk and may be a target for treatment. Currently available options to manage blood pressure variability are long-acting blood pressure lowering medications such as

dihydropyridine calcium channel blockers, angiotensin converting enzyme inhibitors and so on.

2.10 Pathophysiology of hypertension

Hypertension occurs when there is a derangement of regulatory mechanisms. As a result of multiple genetic and environmental factors, there is reduced extensibility of vessel wall and uncoupling of receptors to the vessel wall leading to decreased baroreceptor sensitivity. The baroreflex is then adjusted at a higher set point that sustains hypertension instead of suppressing it. The parasympathetic tone is therefore reduced, and the sympathetic pathway overstimulated. Furthermore, there is overproduction and activation of angiotensin II and impaired activities of vasodilators such as prostacyclin and nitric oxide (80)(81)(83).

2.11 Causes and classification of hypertension

An extensive discussion of the causes of hypertension and its classification is beyond the scope of this thesis and will only be covered briefly. Hypertension is broadly classified into primary and secondary hypertension based on whether an identifiable cause is found or otherwise.

2.11.1 Primary hypertension

Also referred to as “essential hypertension”, it is the type of hypertension in which no identifiable cause is found. The proportion of cases depend on capacity for diagnosis or detection of clearly defined secondary causes. This term applies to about 95% of hypertensive patients denoting that the elevation of blood pressure results from a complex interaction of multiple genetic and environmental factors. It is uncommon

before the age of 20 years and usually occurs between the ages of 25 years and 50 years. Possible pathways resulting from the interaction of genetic and environmental factors include overactivation of the renin-angiotensin-aldosterone system and the sympathetic system, and blunting of the pressure natriuresis relationship, among others. Exacerbating factors include, but are not limited to, weight gain, cigarette smoking, excessive alcohol consumption, high salt intake and low potassium consumption (91)(92).

2.11.2 Secondary hypertension

This refers to the type of hypertension with an identifiable cause and accounts for about 5% of hypertensive patients. Though it can occur at any age, it should be suspected in patients with an elevated blood pressure before the age of 20 years or above the age of 50 years, or in cases of resistance to blood pressure lowering medications. Identifiable causes of hypertension include, but are not limited to, genetic syndromes (e.g. Liddle syndrome), polycystic kidney disease, primary aldosteronism, pheochromocytoma, aortic coarctation, thyroid disease, parathyroid disease, Cushing syndrome and drug induced (treatment with corticosteroid, non-steroidal anti-inflammatory agents, etc.) (93)(94).

2.12 Hypertension in black Africans

Significant racial differences exist in the prevalence, treatment, and control of hypertension. Our previous work (95), as well as work elsewhere (26)(96)(97), has shown that hypertension in native Africans tends to occur in younger, leaner people and increasingly among rural residents as compared to diaspora Africans and other populations. There is therefore an urgent need to conduct more hypertension research

in SSA. Although hypertension is one of the best studied diseases in clinical medicine, most of our current understanding of the aetiological drivers, resultant phenotypes and treatment approaches in Africans derive from studies in diaspora Africans, especially African-Americans (97)(98). Extrapolation to native Africans may therefore not be justified.

2.12.1 Brief review of prevalence and management

The racial disparities in the prevalence and management of hypertension have been highlighted by many studies especially in the United States. A recent review by Abrahamowicz and colleagues showed that non-Hispanic blacks have higher prevalence of hypertension compared to other racial groups especially the non-Hispanic Whites. The latter racial group however had significantly better control rates compared to their non-Hispanic black counterparts (55.7% compared to 48.5%) (99). These were however not consistent with data from South Africa where prevalence and control were assessed and found to be similar in blacks and whites, with the highest prevalence found in South Asians and those of a mixed race (100). The RODAM study, which compared hypertension prevalence, awareness and control among Ghanaians (all blacks) living in Ghana and in various European cities found differences, with better outcomes in those living in Europe (100). The latter study suggests that the causes behind racial disparities are therefore multifactorial, including lifestyle and environmental factors as well as access to quality healthcare (101).

2.12.2 Why is hypertension more common in blacks?

Higher salt retention in black hypertensives

It is well known, as illustrated in the INTERSALT studies (28), that hypertension is rare in “salt-free” societies. Individuals in these environments are in a critical sodium balance and any defect in sodium reabsorption may result in loss of circulatory homeostasis (102). Consequently, this potentially resulted in environmental pressure to select genes that retain sodium. It is hypothesised that this may have been an important factor in the survival of blacks during their passage from Africa (deemed to be a low salt society in the past) to the United States (103). This theory is however contested by some experts (104).

Liddle phenotype tend to be higher in blacks

This is characterised by suppression of both renin and aldosterone resulting from overactivity of epithelial sodium channels. It is thought that this phenotype is more common among blacks. A study in South Africa reported lower renin and aldosterone levels in blacks compared to their white counterparts, suggesting a genetic cause (105). In another study, segmental sodium reabsorption along the nephron was reported to be highly heritable and the capacity for regulation in different segments differs between blacks and whites (106). Data from a study in the United States yielded similar results (107). It is however not clear to what extent these findings in normotensive individuals translate to hypertension.

Primary aldosteronism tend to be more common in blacks

Black patients are more likely to have primary aldosteronism due to bilateral adrenocortical hyperplasia (108)(109)(110). As this type of hypertension is secondary

to bilateral adrenal hyperplasia, medical treatment is the preferred option with only a minority of cases requiring surgery (108). A South African study reported the presence of aldosterone synthase in many or most black patients relative to others (111). This hypothesis however requires further investigation especially with genetic studies.

African Diaspora Hypothesis

It is hypothesised that a natural selection conferred by genetic causes of salt and water retention occurred during the severe condition on slave ships transporting slaves from Africa to the United States and the Caribbean islands (112). The theory implies that mortality was higher among those with less capacity to retain water and salt, and hence they died as a consequence of vomiting, diarrhoea and profuse sweating. This hypothesis is supported by a higher prevalence of hypertension in American blacks versus African residents (112)(113). The 2003-2014 US National Health and Nutrition survey also reported a hypertension prevalence of 42.8% of US-born blacks compared to 27.4% of foreign-born blacks (114).

2.13 Management of hypertension

This section is intended to provide an overview of treatment strategies to address the burden of hypertension. A more detailed description of these strategies is beyond the scope of this thesis. These strategies are broadly divided into lifestyle or non-pharmacological and pharmacological intervention.

2.13.1 Lifestyle intervention

Lifestyle interventions are vital at various levels of the care pathway. In normotensive individuals, lifestyle interventions are known to be effective in reducing blood pressure levels and in preventing hypertension. Their effectiveness is also proven in reducing

blood pressure levels and overall cardiovascular risk among patients with hypertension, and these approaches greatly complement pharmacological interventions. Established lifestyle interventions against rising blood pressure are weight loss, reduction of dietary sodium consumption, increasing potassium intake, adopting a heart-healthy dietary pattern, engaging in physical activity, and reducing alcohol consumption. Table 2 summarises the effect of these lifestyle interventions on blood pressure, which all put together reduce blood pressure by between 20mmHg and 55mmHg (115)(116)(117).

Table 2: Summary of effectiveness of lifestyle interventions in reducing blood pressure

Lifestyle intervention	**Approximate BP reduction (range)**
Weight reduction (10kg of weight loss)	5-20 mmHg
Dietary eating plan (e.g. DASH*)	8-14 mmHg
Dietary sodium reduction	2-8 mmHg
Physical activity	4-9 mmHg
Reduction of alcohol intake	2-4 mmHg

*DASH= Dietary Approaches to Stop Hypertension

A combination of these lifestyle interventions has an additive effect on blood pressure reduction and has been shown to reduce blood pressure significantly more compared to adoption of single lifestyle intervention as has been shown in the ENCORE study (117) and PREMIER trial (118) among others.

2.13.2 Pharmacological treatment

There is established evidence from randomised clinical trials that pharmacological blood pressure lowering treatment reduces the risk of cardiovascular events and

deaths in adults with hypertension. A meta-analysis by Bundy and colleagues showed that blood pressure lowering by 10, 20 or 30 mmHg to 120 to 124 mmHg was associated with reduction in event rates of 29%, 42% and 54% respectively (119). Some experts advise caution on intensity of blood pressure lowering in elderly patients. Where more aggressive lowering is advised in younger patients, slightly higher thresholds are set for older patients as per current treatment guidelines. In older patients, there are concerns about adverse consequences of aggressive blood pressure lowering such as orthostatic hypotension, falls, acute kidney injury, and hypoperfusion of vital organs such as the heart and brain (120). This however remains controversial as per the SPRINT randomized trial where adults aged 75 years or older, even those who were frail or with slow gait, significantly benefited from treatment to a systolic blood pressure target of less than 120 mmHg compared with one of less than 140 mmHg (121).

Generally, first line agents are thiazide diuretics, renin-angiotensin-aldosterone system inhibitors (angiotensin converting enzyme inhibitors and angiotensin receptor blockers) and calcium channel blockers, or available 2-drug combinations of these (24)(76). Simultaneous administration of angiotensin-converting enzyme inhibitors and angiotensin receptor blockers is contraindicated. Beta-blockers on the other hand are generally not recommended as first line agents except in patients with a history of ischaemic heart disease or heart failure (24)(76).

2.14 Individualised therapy for hypertension

Individualised therapy is proposed for pharmacological treatment for hypertension. However, to the best of my knowledge, there is no discrimination for lifestyle

interventions based on race/ethnicity, age group, or other phenotypes. Spence and Ryner in their review (122) proposed determining the physiological drivers of hypertension to aid in individualisation of blood pressure lowering agents. This is particularly applicable in specific phenotypes thought to be the main drivers of hypertension in blacks. In patients with a Liddle phenotype, a potassium sparing diuretic (amiloride) is recommended. Similarly aldosterone antagonists are recommended for primary aldosteronism phenotype (122).

2.15 Barriers to management and control of hypertension: a focus on sub-Saharan Africa

The barriers to effective hypertension management in SSA are multiple and complex. To significantly reduce hypertension related burden, there is a need to improve the whole hypertension cascade of care - from awareness (through screening and diagnosis) to treatment (risk stratification and initiation of treatment) and control (monitoring, adherence and referral) (123).

The barriers to improving hypertension care occur at various levels. These barriers should be addressed to improve hypertension outcomes.

i) Individual-level: These barriers results from the asymptomatic nature of hypertension, the lack of understanding of its potentially serious consequences and the competing priorities around home and work, which often mean that people only seek care very late i.e., when they experience complications (124)(125)(126)(127). These barriers are compounded by misconceptions about the aetiology of the condition and the potential benefits of drug treatment.

ii) Provider-level: The barriers include poor communication between health care workers and patients. There is often a lack of skills and competencies of health workers especially in rural communities. The health facilities also lack sufficient basic resources e.g. blood pressure machines, to care for patients with hypertension (127).

iii) System-level: This includes barriers such as poor access to health care facilities, particularly in rural areas, with overcrowding at clinics and consequent long waiting times; limited, inconsistent or undersupply of antihypertensive medications; lack of affordability of treatment with poor coverage of national health insurance schemes; and underinvestment in health service capacity (128).

CHAPTER THREE: METHODS AND DATA COLLECTION PROCEDURES

3.1 Overview of the 2019 Gambia National Eye Health Survey (GNEHS)

The data used for this PhD thesis was collected as part of the nationally representative GNEHS which took place between February and July 2019. More detailed information on this survey has been published elsewhere (1) and in Appendix 1.

The main aim of the 2019 GNEHS was to assess the prevalence of vision impairment, blindness and its comorbidities, such as hypertension and diabetes and related risk factors, in a nationally representative population-based sample of adults aged 35 years or more in The Gambia. I led the design, planning and implementation of the NCD component of the survey. I also led the data analysis, interpretation, and writing of manuscripts related to NCDs for peer review and publications.

The survey was designed to allow for comparison to national estimates from similar surveys in 1986 and 1996 to assess changes over time. The 1986 and 1996 surveys were stratified to provide precise estimates of blindness in Western, Central and Eastern Gambia (Figure 5). However, in the interim period, substantial internal migration and urbanisation occurred in the Gambia thus limiting the utility of structuring the 2019 survey to provide comparable estimates across these three broad regions.

3.2 Sampling strategy

A multi-stage stratified cluster random sampling with probability proportional to size procedures to identify a nationally representative sample. The clusters were the

standard census enumeration areas, used by the Gambia Bureau of Statistics (GBoS) in the 2013 population census. The country was divided into 3 broad historical regions (Western, Central and Eastern) (map below).

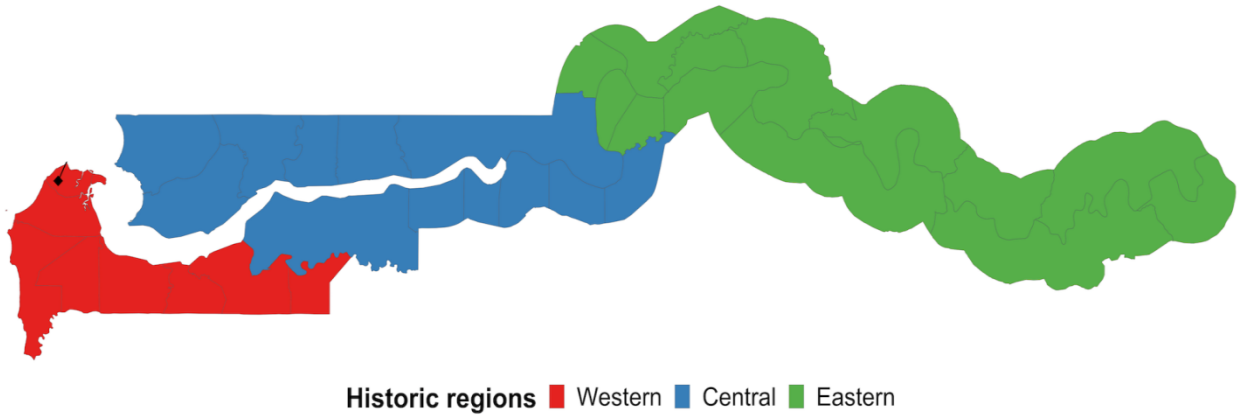

Figure 5: Map of The Gambia showing historic regions used in the 2019 GNEHS (Source: Hydara A et al. Wellcome Open Res. 2021:6:10) (1)

The 3 regions were stratified into an appropriate number of sampling strata reflective of urban and rural populations, according to GBoS benchmarks (129). The number of clusters in each stratum were selected to reflect the stratum size in relation to the regional population. Within each stratum, clusters were selected using probability proportionate to size sampling methods. Compact segment sampling was then used to divide the cluster into equal segments of approximately 30 people aged 35 years or more. A segment per cluster was then randomly selected.

3.3 Sample enumeration and data collection

The data was collected by 4 survey teams. There was an ophthalmologist, one optometrist or optometry technician, one senior ophthalmic medical assistant, one general nurse and two enumerators in each team.

Where geographically feasible, the enumerators in each team visited the cluster one to two days in advance of the data collection. They worked with a local guide to identify a central community location where participants were assembled for data collection. Following this, the enumerator and the local guide visited each household in the segment.

At each household, the purpose of the survey was explained verbally to the household head or an adult key informant by the enumerator using a pre-written study information sheet. Consent was sought from the household head or key informant and from each eligible household member. After obtaining informed consent from eligible household members, the enumerator recorded age, sex and relationship to household head. The eligibility was defined as meeting all the following criteria:

- Being at least 35 years old
- Residing in a selected segment
- Have lived in the household at least 6 months of the last year
- Eating shared meals with other household members
- Does not pay, and is not paid by, other household members

Enumerators visited each house within the segment door-to-door until 30 eligible participants had been recorded. If fewer than 30 eligible participants were identified within a segment, a second segment was selected at random to complete the cluster.

Eligible people who were not available after two repeat visits to the household were recorded as non-responders and their age and sex recorded where possible to allow comparison with responders.

On the day of the survey, the team first visited each household in the segment to take a fasting capillary blood glucose reading, before inviting participants to the central location where breakfast was provided prior to the rest of the survey assessment.

3.4 Summary of data collected used for this thesis

The 2019 GNEHS included a total of 9188 participants. The data collected in this survey primarily included information on eye health, but also included a significant component on non-communicable diseases including information on mental health, physical disability and other impairments. All data were electronically captured by a trained study staff using the Open Data Kit (ODK) application installed in Android tablets. Below is a summary of the data used for this PhD thesis.

1. A questionnaire was used to collect data on age, sex, highest level of education attained, self-attributed ethnic group, marital status, occupation, alcohol consumption, smoking status, wealth status, previous health personnel diagnoses of diabetes and hypertension and current medication use for diabetes and hypertension.

2. Anthropometry: Height was measured with the participants standing fully erect against a stadiometer (Leicester height measure, Birmingham, UK), without footwear or headwear, with the measurement taken to the nearest

0·1 centimetre. Weight was measured to the nearest 10 grams using portable weighing scales (Seca, Hamburg, Germany). Body mass index (BMI) was calculated as weight in kilograms (kg) divided by height in metres squared (m^2).

3. Blood pressure: This was measured with the participant seated after resting for at least 10 minutes and with their arm supported at the level of the heart and resting on a surface. Measurement was taken in triplicate using automated OMRON-Healthcare 10 Series blood pressure monitors (Omron, Kyoto, Japan). The blood pressure measurements were taken five minutes apart, and the average of the last two measures was used for analysis.

4. Capillary glucose: On the day of the survey, the team first visited each household in the segment to take fasting capillary glucose measurements (Accu-Chek Aviva, Roche Diagnostics, Germany with a detection range of 0.6mmol/L and 33.3mmol/L) before inviting participants to a central location where breakfast was provided prior to the rest of the survey assessment.

3.5 Definition of outcome variables and covariates of interest

Hypertension was defined as systolic blood pressure of ≥140mmHg or a diastolic blood pressure ≥90mmHg as per international guidelines(130) or a participant report of receiving medication for hypertension.

Diabetes was defined as elevated blood sugar level, categorised as a fasting blood glucose ≥7 millimoles per litre (mmol/L) or random blood glucose ≥11·1mmol/L or a

“yes” response to either of the following questions: “Have you ever been told by a doctor or nurse that you have diabetes?” or “Are you currently receiving treatment for diabetes?”.

Participants were classified as underweight (<18 kg/m^2), normal weight (18–24·9 kg/m^2), overweight (25–29·9 kg/m^2), and obese (≥30 kg/m^2), based on their calculated BMI.

Multimorbidity was defined as a co-occurrence of at least 2 conditions of hypertension, diabetes, and obesity in a participant.

Level of education was defined according to the highest level attained in either conventional school or madrassa (i.e. Arabic/Islam) system, pre-coded as: pre-school, madrassa (pre-school), primary (lower basic), madrassa (lower basic), secondary (upper basic, junior, senior), secondary (madrassa), higher (tertiary, university, college), vocational, non-standard curriculum. These were further categorised into pre-school/no school, primary, secondary/vocational, higher, don’t know/other, and non-formal/Quranic.

Data on occupation was obtained in pre-coded categories as professional/technical /managerial, clerical, sales and services, skilled manual, unskilled manual, domestic service, agriculture, and other. These were re-categorised as Unemployed, Manual, Trades, Professional, Other and Retired/Old age.

Ethnicity was categorised based on self-attribution to Gambian ethnic groups. We recorded marital status as never married, currently married, widowed or divorced.

Alcohol use was defined as self-report of any alcohol consumption in the past 12 months.

Smoking status was categorised, as reported by participants as never a smoker, current smoker, or past smoker.

3.6 Statistical considerations

3.6.1 Sample size

The sample size was calculated to enable detection of disease prevalence as low as 0.5% such as blindness with a 95% confidence level and a margin of error of 0.25%. Given that samples were drawn from clusters with an average of 30 individuals, a design effect of 2.5 was applied, assuming that samples were moderately clustered with an intraclass correlation coefficient (ICC) of 0.038. A 20% non-response/dropout rate was also factored in, resulting in the final sample size of 10,800.

3.6.2 Handling of missing data

The approach to handling of missing data has been previously described in the published survey protocol (1) and briefly described here. The potential bias with missing data of the wealth quintile was addressed by re-approaching respondents in clusters that had more than 50% missing data. As a result, all clusters in the survey had a higher than 50% response rate. For the remaining missing data in clusters that had more than 30 participants and less than 50% missing data, imputation was

conducted on each of the 12 socioeconomic questions that make up the wealth quantile with the most frequently observed value in the same cluster. The rationale for this approach was that we expected people living in the same cluster to have similar levels of socio-economic status. It should be noted that imputation was conducted only on the socio-economic status questions individually. Imputation was not done on any other variables in the study as missing data was minimised during the initial data collection stage. Sensitivity analysis showed that the imputation did not result in any systematic difference in the overall prevalence of vision impairment as well by the wealth quintile.

3.6.3 Data analysis approach

The final dataset included 9188 participants of whom 6478 (70.5%) were women and 2710 (29.5%) were women. This dataset was used in writing the papers on the prevalence of hypertension and major non-communicable diseases. However, given that the remaining manuscripts focussed on hypertension, the dataset used for them included 9171 participants after exclusion of 17 participants with missing hypertension or blood pressure data.

Considering the disproportionate female population in our sample and to ensure generalisability of study findings, sampling weights were applied according to the population distribution of the 2013 Gambia Population and Housing Census (131), to account for the difference in age, sex, cluster and location as has been previously described (1). The analysis approach for each of the objectives is detailed in the respective chapters.

3.7 Ethics approval

The study protocol was approved by the Joint MRC/Gambia Government Ethics Committee (SCC 1635) (Appendix 4) and the London School of Hygiene & Tropical Medicine Ethics Committee (Ref 16172) (Appendix 5). All participants provided a written informed consent prior to being enrolled in the study.

3.8 Additional survey information

Additional documents on the 2019 GNEHS such as informed consent sheet and study questionnaire are available on the Open Science Framework Registry using the following link: https://doi.org/10.17605/OSF.IO/EKCDT.

CHAPTER 4: PREVALENCE OF HYPERTENSION, DIABETES, OBESITY, MULTIMORBIDITY, AND RELATED RISK FACTORS AMONG ADULT GAMBIANS: A CROSS-SECTIONAL NATIONWIDE STUDY

Introduction to the chapter

This chapter aims to describe the prevalence of hypertension in Gambian adults. As hypertension is related to other NCDs and risk factors, the chapter also examines the prevalence of diabetes, obesity, multimorbidity and related risk factors (smoking and alcohol consumption). Prior to this study, there were two nationwide surveys which included both sexes in The Gambia that were conducted in 1996 and 2010, respectively including age ranges 15 years or more and 25–64 years. This chapter provides up-to-date data of major NCDs and assesses their variation by sex, location, and other socio-demographic characteristics.

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Student ID Number	1405219	**Title**	Dr
First Name(s)	Modou		
Surname/Family Name	Jobe		
Thesis Title	Epidemiological Investigation of hypertension in The Gambia: Evaluating the burden and management in a nationwide survey		
Primary Supervisor	Prof Andrew Prentice		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

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SECTION E

Student Signature	[redacted]
Date	8 January 2024

Supervisor Signature	[redacted]
Date	8 January 2024

Prevalence of hypertension, diabetes, obesity, multimorbidity, and related risk factors among adult Gambians: a cross-sectional nationwide study

Modou Jobe, Islay Mactaggart, Suzannah Bell, Min J Kim, Abba Hydara, Covadonga Bascaran, Modou Njai, Omar Badjie, Pablo Perel, Andrew M Prentice, Matthew J Burton

Summary

Background As countries progress through economic and demographic transition, chronic non-communicable diseases (NCDs) overtake a previous burden of infectious diseases. We investigated the prevalence of hypertension, diabetes, obesity, and multimorbidity in older adults in The Gambia.

Methods We embedded a survey on NCDs into the nationally representative 2019 Gambia National Eye Health Survey of adults aged 35 years or older. We measured anthropometrics, capillary blood glucose, and blood pressure together with sociodemographic information, personal and family health history, and information on smoking and alcohol consumption. Hypertension was defined as systolic blood pressure of 140 mmHg or more, diastolic blood pressure of 90 mmHg or more, or receiving treatment for hypertension. Diabetes was defined as fasting capillary blood glucose of 7 mmol/L or more, random blood glucose of 11·1mmol/L or more, or previous diagnosis or treatment for diabetes. Overweight was defined as BMI of 25–29·9 kg/m² and obesity as 30 kg/m² or more. Multimorbidity was defined as the coexistence of two or more conditions. We calculated weighted crude and adjusted estimates for each outcome by sex, residence, and selected sociodemographic factors.

Findings We analysed data from 9188 participants (5039 [54·8%] from urban areas, 6478 [70·5%] women). The prevalence of hypertension was 47·0%; 2259 (49·3%) women, 2052 (44·7%) men. The prevalence increased with age, increasing from 30% in those aged 35–45 years to over 75% in those aged 75 years and older. Overweight and obesity increased the odds of hypertension, and underweight reduced the odds. The prevalence of diabetes was 6·3% (322 [7·0%] women, 255 [5·6%] men), increasing from 3·8% in those aged 35–44 years to 9·1% in those aged 65–75 years, and then declining. Diabetes was much more common among urban residents, especially in women (peaking at 13% by age 65 years). Diabetes was strongly associated with BMI and wealth index. The prevalence of obesity was 12·0% and was notably higher in women than men (880 [20·2%] *vs* 170 [3·9%]). Multimorbidity was present in 932 (10·7%), and was more common in women than men (694 [15·9] *vs* 238 [5·5]). The prevalence of smoking was 9·7%; 5 (0·1%) women, 889 (19·3%) men. Alcohol consumption in the past year was negligible.

Interpretation We have documented high levels of NCDs and associated risk factors in Gambian adults. This presents a major stress on the country's fragile health system that requires an urgent, concerted, and targeted mutisectoral strategy.

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Introduction

The Sustainable Development Goal target 3.4 is a 33% reduction in premature mortality from non-communicable diseases (NCDs).[1] WHO adopted additional voluntary targets to reduce raised blood pressure by 25%, to halt the rise in diabetes and obesity, and to reduce tobacco use by 30% and harmful alcohol consumption by 10% by 2025.[2] A crucial step to addressing premature mortality from NCDs in countries, such as The Gambia, requires mapping their prevalence at the population level to identify high risk groups for targeted primary and secondary prevention.

The Gambia is a low-income country in West Africa that, like others in the subregion, is faced with a double burden of communicable and non-communicable diseases.[3] The country is undergoing substantial epidemiological, nutritional, and demographic transitions. These transitions, coupled with rapid unplanned urbanisation,[4] will most likely drive further increases in NCDs if left unchecked. The country's under-resourced health system was originally designed to manage infectious diseases. The country operates a three-tier health system, which is widely available to the population. The primary (eg, village and community clinics, and minor health facilities), secondary (eg, minor and major health centres, and regional hospitals) and tertiary (eg, general and teaching hospitals) levels of the national health system all provide care for NCDs at varying levels

Research in context

Evidence before this study

We did a literature search to identify cross-sectional population surveys in sub-Saharan Africa on the burden of hypertension, diabetes, obesity, and multimorbidity. We searched PubMed for articles using the search string "Africa South of the Sahara", "hypertension", "glucose metabolism disorders", "body mass index", "comorbidity", and "epidemiological studies", published between Jan 1, 1990, and July 1, 2022, without language restrictions. There have been several such published studies across sub-Saharan Africa. Prevalence of hypertension, diabetes, obesity, and multimorbidity, respectively, varied between studies, and there were variations in prevalence between sex and residence. There were few studies focusing on middle-aged and older adults. We found only two nationwide surveys including both sexes in The Gambia that were done in 1996 and 2010, including age ranges 15 years or more and 25–64 years, respectively. Besides none of these being recent studies and not focusing on middle-aged and older adults who are disproportionately affected by these chronic conditions, they also did not investigate the clustering of comorbidities. Our research set out to evaluate the prevalence of hypertension, diabetes, obesity, and multimorbidity in middle-aged and older adults in The Gambia.

Added value of this study

Our study provides urgently needed recent data on the prevalence of non-communicable diseases (NCDs) in adults aged 35 years or older in The Gambia. Our findings show a high prevalence of hypertension, diabetes, obesity, and multimorbidity in middle-aged and older adults. Hypertension was particularly high, higher in women than men, and similar in urban and rural areas. The prevalence of diabetes was similar in men and women overall, but women from urban areas were more affected than their rural counterparts, with men in both settings similarly affected. Obesity was five-fold higher in women than in men. Multimorbidity also disproportionately affected women, especially in urban areas. Smoking was almost exclusively in men whereas alcohol consumption was very low in both sexes.

Implications of all the available evidence

The high burden of NCDs and related risk factors is alarming for a country that is already struggling to control infectious diseases, as well as high maternal and under-five mortality rates. This high burden, coupled with overall increasing life-expectancy and rapid unplanned urbanisation, further highlights the need for urgent concerted multisectoral approach to NCDs in The Gambia. The country launched a multisectoral strategy and costed action plan in 2022 to tackle NCDs and this study will help to inform the delivery of this plan and similar local initiatives.

of quality.[5] These facilities, especially those at the primary level, generally do not have adequate human and infrastructural resources for prevention and treatment of NCDs, which increasingly account for a high burden of long-term illness and early death.[6]

Hypertension, diabetes, and obesity are major NCDs leading to complications, such as ischaemic heart disease, stroke, chronic kidney diseases, and cancers.[7] Their prevention and timely management should be a priority. This requires high-quality population-based data and up-to-date studies. The most recent of such studies in The Gambia was the 2010 WHO STEPS survey,[8] which included a much younger population and was limited in investigating issues, such as clustering of comorbidities. The present study provides up-to-date data with a particular focus on middle-aged and older adults who are disproportionately affected by NCDs.[9]

We report a large, nationally representative, cross-sectional study to assess the prevalence of hypertension, diabetes, obesity, multimorbidity, and related risk factors in adults aged 35 years or older in The Gambia.

Methods

Study design and participants

We embedded a survey on NCDs into the nationally representative 2019 Gambia National Eye Health Survey of adults aged 35 years or older. The detailed methodology is described elsewhere.[9] Briefly, between February and July, 2019, we used a multistage stratified cluster random sampling procedure. Clusters were the standard national census enumeration areas, used by The Gambia Bureau of Statistics in the 2013 Population and Housing Census. For the purposes of this survey, we divided the country into three broad historical regions (ie, western, central, and eastern). The three regions were stratified into urban and rural clusters according to The Gambia Bureau of Statistics definition (western: 43 rural and 173 urban; central: 44 rural and 12 urban; eastern: 71 rural and 17 urban).[4] Clusters were selected within each stratum using probability proportionate to size sampling methods. In the selected cluster, enumerators from the Gambia Bureau of Statistics listed all eligible participants and then grouped them into segments of 30 participants. A segment was then selected at random. The study protocol was approved by the Joint MRC–Gambia Government Ethics Committee (SCC 1635) and the London School of Hygiene & Tropical Medicine Ethics Committee (ref 16172).

Sample enumeration and data collection

The data were collected by four survey teams, each having one ophthalmologist, one optometrist or optometry technician, one senior ophthalmic medical assistant, one general nurse, and two enumerators. Study

staff were trained on study procedures and the questionnaire was pretested in a random sample of the population. Consent was sought from the household head or key informant, and from each eligible household member. Household members were considered eligible if they were aged at least 35 years, had lived in the household for at least 6 months of the previous year, ate shared meals with other household members, and did not pay, nor were paid by, other household members.

All consenting eligible household members were invited to attend the survey screening at an identified central community location the following day, and asked not to have breakfast on the survey day until after they had been visited at home by the team nurse.

Enumerators visited each household within the segment door-to-door until 30 eligible participants had been recorded. If the total number of 30 eligible participants was exceeded within a household, the required number of participants needed was selected at random. If fewer than 30 eligible participants were identified within the segment, a second segment was randomly selected to complete the cluster. Individuals were recorded as non-responders when they were not available after two repeated visits.

On the day of the survey, the team first visited each household in the segment to take a fasting capillary glucose measurement (Accu-Chek Aviva, Roche Diagnostics, Mannheim, Germany; detection range of 0·6 mmol/L and 33·3 mmol/L) before inviting participants to a central location where breakfast was provided before the remaining assessments. Sociodemographic and clinical information was electronically captured using the Open Data Kit application.

The questionnaire gathered data on age, sex, highest level of education, ethnic group, marital status, occupation, family history of hypertension, alcohol consumption, smoking status, wealth status, previous diagnoses of diabetes and hypertension, and current medication use for diabetes and hypertension.

Height was measured with the participants standing fully erect against a stadiometer (Leicester Height Measure, Birmingham, UK), without footwear or headwear, with the measurement to the nearest 0·1 cm. Weight was measured to the nearest 10 g (Seca, Hamburg, Germany). BMI was calculated as weight (kg) divided by height squared (m^2).

Blood pressure was measured with the participant seated after resting for at least 10 min and with their arm supported at the level of the heart and resting on a surface. Measurement was initially taken in each arm and then repeated in the arm with the higher reading with automated OMRON-Healthcare 10 Series blood pressure monitors (Omron, Kyoto, Japan). The blood pressure measurements were taken 5 min apart, and an average of the last two measures was recorded for analysis. The EquityTool, as previously reported, was used to calculate wealth status.[9,10]

Definition of outcome variables and covariates

We defined hypertension as systolic blood pressure of 140 mmHg or more, or a diastolic blood pressure of 90 mmHg or more, or a participant report of receiving medication for hypertension. Diabetes was defined as elevated blood sugar level, categorised as a fasting blood glucose of 7·0 mmol/L or more, or random blood glucose of 11·1 mmol/L or more, or a previous diagnosis or participant report of receiving treatment for diabetes. Participants who were identified with elevated blood pressure or elevated blood glucose, or both, were referred to the nearest health facility for further review and management.

Participants were classified as underweight (<18·0 kg/m^2), normal weight (18·0–24·9 kg/m^2), overweight (25·0–29·9 kg/m^2), and obese (≥30·0 kg/m^2), on the basis of their calculated BMI. We defined multimorbidity as a co-occurrence of at least two conditions of hypertension, diabetes, and obesity in a participant.

Level of education was defined according to the highest level attained in either a conventional school or madrassa (ie, Arabic or Islamic school). Data on occupation were categorised (from self-report) as unemployed, manual, trades, professional, other, and retired or due to old age. Ethnicity was categorised on the basis of self-attribution. We recorded marital status as never married, currently married, widowed, or divorced. Alcohol use was defined as any self-report of alcohol consumption in the past 12 months. Smoking status was categorised, as reported by participants, as never a smoker, current smoker, or past smoker.

Statistical analysis

Sample size was calculated to enable detection of disease prevalence as low as 0·5%, such as blindness with a 95% confidence level and a margin of error of 0·25%. Given that the samples were drawn from clusters with an average of 30 individuals, a design effect of 2·5 was applied, assuming that samples were moderately clustered with an intraclass correlation coefficient of 0·038. A 20% non-response or dropout rate was also factored in, resulting in the final sample size of 10800. During data collection, we addressed the potential bias with missing data of the wealth quantile by reapproaching respondents in clusters that had more than 50% missing data. As a result, all clusters in our survey had a higher than 50% response rate. For the remaining missing data in clusters that had more than 30 participants and less than 50% missing data, we did an imputation on each of the 12 socioeconomic questions that make up the wealth quantile with the most frequently observed value in the same cluster. The rationale for this approach was that we expected people living in the same cluster to have similar levels of socioeconomic status. It should be noted that we did an imputation only on the socioeconomic status questions individually. Imputation was not done on any

	All (n=9188)	Men (n=4598)	Women (n=4590)	Urban areas (n=5039)		Rural areas (n=4149)	
				Men (n=2339)	Women (n=2700)	Men (n=2255)	Women (n=1894)
Age, years	49·5 (0·18)	49·7 (0·25)	49·3 (0·22)	50·0 (0·39)	49·3 (0·33)	49·3 (0·28)	49·4 (0·36)
35–44	3995 (43·5%)	1952 (42·5%)	2043 (44·5%)	988 (42·2%)	1190 (44·1%)	962 (42·7%)	855 (45·1%)
45–54	2462 (26·8%)	1259 (27·4%)	1203 (26·2%)	604 (25·8%)	728 (27·0%)	653 (29·0%)	476 (25·1%)
55–64	1350 (14·7%)	715 (15·6%)	635 (13·8%)	392 (16·8%)	388 (14·4%)	323 (14·3%)	248 (13·1%)
65–74	808 (8·8%)	414 (9·0%)	394 (8·6%)	221 (9·4%)	211 (7·8%)	193 (8·6%)	183 (9·7%)
75–84	393 (4·3%)	184 (4·0%)	209 (4·6%)	99 (4·2%)	117 (4·3%)	85 (3·8%)	92 (4·9%)
≥85	180 (2·0%)	74 (1·6%)	106 (2·3%)	35 (1·5%)	66 (2·4%)	39 (1·7%)	40 (2·1%)
Level of education attained							
Preschool or no school	1611 (17·5%)	669 (14·5%)	942 (20·5%)	314 (13·4%)	564 (20·9%)	354 (15·7%)	379 (20·0%)
Primary	979 (10·7%)	511 (11·1%)	468 (10·2%)	279 (11·9%)	355 (13·1%)	231 (10·2%)	115 (6·1%)
Secondary or vocational	1543 (16·8%)	1051 (22·9%)	492 (10·7%)	723 (30·9%)	406 (15·0%)	331 (14·7%)	89 (4·7%)
Higher	403 (4·4%)	333 (7·2%)	70 (1·5%)	279 (11·9%)	65 (2·4%)	58 (2·6%)	6 (0·3%)
Do not know or other	154 (1·7%)	43 (0·9%)	111 (2·4%)	6 (0·3%)	47 (1·7%)	37 (1·6%)	64 (3·4%)
Non-formal or Quranic (Islamic)	4498 (49·0%)	1991 (43·3%)	2507 (54·6%)	738 (31·6%)	1263 (46·8%)	1243 (55·1%)	1241 (65·5%)
Ethnicity							
Mandinka	3423 (37·3%)	1573 (34·2%)	1849 (40·3%)	965 (41·3%)	1226 (45·4%)	611 (27·1%)	629 (33·2%)
Wollof	1361 (14·8%)	724 (15·7%)	637 (13·9%)	247 (10·6%)	286 (10·6%)	473 (21·0%)	349 (18·4%)
Jola or Karoninka	1029 (11·2%)	498 (10·8%)	531 (11·6%)	290 (12·4%)	373 (13·8%)	208 (9·2%)	160 (8·4%)
Fula, Tukulor, or Lorobo	2021 (22·0%)	1158 (25·2%)	862 (18·8%)	501 (21·4%)	416 (15·4%)	654 (29·0%)	444 (23·4%)
Sarahuleh	691 (7·5%)	311 (6·8%)	380 (8·3%)	121 (5·2%)	158 (5·9%)	188 (8·3%)	221 (11·7%)
Other	663 (7·2%)	333 (7·2%)	330 (7·2%)	214 (9·1%)	240 (8·9%)	120 (5·3%)	91 (4·8%)
Marital status							
Never married	208 (2·3%)	177 (3·8%)	31 (0·7%)	123 (5·3%)	27 (1·0%)	55 (2·4%)	4 (0·2%)
Married or living together	7817 (85·1%)	4324 (94·0%)	3494 (76·1%)	2147 (91·8%)	2008 (74·4%)	2170 (96·2%)	1488 (78·6%)
Widowed	992 (10·8%)	29 (0·6%)	963 (21·0%)	17 (0·7%)	577 (21·4%)	12 (0·5%)	387 (20·4%)
Divorced or separated	171 (1·9%)	69 (1·5%)	102 (2·2%)	51 (2·2%)	89 (3·3%)	18 (0·8%)	14 (0·7%)
Occupation							
Unemployed	1052 (11·4%)	365 (7·9%)	687 (15·0%)	268 (11·5%)	483 (17·9%)	98 (4·3%)	207 (10·9%)
Manual	4524 (49·2%)	1956 (42·5%)	2569 (56·0%)	442 (18·9%)	1104 (40·9%)	1496 (66·3%)	1456 (76·9%)
Trades	2569 (28·0%)	1492 (32·4%)	1077 (23·5%)	1122 (48·0%)	941 (34·9%)	378 (16·8%)	146 (7·7%)
Professional	650 (7·1%)	563 (12·2%)	87 (1·9%)	380 (16·2%)	76 (2·8%)	185 (8·2%)	12 (0·6%)
Other	163 (1·8%)	146 (3·2%)	17 (0·4%)	72 (3·1%)	12 (0·4%)	74 (3·3%)	5 (0·3%)
Retired or old age	229 (2·5%)	77 (1·7%)	152 (3·3%)	53 (2·3%)	84 (3·1%)	24 (1·1%)	68 (3·6%)
Wealth quintile							
1 (poorest)	870 (9·5%)	481 (10·5%)	389 (8·5%)	44 (1·9%)	29 (1·1%)	431 (19·1%)	356 (18·8%)
2	1418 (15·4%)	794 (17·3%)	624 (13·6%)	153 (6·5%)	126 (4·7%)	634 (28·1%)	492 (26·0%)
3	2238 (24·4%)	1176 (25·6%)	1062 (23·1%)	213 (9·1%)	203 (7·5%)	951 (42·2%)	848 (44·8%)
4	2141 (23·3%)	1039 (22·6%)	1102 (24·0%)	807 (34·5%)	912 (33·8%)	238 (10·6%)	198 (10·5%)
5 (richest)	2520 (27·4%)	1108 (24·1%)	1412 (30·8%)	1122 (48·0%)	1430 (53·0%)	0	0

Data are in mean (SE) or n (%).

Table 1: **Age and sex-standardised sociodemographic characteristics of participants weighted for cluster size**

other variables in the study because we minimised missing data during the initial data collection stage. Sensitivity analysis (appendix 1 p 4) showed that the imputation did not result in any systematic difference in the overall prevalence of vision impairment as well by the wealth quintile. The approach to handling of missing data in the present study has been described in detail elsewhere[9] and in appendix 1. We accounted for the multistage sampling survey design in the analysis. In the present analysis, we estimated the prevalence rates of hypertension, diabetes, obesity, multimorbidity, and other risk factors, such as smoking and alcohol consumption, stratified by sex and residence (urban *vs* rural). Prevalence estimates of groups whose 95% CIs

See Online for appendix 1

	All (n=9188)	Men (n=4598)	Women (n=4590)	Urban areas (n=5039)		Rural areas (n=4149)	
				Men (n=2339)	Women (n=2700)	Men (n=2255)	Women (n=1894)
Hypertension status							
No	4856 (53·0%)	2535 (55·3%)	2321 (50·7%)	1317 (56·5%)	1374 (51·0%)	1216 (54·0%)	950 (50·3%)
Yes	4311 (47·0%)	2052 (44·7%)	2259 (49·3%)	1014 (43·5%)	1322 (49·0%)	1035 (46·0%)	939 (49·7%)
Missing*	21 (0·2%)	12 (0·3%)	9 (0·2%)	8 (0·4%)	4 (0·2%)	4 (0·2%)	5 (0·3%)
Diabetes status†							
No	8611 (93·7%)	4343 (94·5%)	4268 (93·0%)	2180 (93·2%)	2469 (91·4%)	2158 (95·7%)	1802 (95·2%)
Yes	577 (6·3%)	255 (5·6%)	322 (7·0%)	159 (6·8%)	232 (8·6%)	97 (4·3%)	92 (4·8%)
BMI							
Underweight	627 (7·2%)	382 (8·7%)	246 (5·6%)	153 (6·9%)	92 (3·6%)	227 (10·6%)	152 (8·5%)
Normal	4904 (56·2%)	2888 (66·0%)	2016 (46·2%)	1413 (63·4%)	1010 (39·1%)	1470 (68·7%)	1003 (56·3%)
Overweight	2151 (24·6%)	933 (21·3%)	1218 (27·9%)	563 (25·3%)	813 (31·5%)	372 (17·4%)	408 (22·9%)
Obese	1050 (12·0%)	170 (3·9%)	880 (20·2%)	100 (4·5%)	665 (25·8%)	71 (3·3%)	220 (12·3)
Missing*	455 (5·0%)	225 (4·9%)	230 (5·0%)	109 (4·7%)	119 (4·4%)	115 (5·1%)	111 (5·9%)
Number of conditions (hypertension, obesity, or diabetes)							
None	4117 (47·2%)	2290 (52·5%)	1826 (41·9%)	1177 (53·0%)	1023 (39·7%)	1111 (52·0%)	804 (45·1%)
One	3668 (42·1%)	1835 (42·1%)	1833 (42·1%)	916 (41·2%)	1045 (40·6%)	917 (42·9%)	789 (44·3%)
Two	853 (9·8%)	229 (5·2%)	624 (14·3%)	121 (5·4%)	449 (17·4%)	108 (5·1%)	178 (10·0%)
Three	79 (0·9%)	9·0 (0·2%)	70 (1·6%)	8 (0·4%)	60 (2·3%)	1 (<0·1%)	10 (0·6%)
Missing*	471 (5·1%)	235 (5·1%)	236 (5·1%)	116 (5·0%)	123 (4·6%)	119 (5·3%)	113 (5·9%)
Alcohol consumption‡							
Never	9087 (98·9%)	4523 (98·4%)	4564 (99·4%)	2292 (98·0%)	2693 (99·7%)	2226 (98·7%)	1877 (99·1%)
Ever	101 (1·1%)	75 (1·6%)	26 (0·6%)	47 (2·0%)	8 (0·3%)	29 (1·3%)	17 (0·9%)
Smoking status§							
Current smoker	894 (9·7%)	889 (19·3%)	5 (0·1%)	468 (20·0%)	1 (0·1%)	420 (18·6%)	4 (0·2%)
Never smoked	7611 (82·8%)	3028 (65·8%)	4584 (99·9%)	1507 (64·4%)	2699 (99·9%)	1517 (67·3%)	1890 (99·8%)
Previous smoker	682 (7·4%)	682 (14·8%)	1 (<0·1%)	364 (15·6%)	0	318 (14·1%)	0

Data are n (%). *Missing data are in n (%) of total participants and are not included in the calculation of prevalence estimates. †Defined as a fasting blood glucose level 7·0 mmol/L or more, random blood glucose of 11·1mmol/L or more, or self-reported history of health personnel diagnosis of diabetes or currently receiving treatment for diabetes. ‡Self-reported tobacco use. §Self-report of any alcohol consumption in the past 12 months.

Table 2: **Age and sex-standardised prevalence of hypertension, diabetes, obesity, multimorbidity and related risk factors weighted for cluster size**

did not overlap were regarded to be significantly different. Considering the disproportionate female population in our sample, sampling weights were applied according to the population distribution of the 2013 Gambia Population and Housing Census,[4] to account for the difference in age, sex, cluster, and location.[9] We used logistic regression to investigate the association between each outcome of interest and each potential explanatory variable, stratified by sex and residence. For the adjusted analysis, we used a conceptual framework in which we categorised risk factors for hypertension and diabetes into non-modifiable and contextual factors, assuming these influenced the modifiable factors (appendix 1 p 2). We therefore used this framework to determine factors for inclusion in adjusted models, with one model including non-modifiable and contextual factors (appendix 1 p 2) and fully adjusted model including modifiable factors in addition to non-modifiable and contextual factors. Stata software (version 17) was used for all statistical analysis.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

A total of 11127 participants were enumerated nationwide of whom 9788 took part in the survey. After exclusion of 600 participants with either missing household data or incomplete individual data, we included 9188 participants in the present analysis. The crude (unweighted) sociodemographic characteristics of the participants were previously reported[9] and

	Hypertension in men		Hypertension in women		Diabetes in men		Diabetes in women	
	Unadjusted	Adjusted*	Unadjusted	Adjusted*	Unadjusted	Adjusted*	Unadjusted	Adjusted*
Residence								
Urban	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Rural	1·11 (0·92–1·33)	1·34 (0·98–1·83)	1·03 (0·91–1·16)	1·15 (0·93–1·41)	0·62 (0·43–0·90)	1·31 (0·74–2·31)	0·54 (0·43–0·68)	0·81 (0·56–1·17)
Age group, years								
35–44	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
45–54	1·90 (1·52–2·39)	1·85 (1·46–2·35)	2·34 (2·07–2·64)	2·15 (1·88–2·46)	3·17 (1·81–5·56)	3·21 (1·79–5·75)	1·65 (1·27–2·13)	1·64 (1·24–2·17)
55–64	4·57 (3·64–5·73)	4·04 (3·16–5·15)	3·87 (3·31–4·52)	3·24 (2·72–3·87)	3·62 (2·07–6·32)	3·40 (1·91–6·04)	1·89 (1·45–2·47)	1·74 (1·26–2·40)
65–74	6·78 (5·27–8·71)	5·34 (4·09–6·98)	6·90 (5·47–8·71)	5·05 (3·81–6·69)	3·71 (2·09–6·57)	2·87 (1·49–5·53)	1·94 (1·38–2·71)	1·97 (1·23–3·15)
75–84	7·47 (5·19–10·76)	5·51 (3·59–8·47)	8·06 (5·91–10·98)	4·77 (3·29–6·94)	2·71 (1·31–5·61)	1·51 (0·62–3·72)	1·84 (1·14–2·96)	1·59 (0·81–3·14)
≥85	6·83 (3·79–12·33)	4·57 (2·11–9·91)	9·55 (4·80–19·02)	6·53 (2·65–16·11)	1·89 (0·53–6·69)	2·18 (0·54–8·75)	0·69 (0·16–2·91)	1·35 (0·24–7·65)
Level of education attained								
Preschool or no school	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Primary	0·60 (0·43–0·86)	0·85 (0·58–1·24)	0·62 (0·50–0·77)	0·94 (0·74–1·20)	0·46 (0·22–0·97)	0·50 (0·22–1·16)	1·28 (0·92–1·77)	1·23 (0·84–1·81)
Secondary or vocational	0·64 (0·47–0·85)	0·89 (0·65–1·23)	0·57 (0·46–0·70)	0·87 (0·68–1·12)	0·77 (0·46–1·30)	0·77 (0·41–1·43)	1·15 (0·81–1·62)	1·07 (0·71–1·62)
Higher	0·63 (0·42–0·94)	0·77 (0·49–1·23)	0·61 (0·40–0·95)	0·83 (0·49–1·41)	1·49 (0·73–3·02)	1·32 (0·54–3·24)	0·93 (0·37–2·31)	0·79 (0·26–2·38)
Do not know or other	1·81 (0·92–3·54)	1·05 (0·43–2·58)	1·13 (0·77–1·64)	1·35 (0·84–2·15)	1·23 (0·33–4·67)	1·75 (0·41–7·37)	0·66 (0·31–1·43)	0·77 (0·33–1·81)
Non-formal or Quranic (Islamic)	1·10 (0·84–1·43)	1·05 (0·80–1·38)	0·94 (0·81–1·08)	0·98 (0·83–1·16)	0·72 (0·46–1·12)	0·71 (0·43–1·16)	0·78 (0·60–1·02)	0·85 (0·62–1·16)
Ethnicity								
Mandinka	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Wollof	0·90 (0·69–1·18)	0·82 (0·61–1·10)	0·96 (0·80–1·15)	1·09 (0·90–1·34)	1·01 (0·63–1·63)	1·17 (0·70–1·95)	1·24 (0·92–1·67)	1·33 (0·96–1·85)
Jola or Karoninka	1·03 (0·76–1·41)	0·92 (0·65–1·29)	0·82 (0·69–0·97)	0·76 (0·63–0·92)	0·74 (0·41–1·34)	0·63 (0·31–1·26)	0·74 (0·50–1·10)	0·76 (0·51–1·12)
Fula, Tukulor, or Lorobo	0·92 (0·73–1·17)	0·93 (0·72–1·20)	1·03 (0·88–1·21)	1·22 (1·02–1·46)	0·83 (0·53–1·32)	1·08 (0·65–1·82)	0·80 (0·57–1·12)	0·97 (0·67–1·39)
Sarahuleh	1·58 (1·11–2·26)	1·56 (1·06–2·30)	1·45 (1·19–1·75)	1·59 (1·26–2·00)	0·85 (0·37–1·95)	1·08 (0·45–2·61)	0·84 (0·55–1·27)	0·89 (0·56–1·40)
Other	0·94 (0·62–1·42)	0·81 (0·52–1·28)	1·25 (0·99–1·57)	1·25 (0·95–1·65)	0·68 (0·31–1·48)	0·64 (0·29–1·45)	1·57 (1·05–2·34)	1·50 (1·00–2·27)
Marital status								
Never married	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Married or living together	2·10 (1·25–3·53)	1·14 (0·64–2·03)	1·60 (0·86–2·98)	1·34 (0·69–2·60)	4·51 (0·64–32·02)	2·92 (0·41–20·6)	0·72 (0·25–2·08)	1·21 (0·34–4·29)
Widowed	4·14 (1·20–14·03)	1·31 (0·30–5·76)	5·65 (2·99–10·67)	2·13 (1·09–4·16)	4·38 (0·26–73·54)	4·33 (0·22–85·37)	0·94 (0·33–2·70)	1·33 (0·37–4·77)
divorced or separated	1·99 (0·82–4·84)	1·28 (0·45–3·65)	1·78 (0·89–3·55)	1·43 (0·70–2·91)	6·62 (0·62–70·74)	3·02 (0·24–38·36)	1·54 (0·48–4·94)	1·74 (0·45–6·74)
Occupation								
Unemployed	2·32 (1·73–3·11)	1·49 (1·03–2·16)	0·40 (0·33–0·48)	1·35 (1·08–1·67)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Manual	1 (ref)	1 (ref)	1 (ref)	1 (ref)	0·48 (0·29–0·81)	0·58 (0·31–1·09)	0·63 (0·47–0·82)	0·85 (0·59–1·22)
Trades	0·66 (0·54–0·80)	0·88 (0·69–1·12)	0·37 (0·30–0·45)	0·91 (0·78–1·07)	0·75 (0·45–1·24)	0·91 (0·50–1·66)	1·01 (0·75–1·36)	1·01 (0·69–1·49)
Professional	0·64 (0·48–0·85)	0·98 (0·69–1·39)	0·36 (0·25–0·53)	1·28 (0·82–2·01)	0·85 (0·44–1·65)	0·88 (0·41–1·90)	0·81 (0·39–1·69)	0·87 (0·36–2·15)
Other	0·64 (0·34–1·18)	1·33 (0·88–2·01)	0·87 (0·35–2·15)	1·98 (0·63–6·18)	0·43 (0·13–1·45)	0·63 (0·16–2·56)	4·55 (1·97–10·51)	5·10 (1·94–13·43)
Retired or old age	3·75 (2·15–6·54)	1·17 (0·75–1·84)	2·39 (1·46–3·91)	1·64 (0·98–2·74)	1·46 (0·62–3·44)	1·56 (0·62–3·91)	1·01 (0·53–1·93)	1·09 (0·51–2·36)
Wealth quintile								
1 (poorest)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2	1·01 (0·73–1·41)	1·13 (0·78–1·65)	0·73 (0·58–0·94)	0·71 (0·54–0·92)	0·82 (0·33–2·04)	0·83 (0·33–2·11)	0·56 (0·35–0·92)	0·51 (0·31–0·84)
3	1·02 (0·74–1·41)	0·94 (0·66–1·35)	0·92 (0·73–1·16)	0·89 (0·69–1·14)	1·82 (0·76–4·35)	1·74 (0·71–4·27)	0·71 (0·48–1·04)	0·63 (0·42–0·93)
4	1·11 (0·81–1·53)	1·30 (0·86–1·97)	0·82 (0·65–1·04)	0·75 (0·56–1·01)	1·53 (0·62–3·79)	1·30 (0·51–3·32)	0·93 (0·65–1·35)	0·61 (0·40–0·93)
5 (richest)	0·97 (0·70–1·33)	1·15 (0·74–1·80)	0·93 (0·74–1·16)	0·89 (0·67–1·20)	2·92 (1·25–6·83)	2·73 (1·02–7·31)	1·61 (1·15–2·25)	0·95 (0·61–1·49)
BMI								
Underweight	0·78 (0·57–1·05)	0·63 (0·45–0·88)	0·82 (0·63–1·05)	0·65 (0·49–0·85)	1·01 (0·50–2·02)	1·16 (0·58–2·31)	0·57 (0·30–1·07)	0·56 (0·30–1·06)
Normal	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Overweight	1·51 (1·21–1·88)	1·64 (1·29–2·09)	1·24 (1·09–1·41)	1·47 (1·28–1·69)	1·87 (1·26–2·77)	1·60 (1·06–2·41)	1·41 (1·08–1·84)	1·26 (0·95–1·66)
Obese	1·88 (1·22–2·89)	1·81 (1·18–2·77)	1·98 (0·72–0·85)	2·58 (2·23–2·98)	2·00 (0·92–4·35)	1·50 (0·62–3·62)	2·09 (1·63–2·67)	1·69 (1·30–2·20)

(Table 3 continues on next page)

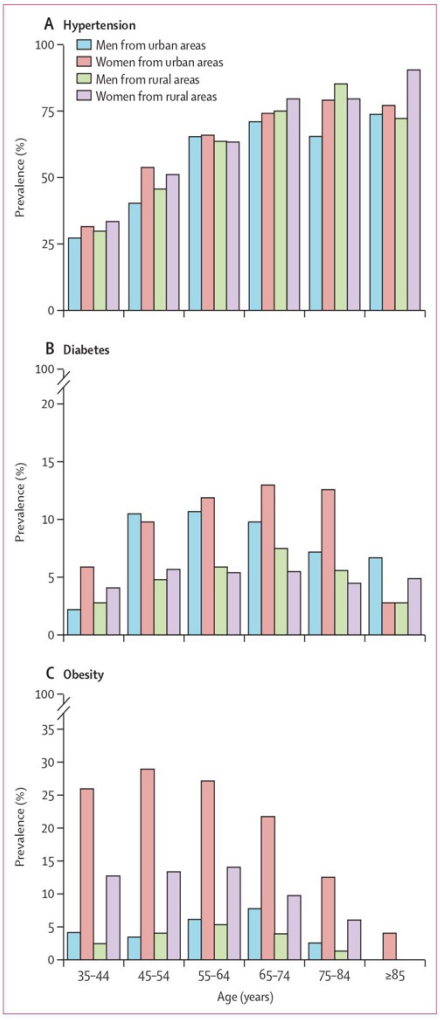

Figure: **Prevalence of obesity, hypertension, and diabetes by age group among adults aged 35 years or older in The Gambia**
Prevalence rates weighted for age, sex, and cluster size.

corresponding prevalences in men were 5·8% (4·6–7·1) and 5·1% (3·8–6·4). Very few people had all three conditions (0·9% [0·7–1·1] overall). The most common combination was hypertension and obesity, which was present in 7·2% (6·6–7·9), 12·2% (11·1–13·3) in women and 2·2% (1·6–2·8) in men. The combination of hypertension and diabetes was present in 4·2% (3·7–4·6); higher in women (4·9% [4·3–5·5]) than men (3·5% [2·8–4·1]). Obesity and diabetes coexisted in only 1·3% (1·0–1·5); 2·2% (1·8–2·6) in women and 0·3% (0·1–0·6) in men (table 2; appendix 1 pp 12–13).

Discussion

Our nationally representative survey recorded very high levels of hypertension, and concerning levels of obesity, diabetes, and multimorbidity in adults aged 35 years or older. Like many developing nations, The Gambia has made good progress in reducing the prevalence of many infectious diseases, and is on track to meet several health targets of the Sustainable Development Goals. Unfortunately, the pendulum is swinging from undernutrition to overnutrition, with its associated ill health.

There have been few nationally representative surveys to evaluate the burden of cardiovascular risk factors in The Gambia. Our study shows a higher burden of hypertension for similar age groups than the 2010 NCD WHO STEP survey,[8] possibly reflecting the pace of urbanisation, and changes in dietary patterns and lifestyle are occurring in The Gambia. Our data are similar to recent reports from neighbouring countries, such as Sierra Leone[11] and Senegal;[12] although, the Senegal study included a younger population. A nationwide survey in Guinea found nearly two-thirds of adults aged 44–64 years had hypertension.[13] The similar prevalence in urban–rural areas in our study was not consistent with the 2010 Gambia NCDs survey in which a significantly higher prevalence in rural areas was reported. This was in contrast with reports elsewhere in sub-Saharan Africa. A meta-analysis of 22 studies in West Africa showed lower odds of hypertension in rural locations.[14] In The Gambia where nearly 60% of the population reside in urban areas,[15] similar high dietary salt intake in urban and rural areas[16] might explain the similar prevalence. We observed a weak association between hypertension and wealth status. A multicentre study from 12 low-income and middle-income sub-Saharan African countries shows that the burden of hypertension is highest in individuals in lowest wealth groups in low-income countries.[17]

The prevalence of diabetes in The Gambia appears to be increasing, especially in rural areas. Compared with a 1997 survey, the prevalence in urban areas remains similar (7·9% in men and 8·7% woman in 1997 *vs* 6·8% and 8·6%, respectively, in 2019 as of current study). However, there is a marked increase in the prevalence of diabetes in rural areas (2·2% in men and 0·8% in women in 1997 *vs* 4·3% and 4·8%, respectively, in 2019).[18] This urban–rural difference in prevalence rates (possibly also applicable for obesity rates) could be due to higher availability and intake of sugars and processed foods in urban areas, and the higher physical activity levels in rural populations. A 2020 survey comparing contemporary prevalence estimates in Sierra Leone reported a diabetes prevalence of 3·5% in people over the age of 40 years.[11] The NCD Risk Factor Collaboration projected, for 2014, a prevalence of diabetes of 9·4% for men and 7·9% for women,[19] compared with 5·6% and 7·0%, respectively, in our survey. Our reported 2019

prevalence of 6·3% greatly exceeds the International Diabetes Federation's Diabetes Atlas 2019 estimates of 1·6% for The Gambia.[20] Although a useful source of information, the Diabetes Atlas has limitations, including extrapolation of data from countries with similar economy, language, and demography.

The high prevalence of obesity, especially in women, is consistent with the 2010 STEP survey in The Gambia.[21] Again, these contemporary estimates show a large increase compared with data from the late 1990s (2·3% nationwide).[22] Notwithstanding the complex causal drivers for the rise in prevalence in low-income and middle-income countries,[23] biocultural factors in our setting appear to be key determinants behind the higher prevalence observed among women. In a study in neighbouring Senegal, middle-aged and older women were found to value being overweight or obese more than their younger counterparts,[24] corroborating earlier findings in The Gambia, which additionally reported that women with an education tended to appreciate a small body size. Obesity in The Gambia is still commonly regarded as a sign of wealth, influence, and strength, especially among women.[25]

We are not aware of any previous studies on multimorbidity in The Gambia. Our data also shows high prevalence of NCDs multimorbidity in The Gambia, with women being disproportionately affected. Our study found a higher prevalence of multimorbidity than was found in Malawi (in a survey also including younger age groups), where the most common combination was also hypertension and obesity.[26] A systematic review of multimorbidity in South Africa found prevalence of multimorbidity depended on the age groups included, ranging from 3% to 23% in studies including participants aged 15 years or older, whereas this was between 30% and 70% in those aged 50 years or older.[27]

Hypertension rates are strongly associated with age, increasing from 30% at 35–45 years to 78% at 75 years or older. Obesity, diabetes, and multimorbidity showed the lowest rates at the extremes of ages—ie, younger than 45 years and older than 75 years. Lower prevalence of hypertension in older age groups might represent either a cohort effect (older adults matured before the main effects of social and economic transition were felt) or a healthy survivor effect (ie, that people without hypertension might live longer).

Both hypertension and diabetes were strongly associated with obesity in the unadjusted analysis. The association is attenuated by adjustment for modifiable, non-modifiable, and contextual factors. Although the association of diabetes with obesity is strong, the odds ratios are much lower than in some White populations in the USA.[28]

Despite its robust design and large sample size, our study should be considered with some limitations. We included only adults aged 35 years or older and hence might not be generalisable to the younger population who account for most of the population. Substitution of missing socioeconomic data with the most frequently observed value, adopted in our approach, might result in artificial reduction in variability of socioeconomic position levels within a cluster. Additional factors that were not collected in the present study, such as physical activity level, salt intake, sugar consumption, and access to food and health care, would have increased

	Men		Women	
	Unadjusted	Adjusted*	Unadjusted	Adjusted*
Residence				
Urban	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Rural	0·73 (0·44–1·21)	1·29 (0·66–2·55)	0·40 (0·33–0·49)	0·71 (0·55–0·91)
Age group, years				
35–44	1 (ref)	1 (ref)	1 (ref)	1 (ref)
45–54	1·14 (0·62–2·09)	1·16 (0·63–2·17)	1·14 (0·96–1·36)	1·25 (1·04–1·49)
55–64	1·82 (1·03–3·20)	1·82 (0·97–3·40)	1·10 (0·90–1·34)	1·30 (1·04–1·63)
65–74	1·89 (1·02–3·48)	2·01 (0·99–4·08)	0·75 (0·58–0·97	1·00 (0·75–1·35)
75–84	0·58 (1·17–1·96)	0·74 (0·20–2·78)	0·41 (0·25–0·67)	0·56 (0·32–0·99)
≥85	..	..	0·11 (0·02–0·76)	0·15 (0·02–1·00)
Level of education attained				
Preschool or no school	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Primary	1·03 (0·39–2·72)	1·05 (0·39–2·80)	2·05 (1·57–2·66)	1·59 (1·22–2·05)
Secondary or vocational	0·92 (0·39–2·13)	0·87 (0·36–2·07)	1·89 (1·48–2·41)	1·35 (1·07–1·72)
Higher	2·19 (0·87–5·04)	1·92 (0·63–5·86)	2·61 (1·72–3·95)	1·69 (1·03–2·77)
Do not know or other	1·24 (0·15–9·97)	1·56 (0·18–13·34)	1·15 (0·71–1·87)	1·21 (0·73–1·99)
Non-formal or Quranic (Islamic)	1·28 (0·65–2·50)	1·33 (0·69–2·59)	0·88 (0·70–1·11)	0·90 (0·73–1·11)
Ethnicity				
Mandinka	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Wollof	0·52 (0·26–1·03)	0·48 (0·22–1·04)	0·89 (0·68–1·18)	0·94 (0·74–1·19)
Jola or Karoninka	0·60 (0·26–1·40)	0·57 (0·24–1·33)	1·20 (0·96–1·50)	1·12 (0·90–1·39)
Fula, Tukulor, or Lorobo	0·61 (0·33–1·13)	0·58 (0·13–1·12)	0·73 (0·57–0·92)	0·83 (0·66–1·04)
Sarahuleh	0·40 (0·14–1·16)	0·38 (0·13–1·13)	0·78 (0·57–1·06)	1·02 (0·76–1·37)
Other	0·92 (0·45–1·88)	0·97 (0·44–2·10)	1·45 (1·11–1·90)	1·18 (0·89–1·55)
Marital status				
Never married	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Married or living together	1·04 (0·31–3·54)	0·82 (0·23–2·93)	0·60 (0·32–1·14)	1·02 (0·54–1·93)
Widowed	2·98 (0·34–26·5)	4·24 (0·26–69·59)	0·46 (0·24–0·88)	0·93 (0·47–1·82)
Divorced or separated	1·00 (0·1–10·33)	1·08 (0·10–12·18)	1·48 (0·72–3·08)	1·73 (0·83–3·60)
Occupation				
Unemployed	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Manual	0·87 (0·39–1·93)	1·17 (0·47–2·87)	0·80 (0·64–1·01)	0·83 (0·65–1·05)
Trades	1·39 (0·65–2·96)	1·99 (0·86–4·59)	2·03 (1·60–2·57)	1·48 (1·16–1·90)
Professional	1·24 (0·51–2·99)	1·31 (0·43–3·99)	1·99 (1·30–3·05)	1·06 (0·63–1·78)
Other	0·72 (0·19–2·76)	1·23 (0·29–5·22)	1·51 (0·56–4·07)	1·23 (0·44–3·43)
Retired or old age	..	..	0·55 (0·31–0·96)	0·93 (0·52–1·64)
Wealth quintile				
1 (poorest)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
2	0·92 (0·35–2·78)	1·00 (0·37–2·73)	0·93 (0·64–1·35)	0·91 (0·62–1·34)
3	1·69 (0·71–4·03)	1·69 (0·68–4·16)	0·94 (0·65–1·35)	0·90 (0·62–1·29)
4	1·75 (0·67–4·55)	1·85 (0·69–5·00)	1·79 (1·26–3·42)	1·11 (0·76–1·60)
5 (richest)	2·08 (0·82–5·29)	1·94 (0·68–5·50)	2·44 (1·73–3·43)	1·30 (0·88–1·92)

(Table 4 continues on next page)

	Men		Women	
	Unadjusted	Adjusted*	Unadjusted	Adjusted*
(Continued from previous page)				
Alcohol consumption†				
Never	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Ever	1·15 (0·32–4·11)	1·00 (0·26–12·18)	0·96 (0·54–1·72)	1·14 (0·64–2·00)
Smoking status‡				
Current smoker	0·39 (0·19–0·80)	0·39 (0·19–0·82)	..	..
Never smoked	1 (ref)	1 (ref)	..	..
Previous smoker	0·98 (0·56–1·71)	0·98 (0·26–3·78)	..	..

Data are in OR (95% CI). *Adjusted for age, ethnicity, education, residence, wealth quintile, occupation, marital status, alcohol consumption, smoking, and BMI. †Self-report of any alcohol consumption in the past 12 months. ‡Self-reported smoking.

Table 4: **Association of risk factors with obesity in the study population, standardised for age and sex**

understanding of the drivers of these NCDs. Furthermore, we used capillary glucose, which is not considered as the gold standard for the assessment of diabetes status. Although this has been shown to be reliable and even performing better than HBA1C in some cases,[29] the estimates might be different from those obtained in clinical care. Finally, in estimating the burden of multimorbidity, we only included three conditions that will likely underestimate the true prevalence in The Gambia.

We have documented high prevalence of NCDs in The Gambia. Due to weak health systems in sub-Saharan Africa, hypertension and diabetes, and obesity and multimorbidity, generally lead to worse outcomes, including premature death. This high prevalence of NCDs and related risk factors presents a major, and likely growing, stress on fragile health systems, highlighting the need for a concerted multisectoral approach to NCDs.

Contributors

IM, AH, and MJB acquired funding. MJ, IM, SB, AH, AMP, and MJB conceived the study. MJ, IM, and MJK curated and validated the data. MJ, IM, SB, AH, AMP, and MJB designed and implemented the study. CB, MN, and OB supported the implementation of the study. MJ did the literature review, with support from AMP and PP. MJ and MJK did the analysis. AMP, MJB, IM, CB, MN, OB, and PP advised on analysis and interpretation of the data. MJ and AMP drafted the manuscript. IM, SB, MJK, AH, CB, MN, OB, PP, and MJB revised the manuscript. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Equitable partnership declaration

See Online for appendix 2

The authors of this paper have submitted an equitable partnership declaration (appendix 2). This statement allows researchers to describe how their work engages with researchers, communities, and environments in the countries of study. This statement is part of *The Lancet Global Health*'s broader goal to decolonise global health.

Declaration of interests

We declare no competing interests.

Data sharing

Survey content is available upon request. For any data requests, please contact Islay Mactaggart (islay.mactaggart@lshtm.ac.uk). Additional documents (eg, study questionnaire and informed consent sheet) are available are at https://doi.org/10.17605/OSF.IO/EKCDT.

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CHAPTER 5: EVALUATING THE HYPERTENSION CARE CASCADE IN MIDDLE-AGED AND OLDER ADULTS IN THE GAMBIA: FINDINGS FROM A NATIONWIDE SURVEY

Introduction to the chapter

This chapter evaluates the continuum of care for hypertension in adult Gambians to identify stages where health resources should be most effectively targeted. As previously stated, there have been two nationwide surveys assessing the prevalence of hypertension in The Gambia. Despite this, the awareness, treatment and control rates of hypertension have not been previously studied. This chapter is a comprehensive population-based assessment of the hypertension care cascade and associated factors in middle-aged and older adults in The Gambia. It seeks to identify gaps in the different stages of care to inform formulation of strategies for improvements.

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Evaluating the hypertension care cascade in middle-aged and older adults in The Gambia: findings from a nationwide survey

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Summary

Background Hypertension is a major public health problem in sub-Saharan Africa with poor treatment coverage and high case-fatality rates. This requires assessment of healthcare performance to identify areas where intervention is most needed. To identify areas where health resources should be most efficiently targeted, we assessed the hypertension care cascade i.e., loss and retention across the various stages of care, in Gambian adults aged 35 years and above.

Methods This study was embedded within the nationally representative 2019 Gambia National Eye Health Survey of adults ≥35 years. We constructed a hypertension care cascade with four categories: prevalence of hypertension (defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, and/or current use of medication prescribed for hypertension); those aware of their diagnosis; those treated; and those with a controlled blood pressure (defined as blood pressure <140/90 mmHg). Analyses were age- and sex-standardised to the population structure of The Gambia. Logistic regression was used to assess the socio-demographic factors associated with prevalence, awareness, treatment and control of hypertension.

Findings Of 9171 participants with data for blood pressure, the prevalence of hypertension was 47.0%. Among people with hypertension, the prevalence of awareness was 54.7%, the prevalence of hypertension treatment was 32.5%, and prevalence of control was 10.0% with little difference between urban and rural residence. The cascade of care performance was better in women. However, there was no difference in achieving blood pressure control between men and women who were receiving treatment. Female sex, older age and higher body mass index were associated with higher hypertension awareness whilst having an occupation compared to being unemployed was associated with higher odds of being treated. Patients in the underweight category had higher odds of achieving blood pressure control.

Interpretation There is a high prevalence of hypertension and low performance of the health care system that impact on the hypertension care cascade among middle-aged and older adults in The Gambia. Addressing the full cascade will be paramount especially in reducing the mounting prevalence and improving diagnosis of patients with hypertension, where the greatest dividends will be gained.

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Keywords: Hypertension; Cascade of care; Epidemiology; Prevalence; Awareness; Treatment; Control; The Gambia

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Research in context

Evidence before this study

We searched PubMed for articles using a combination of search terms "hypertension", "epidemiological studies", "cascade of care" and "Africa South of the Sahara" on 10th February 2023 with no language or date restriction. Despite the availability of studies on prevalence and determinants of hypertension in sub-Saharan Africa, there are only a few on the hypertension care cascade in middle aged and older adults who are disproportionately affected.

Added value of this study

Our study provides a comprehensive population-based assessment of the hypertension care cascade and associated factors in middle-aged and older adults in The Gambia for the first time. This study highlights a remarkably high prevalence of hypertension and a poor cascade of care performance in The Gambia.

Implications of all the available evidence

The findings of this large nationally representative study suggest an urgent need for a comprehensive hypertension strategy, including but not limited to increased public awareness campaign on hypertension, and adoption of healthy dietary and lifestyle strategies, complemented by meaningful government policies, training and recruitment of more healthcare personnel, as well as adopting task-shifting approaches to increase access to management of hypertension.

Introduction

Hypertension affects over 1.39 billion people globally, more than 75% of whom (1.04 billion people) live in low- and middle-income countries (LMICs).[1,2] Sub-Saharan Africa (SSA) is disproportionately affected compared to other LMICs.[3] The World Health Organisation estimates that 46% of the population aged 25 years and above in SSA have hypertension.[4] In SSA as elsewhere, hypertension poses significant direct and indirect economic costs to individual patients, their families and to national economies.[5–7]

The cascade of care framework is a metric used for assessing the retention and loss of patients respectively across the stages of care necessary for achieving a treatment outcome. It is widely used to identify and quantify care gaps in chronic infectious and non-communicable diseases such as HIV/AIDS,[8] tuberculosis,[9] hepatitis C[10] and diabetes.[11] The cascade of care has also been used to evaluate hypertension care and has been found to be poor across all LMIC settings. Data reported from 1.1 million participants living in 44 LMICs show an overall hypertension prevalence of 17.5%, among whom 39.2% were aware of their diagnosis, 29.9% had received treatment, and only 10.3% of these had their blood pressure adequately controlled.[5] In SSA however, control rates were less than 5% of patients in nearly two-thirds of countries[5] and was reported to be 4% in The Gambia according to data from the 2010 WHO STEPwise approach to NCD risk factor surveillance (STEPS survey).[12] According to Mills et al., high-income countries have approximately double the awareness (67.0% vs 37.9%) and treatment (55.6% vs 29.0%) rates and four times the rates of adequate blood pressure control among people with hypertension (28.4% vs 7.7%) compared to LMICs.[13] This therefore calls for action by all stakeholders to contribute to improving detection, diagnosis, management and control especially in SSA.[14]

Despite multiple studies on the prevalence and determinants of hypertension in The Gambia, there is no information on awareness, treatment and control of hypertension to the best of our knowledge. The Gambia recently launched a 5-year multi-sectoral strategic plan to reduce, among others, cardiovascular and other NCDs by one-third by 2027.[15] To achieve these objectives, there is a need for up-to-date evidence on hypertension care gaps to identify areas needing intervention, to assess performance level and formulate strategies for improvements. We conducted the present study in adults aged ≥35 years to determine the gaps in the hypertension care cascade and their associated factors in The Gambia.

Methods

The present analysis was part of a NCD survey embedded into the 2019 Gambia National Eye Health Survey. The detailed study protocol is reported elsewhere.[16] A multistage sampling strategy based on the 2013 Gambia Population and Housing Census data was used to identify a nationally representative sample of adults aged ≥35 years. The census enumeration areas were used as clusters, stratified into urban and rural. The clusters were selected to reflect the regional population using probability proportionate to size sampling methods. The selected clusters were segmented into groups of 30 participants. One group was subsequently selected at random. Detailed study information was provided to selected participants prior to obtaining a signed or thumb printed informed consent. They were subsequently invited to a central location on a given day for data collection.

The study protocol was approved by the Joint MRC/Gambia Government Ethics Committee (SCC 1635) and

the London School of Hygiene & Tropical Medicine Ethics Committee (Ref 16172).

Data collection procedures

Data were collected by trained study staff using a pre-tested questionnaire and captured electronically using the Open Data Kit (ODK) application installed on Android tablets. We collected socio-demographic (age, sex, highest level of education attained, ethnic group, marital status, occupation) and economic information from participants. We also collected data on cardiovascular risk factors such as smoking, alcohol consumption, history of hypertension and diabetes and current medication use for hypertension and diabetes.

We measured height to the nearest 0.1 cm with the participant standing fully erect against a portable stadiometer (Leicester Height Measure, Seca, Hamburg, Germany) and without footwear or headwear. Weight was measured to the nearest 0.01 kg using portable scales (Seca, Hamburg, Germany). Blood pressure was measured with the participant seated after resting for at least 10 min, with their arm supported at the level of the heart and resting on a surface. Measurement was taken in triplicate using automated OMRON-Healthcare 10 Series blood pressure monitors. The blood pressure measurements were taken 5 min apart, and the average of the last two measurements was used for analysis.

Explanatory variables

Males and females were categorised into 6 age bands. Level of education was defined according to the highest level attained in either conventional school or the madrassa system, pre-coded as: pre-school, madrassa (pre-school), primary (lower basic), madrassa (lower basic), secondary (upper basic, junior, senior), secondary (madrassa), higher (tertiary, university, college), vocational, non-standard curriculum. These were further categorised into pre-school/no school, primary, secondary/vocational, higher, don't know/other, and non-formal/Quranic. Ethnicity was categorised based on which Gambian ethnic group participants identify themselves with. We recorded marital status as never married, currently married, widowed or divorced. Data on occupation was obtained in pre-coded categories as: professional/technical/managerial, clerical, sales and services, skilled manual, unskilled manual, domestic service, agriculture, and other. We further categorised this as Unemployed, Manual, Trades, Professional, Other and Retired/Old age. We used socio-economic data to calculate wealth quintiles using the EquityTool as previously described.[16,17] Alcohol use was defined as any self-report of alcohol consumption in the past 12 months. Smoking status was categorised, as self-reported by participants as never smoker, current smoker and past smoker. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. Based on BMI, participants were categorised as underweight (<18 kg/m^2), normal weight (18–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥30 kg/m^2).

Outcome variables

Hypertension was defined as systolic blood pressure of ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, ever diagnosed of hypertension, and/or current use of medication prescribed for hypertension. Participants were classified as aware if they reported having been diagnosed with hypertension by a health professional. Patients were regarded as treated if they reported currently receiving medication for hypertension. Patients with a systolic blood pressure of <140 mmHg and <90 mmHg were considered as having a controlled blood pressure and those not meeting these criteria as uncontrolled. We calculated this separately for the overall sample with hypertension regardless of treatment status for hypertension, and amongst those receiving treatment.

Statistical analysis

This was a nationwide eye health and comorbidities survey where the sample size was calculated to detect disease prevalence as low as 0.5% with a power of 80% and a confidence interval of 95%. Further information on sample size calculation is detailed elsewhere.[16]

We accounted for the multistage design and conducted weighting to account for age, sex, and the clusters of the sample. Poststratification sample weights were calculated to account for the disproportionate age-sex sampling by 5-year band. Sample weights were created to generalize the findings to the 2013 Gambia Census. All weights were then multiplied with the cluster selection probabilities. During data collection, we addressed the potential bias with missing data by re-approaching non-respondents in clusters that had more than 50% missing data. As a result, all clusters in our survey had a higher than 50% response rate. For the remaining missing data in clusters that had more than 30 participants and less than 50% missing data, we conducted imputation with the most frequently observed value in the same cluster. We confirmed that prevalence of vision impairment by wealth quintile remained similar before and after imputation. More information on weighting and the approach to handling missing data is reported elsewhere.[16] We estimated the prevalence of hypertension from the overall population, the prevalence of awareness among those with hypertension, the prevalence of treatment among those who were aware of their condition and the prevalence of control both among those on treatment and among all those with hypertension. Logistic regression was used to assess the factors associated with each outcome above. We then estimated the overall care cascade, keeping the denominator constant (population with hypertension) throughout in assessing the cumulative losses at each

	Total			Urban (N = 2382)		Rural (N = 2031)	
	All (N = 4413)	M (N = 2100)	W (N = 2313)	M (N = 1034)	W (N = 1348)	M (N = 1065)	W (N = 966)
Age (years)							
Mean (SE)	54.3 (0.3)	54.6 (0.4)	54.0 (0.3)	55.1 (0.6)	53.9 (0.4)	54.2 (0.5)	54.1 (0.5)
35–44	1246 (28.2%)	570 (27.1%)	676 (29.3%)	274 (26.5%)	382 (28.4%)	295 (27.7%)	294 (30.5%)
45–54	1203 (27.3%)	553 (26.4%)	649 (28.1%)	247 (23.9%)	399 (29.6%)	305 (28.7%)	251 (26.0%)
55–64	894 (20.3%)	472 (22.5%)	422 (18.3%)	260 (25.2%)	261 (19.4%)	212 (19.9%)	162 (16.8%)
65–74	619 (14.0%)	310 (14.7%)	309 (13.4%)	160 (15.5%)	159 (11.8%)	149 (14.0%)	149 (15.5%)
75–84	309 (7.0%)	140 (6.7%)	169 (7.3%)	65 (6.3%)	94 (7.0%)	75 (7.0%)	75 (7.8%)
85+	142 (3.2%)	56 (2.3%)	86 (3.7%)	27 (2.6%)	52 (3.9%)	29 (2.7%)	34 (3.6%)
Level of education attained							
Pre-school/no school	842 (19.1%)	331 (15.8%)	511 (22.1%)	161 (15.6%)	317 (23.5%)	169 (15.9%)	194 (20.1%)
Primary	386 (8.8%)	189 (9.0%)	197 (8.5%)	99 (9.6%)	152 (11.3%)	90 (8.4%)	46 (4.8%)
Secondary/vocational	594 (13.5%)	399 (19.0%)	195 (8.4%)	267 (25.9%)	161 (11.9%)	133 (12.5%)	35 (3.6%)
Higher	154 (3.5%)	125 (6.0%)	29 (1.3%)	107 (10.4%)	27 (2.0%)	19 (1.8%)	2 (0.3%)
Don't know/other	92 (2.1%)	28 (1.3%)	64 (2.8%)	5 (0.5%)	27 (2.0%)	23 (2.2%)	36 (3.4%)
Non-formal/Quranic	2346 (53.2%)	1029 (49.0%)	1317 (56.9%)	394 (38.1%)	665 (49.3%)	632 (59.3%)	652 (67.4%)
Ethnicity							
Mandinka	1640 (37.2%)	720 (34.3%)	920 (39.8%)	406 (39.2%)	598 (44.4%)	314 (29.5%)	324 (33.5%)
Wollof	624 (14.1%)	313 (14.9%)	310 (13.4%)	112 (10.8%)	147 (10.9%)	200 (18.8%)	163 (16.9%)
Jola/Karoninka	469 (10.6%)	232 (11.0%)	237 (10.3%)	144 (14.0%)	158 (11.7%)	88 (8.2%)	80 (8.3%)
Fula/Tukulor/Lorobo	945 (21.4%)	508 (24.2%)	437 (18.9%)	219 (21.2%)	219 (16.3%)	288 (27.1%)	217 (22.5%)
Sarahuleh	404 (9.2%)	179 (8.5%)	225 (9.7%)	59 (5.7%)	90 (6.6%)	119 (11.2%)	135 (14.0%)
Others	331 (7.5%)	148 (7.0%)	183 (7.9%)	93 (9.0%)	137 (10.1%)	55 (5.2%)	47 (4.9%)
Marital status							
Never married	62 (1.4%)	51 (2.4%)	10 (0.4%)	40 (3.9%)	8 (0.6%)	11 (1.1%)	2 (0.2%)
Married/living together	3540 (80.2%)	2000 (95.2%)	1540 (66.6%)	959 (92.8%)	883 (65.5%)	1039 (97.6%)	658 (68.1%)
Widowed	733 (16.6%)	18 (0.9%)	715 (30.9%)	11 (1.15%)	415 (65.5%)	7 (0.7%)	301 (31.1%)
Divorced/separated	79 (1.8%)	31 (1.5%)	48 (2.1%)	24 (2.3%)	42 (3.1%)	7 (0.7%)	6 (0.6%)
Occupation							
Unemployed	726 (16.5%)	253 (12.0%)	473 (20.5%)	183 (11.7%)	327 (24.3%)	70 (6.6%)	147 (15.2%)
Manual	2136 (48.4%)	952 (45.3%)	1184 (51.2%)	210 (20.4%)	502 (37.2%)	736 (69.1%)	680 (70.4%)
Trades	1046 (23.7%)	570 (27.1%)	476 (20.6%)	419 (40.5%)	408 (30.3%)	153 (14.4%)	71 (7.4%)
Professional	248 (5.6%)	210 (10.0%)	38 (1.7%)	144 (14.0%)	32 (2.4%)	67 (6.3%)	6 (0.6%)
Other	66 (1.5%)	55 (2.6%)	12 (0.5%)	35 (3.4%)	9 (0.6%)	20 (1.9%)	3 (0.3%)
Retired/old age	190 (4.3%)	61 (2.9%)	129 (5.6%)	42 (4.1%)	70 (5.2%)	19 (1.8%)	59 (6.1%)
Wealth quintile							
1 (Lowest)	423 (9.6%)	216 (10.3%)	207 (9.0%)	20 (1.9%)	13 (0.9%)	194 (18.3%)	193 (20.0%)
2	648 (14.7%)	361 (17.2%)	287 (12.4%)	61 (5.9%)	56 (4.2%)	298 (28.0%)	229 (23.7%)
3	1087 (24.6%)	538 (25.6%)	549 (23.8%)	88 (8.5%)	105 (7.8%)	446 (41.9%)	441 (45.6%)
4	1035 (23.4%)	497 (23.7%)	537 (23.2%)	373 (36.1%)	436 (32.3%)	126 (11.8%)	104 (10.8%)
5 (Highest)	1220 (27.6%)	487 (23.3%)	732 (31.7%)	492 (47.6%)	739 (54.8%)	0	0
BMI							
Mean (SE)	24.9 (0.1)	23.3 (0.1)	26.4 (0.1)	23.9 (0.2)	27.7 (0.2)	27.7 (0.2)	24.6 (0.2)
Underweight	236 (5.7%)	138 (7.1%)	98 (4.5%)	41 (4.3%)	40 (3.2%)	96 (9.7%)	57 (6.4%)
Normal	2132 (51.8%)	1227 (62.7%)	906 (41.9%)	575 (60.0%)	430 (34.0%)	650 (65.2%)	474 (52.9%)
Overweight	1106 (26.9%)	492 (25.2%)	614 (28.4%)	288 (30.0%)	394 (31.1%)	205 (20.6%)	221 (24.7%)
Obese	645 (15.7%)	100 (5.1%)	545 (25.2%)	55 (5.7%)	403 (31.8%)	45 (4.6%)	144 (16.1%)
Missing[a]	297 (6.7%)	145 (6.9%)	152 (6.6%)	78 (7.5%)	84 (6.2%)	67 (6.3%)	69 (7.1%)
Alcohol consumption in the past year							
Never	4355 (98.7%)	2058 (98.1%)	2297 (99.3%)	1004 (97.2%)	1343 (99.6%)	1051 (98.8%)	956 (98.9%)
Ever	58 (1.3%)	43 (2.0%)	16 (0.7%)	29 (2.8%)	5 (0.4%)	12 (1.3%)	10 (1.1%)

(Table 1 continues on next page)

	Total			Urban (N = 2382)		Rural (N = 2031)	
	All (N = 4413)	M (N = 2100)	W (N = 2313)	M (N = 1034)	W (N = 1348)	M (N = 1065)	W (N = 966)
(Continued from previous page)							
Smoking status							
Current smoker	308 (7.0%)	306 (14.6%)	2 (0.1%)	160 (15.5%)	0 (0.0%)	146 (13.7%)	2 (0.2%)
Never smoked	3765 (85.3%)	1454 (69.3%)	2311 (99.95)	687 (66.5%)	1348 (100%)	765 (71.9%)	964 (99.8%)
Previous smoker	340 (7.7%)	340 (16.2%)	0 (0.0%)	186 (18.0%)	0 (0.0%)	153 (14.4%)	0 (0.0%)

Data are in n (%); Abbreviations: M = men; W = women; SE = standard error. [a]Missing data are in n(%) of total participants, and are not included in calculation of prevalence estimates.

Table 1: **Age and sex-standardised socio-demographic characteristics of participants with hypertension weighted for cluster size.**

years (Table 2 and Fig. 1D and E). The biggest loss in the cascade of care in those aged ≥55 years was between treatment to achieving controlled BP being 34.2%, 39.5%, 44.9% and 41.0% in the age groups 55–64, 65–74, 75–84 and ≥ 85 years respectively. This was 14.2% and 28.3% respective among those aged 35–44 and 45–54 tears respectively (Supplementary Figure S1). Women were more likely to achieve adequate BP control [OR = 2.22 (1.55–3.15)] compared to men, but there was no difference between sexes when restricted to those on treatment. There was no variation in BP control in the overall population by age group. When this was compared among those receiving treatment, those in the older age categories were much less likely to achieve BP control compared to the 35–44-year group with odds ratios between 0.37 and 0.25 for those over 65 years. There appears to be no effect of higher BMI on BP control among those receiving treatment compared with those in the normal category, but underweight patients were more likely to achieve BP control [1.81 (1.06–3.07)] (Table 3).

Gaps in the hypertension care cascade

Among hypertensive patients, the prevalence of awareness was 54.7%, the prevalence of hypertension treatment was 32.5% and prevalence of control was 10.0%. Among men with hypertension, 43.6% were aware of their diagnosis, 29.4% receiving treatment and 6.8% had their BP controlled. In women, 64.8% were aware of their hypertension, 35.2% were receiving treatment and 13.0% with a controlled BP (Table 2 and Fig. 2). Of the total 93.2% of men who were lost in the care cascade, 56.4% were at the diagnosis stage, 14.2% at the treatment stage and 22.6% at the control stage of the cascade respectively. Among the 87% of women not achieving adequate control the corresponding losses were 35.2%, 29.6% and 22.2% respectively (Fig. 2).

Discussion

This nationally representative study found that nearly half of Gambian adults aged ≥35 years had hypertension. More than half of those were aware of their diagnosis of whom a little over two-thirds were receiving treatment for hypertension. However only 10% overall and nearly 25% of treated patients had a controlled blood pressure. This remarkably high prevalence and poor cascade of care performance calls for an urgent and concerted hypertension strategy to reduce a mounting cardiovascular diseases burden. This would be critical to prevent or delay target organ damage such as stroke and chronic kidney disease which are especially common among blacks with a tendency to affect the most productive base of the population.[18–20] Additionally, these complications will put further strain on the country's meagre health resources.[21]

The findings in our study are consistent with reports in other low-income countries.[5,22,23] High-income countries such as the United States and Canada have greatly improved hypertension prevention, detection and management through effective population strategies, improved healthcare access and blood pressure measurements.[24] The Gambia like others in the sub-region, have considerable challenges in implementing such comprehensive programmes. The health system continues to be plagued by inadequate and inequitable distribution of physicians, support services personnel, infrastructure and equipment.[25] There should therefore be a more consistent supply and maintenance of basic equipment such as blood pressure monitors for diagnosis and management of patients. Community-based programmes to improve hypertension control and increase awareness and education about hypertension and its risk factors, as being implemented in SSA,[26,27] may greatly improve outcomes. There is also a critical shortage of physicians to care for the large number of patients with the national health workforce index currently at 1.53 per 1000 population against the WHO's recommended 4.45 per 1000 population.[28] Our results do not show any difference at any stage of the care cascade by rural-urban location. In The Gambia where majority of population reside in urban areas, lifestyles are increasingly similar regardless of location. Travel between areas is common especially during the dry season when farming activities are at a minimum.

The prevalence of hypertension recorded in this study is considerably higher than previously reported in The Gambia. Though there have only been a few

Variable	Number of participants	Number of individuals with hypertension	Prevalence of hypertension (%)	Proportion with diagnosed hypertension (aware) (%)	Proportion of diagnosed patients receiving treatment (%)	Controlled	
						Among all hypertensives (%)	Among treated (%)
Overall	9171	4313	47.0 (45.6–48.5)	54.7 (52.8–56.6)	70.4 (67.6–73.3)	10.0 (9.0–11.1)	24.2 (22.0–26.4)
Sex							
Men	4589	2052	44.7 (42.4–47.0)	43.6 (40.5–46.8)	69.5 (65.1–73.9)	6.8 (5.3–8.2)	21.7 (17.5–25.9)
Women	4582	2261	49.3 (47.8–50.8)	64.8 (62.7–66.9)	71.0 (67.9–74.0)	13.0 (11.7–14.3)	25.6 (23.3–27.9)
Residence							
Urban	4966	2308	46.5 (44.7–48.3)	54.8 (52.3–57.3)	68.8 (64.7–73.0)	9.5 (8.2–10.9)	23.2 (20.3–26.1)
Rural	4204	2005	47.7 (45.3–50.0)	54.7 (51.8–57.5)	72.4 (68.4–76.4)	10.6 (9.0–12.3)	25.3 (21.9–28.7)
Age group							
35–44	3992	1218	30.5 (28.7–32.4)	42.0 (38.3–45.7)	60.9 (55.9–65.9)	11.3 (9.1–13.4)	37.0 (31.5–42.5)
45–54	2454	1175	47.9 (45.3–50.5)	56.4 (52.7–60.0)	69.6 (64.8–74.4)	10.9 (8.9–12.9)	25.9 (21.3–30.4)
55–64	1349	874	64.8 (62.2–67.3)	59.3 (56.1–62.6)	73.9 (69.9–77.8)	9.6 (7.7–11.5)	20.8 (16.9–24.6)
65–74	808	605	74.9 (72.0–77.7)	63.8 (60.3–67.4)	75.4 (71.0–79.8)	8.6 (6.5–10.6)	17.4 (13.6–21.3)
75–84	391	302	77.3 (73.2–81.4)	64.7 (59.3–70.1)	81.1 (75.4–86.8)	7.4 (4.5–10.2)	13.9 (8.7–19.0)
85+	177	139	78.3 (70.9–85.8)	62.6 (51.7–73.6)	76.5 (64.2–88.8)	7.2 (1.8–12.5)	15.8 (4.4–27.1)
Level of education attained							
Pre-school/no school	1612	823	51.0 (47.8–54.3)	59.7 (55.7–63.6)	82.4 (78.7–86.1)	11.0 (8.9–13.2)	20.8 (16.8–24.8)
Primary	979	377	38.5 (34.5–42.5)	50.0 (43.9–56.2)	69.2 (62.0–76.3)	12.3 (8.6–16.1)	31.9 (23.5–40.3)
Secondary/ vocational	1537	580	37.8 (34.5–41.0)	46.8 (41.7–52.0)	62.9 (55.9–70.0)	8.2 (5.8–10.7)	25.3 (18.3–32.4)
Higher	401	151	37.6 (31.0–44.1)	41.1 (31.3–50.8)	69.8 (55.4–84.2)	5.6 (0.9–10.3)	18.6 (4.3–32.9)
Don't know/other	155	89	57.9 (49.8–66.0)	58.5 (47.3–69.8)	78.0 (66.0–90.1)	14.5 (7.0–22.0)	34.8 (19.6–50.1)
Non-formal/Quranic	4488	2292	51.1 (49.0–53.1)	56.5 (54.0–59.0)	67.5 (63.8–71.3)	9.9 (8.5–11.3)	24.2 (21.3–27.1)
Ethnicity							
Mandinka	3413	1603	47.0 (44.9–49.0)	56.5 (53.7–59.4)	70.0 (66.0–74.0)	10.1 (8.4–11.7)	23.3 (19.9–26.6)
Wollof	1358	610	44.9 (41.4–48.4)	56.3 (51.5–61.0)	69.4 (63.6–75.2)	10.9 (7.8–14.0)	26.0 (19.8–32.1)
Jola/Karoninka	1026	459	44.7 (40.8–48.6)	48.8 (44.1–53.6)	65.9 (57.5–74.3)	9.1 (6.5–11.6)	26.0 (20.0–32.1)
Fula/Tukulor/ Lorobo	2019	924	45.7 (42.5–49.0)	51.1 (47.0–55.3)	68.9 (63.4–74.5)	9.9 (7.6–12.1)	26.1 (21.1–31.2)
Sarahuleh	692	395	57.2 (52.5–61.8)	57.0 (50.4–63.5)	78.6 (72.8–84.3)	11.0 (8.1–13.8)	23.0 (16.8–29.3)
Others	664	323	48.7 (42.9–54.6)	58.9 (51.5–66.4)	74.7 (64.6–84.7)	8.8 (5.7–11.9)	20.1 (13.7–26.4)
Marital status							
Never married	208	60	28.9 (19.7–38.0)	22.5 (7.5–37.6)	65.9 (39.0–92.9)	4.5 (−4.1–12.1)	25.2 (−16.6–67.0)
Married/living together	7804	3459	44.3 (42.7–45.9)	52.5 (50.3–54.6)	68.7 (65.6–71.9)	9.9 (8.7–11.0)	25.2 (22.6–27.7)
Widowed	988	716	72.5 (69.9–75.2)	69.4 (66.1–72.8)	77.5 (73.4–81.6)	11.4 (9.0–13.7)	20.7 (16.7–24.7)
Divorced/separated	171	77	45.1 (37.2–52.9)	45.0 (32.8–57.2)	67.9 (53.8–82.1)	8.5 (11.2–15.8)	24.7 (5.9–43.6)
Occupation							
Unemployed	1049	710	67.6 (64.5–70.7)	64.4 (60.4–68.3)	67.4 (62.0–72.8)	9.9 (7.6–12.2)	21.8 (17.2–26.4)
Manual	4518	2088	46.2 (44.2–48.2)	54.6 (51.8–57.4)	72.3 (69.0–75.5)	11.2 (9.7–12.6)	26.1 (23.0–29.2)
Trades	2565	1022	39.8 (37.4–42.3)	49.6 (45.3–53.9)	63.6 (58.3–68.9)	9.1 (7.1–11.0)	26.1 (21.2–30.9)
Professional	646	243	37.6 (32.5–42.7)	40.9 (32.5–49.3)	71.6 (60.6–82.6)	8.9 (4.4–13.4)	27.8 (15.4–40.3)
Other	163	65	39.6 (26.4–52.9)	47.4 (32.0–62.8)	94.2 (86.4–1.02)	6.2 (−0.2–12.7)	13.9 (−0.5–28.3)
Retired/old age	229	186	81.3 (76.1–86.4)	68.5 (61.0–76.0)	87.6 (81.3–94.0)	6.0 (2.4–9.5)	10.0 (4.3–15.6)
Wealth quintile							
1 (Lowest)	862	413	47.9 (43.2–52.6)	52.9 (47.0–58.8)	67.6 (59.1–76.0)	11.1 (7.1–15.2)	28.8 (20.5–37.2)
2	1419	634	44.7 (41.4–47.9)	53.9 (48.6–59.3)	67.0 (60.3–73.8)	8.6 (5.7–11.5)	22.2 (15.1–29.2)
3	2238	1063	47.5 (44.6–50.4)	55.4 (51.6–59.1)	75.6 (71.5–79.7)	11.8 (9.7–13.9)	26.4 (22.3–30.5)
4	2140	1011	47.2 (44.5–50.0)	56.5 (52.3–60.6)	68.4 (63.0–73.9)	9.1 (7.2–11.1)	21.8 (17.4–26.1)
5 (Highest)	2511	1192	47.5 (45.2–49.8)	53.8 (50.5–57.0)	70.3 (65.4–75.3)	9.6 (7.8–11.5)	23.7 (19.8–27.5)

(Table 2 continues on next page)

Variable	Number of participants	Number of individuals with hypertension	Prevalence of hypertension (%)	Proportion with diagnosed hypertension (aware) (%)	Proportion of diagnosed patients receiving treatment (%)	Controlled	
						Among all hypertensives (%)	Among treated (%)
(Continued from previous page)							
Alcohol consumption in the past year							
Never	9070	4256	46.9 (45.5–48.4)	54.9 (53.1–56.8)	70.3 (67.5–73.2)	10.1 (9.0–11.1)	24.2 (22.0–26.5)
Ever	101	57	56.3 (46.9–65.8)	38.8 (18.2–59.4)	83.4 (63.7–1.03)	6.0 (−0.5–12.5)	18.4 (3.8–33.0)
Smoking status							
Current smoker	894	301	33.7 (29.1–38.3)	31.5 (23.8–39.2)	69.9 (55.2–84.6)	6.7 (2.3–11.2)	29.2 (13.0–45.4)
Never smoked	7598	3680	48.4 (46.9–49.9)	57.3 (55.4–59.3)	70.0 (67.0–73.0)	10.4 (9.3–11.4)	23.9 (21.8–26.1)
Previous smoker	679	332	49.0 (43.1–54.9)	46.9 (38.4–55.3)	77.1 (68.4–85.7)	9.5 (5.4–13.5)	24.4 (14.0–34.7)
BMI							
Underweight	623	230	36.9 (32.0–41.8)	52.4 (44.4–60.3)	70.6 (61.1–80.1)	12.9 (7.6–18.3)	32.7 (21.0–44.4)
Normal	4893	2079	42.5 (40.6–44.4)	46.8 (44.2–49.3)	69.1 (65.3–72.8)	8.2 (7.0–9.5)	23.6 (20.4–26.8)
Overweight	2143	1079	50.3 (47.6–53.0)	58.3 (54.7–62.0)	71.8 (67.7–75.9)	10.1 (8.1–12.0)	22.4 (18.3–26.4)
Obese	1047	629	60.0 (57.2–62.9)	71.3 (67.8–74.8)	69.3 (64.6–74.0)	15.6 (12.9–18.4)	28.5 (24.0–32.9)

Table 2: **Age and sex-standardised prevalence, diagnosis, treatment, and control of hypertension by socio-demographic factors.**

nationally representative studies in The Gambia, the estimates are not directly comparable given the difference in age of participants included in the respective studies and the age standardisation in our study. The nationwide survey in 1997 including participants aged ≥15 years found a prevalence of 24.1%[29] whilst the prevalence in the 2010 STEPS survey including adults aged 25–64 years was 29%.[12] However, the findings are consistent with those of Akpa et al. in native Africans with a mean age of 48.5 years from 13 countries.[30]

Overall, we observed a better cascade of care performance in women compared to men. This could be attributed to the greater healthcare utilization by women compared to men as has been widely reported.[31–35] Compared to studies other low income settings such as in Senegal,[36] and Sierra Leone,[37] the overall control rates was similar in men and women, although women were more likely to be aware of their status. However, we observed that women in the older age categories (70 years and above) were less likely to be retained in the care process. This age group may be more vulnerable with possibly greater financial and other barriers to accessing healthcare.[38] Though our study found that women were more likely to be treated for hypertension, there was however no significant difference in the odds of achieving BP control. This is consistent with reports elsewhere[39,40] suggesting the need to explore a sex-specific approach for hypertension treatment owing to differences in presentation and progression.

The biggest loss in the hypertension care cascade in our study was from the stage of being hypertensive to being diagnosed. This was nearly half of all hypertensive patients, noting a higher loss in men (56.4%) than in women (35.2%). The proportion of undiagnosed hypertension was significantly higher in the 2010 STEPS survey (79% overall; 86% in men and 71.4% in women). This, as in our study, found younger populations to be disproportionately affected.[12] Perceptions and health-seeking behaviours of young people, especially as it differs from those of older generations, should be explored for more targeted intervention in sub-Saharan Africa. Johnson and colleagues, in exploring barriers to hypertension care in the United States found that young people did not usually take a hypertension diagnosis well and were surprised and angry about a hypertension diagnosis.[41] They generally expected to develop hypertension at a much older age and perceived that a hypertension diagnosis negatively altered their young identity.[41]

Our study as in the 2010 STEPS survey[12] found obese individuals to be more likely to have their hypertension status detected. This is not surprising given their greater contact with healthcare, due to the presence of comorbidities, and therefore they are more likely to be screened and diagnosed.[42,43]

We observed that the treatment coverage for hypertension i.e., diagnosed patients who were receiving treatment was relatively high at 70.4%. However, barriers to treatment in the remaining patients should be investigated and addressed. Socio-economic challenges could be a huge factor as medication for hypertension require usage in the long term and are generally beyond reach to many financially disadvantaged populations.[44] There is still limited knowledge or misunderstanding on hypertension in both patients and healthcare providers. A lot of patients fear initiating antihypertensive treatment and commonly resort to traditional practices even after being initiated on treatment, as has been reported in a study in 12 African countries.[45] The limited understanding and the asymptomatic nature of the

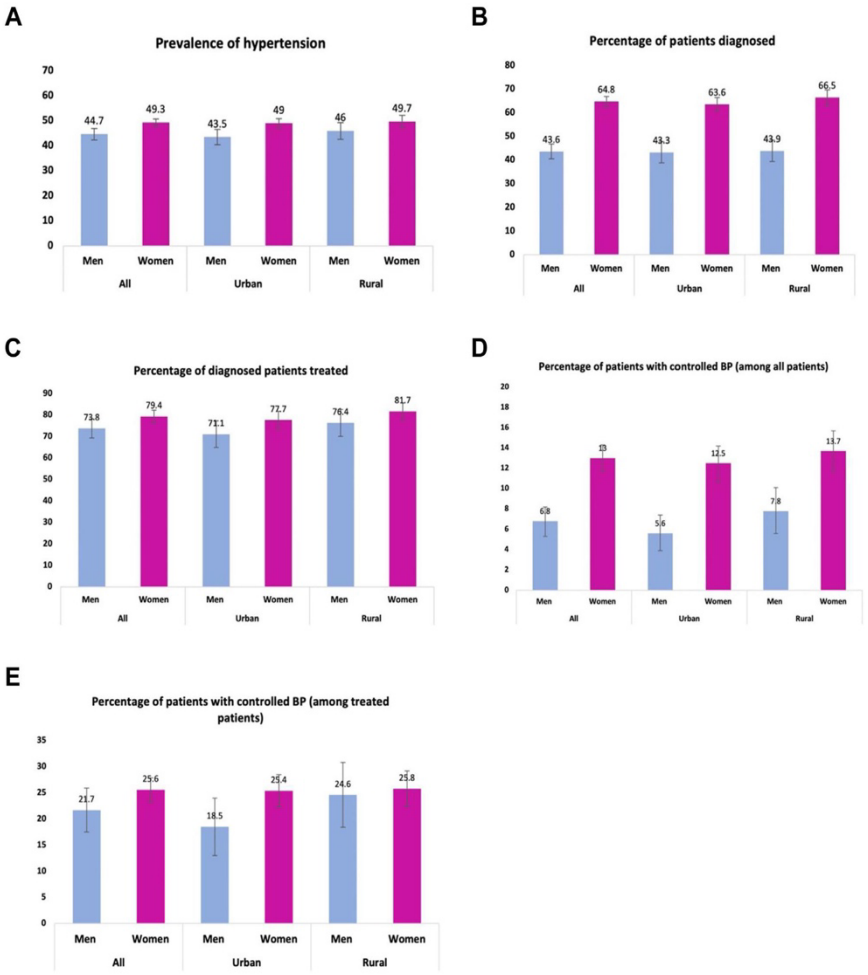

Fig. 1: Prevalence, diagnosis, treatment, and control of hypertension by sex and location. Figure uses age and sex standardised rates accounting for multistage sampling design. y-axis: percentage of participants.

condition also has a big impact on medication adherence.[46,47]

We found that only 10% of hypertensive patients and 24.2% of those receiving treatment had a controlled blood pressure. These respective rates in our study were higher than those observed in the sub-region. Macia et al. in older Senegalese adults of ≥50 years found 6.7% of hypertensives and 17.4% of treated patients to have a controlled blood pressure.[36] Geraedts et al. found these to be 5% and 11% respectively in Sierra Leoneans aged ≥18 years.[37] A meta-analysis of 33 surveys in sub-Saharan Africa with a mean age of 40 years found only 7% were retained in the hypertension care cascade.[48] Beyond offering treatment to patients, other factors limiting treatment success should be investigated. Commonly used guidelines for treating patients in sub-Saharan Africa are mostly extrapolations from data derived from the diaspora Africans in the United States. This requires caution as differences in socio-economic status, cardiovascular risk and response to antihypertensive drug treatment exist.[49] Other potential factors affecting treatment success

Variable	Prevalence of hypertension	Proportion with diagnosed hypertension	Proportion of hypertensive patients treated	Controlled	
				Among all hypertensives	Among treated
Sex					
Men	1	1	1	1	1
Women	0.88 (0.76–1.03)	2.15 (1.75–2.64)	1.85 (1.27–2.66)	2.22 (1.57–3.15)	1.21 (0.81–1.81)
Residence					
Urban	1	1	1	1	1
Rural	1.24 (1.02–1.52)	1.15 (0.88–1.51)	1.25 (0.76–2.06)	1.06 (0.76–1.47)	0.99 (0.69–1.41)
Age group (years)					
35–44	1	1	1	1	1
45–54	1.99 (1.75–2.27)	1.91 (1.54–2.36)	1.26 (0.88–1.79)	0.96 (0.71–1.30)	0.59 (0.42–0.83)
55–64	3.63 (3.12–4.23)	2.28 (1.81–2.87)	1.62 (1.10–2.39)	0.90 (0.64–1.27)	0.45 (0.31–0.65)
65–74	5.22 (4.32–6.31)	2.59 (1.97–3.41)	1.56 (0.99–2.39)	0.81 (0.56–1.18)	0.37 (0.23–0.57)
75–84	5.23 (3.94–6.95)	2.65 (1.85–3.80)	2.43 (1.34–4.39)	0.72 (0.40–1.30)	0.28 (0.15–0.53)
85+	5.57 (3.14–9.86)	1.95 (1.04–3.64)	2.99 (0.96–9.30)	0.57 (0.18–1.78)	0.25 (0.08–0.84)
Level of education attained					
Pre-school/no school	1	1	1	1	1
Primary	0.91 (0.72–1.15)	0.89 (0.65–1.21)	0.49 (0.30–0.82)	1.05 (0.69–1.59)	1.28 (0.82–1.99)
Secondary/vocational	0.91 (0.73–1.13)	0.94 (0.70–1.27)	0.35 (0.22–0.55)	0.75 (0.50–1.13)	1.04 (0.66–1.63)
Higher	0.79 (0.55–1.13)	0.91 (0.52–1.58)	0.41 (0.17–1.02)	0.50 (0.19–1.38)	0.52 (0.17–1.57)
Don't know/other	1.24 (0.78–1.95)	0.82 (0.52–1.29)	0.54 (0.22–1.29)	1.10 (0.56–2.15)	1.43 (0.68–3.02)
Non-formal/Quranic	1.01 (0.85–1.19)	0.89 (0.71–1.11)	0.33 (0.22–0.48)	0.82 (0.62–1.10)	1.17 (0.86–1.59)
Ethnicity					
Mandinka	1	1	1	1	1
Wollof	0.95 (0.80–1.14)	1.07 (0.84–1.37)	1.02 (0.69–1.52)	1.23 (0.87–1.74)	1.32 (0.94–1.85)
Jola/Karoninka	0.84 (0.69–1.01)	0.74 (0.57–0.94)	0.35 (0.22–0.55)	0.85 (0.61–1.18)	1.10 (0.78–1.55)
Fula/Tukulor/Lorobo	1.07 (0.91–1.26)	0.90 (0.72–1.13)	0.41 (0.17–1.02)	1.02 (0.73–1.42)	1.17 (0.83–1.65)
Sarahuleh	1.59 (1.26–2.00)	0.96 (0.70–1.32)	0.54 (0.22–1.29)	0.96 (0.68–1.37)	0.91 (0.60–1.37)
Others	1.01 (0.75–1.35)	0.99 (0.70–1.40)	0.33 (0.22–0.48)	0.85 (0.54–1.35)	0.81 (0.48–1.38)
Marital status					
Never married	1	1	1	1	1
Married/living together	1.19 (0.73–1.94)	1.72 (0.64–4.64)	0.42 (0.07–2.63)	1.57 (0.19–12.77)	1.18 (0.79–17.68)
Widowed	1.77 (1.05–2.99)	1.59 (0.58–4.34)	0.48 (0.08–3.01)	1.71 (0.21–14.03)	1.37 (0.91–21.05)
Divorced/separated	1.34 (0.72–2.48)	1.23 (0.40–3.78)	0.41 (0.56–3.04)	1.30 (0.13–13.37)	1.33 (0.07–23.66)
Occupation					
Unemployed	1	1	1	1	1
Manual	0.72 (0.60–0.87)	0.82 (0.64–1.04)	1.51 (1.06–2.16)	0.98 (0.68–1.40)	0.95 (0.65–1.40)
Trades	0.65 (0.53–0.79)	0.81 (0.61–1.06)	1.09 (0.73–1.61)	0.83 (0.56–1.23)	0.85 (0.56–1.28)
Professional	0.73 (0.54–1.00)	0.84 (0.53–1.33)	2.17 (1.03–4.57)	1.33 (0.63–2.81)	1.22 (0.53–2.78)
Other	0.59 (0.32–1.07)	1.12 (0.54–2.32)	7.75 (1.53–39.30)	0.67 (0.17–2.65)	0.33 (0.07–1.55)
Retired/old age	1.18 (0.78–1.77)	0.92 (0.59–1.44)	2.07 (0.84–5.09)	0.51 (0.25–1.06)	0.51 (0.25–1.07)
Wealth quintile					
1 (lowest)	1	1	1	1	1
2	0.93 (0.73–1.18)	1.23 (0.87–1.73)	1.07 (0.62–1.86)	0.83 (0.51–1.33)	0.61 (0.40–0.99)
3	0.93 (0.73–1.17)	1.06 (0.78–1.44)	1.82 (1.08–3.09)	1.14 (0.74–1.76)	0.93 (0.60–1.42)
4	1.01 (0.77–1.32)	1.19 (0.83–1.72)	1.35 (0.73–2.52)	0.87 (0.52–1.46)	0.72 (0.43–1.20)
5 (richest)	1.05 (0.79–1.39)	0.89 (0.61–1.31)	1.24 (0.65–2.38)	0.85 (0.50–1.45)	0.88 (0.52–1.49)
Alcohol consumption in the past year					
Never	1	1	1	1	1
Ever	1.38 (0.83–2.30)	0.76 (0.37–1.55)	2.19 (0.39–12.30)	0.98 (0.31–3.11)	1.08 (0.36–3.27)
Smoking status					
Current smoker	0.80 (0.63–1.02)	0.71 (0.47–1.07)	1.26 (0.55–2.91)	1.29 (0.58–2.84)	1.73 (0.77–3.89)
Never smoked	1	1	1	1	1
Previous smoker	1.07 (0.81–1.42)	1.05 (0.69–1.58)	1.86 (1.01–3.43)	1.75 (0.99–3.08)	1.52 (0.77–2.98)

(Table 3 continues on next page)

Variable	Prevalence of hypertension	Proportion with diagnosed hypertension	Proportion of hypertensive patients treated	Controlled	
				Among all hypertensives	Among treated
(Continued from previous page)					
BMI					
Underweight	0.65 (0.51–0.82)	1.17 (0.84–1.64)	1.24 (0.68–2.26)	1.82 (1.13–2.93)	1.81 (1.06–3.07)
Normal	1	1	1	1	1
Overweight	1.54 (1.34–1.76)	1.63 (1.37–1.95)	1.20 (0.91–1.58)	1.17 (0.89–1.53)	0.86 (0.65–1.14)
Obese	2.46 (2.13–2.84)	2.48 (2.01–3.08)	1.11 (0.81–1.51)	1.69 (1.27–2.26)	1.14 (0.83–1.55)

Table 3: **Mutually adjusted analysis of factors associated with prevalence, diagnosis, treatment, and control of hypertension by socio-demographic factors.**

could be lack of sufficient and constant supply of high-quality drugs, and where available, the level of adherence by patients. The latter could be improved by reducing pill burden through the provision of combination therapy.[50,51]

Our study has several strengths including the use of a nationally representative sample. However, the results should be considered in light of some limitations. We only included adults aged 35 years and above, so results are not generalisable to younger age groups. Diagnosis of hypertension also included an element of self-report as part of the composite definition of hypertension which may have introduced bias. Our inclusion of potential confounders in multivariate analysis may not be exhaustive and we cannot therefore rule out the possibility of residual confounding. Furthermore, we used only a cross-sectional measurement of blood pressure when current clinical approaches require several

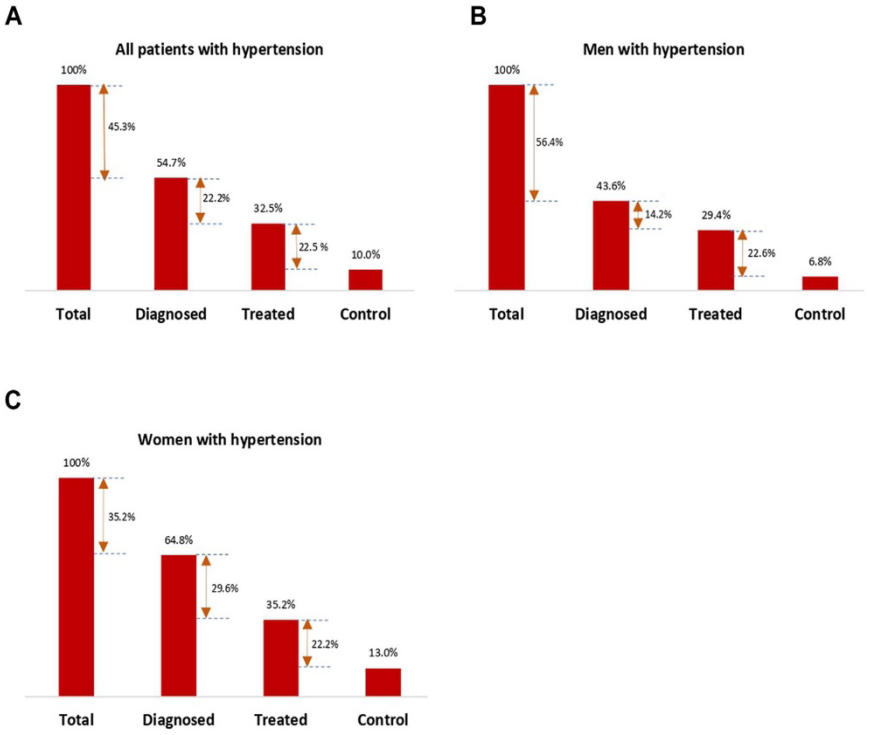

Fig. 2: Hypertension care cascade in The Gambia of adults aged 35 years and above. The numbers between bars represent percentage loss at each step of the cascade. Total = total participants with hypertension.

measurements at different timepoints. Our assessment also only considered drug treatment and did not include other lifestyle approaches. Furthermore, our assessment of treatment status for hypertension was based on participant report, and hence the possibility of recall bias could not be ruled out.

In conclusion, the data shows that improvements are required at all stages of the cascade. The greatest dividends will be gained in reducing the mounting prevalence and improving diagnosis of patients with hypertension, the stage where the greatest loss in the cascade occur. Currently, there are insufficient population approaches for hypertension prevention. The high prevalence of hypertension should therefore be addressed through a comprehensive national multisectoral strategy to increase public awareness about hypertension, as well as providing information on preventative methods including dietary and lifestyle modifications. Policies against the selling and consumption of sodium-rich, and energy dense foods respectively should be formulated and implemented. There should also be increased population screening for hypertension using a community-centred hypertension programme. Blood pressure monitors should be provided to health facilities to ease mass screening of patients and otherwise healthy population wishing to have their blood pressure measured. This will require training and recruitment of more healthcare personnel, as well as adopting task-shifting approaches to increase access to diagnosis and management of hypertension. There should also further research, besides greater efforts to improve adherence to understand reasons for low control rates among treated patients. Such research should systematically assess the health service and system structures, strengthen the evidence base for how to identify those who would benefit most from treatment and to find better approaches for risk stratification that will work in a low-income setting.

Contributors

MJB acquired the funding for this study. MJ, IM, AH, AMP and MJB conceived the study. MJ, IM and MJK curated and validated the data. MJ, IM, SB, AH, AMP, and MJB designed and implemented the study. OB supported the implementation of the study. MJ conducted the literature review, with support from AMP and PP. MJ and MJK performed the analysis. AMP, MJB, IM, OB, MB and PP advised on analysis and interpretation of the data. MJ drafted the manuscript. IM, SB, MJK, AH, MB, OB, PP, AMP and MJB revised the manuscript. All authors had final responsibility for the decision to submit for publication.

Data sharing statement

Survey content is available upon request. For any data requests, please contact Islay Mactaggart (Islay.Mactaggart@lshtm.ac.uk).

Declaration of interests

None.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2023.102226.

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CHAPTER 6: BLOOD PRESSURE AND THE HYPERTENSION CARE CASCADE IN THE GAMBIA: FINDINGS FROM A NATIONWIDE SURVEY

Introduction to the Chapter

This chapter builds on findings from the previous chapter. The hypertension cascade of care is a useful framework for assessing the prevalence of hypertension, the proportion of hypertensive patients who are aware of their condition, the proportion receiving treatment and those achieving the desired level of blood pressure control when treated. The framework however does not give insights into blood pressure levels of individuals at different stages of the care cascade. This chapter focuses on investigating blood pressure levels in different groups: i) individuals with a BP <140/90mmHg and with no self-reported history or treatment of hypertension ("normotensive"); ii) individuals with an elevated blood pressure (BP≥140/90mmHg) and no self-reported diagnosis or treatment for hypertension ("unaware"); iii) individuals with self-reported hypertension but not receiving treatment ("untreated"); and iv) individuals with self-reported hypertension who were receiving treatment ("treated").

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Blood pressure and the hypertension care cascade in The Gambia: findings from a nationwide survey

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Abstract

Background: Community treatment of hypertension in sub-Saharan Africa is hampered by gaps at several stages of the care cascade. We compared blood pressure (BP) levels (systolic, diastolic and pulse pressures) in four groups of participants by hypertension and treatment status: i) individuals with a BP <140/90mmHg and with no self-reported history or treatment of hypertension ("normotensive"); ii) individuals with an elevated blood pressure (BP≥140/90mmHg) and no self-reported diagnosis or treatment for hypertension ("unaware"); iii) individuals with self-reported hypertension but not receiving treatment ("untreated"); and iv) individuals with self-reported hypertension who were receiving treatment ("treated").

Methods: We conducted a nationally representative survey of adults 35 years and older using a multistage sampling strategy based on the 2013 Gambia Population and Housing Census. The census enumeration areas were used as clusters, stratified into urban and rural. BP was measured in triplicate using automated OMRON-Healthcare 10 Series BP monitors under standardised conditions. The BP measurements were taken in triplicate five minutes apart, and the average of the last two measurements was used for analysis. Systolic, diastolic BP levels and pulse pressure were compared by hypertension status using mean and 95% confidence intervals (CI).

Results: 53.1% of the sample were normotensive with mean systolic BP (SBP) of 119.2mmHg (95% CI, 118.7-119.6) and diastolic blood pressure (DBP) of 78.1mmHg (77.8-78.3). Among individuals with hypertension, mean SBP was 148.7 (147.7-149.7) among those unaware of their hypertension, 152.2mmHg (151-153.5) among treated individuals and was highest in untreated individuals at 159.3mmHg (157.3-161.2). The findings were similar for DBP levels, being 93.9mmHg (93.4-94.4) among the unaware, 95.1mmHg (94.4-95.8) among the treated and highest at 99.1mmHg (98.1-100.2) in untreated participants. SBP and DBP were higher in men, and systolic pressure was as expected higher in those aged ≥55 years. BP level was similar in urban and rural areas.

Conclusions: Our data shows high BP levels among participants with hypertension including those receiving treatment. Efforts to reduce the health burden of hypertension will require inputs at all levels of the care cascade.

Keywords: hypertension, blood pressure, pulse pressure, hypertension care cascade, sub-Saharan Africa

Background

Hypertension continues to be a major risk factor for cardiovascular disease and mortality globally [1,2,3]. It is highly prevalent in low- and middle-income countries especially in sub-Saharan Africa [4] and as such, poses significant direct impact on patients, their families and to national health services. The complications of hypertension in these countries are increasingly experienced by younger people who form the productive base of the economy. This can impede economic development and exacerbates poverty by diverting vital economic resources from other areas of national development [5–7].

Hypertension is frequently undetected, and untreated or sub-optimally treated [8]. Each of these scenarios is associated with complications. The access and quality of care for hypertension has been widely assessed with the cascade of care framework [9,10]. This framework provides important information on the prevalence of hypertension, the proportion of hypertensive patients who are aware of their condition, the proportion receiving treatment and those achieving the desired level of blood pressure control when treated [11]. This framework however does not give insights into blood pressure levels of individuals at different stages on the care cascade.

Elevated blood pressure levels, especially systolic, are a well-established factor for predicting cardiovascular risk [12–14]. A recent analysis of global data estimated that at age 50 years a 20mmHg increase in systolic blood pressure increases the risk of cardiovascular disease by approximately 60% and the risk of dying from all causes by 35-45% [3]. Previous studies have found a high prevalence of cardiovascular complications in individuals with hypertension regardless of awareness or treatment status [10]. However, the extent to which this occurs in sub-Saharan Africa where hypertension levels are often extremely high is unknown.

In the present study, we assessed and compared blood pressure and pulse pressure levels in normotensive individuals (those with a blood pressure <140/90mmHg and with no self-reported history or treatment of hypertension), individuals found with an elevated blood pressure level (≥140/90mmHg) but no previous diagnosis of hypertension or history of treatment ("unaware"), individuals with self-reported hypertension who were not receiving treatment ("untreated"), and individuals with self-reported hypertension who were receiving treatment ("treated"). We further examined this by age group, sex and urban/rural residence among adults aged ≥35 years in The Gambia.

Methods

We analysed data from a non-communicable disease (NCD) survey embedded in the 2019 Gambia National Eye Health Survey. The detailed study protocol is published elsewhere [15]. The survey identified a nationally representative sample of adults aged ≥35 years using a multistage sampling strategy based on the 2013 Gambia Population and Housing Census. The census enumeration areas were used as clusters, stratified into urban and rural. The clusters were selected to reflect the regional population using probability proportionate to size sampling methods. In the selected cluster, enumerators listed all eligible participants and then grouped them into segments of 30 participants. A segment was then selected at random by drawing a number out of a hat. Detailed study information was provided to selected participants prior to obtaining a signed or thumb printed informed consent. They were subsequently invited to a central location on a given day for data collection.

Data collection procedures

We collected data electronically using the Open Data Kit (ODK) platform installed on Android tablets. Prior to data collection, staff were trained on study procedures and the questionnaire was pre-tested in a sample of the general population. Consenting participants were interviewed to collect their socio-demographic and economic information. Men and women were categorised into 5 age bands. Level of education was defined according to the highest level attained in either conventional school or the madrassa system, pre-coded as: pre-school, madrassa (pre-school), primary (lower basic), madrassa (lower basic), secondary (upper basic, junior, senior), secondary (madrassa), higher (tertiary, university, college), vocational, non-standard curriculum. These were further categorised into pre-school/no school, primary, secondary/vocational, higher, don't know/other, and non-formal/Quranic. Ethnicity was categorised based on the Gambian ethnic group with which participants identify themselves. We recorded marital status as never married, currently married, widowed or divorced. Data on occupation was obtained in pre-coded categories as: professional/technical/managerial, clerical, sales and services, skilled manual, unskilled manual, domestic service, agriculture, and other. We further categorised this as unemployed, manual, trades, professional, other and retired/old age. We used socio-economic data to calculate wealth quintiles using the EquityTool as previously described [15,16]. We also collected information on smoking and alcohol consumption. We measured height to the nearest 0.1cm with the participant standing fully erect against a portable stadiometer (Leicester Height Measure, Seca, Hamburg, Germany) and without footwear or headwear. Weight was measured to the nearest 0.01kg using portable scales (Seca, Hamburg, Germany). Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. Based on BMI, participants were categorised as underweight (<18 kg/m^2), normal weight (18–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obese (≥30 kg/m^2).

Blood pressure was measured with the participant seated after resting for at least 10 minutes, with their arm supported at the level of the heart and resting on a surface. Measurement was

taken in triplicate using automated OMRON-Healthcare 10 Series blood pressure monitors (Omron, Kyoto, Japan). The blood pressure measurements were taken five minutes apart, and the average of the last two measurements was used for analysis.

Outcome variables

We classified individuals into 4 categories as follows: i) individuals with a normal blood pressure and no self-reported history or treatment of hypertension ("normotensive", see definition above) ii) individuals with an elevated blood pressure but without a self-reported history of hypertension ("unaware", see hypertension definition above) iii) individuals with a self-reported history of hypertension but not receiving treatment ("untreated") and iv) individuals with a self-reported history of hypertension and receiving treatment ("treated").

Statistical analysis

This was a nationwide eye health and comorbidities survey where the sample size ample size was calculated to detect disease prevalence as low as 0.5% (blindness) with a 95% confidence level and a margin of error of 0.25%. Given that samples will be selected from clusters of 40 persons each, a design effect of 2.5 was applied, assuming that samples will be moderately clustered with an intraclass correlation coefficient of 0.038. A 20% non-response/dropout rate was also applied, resulting in the final sample size of 10,800. Further information on sample size calculation is detailed elsewhere [15].

We compared the sample population with the target population on demographic indicators including sex, age and cluster. The survey oversampled women compared to men by more than twofold (70.3% women vs. 29.7% men). It also showed that selection probabilities were lower than expected in several age groups (5-year age band) and in clusters. Poststratification sample weights were calculated to account for the disproportionate sampling of one group

over another. The dataset was weighted to generalize the findings to the population of The Gambia according to the 2013 Population and Housing Census [17]. These weights were adjusted to ensure that sex and age (5-year age band) match those of the standard population. These weights were then multiplied with the cluster selection probabilities, provided that each cluster represents about 30 individuals.

We summarised the demographic characteristics of participants overall and by sex and location. We considered age of participants first as a continuous variable which was summarised using mean (standard deviation, SD). We then categorized age into 5 deciles and summarised it, as well as other categorical variables using count and proportion (column percentage). After weighting, we rounded up to the nearest integer for absolute frequencies. Percentages were calculated to one decimal place. Variables were then summarized by participant hypertension status where we used row percentages. Finally, we compared blood pressure levels by hypertension status group using mean and 95% confidence interval (CI). Data analyses were conducted using R (version 4.1.1).

Results

We enumerated a total of 11127 in this nationwide survey of whom 9788 (88%) took part. In the present analysis, we excluded 600 (6.1%) participants with either missing household data or incomplete data and a further 17 (0.2%) participants with missing hypertension data. A total of 9171 participants were therefore included in the present analysis. Table 1 shows the socio-demographic characteristics of the participants. Overall, after post-stratification weighting, we achieved approximately equal proportions of men (4589, 50%) and women (4582, 50.0%). More than half (54.1%) of the participants were urban residents. The mean age was 49.5 years (SD, 13) and was similar between men and women. The dominant age group was 35 to 44 years accounting for 42.5% of the men and 44.5% of the women; a similar

proportion in urban and rural areas. Overall, about half (48.9%) of the participants had non-formal education; more than half (54.6%) of women compared to men (43.3%). Participants with at least primary education accounted for 31.9% of the participants overall; 41.1% of the men and 22.4% of the women. The Mandinka ethnic group was the most common representing 37.2% of the sample whilst 22% belonged to the Fula ethnic group. Eighty-five percent of the participants were currently married and only 2.3% were never married. Manual occupation represented about half (49.3%) of the participants. Slightly less than ten percent (9.5%) of the participants were classified into poorest quintile compared to 27.4% into the richest quintile.

Table 2 shows the characteristics of the population by hypertension status. The majority (53.1%) of the participants were normotensive whilst 21.5% were unaware of their hypertension, 19.6% were receiving treatment and 5.8% were untreated. Whilst the proportion of men was higher in the normotensive and unaware categories, 64.2% of treated and 56.3% of untreated individuals were women.

Participants with normotension were younger with a mean age of 45.2 years (SD, 10.6) compared to the other groups. While most participants aged between 35 and 54 years did not have hypertension, only the minority of those aged 55 years and above were normotensive. For all categories of hypertension, the majority (61.4%) did not attain primary level of education or had non-formal education. Similarly, those in active occupation (manual occupation, trader, professional) formed the majority in all categories.

The mean SBP and DBP respectively in the overall population was 134.4mmHg (95% CI, 133.7-135.1) and 86.1mmHg (95% CI, 85.7 - 86.4). However, those without hypertension had

a mean SBP of 119.2mmHg (95%CI, 118.7-119.6) and a mean DBP of 78.1mmHg (95%CI, 77.8-78.3) (Table 3). The mean SBP was unsurprisingly highest among the untreated at 159.3mmHg (95%CI, 157.3-161.2) followed by those receiving treatment at 152.2mmHg (95%CI, 151-153.5) and was 148.7mmHg (95%CI, 147.7-149.7) among those unaware of their hypertension. A similar pattern was observed for DBP being 99.1mmHg (95%CI, 98.1-100.2) in the untreated, 95.1mmHg (95%CI, 94.4-95.8) in the treated and lowest at 93.9mmHg (95%CI, 93.4-94.4) among those unaware of their hypertension. Generally, and irrespective of hypertension status, men had higher SBP but not DBP. As for location, except for those unaware of their hypertension, the average SBP was similar across urban and rural areas. For those who were unaware of their hypertension, SBP was higher in rural versus urban areas. Irrespective of the hypertension status, average DBP was similar between rural and urban areas (Table 3).

We also compared pulse pressure between groups and found that this was significantly lower in those without hypertension at 41.1mmHg (95%CI, 40.7-41.5). Hypertensive individuals not receiving treatment had significantly wider pulse pressure at 60.1mmHg (95%CI, 58.3 - 62) compared to the other groups with hypertension. This was followed by the treated group and was lowest in those unaware of their hypertension. We observed a wider pulse pressure among men compared to women in all groups. The pulse pressure was essentially similar between urban and rural residents regardless of hypertension and treatment status (Table 3).

We observed an increasing SBP with age in all groups with hypertension (Figure 1). Those unaware of their hypertension in the youngest age group had significantly higher mean SBP compared to the other groups. As expected, there was widening pulse pressure with increasing age in all groups with hypertension. When we stratified blood pressure by age categories (<55 years vs ≥55 years), we observed significantly higher mean SBP in all

hypertension categories in those aged ≥55 years. This was not observed for DBP apart from among those untreated for their hypertension (Figure 2A and Figure 2B).

Discussion

In this nationally representative survey, hypertensive patients who were not receiving treatment had the highest mean blood pressure, followed by patients undergoing treatment and those who were unaware of their hypertension.

The association between elevated blood pressure, especially SBP, and cardiovascular risk is well established [3,18–21] and hence the very high prevalence of elevated blood pressure in our population is a cause for concern. There may be ongoing sub-clinical organ damage which either now, or in the future, will manifest as overt cardiovascular disease in the form of atherosclerosis, stroke, ischaemic heart disease or kidney disease.

The need for improved awareness and surveillance of hypertension is underscored by the fact that 58.3% of hypertensives were not receiving treatment; nearly half of whom were unaware that they had high blood pressure. The greatest public health benefit would derive from better identification of patients with hypertension and a successful treatment programme [22].

However, we found that patients receiving treatment still maintained high blood pressure levels. Excluding the possibility that treatment exacerbates the problem the most likely explanation is that treatments are only allocated to patients with extremely high BP and the treatment is only partially effective. A study of older persons (aged 60-69 years) in the United Kingdom found significantly higher blood pressure levels amongst individuals receiving

treatment compared to those not receiving treatment [23]. In Peru however, those unaware of their hypertension had the highest mean blood pressure, followed by the treated, then those aware but not receiving treatment [24]. Treatment failure in our study could be explained by several patient-related factors including poor adherence which might be related to side effects and local beliefs or misconceptions around hypertension [25–27], or a lack of awareness of the serious risks to their future health. Medication adherence is a vital component to treatment success which has been previously evaluated in The Gambia and found to be sub-optimal [28]. Other factors potentially influencing blood pressure control are lifestyle factors, such as weight control, dietary habits and physical activity levels [29–31]. Although these were not assessed in the present study, these factors may be more highly prevalent among treated hypertensive patients compared to the other groups.

Most of the available evidence is extrapolated from treatment of North Americans blacks. This may not be justified due to differences in cardiovascular risk, socio-economic status, and response to antihypertensive treatment between North American blacks and other blacks especially native Africans [32]. To the best of our knowledge there have only been 2 multi-country studies conducted exclusively on sub-Saharan African populations. These are the newer versus older antihypertensive agents in African hypertensive patients (NOAAH) trial [33] and Comparison of Three Combination Therapies in Lowering Blood Pressure in Black Africans (CREOLE) clinical trials [34]. The NOAAH trial found a combination of amlodipine/valsatan to be more effective at controlling systolic blood pressure compared to bisoprolol/hydrochlorothiziade in native Africans. In the CREOLE study, amlodipine plus either hydrochlorothiazide or perindopril was more effective than perindopril plus hydrochlorothiazide at lowering blood pressure at 6 months. From baseline, the reduction in systolic blood pressure in the latter study were -3.14 mm Hg (95% CI, -5.90 to -0.38; P=0.03), -3.00 mm Hg (95% CI, -5.81 to -0.20 mm Hg; P=0.04) and -0.14 mm Hg (95% CI, -2.90 to 2.61; P=0.92) respectively.

The quality of medicines dispensed to patients may also be a major factor leading to sub-optimal care. In a quality evaluation of 7 routinely used cardiac drugs in 10 sub-Saharan countries, 2 of the common antihypertensive agents (amlodipine and captopril) were found to be underdosed with the lowest ratio of measured to expected content of active ingredient of 49.2% [35]. In sub-Saharan Africa, factors such as shortage of medicines, high cost of medicines, busyness of doctors due to high patient load, lack of appropriate education and counselling services, poor patient-provider interaction, and long waiting times have been reported as possible factors [36,37].

There should be more localised data to understand determinants of and barriers to treatment uptake to adapt public health interventions to the local context. As reported elsewhere, these factors include patients being worried about the need to take medication for life, perceived side effects of drugs, loss to follow-up, and inadequate counselling from physician at the time of diagnosis [38,39,40,41]. Our study also highlights the need to identify factors leading to non-treatment of patients with hypertension. A lot of patients rely on traditional treatment methods whose effect has not been evaluated. There are suggestions that patients who are physically active, on a low salt diet, and current smokers had an increased chance of being untreated [42], which has not been evaluated in this setting.

Our study found a high proportion with undiagnosed hypertension with concerning levels of blood pressure. As reported in a separate analysis, young people, those without comorbidities or risk factors such as smoking are disproportionately under-diagnosed [22]. In young people and those without risk factors, perceptions, health-seeking behaviours, and level of contact with healthcare providers are therefore lower and hence are less likely to be screened and

diagnosed. This therefore calls for a better strategy of identifying hypertension in this population for targeted intervention.

The main strength of our study is the use of an age and sex-standardised analysis of a nationally representative sample. However, the findings should be considered with some limitations. The results are not generalisable to the general population given we only included adults aged 35 years and above. Furthermore, we used only a cross-sectional measurement of blood pressure when current clinical approaches require several measurements at different timepoints. Our assessment also only considered pharmacological treatment and did not include other lifestyle approaches.

Conclusion

The present analysis shows concerningly high levels of blood pressure in all groups with hypertension. This is particularly concerning in patients undergoing blood pressure treatment and calls for reinforcing treatment adherence, revisiting current pharmacological treatment guidelines as well as emphasising lifestyle interventions in patient management. A culturally sensitive comprehensive programme to improve treatment allocation of untreated cases as well as detection of undiagnosed cases should be developed and implemented.

List of abbreviations

BMI	body mass index
BP	blood pressure
CI	confidence interval
CREOLE	Comparison of Three Combination Therapies in Lowering Blood Pressure in Black Africans

DBP	diastolic blood pressure
NCD	non communicable diseases
NOAAH	newer versus older antihypertensive agents in African hypertensive patients trial
ODK	Open Data Kit
SBP	systolic blood pressure
SCC	Scientific Coordinating Committee
SD	Standard deviation

Declarations

Ethics approval and consent to participate

The study was approved by the Joint MRC/Gambia Government Ethics Committee (SCC 1635) and the London School of Hygiene & Tropical Medicine Ethics Committee (Ref 16172). Informed consent was obtained from all participants prior to any study procedures.

Availability of data and materials

Survey content is available upon request. For any data requests, please contact Islay Mactaggart (Islay.Mactaggart@lshtm.ac.uk).

Competing interests

None

Consent for publication

Not applicable

Declaration of Interests

None

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The funders of the study had no role in study design, data collection, analysis, data interpretation, writing the report or the decision to submit for publication.

Authors' contributions

MJB acquired the funding for this study. MJ, IM, AH, AMP and MJB conceived the study. MJ, IM and MJK curated and validated the data. MJ, IM, SB, AH, AMP, and MJB designed and implemented the study. OB supported the implementation of the study. MJ conducted the literature review, with support from AMP. MJ and GBK performed the analysis. AMP, MJB, MJK, IM, OB and advised on analysis and interpretation of the data. MJ and GBK drafted the manuscript. IM, SB, MJK, AH, OB, AMP and MJB revised the manuscript. All authors had final responsibility for the decision to submit for publication.

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Table 1: Socio-Demographic characteristics of participants

Characteristics	Total			Urban (N=4966)		Rural (N=4205)	
	All (9171)	M (N= 4589)	W (N=4582)	M (N=2302)	W (N=2664)	M (N=2286)	W (N=1919)
Mean age (SD)	49.5 (13)	49.7 (12.7)	49.3 (13.3)	50 (12.8)	49.3 (13.3)	49.3 (12.6)	49.3 (13.3)
Age Group							
35-44	3992 (43.5)	1951 (42.5)	2041 (44.5)	974 (42.3)	1174 (44.1)	977 (42.7)	867 (45.2)
45-54	2454 (26.8)	1252 (27.3)	1202 (26.2)	593 (25.8)	718 (27)	659 (28.8)	484 (25.2)
55-64	1349 (14.7)	714 (15.6)	635 (13.9)	386 (16.8)	383 (14.4)	328 (14.3)	252 (13.1)
65-74	808 (8.8)	414 (9)	393 (8.6)	218 (9.5)	208 (7.8)	196 (8.6)	185 (9.6)
75+	568 (6.2)	257 (5.6)	311 (6.8)	131 (5.7)	181 (6.8)	126 (5.5)	131 (6.8)
Level of education							
Pre-school/no school	1612 (17.6)	669 (14.6)	942 (20.6)	310 (13.5)	558 (20.9)	359 (15.7)	385 (20.1)
Primary	979 (10.7)	511 (11.1)	468 (10.2)	276 (12)	351 (13.2)	235 (10.3)	117 (6.1)
Secondary/ vocational)	1527 (16.7)	1043 (22.7)	484 (10.6)	706 (30.7)	396 (14.9)	337 (14.7)	88 (4.6)
Higher	410 (4.5)	336 (7.3)	74 (1.6)	278 (12.1)	67 (2.5)	59 (2.6)	7 (0.4)
Don't know/other	155 (1.7)	43 (0.9)	111 (2.4)	6 (0.3)	47 (1.8)	38 (1.7)	65 (3.4)
non-formal/Quranic	4488 (48.9)	1986 (43.3)	2502 (54.6)	727 (31.6)	1246 (46.8)	1259 (55.1)	1257 (65.5)
Ethnicity							
Mandinka/Jahanka	3413 (37.2)	1568 (34.2)	1845 (40.3)	949 (41.2)	1210 (45.4)	619 (27.1)	635 (33.1)
Wollof	1358 (14.8)	723 (15.8)	635 (13.9)	244 (10.6)	281 (10.6)	479 (21)	354 (18.4)
Jola/Karoninka	1026 (11.2)	496 (10.8)	530 (11.6)	284 (12.3)	368 (13.8)	211 (9.2)	162 (8.4)
Fula/Tukulor/Lorobo	2019 (22)	1157 (25.2)	862 (18.8)	493 (21.4)	411 (15.4)	664 (29)	451 (23.5)
Sarahuleh	692 (7.5)	311 (6.8)	380 (8.3)	120 (5.2)	156 (5.9)	191 (8.4)	225 (11.7)
Others	664 (7.2)	334 (7.3)	330 (7.2)	211 (9.2)	237 (8.9)	122 (5.3)	92 (4.8)
Marital status							
never married	208 (2.3)	177 (3.9)	31 (0.7)	122 (5.3)	26 (1)	56 (2.4)	5 (0.3)
married/living together	7804 (85.1)	4314 (94)	3490 (76.2)	2113 (91.8)	1981 (74.4)	2201 (96.2)	1510 (78.7)
widowed	988 (10.8)	29 (0.6)	959 (20.9)	17 (0.7)	569 (21.4)	12 (0.5)	390 (20.3)
divorced/ separated	171 (1.9)	69 (1.5)	102 (2.2)	50 (2.2)	88 (3.3)	18 (0.8)	14 (0.7)
Occupation							
Unemployed	1049 (11.4)	364 (7.9)	685 (14.9)	264 (11.5)	477 (17.9)	100 (4.4)	208 (10.8)
Manual	4518 (49.3)	1953 (42.6)	2565 (56)	436 (18.9)	1088 (40.9)	1518 (66.4)	1476 (77)
Trade	2565 (28)	1489 (32.5)	1076 (23.5)	1107 (48.1)	928 (34.8)	382 (16.7)	148 (7.7)
Professional	646 (7)	559 (12.2)	87 (1.9)	371 (16.1)	75 (2.8)	188 (8.2)	12 (0.6)
Other	163 (1.8)	146 (3.2)	17 (0.4)	71 (3.1)	12 (0.5)	75 (3.3)	5 (0.3)
Retired	229 (2.5)	77 (1.7)	152 (3.3)	53 (2.3)	83 (3.1)	24 (1)	69 (3.6)
Wealth quintile							
1 (Poorest)	862 (9.4)	478 (10.4)	385 (8.4)	43 (1.9)	28 (1.1)	434 (19)	357 (18.6)
2	1419 (15.5)	795 (17.3)	624 (13.6)	151 (6.6)	125 (4.7)	644 (28.2)	500 (26.1)
3	2238 (24.4)	1176 (25.6)	1062 (23.2)	211 (9.2)	201 (7.5)	966 (42.3)	861 (44.9)
4	2140 (23.3)	1039 (22.6)	1101 (24)	797 (34.6)	899 (33.7)	242 (10.6)	201 (10.5)
5 (Richest)	2511 (27.4)	1100 (24)	1411 (30.8)	1100 (47.8)	1411 (53)	0 (0)	0 (0)

Table 2: Socio-demographic characteristic of participants by hypertension status

Characteristics	All	Hypertension status				
		Normotensive (N=4869)	Untreated (N=535)	Treated (N= 1794)	Unaware (N=1973)	Missing
Sex						
Men	4589 (50)	2542 (52.2)	234 (43.7)	643 (35.8)	1168 (59.2)	0
Women	4582 (50)	2327 (47.8)	301 (56.3)	1151 (64.2)	805 (40.8)	
Location						
Urban	4966 (54.1)	2664 (54.7)	313 (58.5)	949 (52.9)	1047 (53.1)	0
Rural	4205 (45.9)	2205 (45.3)	222 (41.5)	844 (47.1)	926 (46.9)	
Age (years)						
Mean (SD)	49.5 (13)	45.2 (10.6)	54.5 (13)	56.6 (13.7)	52.1 (13.6)	0
Age group						
35-44	3992 (43.5)	2780 (57.1)	138 (25.8)	371 (20.7)	710 (36)	0
45-54	2454 (26.8)	1281 (26.3)	155 (29)	496 (27.6)	519 (26.3)	
55-64	1349 (14.7)	476 (9.8)	114 (21.3)	405 (22.6)	357 (18.1)	
65-74	808 (8.8)	204 (4.2)	83 (15.5)	298 (16.6)	222 (11.3)	
75+	568 (6.2)	127 (2.6)	45 (8.4)	224 (12.5)	165 (8.4)	
Level of education						
Pre-school/no school	1612 (17.6)	791 (16.2)	49 (9.2)	437 (24.4)	336 (17)	0
Primary	979 (10.7)	603 (12.4)	43 (8)	146 (8.1)	189 (9.6)	
Secondary/vocational)	1527 (16.7)	951 (19.5)	78 (14.6)	189 (10.5)	309 (15.7)	
Higher	410 (4.5)	258 (5.3)	17 (3.2)	46 (2.6)	90 (4.6)	
Don't know/other	155 (1.7)	65 (1.3)	9 (1.7)	37 (2.1)	40 (2)	
non-formal/Quranic	4488 (48.9)	2200 (45.2)	339 (63.4)	939 (52.3)	1008 (51.1)	
Ethnicity						
Mandinka/Jahanka	3413 (37.2)	1814 (37.3)	203 (38)	696 (38.8)	703 (35.6)	0
Wollof	1358 (14.8)	750 (15.4)	78 (14.6)	257 (14.3)	272 (13.8)	
Jola/Karoninka	1026 (11.2)	569 (11.7)	61 (11.4)	160 (8.9)	236 (12)	
Fula/Tukulor/Lorobo	2019 (22)	1098 (22.6)	118 (22.1)	349 (19.5)	455 (23)	
Sarahuleh	692 (7.5)	297 (6.1)	36 (6.7)	189 (10.5)	171 (8.7)	
Others	664 (7.2)	341 (7)	38 (7.1)	142 (7.9)	137 (6.9)	
Marital status						
never married	208 (2.3)	148 (3)	3 (0.6)	11 (0.6)	47 (2.4)	0
married/living together	7804 (85.1)	4355 (89.4)	434 (81.1)	1363 (76)	1657 (84)	
widowed	988 (10.8)	272 (5.6)	90 (16.8)	394 (22)	226 (11.5)	
divorced/separated	171 (1.9)	94 (1.9)	8 (1.5)	26 (1.4)	42 (2.1)	
Occupation						
Unemployed	1049 (11.4)	340 (7)	126 (23.6)	324 (18.1)	256 (13)	0
Manual	4518 (49.3)	2436 (50)	225 (42.1)	894 (49.8)	960 (48.7)	
Trade	2565 (28)	1547 (31.8)	151 (28.2)	357 (19.9)	517 (26.2)	
Professional	646 (7)	404 (8.3)	22 (4.1)	78 (4.3)	144 (7.3)	
Other	163 (1.8)	99 (2)	2 (0.4)	29 (1.6)	34 (1.7)	
Retired	229 (2.5)	43 (0.9)	9 (1.7)	112 (6.2)	62 (3.1)	
Wealth quintile						
1 (Poorest)	862 (9.4)	450 (9.2)	53 (9.9)	160 (8.9)	198 (10)	0
2	1419 (15.5)	787 (16.2)	90 (16.9)	246 (13.7)	296 (15)	

3	2238 (24.4)	1179 (24.2)	95 (17.8)	475 (26.5)	484 (24.5)	
4	2140 (23.3)	1131 (23.2)	141 (26.4)	426 (23.7)	443 (22.4)	
5 (Richest)	2511 (27.4)	1322 (27.2)	155 (29)	487 (27.1)	553 (28)	
BMI (kg/m2)						
Mean (SD)	24.2 (5.1)	23.5 (4.7)	25.9 (5.4)	25.8 (5.7)	24 (4.9)	467
Obesity						
No	7658 (88)	4280 (91.1)	391 (79.1)	1304 (79)	1681 (90.3)	467
Yes	1046 (12)	419 (8.9)	103 (20.9)	346 (21)	180 (9.7)	
Obesity						
underweight	623 (7.2)	394 (8.4)	24 (4.9)	91 (5.5)	112 (6)	465
normal	4893 (56.2)	2820 (60)	225 (45.6)	726 (44)	1119 (60.1)	
overweight	2143 (24.6)	1067 (22.7)	141 (28.6)	487 (29.5)	451 (24.2)	
obese	1047 (12)	419 (8.9)	103 (20.9)	346 (21)	181 (9.7)	

Table 3: Mean blood pressure (mmHg and 95% CI) according to hypertension status by sex and location

	All	Normal	Untreated	Treated	Unaware
			Systolic blood pressure, mmHg (95% confidence interval)		
Overall	134.4 (133.7-135.1)	119.2 (118.7-119.6)	159.3 (157.3 - 161.2)	152.2 (151 - 153.5)	148.7 (147.7 - 149.7)
Sex					
Men	135.5 (134.4 - 136.5)	121.4 (120.7-122)	162.4 (158.7 - 166.2)	155.9 (153.3 - 158.4)	149.5 (148.2 - 150.8)
Women	133.2 (132.5 - 134)	116.7 (116.3-117.2)	156.8 (154.7 - 159)	150.2 (148.9 - 151.6)	147.5 (146.2 - 148.8)
Location					
Urban	133.8 (133 - 134.7)	119.1 (118.5-119.6)	158.7 (156.3 - 161)	152.4 (150.6 - 154.1)	147.2 (146 - 148.4)
Rural	135 (133.8 - 136.1)	119.2 (118.6-119.9)	160.1 (156.7 - 163.5)	152.1 (150.2 - 154)	150.4 (148.9 - 151.9)
			Diastolic blood pressure, mmHg (95% confidence interval)		
Overall	86.1 (85.7 - 86.4)	78.1 (77.8 - 78.3)	99.1 (98.1 - 100.2)	95.1 (94.4 - 95.8)	93.9 (93.4 - 94.4)
Sex					
Men	85.7 (85.1 - 86.3)	78 (77.6 - 78.4)	100.1 (98.1 - 102.1)	96.5 (95 - 97.9)	93.7 (93 - 94.5)
Women	86.4 (86 - 86.8)	78.2 (77.9 - 78.4)	98.4 (97.4 - 99.4)	94.4 (93.7 - 95.1)	94.2 (93.5 - 94.8)
Location					
Urban	86 (85.5 - 86.4)	78.2 (77.9 - 78.6)	99.4 (98 - 100.7)	94.9 (94 - 95.9)	93.6 (92.9 - 94.3)
Rural	86.2 (85.5 - 86.8)	77.9 (77.5 - 78.3)	98.8 (97.2 - 100.4)	95.3 (94.3 - 96.4)	94.3 (93.5 - 95.1)
			Pulse pressure, mmHg (95% confidence interval)		
Overall	48.3 (47.8 - 48.8)	41.1 (40.7 - 41.5)	60.1 (58.3 - 62)	57.1 (56.1 - 58.1)	54.8 (53.9 - 55.7)
Sex					
Men	49.8 (49.1 - 50.4)	43.4 (42.8 - 43.9)	62.3 (59 - 65.7)	59.4 (57.7 - 61.1)	55.8 (54.6 - 56.9)
Women	46.8 (46.3 - 47.4)	38.6 (38.2 - 38.9)	58.5 (56.4 - 60.5)	55.9 (54.7 - 57)	53.3 (52.1 - 54.6)
Location					
Urban	47.9 (47.2 - 48.5)	40.9 (40.3 - 41.4)	59.3 (57.2 - 61.5)	57.4 (56 - 58.8)	53.6 (52.4 - 54.8)
Rural	48.8 (48.1 - 49.5)	41.3 (40.8 - 41.9)	61.3 (58.1 - 64.5)	56.8 (55.4 - 58.2)	56.1 (54.8 - 57.4)

Figure 1: Blood pressure level by hypertension treatment status and by age group

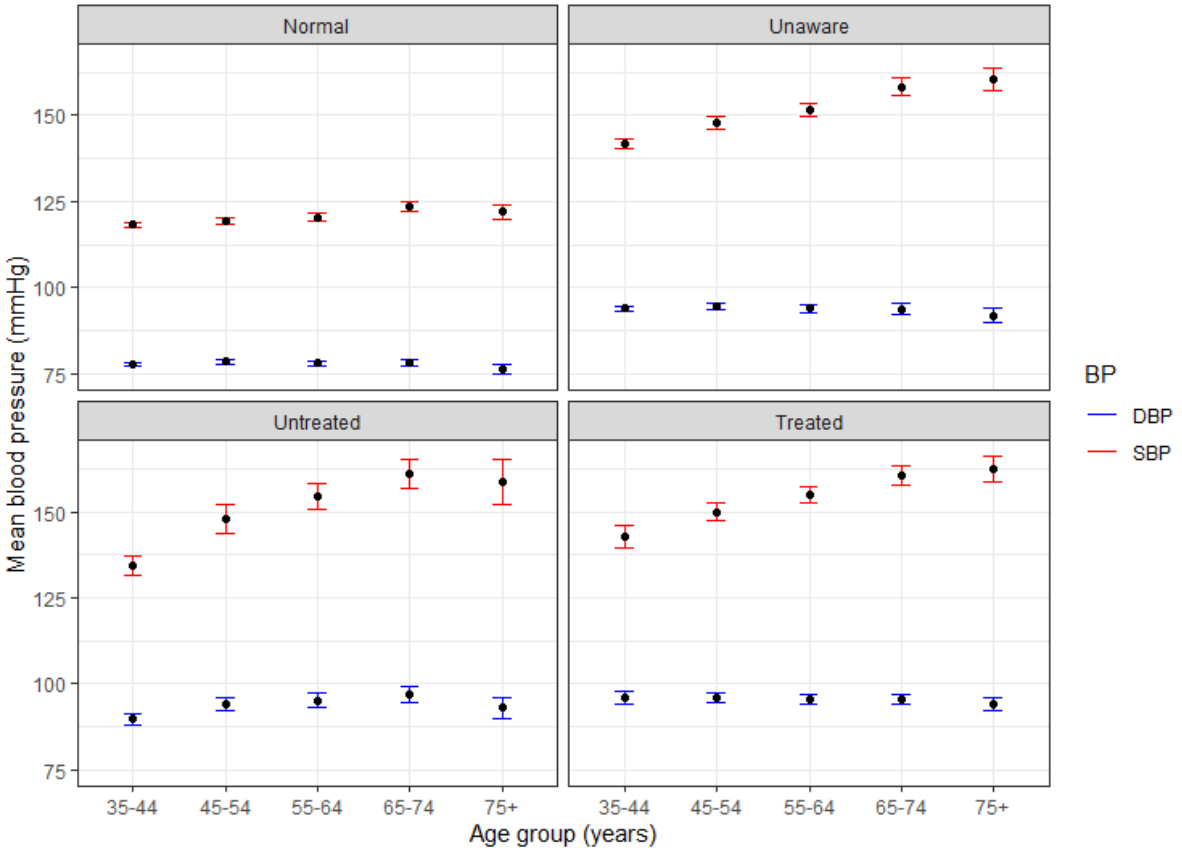
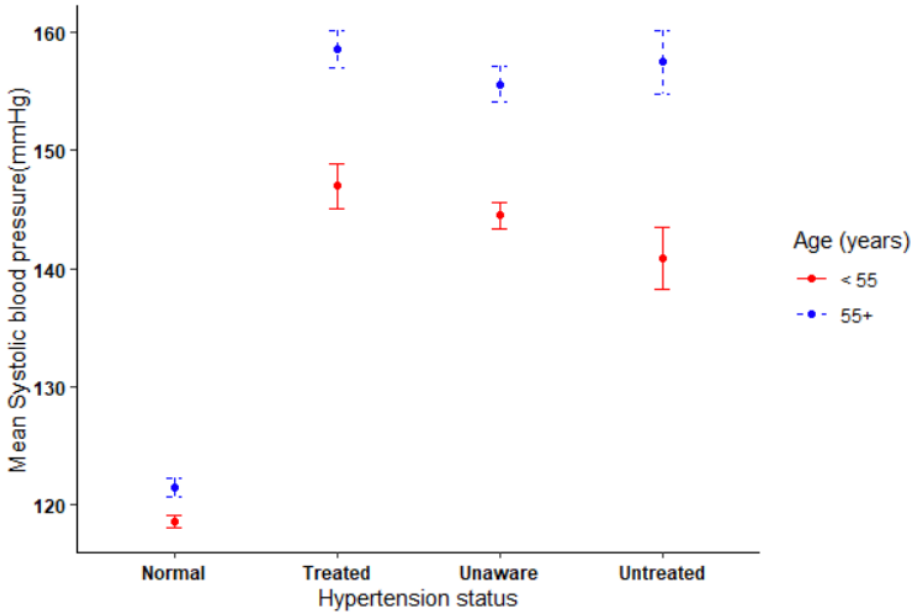
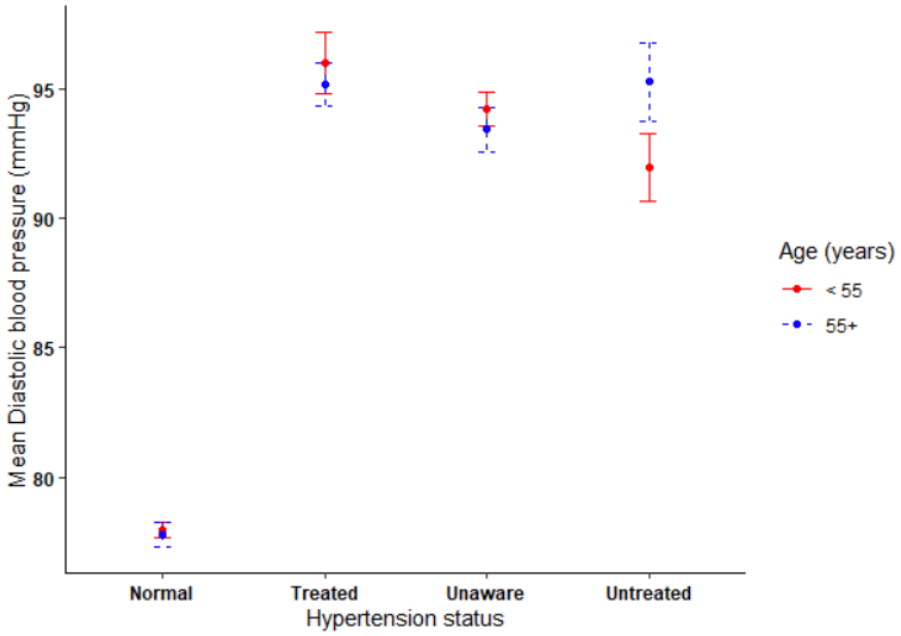


Figure 2: Blood pressure level stratified by age group (<55 years vs ≥55 years) and by hypertension treatment status. A, systolic blood pressure level; B, diastolic blood pressure level

A



B



CHAPTER 7: SEX DIFFERENCES IN THE ASSOCIATION BETWEEN BODY MASS AND BLOOD PRESSURE IN ADULT GAMBIANS: FINDINGS FROM A NATIONWIDE SURVEY

Introduction to the chapter

Obesity assessed by BMI of 30kg/m^2 or more is causally related to hypertension. Similarly, weight loss is associated with improvements in blood pressure levels among patients with hypertension, hence included as an integral part in treatment guidelines. There is evidence to suggest that blood pressure regulation, as well as cardiovascular manifestations, differs between men and women. Despite these differences, there is no sex discrimination in current guidelines for the management of hypertension.

Investigating the association between BMI and blood pressure using specific categories has limitations as each of these phenotypes are continuous traits. Studies on the continuous association between BMI and blood pressure, in a region showing significantly higher BMI levels among women, are generally lacking. This chapter investigates the association between body mass index and blood pressure and assesses its variation by sex and other sociodemographic factors. The findings in this chapter therefore have significant clinical and public health implications for treatment and prevention of adverse cardiovascular outcomes.

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Student ID Number	1405219	**Title**	Dr
First Name(s)	Modou		
Surname/Family Name	Jobe		
Thesis Title	Epidemiological Investigation of hypertension in The Gambia: Evaluating the burden and management in a nationwide survey		
Primary Supervisor	Prof Andrew Prentice		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?			
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Where is the work intended to be published?	Global Heart
Please list the paper's authors in the intended authorship order:	Modou Jobe, Islay Mactaggart, Abba Hydara, Brezesky Kotanmi Gaetan, Suzannah Bell, Pablo Perel, Matthew J Burton, Andrew M Prentice
Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Conceived the study, curated and validated the data. I led the design and implementation of the sudy. I conducted the literature review, data analysis and wrote the first draft of the paper and revised it according to the co-authors and peer-reviewers.

SECTION E

Student Signature	[redacted]
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Date	8 January 2024

Sex differences in the association between body mass and blood pressure in adult Gambians: Findings from a nationwide survey

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Abstract

Introduction: The increasing burden of hypertension in sub-Saharan Africa is partly attributable to increasing adiposity at the population level. A greater understanding of the sex-specific nature of the association between body mass index (BMI) and blood pressure will aid in the prioritisation of public health interventions. We evaluated the association between BMI and blood pressure in the general population, by sex and by selected sociodemographic factors in adult Gambians aged 35 years and above.

Methods: In this nationwide cross-sectional survey, we measured blood pressure and anthropometric parameters, and collected socio-demographic and economic information from participants. Natural spline subgroup regression analysis with 3 degrees of freedom was performed following post-stratification weighting designed to provide country-wide representative estimates.

Results: A total of 8548 participants were included in the present analysis, with a mean age of 48.8 years and 54.6% of whom were urban residents. The mean BMI was significantly higher in women (25.6kg/m^2) than in men (22.9kg/m^2). As expected, systolic blood pressure increased with age and BMI, but the association with BMI differed markedly by sex. In men, SBP increased sharply as BMI increased from around 30kg/m^2, but the increase was more gradual in women. This was particularly true in urban areas. SBP was ~ 27mmHg higher in patients receiving treatment but diminished with increasing BMI in women, not in men. Diastolic blood pressure was little influenced by BMI.

Conclusion: The steeper association between BMI and SBP in men has immediate implications for preventive and treatment regimes. Further research into the mechanisms behind the sex-differential response to adiposity may inform future therapeutics.

Keywords: hypertension, blood pressure, body mass index, sex-differences, obesity

Introduction

The increasing burden of hypertension in sub-Saharan Africa is attributed, at least in part, to the rising prevalence of risk factors such as obesity, urbanisation, ageing, smoking, and sedentarism (1)(2). Previous studies have demonstrated that obesity, assessed systematically by body mass index (BMI), is positively associated with blood pressure (3)(4)(5). Similarly, weight loss has been shown to be associated with a reduction in blood pressure levels, therefore suggesting a causal association (6)(7). Weight loss has become an integral part of hypertension management and a major recommendation in treatment guidelines (8)(9).

A greater understanding of the association between BMI and blood pressure could have important clinical and public health implications. In The Gambia like other countries in the region, hypertension is already highly prevalent (10)(11). The rate of overweight and obesity in this region has been steadily increasing especially among women (12)(13)(14).

Conventional evidence highlights differences in cardiovascular manifestations between men and women, with disease onset observed to be delayed in women compared to men (15)(16). In contrast, there is recent evidence to suggest that blood pressure levels progress more rapidly in women than in men beginning in early life (17). Despite the differences, treatment guidelines for hypertension, including lifestyle recommendations, are similar for both sexes (18). It is therefore crucial to understand the sex-specific nature of the association between BMI and blood pressure in diverse population groups, and this will help in the prioritisation of where intervention will yield the greatest dividends.

Using data from a representative sample of Gambian adults aged 35 years and above, we systematically evaluated the sex differences in the association between BMI and blood pressure in the general population and by selected sociodemographic factors.

Methods

The objectives, study design and conduct of this nationwide survey is described elsewhere (19)(20)(21). Briefly, the present analysis is part of a non-communicable diseases survey which was embedded into the 2019 Gambia National Eye Health Survey. We used a multistage sampling strategy based on the 2013 Gambia Population and Housing Census data to identify a nationally representative sample of adults aged 35 years and above. The census enumeration areas were used as clusters, stratified into urban and rural. The clusters were selected to reflect the regional population using probability proportionate to size sampling methods. The selected clusters were segmented into groups of 30 participants. One group was subsequently selected at random. Selected participants were provided with detailed study information prior to obtaining a signed or thumb printed informed consent. They were subsequently invited to a central location on a given day for data collection.

Data were collected by trained study staff using a pre-tested questionnaire and captured electronically using the Open Data Kit (ODK) application installed on Android tablets. We collected socio-demographic and economic information from participants. We also collected data on cardiovascular risk factors such as smoking, alcohol consumption, history of hypertension and current medication use for hypertension. We measured height to the nearest 0.1cm with the participant standing fully erect against a portable stadiometer (Leicester Height Measure, Seca, Hamburg, Germany) and without footwear or headwear.

Weight was measured to the nearest 0.01kg using portable scales (Seca, Hamburg, Germany). BMI was calculated as weight in kilograms divided by height in metres squared. Blood pressure was measured with the participant seated after resting for at least 10 minutes, with their arm supported at the level of the heart and resting on a surface. Blood pressure was measured in triplicate using automated OMRON-Healthcare 10 Series blood pressure monitors (Omron, Kyoto, Japan). The blood pressure measurements were taken five minutes apart, and the average of the last two measurements was used for analysis.

The study protocol was approved by the Joint MRC/Gambia Government Ethics Committee (SCC 1635) and the London School of Hygiene & Tropical Medicine Ethics Committee (Ref 16172).

Statistical analysis

The present analyses were weighted for cluster size and age- and sex-standardised to the 2013 Gambia Population and Housing Census to ensure generalisability of the results to the Gambian population. Given the low numbers at BMI of <16.0 kg/m^2 and >45kg/m^2 respectively, we restricted the present analysis to those with BMI ranging from 16.0 kg/m^2 to 45kg/m^2. Men and women were categorised into 4 age bands (35-44 years; 45-54 years; 55-64 years, and 65 years and above) to allow for sensible point estimates and standard errors. Natural spline subgroup regression analysis with 3 degrees of freedom were performed considering the post-stratification weighting. Subgroups were formed respectively considering sex, location (rural and urban), age group, age group and sex, sex and location.

Results

A total of 11127 were enumerated in this nationwide survey of whom 9788 (88%) took part. We initially excluded 600 (6.1%) participants with either missing household data or incomplete data and a further 17 (0.2%) participants with missing hypertension data. As specified above, we therefore included 8548 participants after excluding participants (n=623) with BMI below 16 kg/m^2 and above 45 kg/m^2.

Table 1 shows the socio-demographic characteristics of participants included in the present analysis. There was an equal number of men (50.0%) and women (50.0%). The overall mean age was 48.8 years, and was similar between men (49.0 years) and women (48.6 years). Irrespective of sex, more than half of the participants were urban residents. The mean BMI in the overall population was 24.3 kg/m^2 and was significantly higher in women (25.6kg/m^2) than in men (22.9kg/m^2). By design, the present analyses excluded all those with a BMI of less than 16.0kg/m^2 and above 45kg/m^2. However, most of the study population were in the normal BMI category accounting for 57.3%. 25.1% of the overall study population (21.7% of men and 28.4% of women) were overweight whilst 12.0% (3.9% of men and 20.0% of women) were obese.

We explored the association between BMI and systolic and diastolic blood pressure respectively. The association with systolic blood pressure are described here. Results for diastolic blood pressure revealed no clear associations and hence are included in the Supplementary Appendix.

There was a positive and somewhat linear association between BMI and systolic blood pressure in the overall sample rising from ~127 mmHg in underweight individuals to ~138 mmHg at a BMI of 45 kg/m^2 (Figure 1), but the patterns for men and women differed markedly

(Figure 2). We observed a sharp rise in systolic blood pressure with increasing BMI in men. In women, there was almost no increase in systolic blood pressure with increasing BMI until around a BMI of 28kg/m^2. The confidence intervals in both sexes overlap at the extremes of the BMI ranges but were separated between BMI of 30 kg/m^2 and 42 kg/m^2.

Figure 3A illustrates the anticipated increase in systolic blood pressure with age and the interaction with BMI. Systolic blood pressure rose with increasing adiposity in all age bands, but the association was steeper at older ages. After stratifying by age group and sex, the pattern of a steeper association between BMI and systolic blood pressure in men was apparent in all age categories apart from those aged 65 years and above (Figure 3B). The difference was more obvious in the youngest aged group (35-44 years) where there is evidence of a higher and a steeper rise in systolic blood pressure among men with increasing body BMI especially after BMI of 24 kg/m² and before 40 kg/m².

Analysis by urban versus rural residence revealed distinct differences at low BMI (Figure 4A); systolic blood pressure was ~ 2.7mmHg higher in the rural subjects. This was apparent in both men and women (Figure 4B). The systolic blood pressure curves converged at higher BMI. The right-hand panel of Figure 4B shows that the rise in systolic blood pressure in urban men was significantly higher than in women from BMI between 28kg/m^2 to 39kg/m^2.

Systolic blood pressure was approximately 27 mmHg higher among people receiving treatment for hypertension (Figure 5A) with a tendency to a gradual reduction in systolic blood pressure with BMI among patients receiving treatment from a BMI of 25kg/m^2 (Figure 5A). This pattern was dominated by the effect in men (Figure 5B) where there was a gradual decrease

in blood pressure in women. On the contrary, we observed a linear association among those not receiving treatment, and this was observed for both men and women (Figure 5B).

Discussion

We confirm the well-known increases in systolic blood pressure with increasing BMI (~11 mmHg between BMI 16.0 and 45.0 kg/m^2) and age (~22 mmHg between ages 35-44 years and 65 years at BMI 16.0 kg/m^2 and ~36 mmHg at BMI 45 kg/m^2). Blood pressure is much higher among people under treatment for hypertension (by ~20 mmHg) reflecting the inadequacy of treatment as previously reported (22). We show that systolic blood pressure is surprisingly slightly higher in rural residents at all BMI. But our data reveal distinct differences between men and women in how systolic blood pressure is affected by each of these factors.

We have previously reported in this population that obesity increases the odds of hypertension by 1.81 (95% CI: 1.18-2.77) in men and by 2.58 (95% CI: 2.23-2.98) in women (20). This is consistent with the H3Africa CHAIR study which used data from 13 African countries in which the odds of hypertension in obese individuals was found to be 2.8 (2.4–3.3) in men and 2.2 (2.0–2.4) in women after adjusting for age and country of residence (23). Although this gives valuable insights into the association between body weight and hypertension, it has limitations as both BMI and blood pressure are continuous traits. Furthermore, the thresholds for defining obesity and hypertension respectively are artificial, not universal and can potentially evolve over time (24)(25).

Here we examined the continuous association between BMI and blood pressure, and the observed differences in our study could have important public health implications. As previously reported in The Gambia and elsewhere in sub-Saharan Africa, the prevalence of

obesity is consistency higher in women (12)(26). The more gradual increase in systolic blood pressure with BMI observed in women in the current analysis suggests that increasing adiposity may not be the principal driver of hypertension in women and therefore calls for investigations of other possible drivers. On the other hand, the steep association especially in urban men, suggests that weight gain is a major driver of hypertension. Weight loss might yield greater dividends in terms of blood pressure control among men.

The reason for the much steeper association between BMI and blood pressure in urban men is not clear from our available data but is consistent with prior research on the effect of urbanisation on cardiovascular health (27)(28). Urbanisation has been shown to have profound impact on blood pressure and cardiovascular risk, others have found that urban residents are more likely to engage in healthy behaviours, have better access to healthcare and hence better cardiovascular outcomes (27)(28). The degree of urbanisation may also play a role. In China, the positive longitudinal association of urbanization with systolic or diastolic blood pressure was stronger in less urbanized than more urbanized communities (29). In Peru, those in peri-urban areas had higher incidence of hypertension compared to those in urban areas (30).

The blood pressure patterns observed remained even after we stratified by age, apart from those in the oldest (≥65 years) age category. The findings are consistent with those of studies by Wiinberg et al (31) and Khoury et al (32) which all demonstrated higher blood pressure in men compared to women at similar ages, but which tend to reverse after menopause. Hormonal changes in women characterised by reduced oestrogen levels and little or no reduced androgen level occurring during the post-menopausal period may be a factor. The lack of effect with hormone replacement at menopause suggests possible other mechanisms may be at play in women (33).

Among those receiving treatment, the gradual decline in systolic blood pressure with increasing BMI especially in overweight and obese patients was only among women. This is surprising given that weight loss remains a cornerstone of treatment in obesity-associated hypertension in both sexes (7). Differences in lifestyle and behavioural factors such as level of treatment adherence, physical activity and dietary factors may account for this (34–36). However data on these factors were not collected in the present study.

Our study provides insights for future mechanistic studies and possible areas of intervention into the sex association between BMI and systolic blood pressure in Gambian adults. However, the findings should be understood considering some limitations. The data is cross-sectional and therefore cannot be used to infer causal relationship between BMI and systolic blood pressure. Other diet and lifestyle factors may potentially influence the association which are not assessed in the present study. BMI is a crude method for assessing adiposity with several limitations. Another alternative, although not the gold standard, is assessment with hip circumference which we did not collect in this study.

Conclusion

The data confirms the increases in systolic blood pressure with BMI. The association was steeper in men and was more benign in women. This has important implication for prevention and treatment, suggesting that weight loss may have greater dividends on blood pressure in men. Further mechanistic studies behind the sex-differential blood pressure response to adiposity may inform future therapeutic strategies.

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Table 1: Age and sex-standardised sociodemographic characteristics of participants

Characteristics	Overall: n (%)	Men: n (%) 4273 (50)	Women: n (%) 4272 (50)	Missing
Age, years	48.8 (12.4)	49 (12.2)	48.6 (12.6)	0
Age groups				
35-44	3834 (44.9)	1878 (44)	1955 (45.8)	0
45-54	2327 (27.2)	1178 (27.6)	1149 (26.9)	
55-64	1245 (14.6)	651 (15.2)	593 (13.9)	
65+	1140 (13.3)	566 (13.2)	574 (13.4)	
Location				
Urban	4666 (54.6)	2158 (50.5)	2508 (58.7)	0
Rural	3879 (45.4)	2115 (49.5)	1763 (41.3)	
Level of education				
Pre-school/no school	1522 (17.8)	631 (14.8)	891 (20.9)	0
Primary	945 (11.1)	495 (11.6)	450 (10.5)	
Secondary/vocational	1455 (17)	989 (23.2)	466 (10.9)	
Higher	399 (4.7)	326 (7.6)	73 (1.7)	
Don't know'	136 (1.6)	38 (0.9)	98 (2.3)	
Non-formal or Quranic (Islamic)	4087 (47.8)	1793 (42)	2293 (53.7)	
Marital status				
Never married	198 (2.3)	169 (4)	29 (0.7)	0
Married	7351 (86)	4022 (94.1)	3329 (77.9)	
Widowed	841 (9.8)	22 (0.5)	820 (19.2)	
Divorced	155 (1.8)	60 (1.4)	94 (2.2)	
Occupation				
Unemployed	858 (10)	286 (6.7)	572 (13.4)	0
Manual	4239 (49.6)	1808 (42.3)	2431 (56.9)	
Trade	2465 (28.9)	1431 (33.5)	1034 (24.2)	
Professional	626 (7.3)	542 (12.7)	84 (2)	
Other	153 (1.8)	138 (3.2)	15 (0.4)	
Retired	203 (2.4)	68 (1.6)	135 (3.2)	
Ethnicity				
Mandinka/Jahanka	3222 (37.7)	1488 (34.8)	1734 (40.6)	0
Wollof	1242 (14.5)	657 (15.4)	585 (13.7)	
Jola/Karoninka	969 (11.3)	462 (10.8)	506 (11.8)	
Fula/Tukulor/Lorobo	1863 (21.8)	1072 (25.1)	791 (18.5)	
Sarahuleh	642 (7.5)	285 (6.7)	357 (8.4)	
Others	608 (7.1)	309 (7.2)	298 (7)	
Wealth status				
1	799 (9.3)	437 (10.2)	362 (8.5)	0
2	1325 (15.5)	741 (17.3)	584 (13.7)	
3	2048 (24)	1084 (25.4)	964 (22.6)	
4	2012 (23.5)	980 (22.9)	1032 (24.2)	
5	2362 (27.6)	1030 (24.1)	1331 (31.1)	
BMI, mean (SD)	24.3 (4.8)	22.9 (3.7)	25.6 (5.4)	0

BMI categories (kg/m^2)				
underweight	487 (5.7)	298 (7)	190 (4.4)	0
normal	4893 (57.3)	2880 (67.4)	2012 (47.1)	
overweight	2143 (25.1)	928 (21.7)	1215 (28.4)	
obese	1022 (12)	167 (3.9)	855 (20)	
Systolic blood pressure [mean (SD)]	133.8 (23.1)	135.2 (22.2)	132.5 (24)	9
Systolic blood pressure [mean (SD)]	85.9 (12.6)	85.6 (12.5)	86.2 (12.6)	9

Data are in mean (SD) or n (%).

Figure 1: Natural spline regression analysis of body mass index and systolic blood pressure in the study population

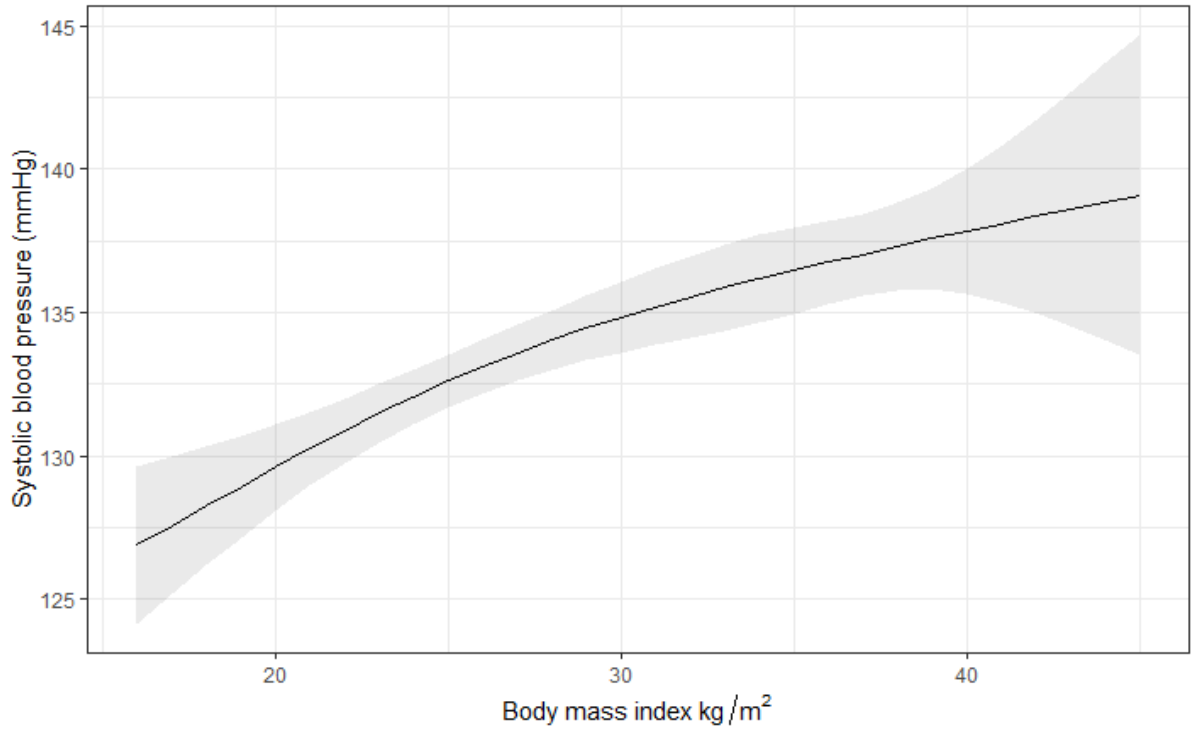


Figure 2: Natural spline regression analysis of body mass index and systolic blood pressure in the study population by sex

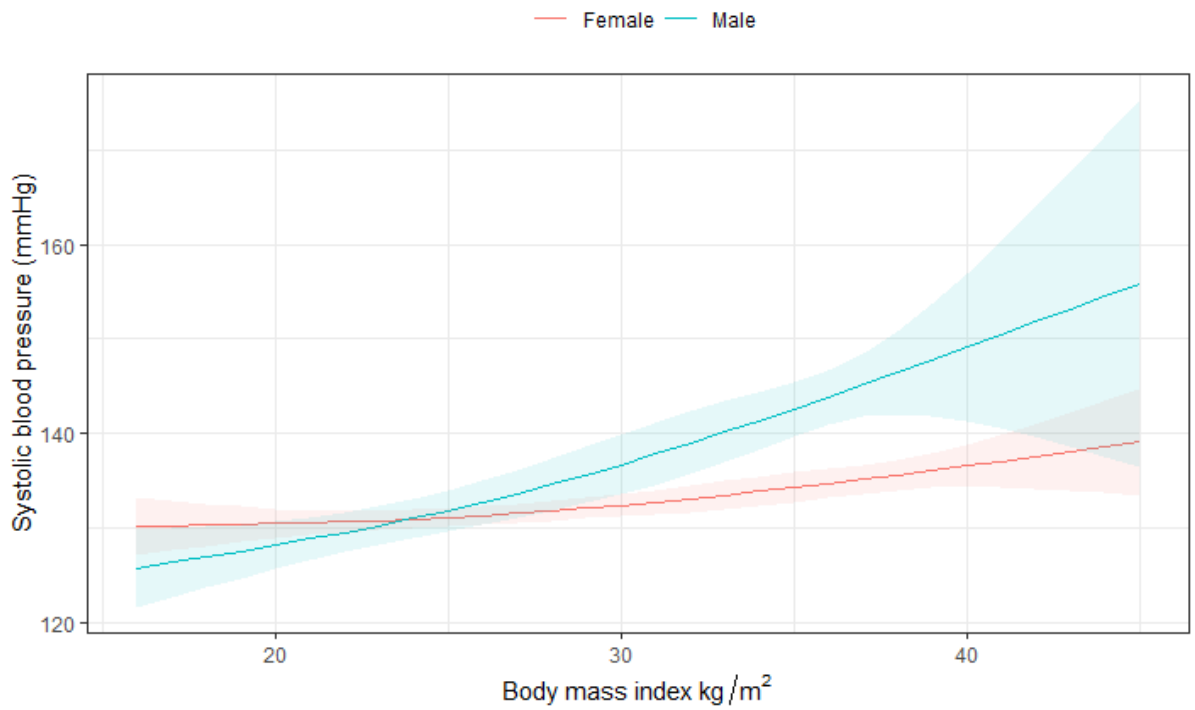
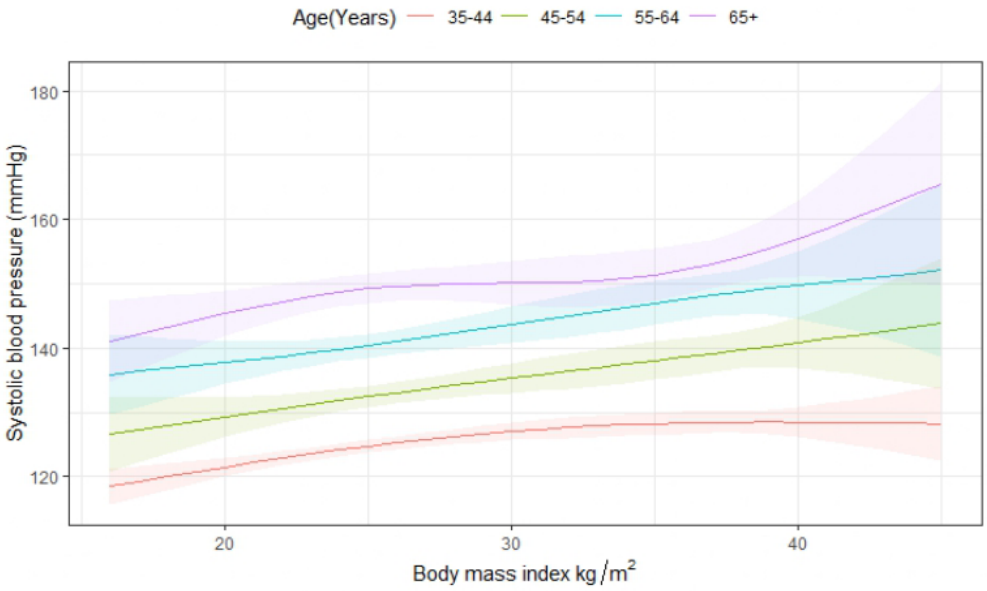


Figure 3: Natural spline regression analysis of body mass index and systolic blood pressure in the study population by A) age group B) age group stratified by sex

A



B

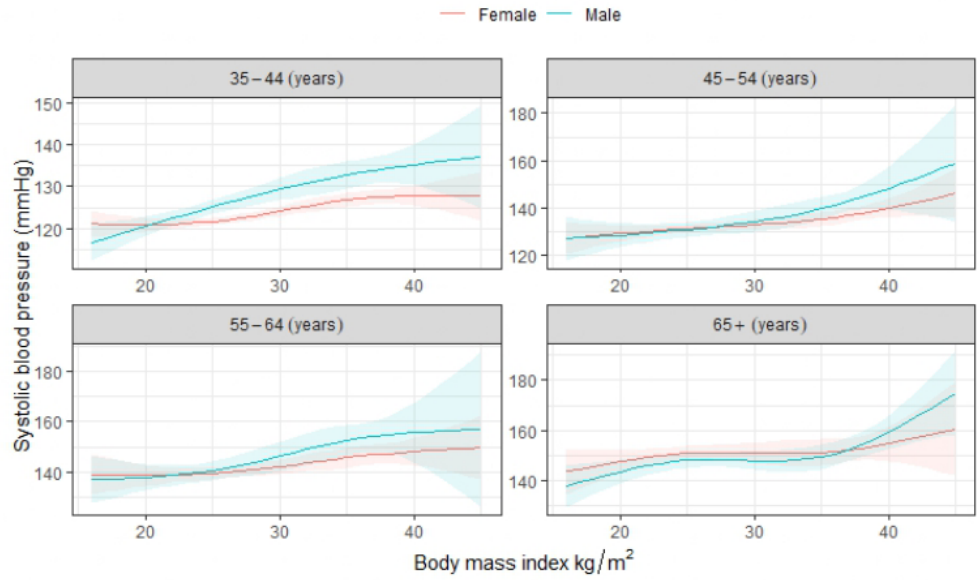
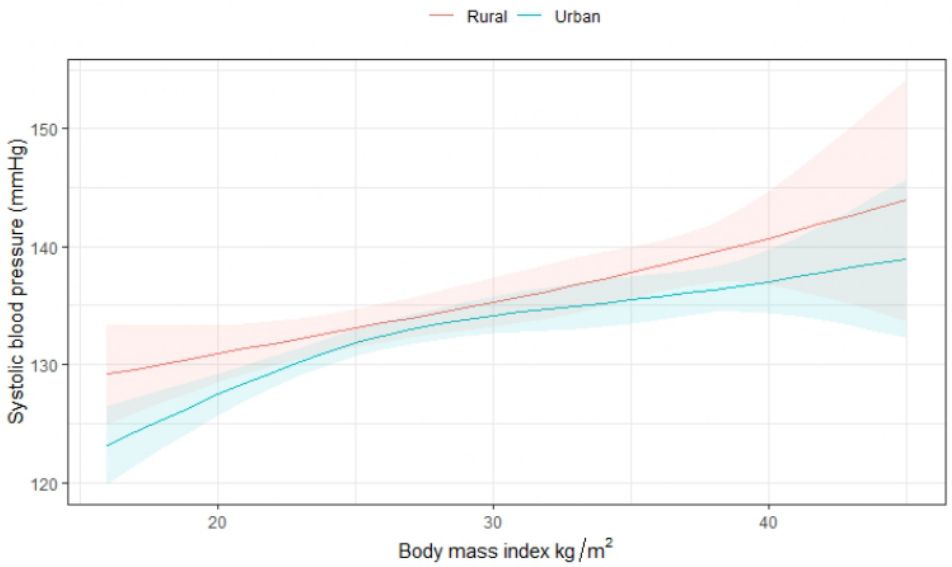


Figure 4: Natural spline regression analysis of body mass index and systolic blood pressure in the study population by A) Location B) Location stratified by sex

A



B

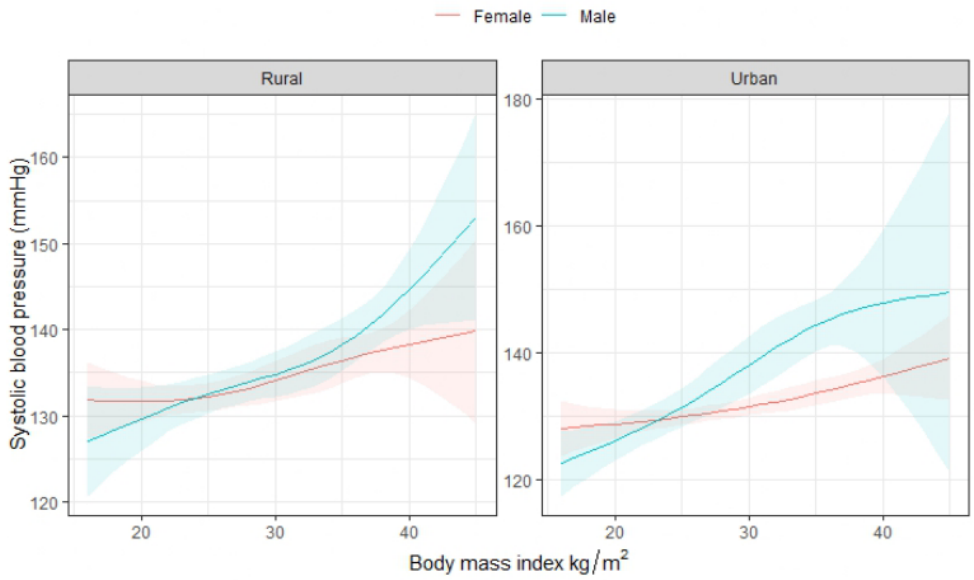
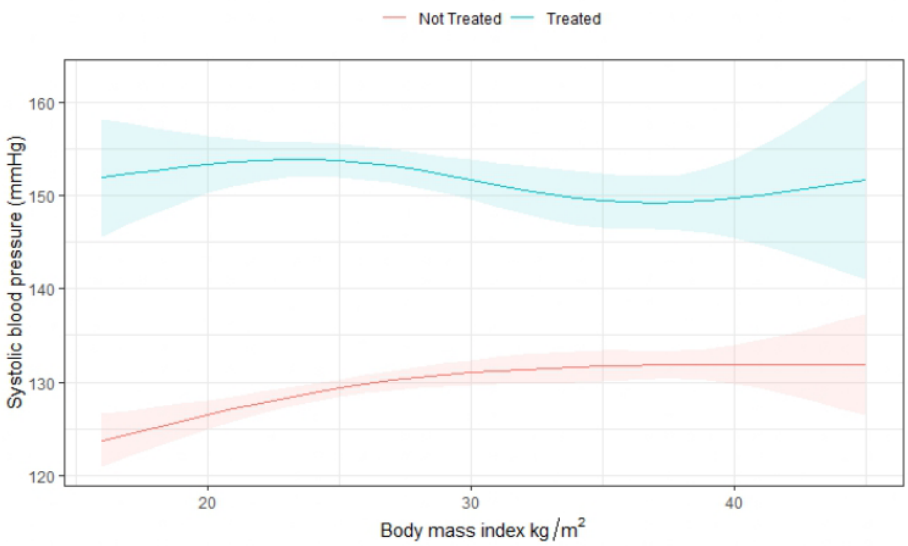
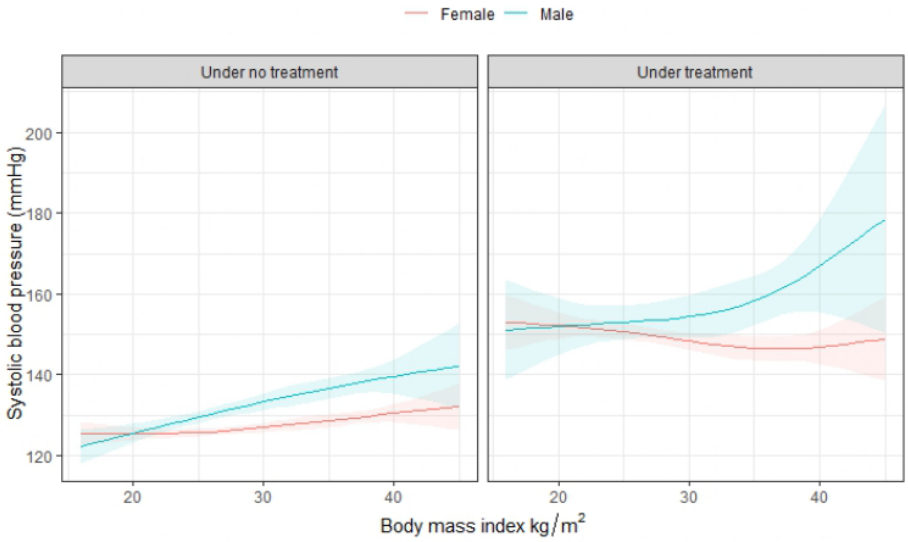


Figure 5: Natural spline regression analysis of body mass index and systolic blood pressure in the study population by A) treatment status B) treatment status stratified by sex

A



B



Additional analysis

Additional analysis Table 1: Age and sex-standardised sociodemographic characteristics of participants by obesity status

Characteristics	Overall	BMI <30: n (%) 7523 (88)	BMI ≥30 kg/m^2: n (%) 1022 (12)	Missing
Age, years	48.8 (12.4)	48.9 (12.6)	47.9 (10.7)	0
Age groups				
35-44	3834 (44.9)	3379 (44.9)	455 (44.5)	0
45-54	2327 (27.2)	2023 (26.9)	304 (29.8)	
55-64	1245 (14.6)	1082 (14.4)	163 (15.9)	
65+	1140 (13.3)	1039 (13.8)	100 (9.8)	
Sex				
Men	4273 (50)	4106 (54.6)	167 (16.3)	0
Women	4272 (50)	3417 (45.4)	855 (83.7)	
Location				
Urban	4666 (54.6)	3931 (52.3)	735 (71.9)	0
Rural	3879 (45.4)	3592 (47.7)	287 (28.1)	
Level of education attained				
Pre-school/no school	1522 (17.8)	1338 (17.8)	185 (18.1)	0
Primary	945 (11.1)	789 (10.5)	156 (15.3)	
Secondary/vocational	1455 (17)	1291 (17.2)	164 (16)	
Higher	399 (4.7)	350 (4.7)	49 (4.8)	
Don't know	136 (1.6)	116 (1.5)	21 (2)	
Non-formal or Quranic (Islamic)	4087 (47.8)	3639 (48.4)	448 (43.8)	
Marital status				
Never married	198 (2.3)	183 (2.4)	15 (1.5)	0
Married	7351 (86)	6523 (86.7)	829 (81.1)	
Widowed	841 (9.8)	702 (9.3)	140 (13.7)	
Divorced	155 (1.8)	116 (1.5)	39 (3.8)	
Occupation, n (%)				
Unemployed	858 (10)	742 (9.9)	116 (11.4)	0
Manual	4239 (49.6)	3803 (50.6)	437 (42.7)	
Trade	2465 (28.9)	2070 (27.5)	395 (38.6)	
Professional	626 (7.3)	575 (7.6)	51 (5)	
Other	153 (1.8)	145 (1.9)	8 (0.8)	
Retired or old age	203 (2.4)	188 (2.5)	15 (1.5)	
Ethnicity, n (%)				
Mandinka/Jahanka	3222 (37.7)	2788 (37.1)	434 (42.4)	0
Wollof	1242 (14.5)	1114 (14.8)	128 (12.5)	
Jola/Karoninka	969 (11.3)	834 (11.1)	135 (13.2)	
Fula/Tukulor/Lorobo	1863 (21.8)	1698 (22.6)	164 (16.1)	
Sarahuleh	642 (7.5)	576 (7.7)	66 (6.4)	

Others	608 (7.1)	512 (6.8)	96 (9.3)	
Wealth status, n (%)				
1 (poorest)	799 (9.3)	737 (9.8)	62 (6.1)	0
2	1325 (15.5)	1230 (16.3)	95 (9.3)	
3	2048 (24)	1879 (25)	169 (16.6)	
4	2012 (23.5)	1739 (23.1)	273 (26.7)	
5 (richest)	2362 (27.6)	1939 (25.8)	422 (41.3)	
SBP Mean (SD)	133.8 (23.1)	133.3 (22.9)	137.6 (24.6)	9
DBP Mean (SD)	85.9 (12.6)	85.4 (12.4)	89.5 (12.8)	9

Additional analysis Table 2: Population attributable fraction of hypertension by BMI category

Overall	**Prevalence**	**Crude relative risk**	**Crude PAF**	**Adjusted (age and Sex) relative risk**	**Adjusted (age and Sex) PAF**
BMI (<25 vs 25+)	0.370392	1.278514	0.217842	1.291185	0.2255175
BMI (<30 vs 30+)	0.1196021	1.353141	0.2609788	1.342717	0.2552415
Men	**Prevalence**	**Crude relative risk**	**Crude PAF**	**Adjusted (age) relative risk**	**Adjusted (age) PAF**
BMI (<25 vs 25+)	0.256255	1.293378	0.2268309	1.29385	0.2271126
BMI (<30 vs 30+)	0.03914447	1.308123	0.2355459	1.223456	0.1826436
Women	**Prevalence**	**Crude relative risk**	**Crude PAF**	**Adjusted (age) relative risk**	**Adjusted (age) PAF**
BMI (<25 vs 25+)	0.4845888	1.23911	0.192969	1.285975	0.2223798
BMI (<30 vs 30+)	0.2000989	1.328529	0.2472879	1.369468	0.2697893

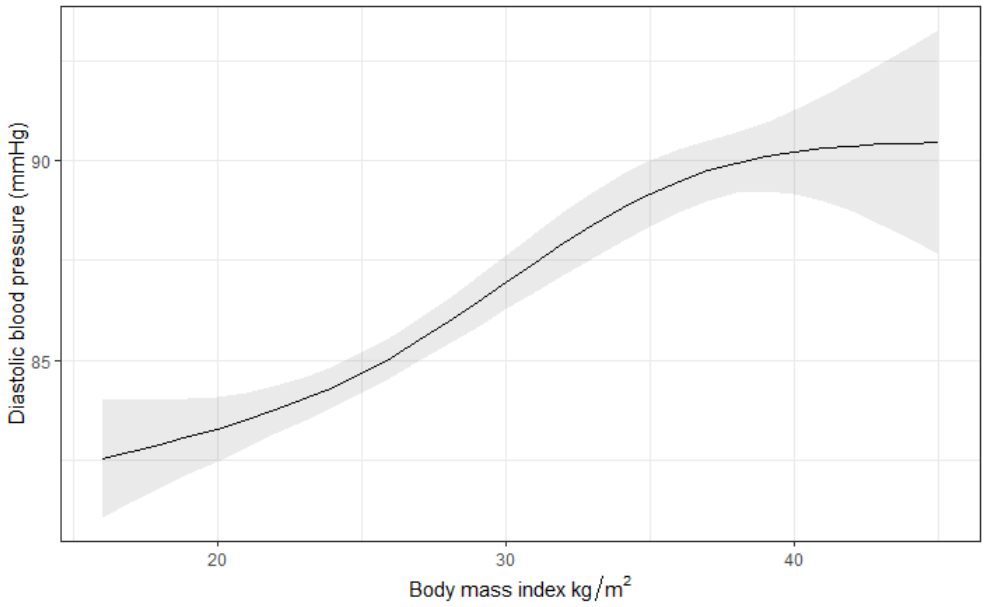
PAF= Population attributable fraction

The data shows that 37.0% of the overall population were either overweight or obese, with obesity accounting for 12.0% of the study population. Those with a body mass index of ≥25 were 1.29 times more likely to have hypertension compared to those with a body mass index <25kg/m^2. Those with a body mass index of ≥30kg/m^2 were 1.35 times more likely to have hypertension compared to those with a body mass index of <30kg/m^2. Assuming causality and after adjusting for age and sex, the population attributable fraction of hypertension was 22.6% for body mass index of ≥25 kg/m^2, and 25.5% for ≥30kg/m^2.

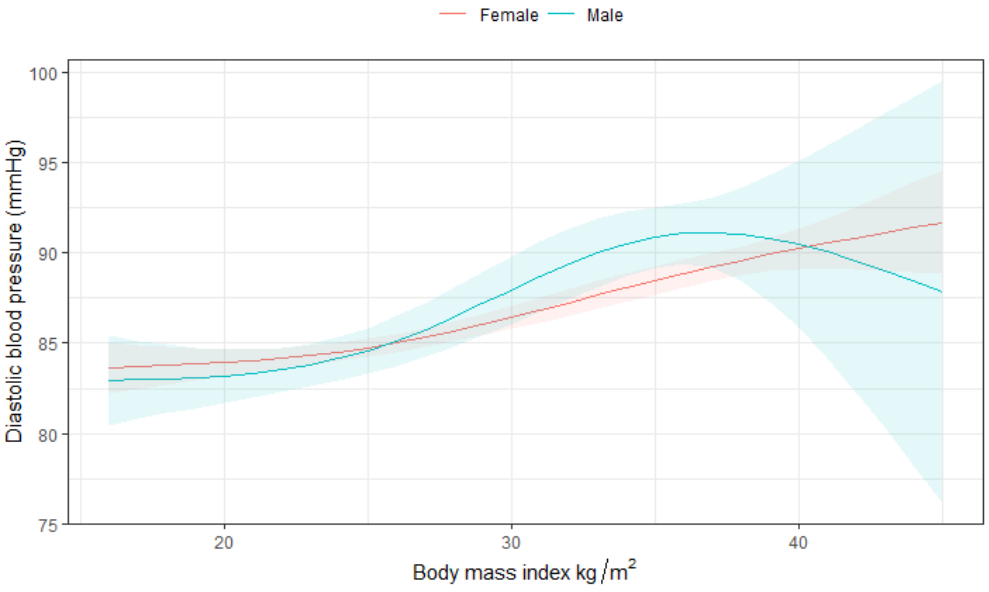
Whilst the population attributable fraction for a BMI of 25 kg/m^2 was the same for men and women compared to those with less, the population attributable fraction for a BMI of 30 kg/m^2 was much higher in women (27.0%) compared to men (18.3%).

Supplementary Figures

Supplementary Figure 1: Natural spline regression analysis of body mass index and systolic blood pressure in the study population

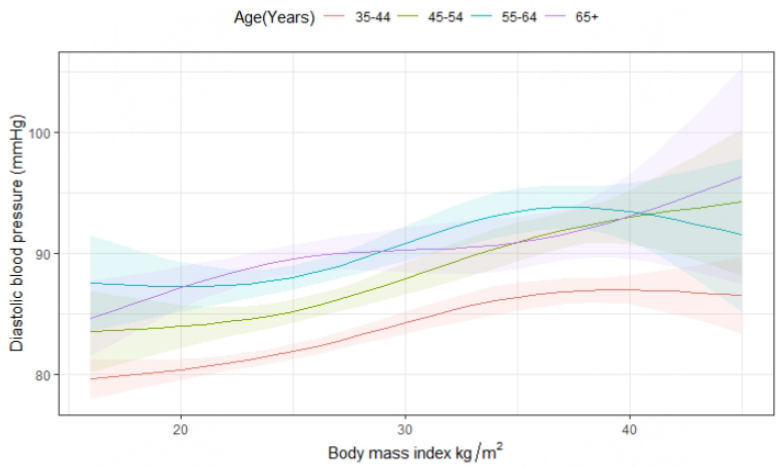


Supplementary Figure 2: Natural spline regression analysis of body mass index and diastolic blood pressure in the study population by sex

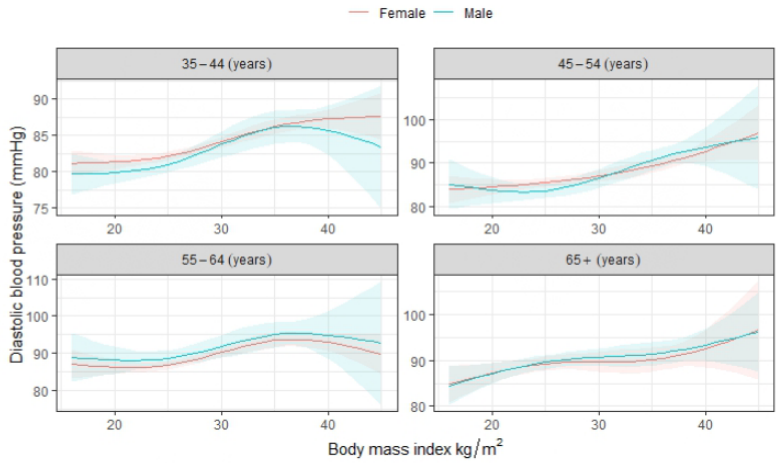


Supplementary Figure 3: Natural spline regression analysis of body mass index and diastolic blood pressure in the study population by A) age group B) age group stratified by sex

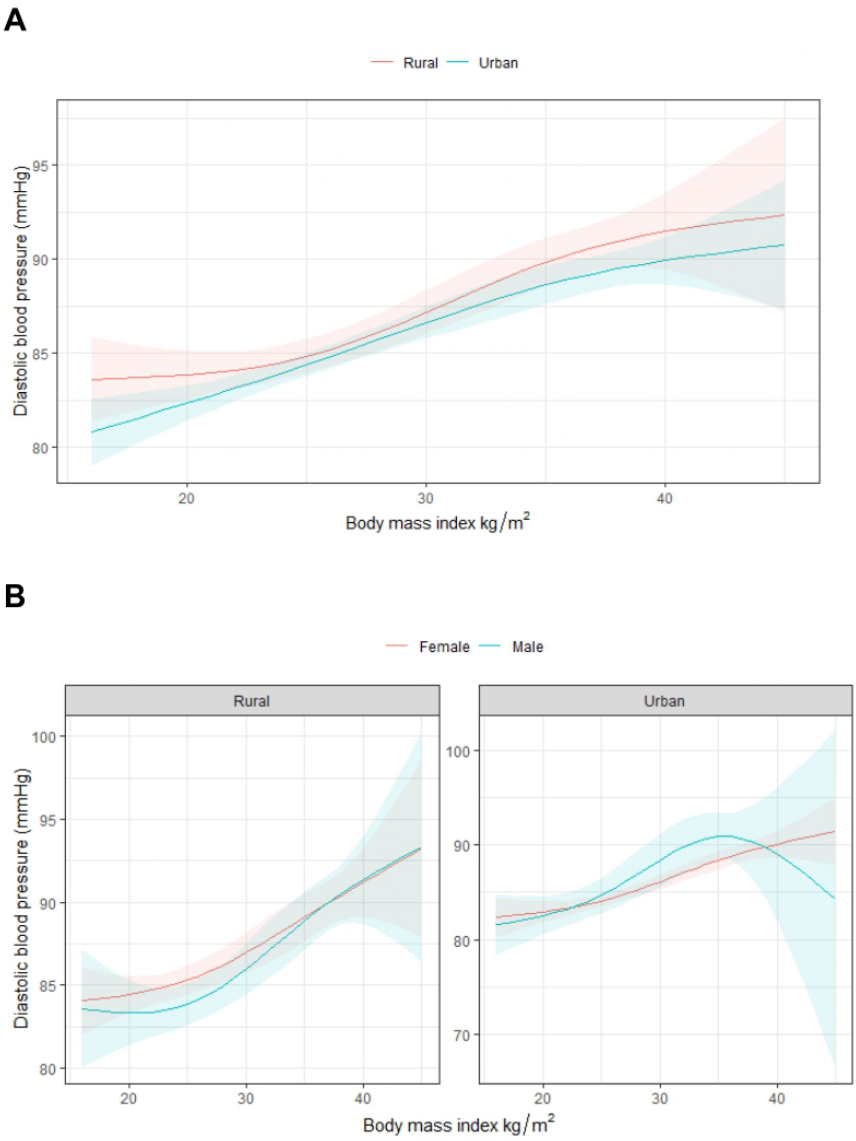
A



B

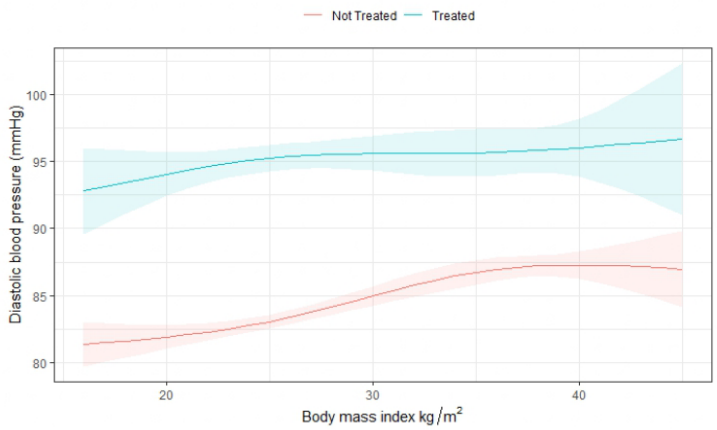


Supplementary Figure 4: Natural spline regression analysis of body mass index and diastolic blood pressure in the study population by A) Location B) Location stratified by sex

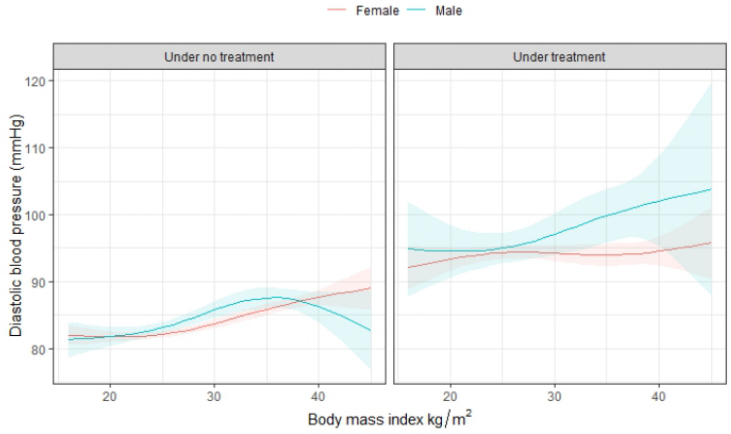


Supplementary Figure 5: Natural spline regression analysis of body mass index and diastolic blood pressure in the study population by A) treatment status B) treatment status stratified by sex

A



B



CHAPTER 8: SUMMARY OF KEY FINDINGS FROM THE PHD THESIS, THEIR IMPLICATIONS FOR POLICY AND PRACTICE, STRENGTHS, AND LIMITATIONS

This PhD thesis provides up-to-date data on the prevalence estimates of major NCDs in adults aged 35 years or more in The Gambia. The thesis further evaluates the cascade of care performance for hypertension in The Gambia, compared blood pressure levels in specific population groups according to their hypertension and treatment status. Finally, it describes the association between BMI and blood pressure, and the sex-differences in this association by various socio-demographic factors.

8.1 Prevalence of major NCDs and related risk factors

The weighted prevalence estimates show a high prevalence of hypertension, diabetes, obesity, and multimorbidity in individuals aged 35 years or more in The Gambia. Hypertension was particularly high at 47% and was significantly higher amongst women than men. The higher prevalence in this study for similar age groups in earlier nationwide surveys in 1996 (39) and 2010 (132) reflects the rapid pace at which drivers such as urbanisation, changes in dietary patterns and lifestyle changes are occurring in The Gambia. However the study found no rural-urban differences in The Gambia which is in contrast to the 2010 WHO STEP survey where there was a significantly higher prevalence in rural areas (132). The prevalence of hypertension was expected to be lower in rural areas as reported in a meta-analysis of 22 studies in West Africa (133). The similar rural-urban prevalence of hypertension in this thesis may be attributed to the similarities in dietary salt intake as previously reported in The Gambia (134).

The prevalence of diabetes was 6.3% and was similar in men and women overall. However, women from urban areas were more affected than their rural counterparts, with men in both settings similarly affected. Compared to a survey conducted in 1997, the prevalence in urban areas remains similar (7.9% in men and 8.7% women in 1997 vs 6.8% and 8.6% in 2019). However, there is a marked increase in the prevalence of diabetes in rural areas (2.2% in men and 0.8% in women in 1997 vs 4.3% and 4.8% in 2019) (135). This urban-rural difference in prevalence rates, possibly also applicable for obesity rates, could be due to higher availability and intake of sugars and processed foods in urban areas and the higher physical activity levels in rural populations. The study highlights the importance and strengths of conducting surveys to estimate population level data. It also highlights the limitation of extrapolations of data based on relying on data from countries with similar economy, language, and demography. This is as documented in two of the most referenced source of estimates for diabetes, the NCD-RisC (136) and the International Diabetes Federation (IDF) Diabetes Atlas (137). Whilst the former projected higher estimates for The Gambia, the IDF estimates provided much lower estimates for The Gambia.

The nationwide prevalence of obesity was 12.0% and was five-fold higher in women than in men. The high prevalence of obesity especially in women is consistent with the 2010 STEP survey in The Gambia (138) and also with findings from other settings in SSA (139–141). These contemporary estimates show a large increase compared to data from the late 1990s (2.3% nationwide) (39). Obesity in this setting is still commonly regarded as a sign of wealth, influence and strength especially among women (142).

The research study illustrates some important differences between hypertension and diabetes in relation to wealth and rural/urban residence. Hypertension shows no relationship with wealth or with residency in either men or women, whereas diabetes is more common in urban residents and in richer people, effects that are consistent in men and women. This disparity might provide insights into specific aetiological factors in Africans in a future study measuring the known common risk factors (inactivity, salt, fats, ultraprocessed foods, medications).

Multimorbidity, defined as the coexistence of 2 or more of hypertension, diabetes, and obesity, also disproportionately affected women especially those in urban areas. This was, to the best of my knowledge the first such evaluation of multimorbidity in The Gambia. There are also very few studies in SSA providing information on multimorbidity. Comparisons and interpretation are difficult due to differences in the definition of multimorbidity, the number of conditions investigated, how the conditions are measured, and the age group of the populations included. The findings in this thesis which was a nationwide survey were significantly higher than found in rural Kiang West district in The Gambia. Whilst the prevalence was much lower compared to urban Malawi (22.5%), they were largely similar to estimates from rural Malawi (11.7%) and Uganda (8.2%) (143).

Patients with multimorbidity deserve clinical attention as their management is more challenging and they are potentially at a higher risk of complications. This is especially the case in settings where care is not integrated, and patients have to attend single disease-based clinics for their respective conditions which increase patient and carer

fatigue as well as reducing compliance to treatment. This therefore calls for multimorbidity based guidelines rather than focusing on single diseases, as well as integrated clinics for patients with multimorbidity (144–146).

The nationwide prevalence of smoking was 9.7%, however this was almost exclusively in men (19.3% compared to 0.1% of women). Alcohol consumption was very low in both sexes. There were too few women smokers and drinkers of either sex to allow for meaningful analysis.

8.2 Hypertension care cascade performance in The Gambia

The study shows a poor cascade of care performance in The Gambia. Of the total 90% of hypertensive individuals lost in the cascade of care, 45.3% were at the diagnosis stage, 22.2% at the treatment stage and 22.5% at the control stage. The care cascade was however better in women compared to men. The reasons behind this observation were not investigated but could be attributed to greater healthcare utilisation by women as is widely reported in other settings (147–151). Improvements are therefore required at all stages of the care cascade. The greatest dividends will be gained in reducing the mounting prevalence and improving diagnosis of patients with hypertension, the stage where the greatest loss in the cascade occur.

8.3 Mean BP and the cascade of care

The study provides further insights into the cascade of care performance by exploring blood pressure levels in respective groups with hypertension. The findings show

alarming levels of blood pressure among all participants with hypertension, including those receiving blood pressure treatment. The mean systolic blood pressure was 159.3mmHg (95%CI, 157.3-161.2) among untreated participants, 152.2mmHg (95%CI, 151-153.5) in those receiving treatment and was 148.7mmHg (95%CI, 147.7-149.7) among those who were unaware of their hypertension status. It was quite unexpected that patients receiving treatment still maintained such high blood pressure levels. I hypothesise that current treatment approaches and prescribed medications are only partially effective. It is also likely that among those requiring treatment, it is only patients with extremely high blood pressure levels who are allocated treatments. The data in this study is however similar to findings elsewhere. A study of older persons (aged 60 to 69 years) in the UK found significantly higher blood pressure levels amongst individuals receiving treatment compared to those not receiving treatment (48). This was not however consistent in a Peruvian study where those unaware of their hypertension were found to have the highest mean blood pressure, followed by the treated, then those aware but not receiving treatment (49).

8.4 The association between BMI and blood pressure

This study provides insight into the association between BMI and blood pressure in a sample of Gambian adults aged 35 years and above. This has been mostly studied using BMI categories and blood pressure categorised as hypertension or normotension. Previous studies have studied the association between obesity (152). Although this gives valuable insights, it has limitations as both BMI and blood pressure are continuous traits. Furthermore, the thresholds for defining obesity and hypertension respectively are artificial, not universal and can potentially evolve over time (153)(154). This study, the first to the best of our knowledge in SSA, observed a

positive association between BMI and blood pressure. However, there were sex-specific differences characterised by a sharp increase in blood pressure with BMI among men, and a gradual increase among women. The data has important policy and public health implications emphasising the importance of controlling body weight especially among men.

8.5 Implications of findings for practice and policy

8.5.1 Preventative

These high rates of hypertension and concerning levels of diabetes, obesity and multimorbidity call for a concerted multisectoral and comprehensive non-communicable diseases prevention and control programme. Currently, there are insufficient population approaches for prevention of hypertension and other non-communicable diseases. A lot of NCD programmes in SSA continue to be more clinical and less preventative, and where programmes exist, they tend to be confined to a few municipalities (155). Without such intervention, the country's under-resourced health system will likely face a high burden of complications of target organ damage such as stroke, ischaemic heart disease, chronic kidney diseases and cancers. These complications may affect the most productive age groups hence resulting in greater economic burden to individuals, their families and national economies, and premature mortality. A strategy developed using a participatory approach and reaching all sectors of society is critically and urgently needed. A coordinated multiprong approach addressing three main areas should be considered:

i) Health and nutrition education and promotion: These programmes have been shown to be effective in reducing the burden of NCDs (155)(156)(157) and should be adapted and embedded in school programmes, workplaces, health facilities and into community activities to achieve the maximum effect. These health programmes could be held through the electronic (radio and television) and print (e.g. newspapers) media and other means and led by the Health Education Unit at the Ministry of Health and partners such as the Association of Health Journalists of the Gambia. The WHO recognises and promotes this approach as a social practice which provides a pragmatic approach to health literacy development for the prevention and control of noncommunicable diseases (NCDs) (158). If properly implemented, such programmes have the potential to empower the general population especially the younger generation with vital health and nutrition information, ensuring better health in the medium and long-term.

ii) Improve quality of food supply: This entails policy formulation and implementation to improve the processing and manufacturing of foods, increase their availability and affordability, promoting healthy food choices and limiting aggressive marketing of unhealthy options such as sodium-rich, and energy dense foods. The country's 2021-2025 national nutrition policy is mainly focussed on addressing undernutrition or nutritional deficiencies (159). It also seeks to address diet related NCDs through awareness creation, capacity building and advocacy. It is evident from this thesis that NCDs are increasing in The Gambia and hence require a more results driven, and better implemented nutrition strategy. A multisectoral approach

involving the Ministries such as of Health, Agriculture, Justice, Finance and other relevant sectors will enhance success.

iii) Transportation policy and environmental design: The Gambia has been experiencing rapid unplanned urbanisation over the years. Nearly 60% of the population reside in urban areas compared to 20% in 1973 (160). Most of the urbanisation has occurred in the Western Region (southwestern part) of The Gambia which is experiencing the most in-migration hence a lot of pressure on land use for habitation (161) (Figure 6). Urbanisation is strongly associated with NCDs, and there should be strong governmental policies which will ensure urban designing to promote health, limit automobile use, promote walking and bicycle riding, and improve security (162). A recent systematic review indicates that urban planning and design play a crucial role in creating healthy cities. It stresses that the policies of urban planning and design should be supported by the concepts of health for any meaningful improvement in NCD prevention (163).

The Gambia is already making strides in the above-mentioned strategies. The country launched a 5-year multisectoral strategy and costed action plan in 2022 to tackle NCDs. I was involved in the formulation of the strategy and action plan and presently contributing towards its implementation. The overarching goal of this plan is to reduce premature deaths from NCDs in The Gambia by one-third by 2027 (164). A major limitation in the implementation of the plan is the lack of up-to-date data on the major NCDs and associated risk factors to identify priority areas and high-risk populations

for targeted interventions. The findings in this thesis are therefore timely in informing the successful implementation of this plan and similar local initiatives.

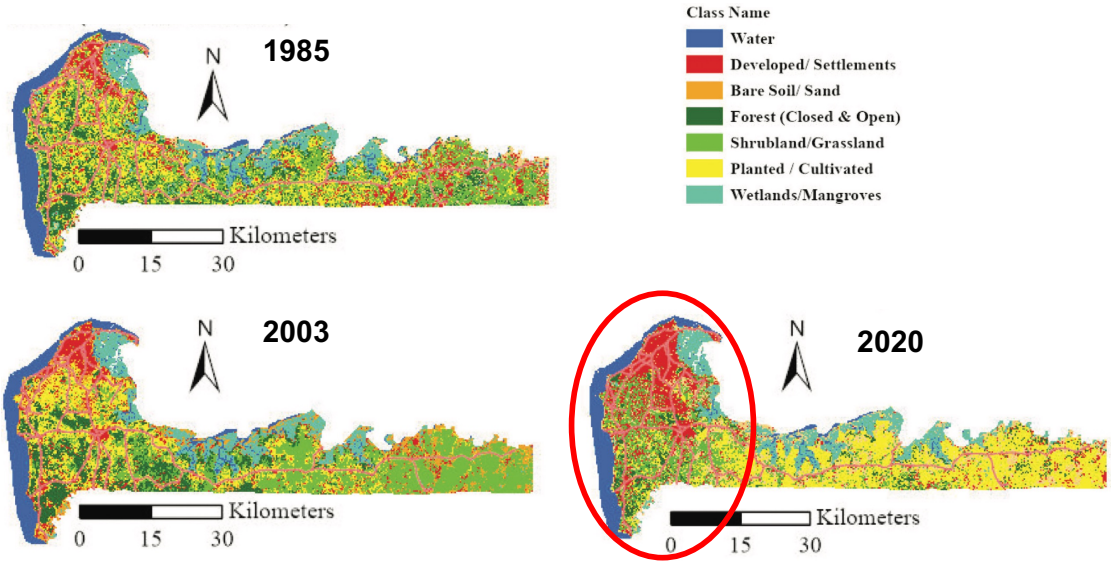


Figure 6: Change in land use land cover in the Western Region of The Gambia from 1985 to 2020. (Source: Dampha NK. Sustainable Environment. 2021;7:1 (161))

8.5.2 Clinical

1. Enhance screening: Currently, there is no policy for population screening for hypertension in The Gambia. Although opportunistic screening occurs during consultations in healthcare settings, this is not always available due to lack of resources (e.g. blood pressure monitors). Blood pressure monitors should therefore be provided to health facilities to ease mass screening of patients and otherwise healthy populations wishing to have their blood pressure measured. There is evidence to suggest that screening programmes in different workplace settings (e.g. schools, mosques and churches, markets, barbershops, etc.) complement traditional clinical self-directed consultations and seems to be an effective method of identifying risk

factors, detecting undiagnosed disease, and triggering the initiation of proper therapeutic and long-term management (165). As per the findings presented in this thesis, nearly half of the population studied were found to have hypertension. A policy for screening on a periodic basis for this age group, or possibly including younger age groups, should be considered, and implemented. This will however require training and recruitment of more healthcare personnel, as well as adopting task-shifting approaches to increase access to diagnosis and management of hypertension.

The IHCoR-Africa project (https://www.lshtm.ac.uk/research/centres-projects-groups/ihcor-africa), which I currently lead in The Gambia, is seeking to evaluate the feasibility of a community health worker (CHW)-led approach to screen and diagnose hypertension in rural settings. As part of this project, we will evaluate the accuracy of three alternative blood pressure measurement methods (home blood pressure measurement, attended and unattended blood pressure measurements respectively) performed by CHWs, in identifying individuals with hypertension relative to the gold standard (i.e. 24-hour blood pressure measurement). The impact of this study (together with other activities of the IHCoR-Africa study) is expected to improve diagnosis and the outcome of people living with high blood pressure in rural SSA.

2. Increase treatment allocation: Treatment allocation should be improved to ensure untreated patients receive treatment. There are several barriers to this, including patient/individual level and system level factors. Individual level factors include poor understanding of hypertension, fear of taking treatment for hypertension and unwillingness of patients to take treatment especially when they are asymptomatic (166). These factors underline the need for education about hypertension and the

benefits of treatment. Health system factors on the other hand include lack of understanding of guidelines by healthcare workers or their unwillingness to follow hypertension guidelines. It is therefore imperative to regulate and develop policies to train healthcare workers to adhere to established treatment protocols.

3. **Improve treatment outcomes**: This requires a multifaceted approach involving developing a comprehensive approach including strengthening support for patients and their carers. Adherence to treatment should be reinforced in those currently receiving treatment. Given that a lot of patients receiving treatment do not achieve success, current pharmacological treatment guidelines should be revisited complemented by further research to generate better treatments in native Africans. Some guidelines recommend a combination of thiazide diuretic and calcium-channel blockers as first line agent in black patients, as they have been found to be superior to renin-angiotensin blockers (76). However, such research has only been conducted in diaspora Africans (Afro-Americans) and I am not aware of any such studies comparing these blood pressure agents in native Africans. Such research should also systematically assess the health service and system structures, strengthen the evidence base for how to identify those who would benefit most from treatment and to find better approaches for risk stratification that will work in a low-income setting.

8.6 Implications for future research

There has been a lot of research on hypertension globally and to some extent in some SSA. In the region especially, the current research evidence has three major limitations. First, most of the research conducted to address NCDs focuses on

individual cardiovascular risk factors. As we have seen from the thesis and from evidence elsewhere, hypertension seldom exists in isolation but rather together with other co-morbid conditions (including diabetes, obesity, and dyslipidaemia) which further increases cardiovascular risk. Such a research approach also neglects international consensus for an overall CVD risk approach which considers multiple cardiometabolic risk factors to inform risk assessment and management (167).

Second, existing research has largely studied isolated implementation strategies at the facility or provider level, despite lessons from other chronic diseases such as HIV in SSA that highlight the importance of community-based, multi-faceted approaches (168).

Finally, studies thus far have failed to consider the broader health system context, hindering scale-up and sustainability. A contextualised community-based programme that addresses overall cardiovascular diseases risk through a combination of strategies has the potential to significantly improve cardiovascular diseases outcomes in SSA, but evidence to guide such an approach is lacking.

8.7 Strengths

This was the largest cross-sectional survey conducted on NCDs in The Gambia. The study focussed on adults aged 35 years or more who are disproportionately affected by chronic NCDs. The analyses were weighted and standardised to the Gambian population to ensure generalisability to the population (of this age group). This study is the first to investigate issues such as the clustering of comorbidities, the evaluation of the cascade of care for hypertension, blood pressure levels according to the care cascade and the continuous association between BMI and blood pressure levels.

8.8 Limitations

Despite its robust design, the findings in this thesis should be considered with some limitations. The study included only adults aged 35 years or more and hence is not generalisable to the younger population who account for the majority of the Gambian population. Additional factors that were not collected in the study, such as physical activity level, salt intake, sugar and ultraprocessed food consumption, and access to food and health care, would have increased the understanding of the drivers of these NCDs. We used capillary glucose, which is not considered as the gold standard for the assessment of diabetes status. We included only three conditions in estimating the burden of multimorbidity which will underestimate its prevalence in The Gambia. The blood pressure measurements were cross-sectional whereas current clinical approaches require several measurements at different timepoints to establish diagnosis and confirm treatment effects. The evaluation of the care cascade and blood pressure levels only considered pharmacological treatment as data on other lifestyle approaches such as weight loss and salt intake, were not collected.

Future research priorities

My future research priorities will focus on decreasing the substantial burden of hypertension in SSA. Immediately following the PhD, I will analyse additional data which I collected during the PhD. This includes follow up data on 400 individuals with hypertension who took part in the 2019 GNEHS. In these individuals, I will combine sociodemographic, clinical, laboratory, ECG, echocardiography and vascular function variables to explore whether hypertension phenotypes cluster into identifiable sub-

groups that would better characterise the possible mechanism(s) of their hypertension. I will further investigate the burden, characteristics, and associated factors of hypertension-mediated organ damage. Finally, I will use paired ECG and echocardiography data to validate the potential for artificial intelligence-enabled ECG to screen for cardiac contractile dysfunction in low resource settings.

I will also continue the ongoing the IHCoR-Africa project whose overall aim is to test innovative methods of detecting hypertension and target organ damage that can then be applied on a wider scale in similar resource limited settings. In collaboration with partners in Kenya and the UK, we envisage that this will deliver the strongest evidence to date about different diagnostic approaches for high blood pressure in rural SSA, a unique understanding of the prevalence and characteristics of organ damage related to high blood pressure in this population, and a robust assessment of the role of innovative, simple, point-of-care devices to manage high blood pressure in rural SSA. In addition, it will provide new evidence of high blood pressure phenotypes in rural SSA. Ultimately, the impact of this study (together with other activities of the IHCoR-Africa study) is expected to improve the outcome of people living with high blood pressure in rural SSA.

Together with colleagues in North-West University in South Africa, we have recently established the Childhood Hypertension Consortium. Through this consortium, we will pool existing data to develop a high impact analysis to develop a call to action for developing African-specific nomograms for childhood blood pressure and body composition. We believe that by analysing already collected data in a pooled analysis will give us meaningful information to develop African nomograms and to spearhead large international funding to support this cause.

Finally, I will be developing a proposal for a fellowship to characterise renin-angiotensin-aldosterone system in sub-Saharan Africans and to examine treatment responses in tightly experimental studies to inform larger clinical trials.

Conclusion

The PhD documented a high prevalence of NCDs in The Gambia, a poor cascade of care performance for hypertension and unacceptably high levels of blood pressure including for those receiving treatment. The study also shows that although blood pressure increases with BMI, this rise was steep in men and gradual or benign in women. The data therefore calls for an urgent, multisectoral strategy to reduce the burden of NCDs in The Gambia. Population screening to improve diagnosis, increase treatment allocation of untreated cases and adopting better treatment strategies to improve treatment success.

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APPENDICES

Wellcome Open Research

Wellcome Open Research 2021, 6:10 Last updated: 27 OCT 2022

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STUDY PROTOCOL

REVISED The Gambia National Eye Health Survey 2019: survey protocol [version 2; peer review: 2 approved]

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Abstract

Two national surveys of vision impairment and blindness were undertaken in The Gambia in 1986 and 1996. These provided data for the inception of The Gambia's National Eye Health Programme (NEHP) within the Ministry of Health and Social Welfare. There have been important developments in the eye health services provided by the NEHP in the last 20 years. At the same time, the population has also undergone major demographic changes that may have led to substantial changes in the burden of eye disease.

We conducted a National Eye Health Survey of vision impairment, blindness and its comorbidities in adults in The Gambia in 2019. We examined a nationally representative population-based sample of adults 35 years and above to permit direct comparison with the data available from the previous surveys.

Alongside a comprehensive vision and eye examination, the survey provides nationally representative data on important comorbidities in this population: diabetes, hypertension, obesity, hearing impairment, disability and mental health. Secondly, it estimates access to assistive technologies and eye health services. Thirdly, it is powered to allow a five-year follow up cohort study to measure the incidence and

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progression of eye disease.

Keywords
Eye health survey, vision impairment, blindness, comorbidity, non-communicable diseases, mental health, disability, assistive technology, mobile tools

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Any reports and responses or comments on the article can be found at the end of the article.

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REVISED **Amendments from Version 1**

Minor revisions have been made to the manuscript to address reviewers' comments. This includes two new outcome indicator definitions in Table 1, and additional information related to monitoring teams, comparability between surveys and management of under-sampling of males.

Any further responses from the reviewers can be found at the end of the article

Introduction

National surveys of vision impairment (VI) and blindness were undertaken in The Gambia in 1986 and 1996[1,2]. The 1986 survey provided baseline data on the prevalence and causes of VI and blindness to support the inception of The Gambia's National Eye Health Programme (NEHP) within the Ministry of Health and Social Welfare. The 1996 survey was completed on an independent sample using the same sampling and examination techniques to provide updated prevalence estimates and relative risk ratios compared to 1986.

The national all-age prevalence of blindness (presenting visual acuity [VA]<3/60, in the better seeing eye) was 0.7% in 1986 and 0.4% in 1996 (confidence intervals [CI] not reported)[1,2]. The age-standardised difference between the estimates was not significant at the national level, but there was a higher relative risk of blindness in 1986 compared to 1996 (age adjusted risk ratio [adjRR] 2.2, 95% CI 1.2 – 3.8%) in the Western Region, where NEHP had first been instigated. Both surveys categorised "low vision" as VA <6/18 and ≥3/60, and a modest increase in this category from 1.4% to 1.6% was observed nationally over the same period (adjRR 0.7, 0.6 – 0.9)[2]. Data on the prevalence of eye disease highlighted cataract, aphakia, uncorrected refractive errors and corneal infections as the leading causes of blindness and low vision in both studies[1,2].

The 1996 survey also provided an opportunity to investigate the burden of non-communicable diseases (NCDs) in The Gambia. The nationwide prevalence of being overweight and obese were 8.1% and 2.1% respectively, hypertension was 24.2% and diabetes mellitus was 0.3%[3].

In the more than twenty years since the last comprehensive eye health survey in The Gambia, the NEHP has developed further. This has included the establishment of a new Regional Eye Care Centre in 2007 and several additional centres offering cataract surgery, distributed across the country. In addition, there has been major investment in the development of refractive error services and new in-country capacity to manufacture spectacles[4].

During this same period The Gambia has undergone major demographic changes. The population has grown: from 800,000 in 1986 to 1,170,000 in 1996 and 2,300,000 in 2018[1,2,5]. Life expectancy has increased from 44 years in 1983 to 62 years in 2018, driving a relative and absolute increase in the proportion of the population who are older and in whom prevalence of VI and blindness is highest[6,7]. There has also been considerable migration from rural to urban areas, with an associated change in lifestyle. Globally, increased urbanisation has been linked to increases in the prevalence of NCDs, particularly diabetes and hypertension[8]. Taken together, it is likely that the current population burden of eye disease in The Gambia differs substantially from previous estimates. To address this need for updated eye health data, we conducted a national survey of eye health and its comorbidities between February and July 2019.

Comprehensive eye health surveys are relatively resource intensive in comparison to commonly used rapid methodologies, such as the Rapid Assessment of Avoidable Blindness (RAAB)[9]. RAAB uses simplified examination procedures and equipment and only samples the population 50 years and older (blindness prevalence is higher in this group than among all ages)[10]. RAAB provides a substantial proportion of Global Burden of Disease data on vision impairment and blindness[11], but recent data comparing RAAB outputs to a more comprehensive methodology are lacking. As an additional objective, we nested the RAAB methodology within this comprehensive survey methodology, to compare findings from a comprehensive versus rapid methodology on the same sample.

This protocol has been prepared to provide a detailed summary of the survey methods, sample characteristics and analytical approaches, in advance of results to be published later in 2021.

Protocol

Study aim

To assess the prevalence of vision impairment and its causes and comorbidities in a nationally representative population-based sample of adults 35 years and older in The Gambia, and compare this with the situation in 1996.

Study objectives

1. To estimate the prevalence and causes of vision impairment and blindness in The Gambia in adults 35 years and older, and in the sub-group 50 years and older, stratified by sex
2. To estimate the prevalence of cataract, corneal blindness/ocular trauma, uncorrected refractive error, trichiasis, glaucoma, diabetic retinopathy and age-related macular degeneration in the Gambia in adults 35 years and older and 50 years and older
3. To evaluate the impact of current Gambia National Eye Health Programme activities, including the provision of cataract and refractive error services
4. To estimate the prevalence of diabetes, hypertension and associated risk factors (body mass index, alcohol and tobacco) of NCDs in the Gambia in adults 35 years and older, and relate these to ocular health
5. To estimate the prevalence of hearing impairment, musculoskeletal impairment, disability and mental health limitations in the Gambia in adults 35 years and older, and relate these to ocular health and the need for vision and hearing assistive products

6. To establish a phenotyped baseline for a long-term eye health cohort study
7. To compare outputs from a comprehensive eye health survey to a rapid methodology

Sample frame and size

The 2013 Gambia National Census population estimates were used as the sampling frame[12]. Multi-stage stratified cluster random sampling with probability proportional to size procedures were used to identify a nationally representative sample of adults 35 years and older, in clusters of 30. Clusters of 30 were selected as the pragmatic number of examinations each team could complete per day. These were selected from standard Gambia Bureau of Statistics (GBoS) Census Enumeration Areas (EAs). The country was divided into three broad regions for comparability to the 1996 estimates: Central, Eastern and Western (Figure 1). Each of these regions was further stratified to reflect urban and rural population proportions, using Gambia Bureau of Statistics' definitions.

The sample was powered to detect disease prevalence as low as 0.5% based on relevant literature on glaucoma, diabetic retinopathy and blindness prevalence in the region[2,13,14]. The calculation included a design effect of 2.5 to account for cluster sampling, assuming that samples would be moderately clustered, with an intraclass correlation coefficient (ICC) of 0.038 in clusters of approximately 30 adults 35 years and older[15]. Accounting for response/follow-up drop-out rate of 20%, regional and urban/rural stratification, and stratification by 35 years and older and 50 years and older, the 5-year expected incidence rate of blindness, and a binomial exact distribution with an estimated margin of error of 0.25% to account for rare conditions ($p<0.1$), the overall sample size calculated was 10,800 adults age 35 years and older in 360 clusters of approximately 30 adults per cluster.

Team composition and training

Four teams collected the survey data. Each team was comprised of one ophthalmologist, one optometrist or optometry technician, one senior ophthalmic medical assistant (SOMA), one general nurse, one mental health nurse, and two enumerators. There is only one practicing audiology nurse in The Gambia, who joined one of the teams. This was sufficient given an expected prevalence of hearing impairment of 9%, requiring a sample size of 2,700 (1/4 the overall sample)[16].

Teams underwent ten days of training in February 2019, including standardised tests of protocol adherence, practice examinations and pilot testing. Questionnaires were pre-tested, and revised where necessary following the pilot. A formal interobserver variability test was completed for vision testing. Compared to an arbitrarily selected gold standard, two teams achieved substantial agreement (0.7 and 0.8, both $p<0.001$), while one achieved fair agreement (0.4, $p<0.001$), requiring further consolidation of research protocol material before beginning data collection.

Team ophthalmologists were trained in the conduction of eye examinations according to protocol by the study PI, a senior consultant ophthalmologist. Only two ophthalmologists were available for the entire duration of data collection. Two teams therefore included a number of different ophthalmologists over the course of the data collection, each trained by a predecessor during a minimum two-day handover. The study PI continued to observe the teams regularly throughout data collection, to ensure that protocol was being followed.

Pre-data collection preparation

Data collection was scheduled to progress from the east to the west of the country, with all four teams travelling together and completing nearby clusters before moving to the next location. An advance team of enumerators moved ahead of survey teams to notify regional administrative stakeholders, sensitise communities (both for cooperation and acceptance) and manage survey logistics. A vehicle maintenance and servicing schedule was prepared and regional fuel suppliers were identified. The Ministry of Health provided five 4-wheel drive vehicles for the study fieldwork, and released 24 clinical and 19 support staff from their roles, to participate in the survey. The Statistician General of GBoS released eight experienced survey field enumerators and a supervisor, and provided the study teams with EA and regional maps.

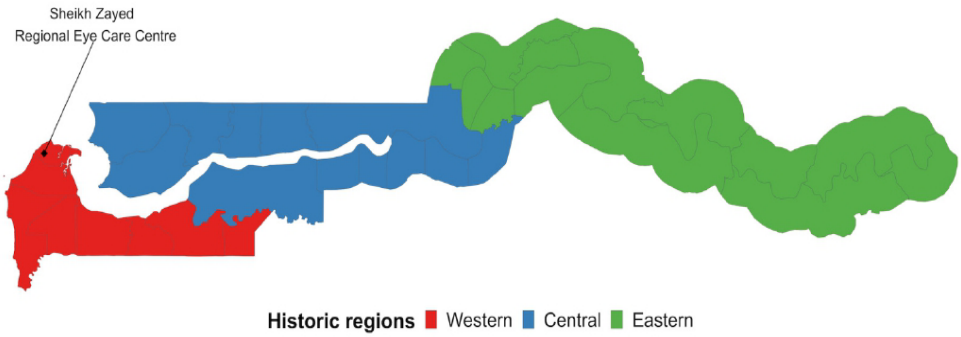

Figure 1. Historic regions of the Gambia.

Data collection procedures

Participant recruitment and informed consent. Enumerators used EA maps to visit each cluster in advance, complete a household listing of all eligible residents and identify a central location for the examination. At each household, the purpose of the survey was explained verbally to the household head or an adult key informant using a pre-written study participant information sheet (*Extended data*[17]).

If the household head or adult key informant agreed to participate, the enumerator recorded the age, sex and relationship to household head of all eligible household members, irrespective of availability.

Household members were eligible if they were 35 or older, residing in a household in the EA and:

- Had lived in the house at least 6 months of the last year
- Ate shared meals with other household members
- Did not pay, and were not paid by, other household members

Once the listing was completed, enumerators segmented the list into groups of 30 participants, numbered these and selected one segment at random by drawing a number out of a hat. Enumerators returned to the selected segment to provide further information to household members about the details of examination at a central location (within the EA) the following day, and to collect a Global Positioning System (GPS) point reading and data on household characteristics and indicators of socio-economic position (see below). Participants were given urine receptacles to fill the following morning and requested not to have breakfast until after the survey team had arrived.

Enrolment was completed the morning after enumeration, when enumerators returned to the household with the team's general nurse. Written informed consent was collected by fingerprint or signature for each available participant. Eligible participants who were not available after two repeat visits to the household were recorded as non-responders.

Data collection at the household. On the day of the examination, an enumerator and a general nurse first visited each household in the segment. Each participant was provided with a cardboard participant ID slip recording the household data collection outputs. This was used to track completion of each subsequent component of the examination protocol.

Participants first undertook a fasting Boehringer Mannheim glucose test at their household, completed by the general nurse using sterile lancets, test strips and a glucometer (Accu-chek Aviva Meter). If the participant had not fasted (defined as only ingesting water in the last eight hours), the test was recorded as random. Our original protocol also included HbA_{1c} testing using a portable HbA_{1c} machine (A1CNow+, Bayer) and finger blood sample for participants with fasting blood glucose >= 5.6mmol/L, random blood glucose >= 7.8 mmol/L, or a known history of diabetes. However, the ambient field work conditions (temperature and humidity) were such that the HbA_{1c} test performance was unreliable, and consequently this was abandoned.

Urinalysis was completed using Multistix 10 SF Urinalysis strips (Siemens). Tests for leucocytes, nitrates, proteins, blood, glucose, ketones and pH level were recorded on the participant slip. Participants were then invited to receive breakfast or lunch (staggered per 10 participants to avoid congestion at field stations) at the central location prior to the remainder of the survey assessment.

Data collection at the central location. Participant attendance was recorded on entry at the central location, and data collected at the household was transferred from the participant ID slip to a mobile data collection form on a Huawei MediaPad M3 tablet device. Assessments were split across several stations within the central location. The participant ID slip was used by team members to document assessment completion and relay information on referrals (see below). The full study questionnaire is available as *Extended data*[17].

Demographics and general health assessment

The team general and mental health nurses completed the demographics and general health assessment.

Demographics and self-reported socio-economic position

A face photograph was taken of each participant to aid follow up, and demographic data including education, ethnic group and household composition was captured. EquityTool, an objective tool comprised of 12 country-specific assets, was used to generate a relative wealth index[18]. Three self-reported socio-economic position tools were also used: perceived adequacy of household food consumption, perceived adequacy of household income and a socio-economic ladder question[19].

Anthropometry

Height was measured using a Leicester height measure Mk II, with participant head positioned in the Frankfurt plane. Weight and body fat percentage were measured using a Tanita BC-545n body composition monitor.

Blood pressure

Blood pressure was measured in triplicate, once per arm and then repeated in the arm with the higher reading. The participant was seated, with their arm supported at the level of the heart and resting on a surface, and measured using an automated OMRON-Healthcare 10 Series blood pressure monitor (Omron). Measurements were taken five minutes apart, and an average of the last two measures was recorded for analysis.

Genetic sample

A genetic sample was taken for each consenting participant, for archiving and future genetic testing. One upper cheek buccal swab sample was collected per participant using a cyto-brush. Each specimen was sealed in an envelope labelled with the participant ID and stored at room-temperature.

Self-reported NCD history and risk factors

Participants responded to a pre-coded questionnaire module on personal and family history of diabetes, hypertension and

cholesterol level. Smoking and alcohol consumption habits were recorded and body image and attractiveness were assessed using the Figure Rating Scale[20]. Medication and treatment history were recorded for known diabetics and hypertensives.

Eye health assessment

Visual acuity was measured indoors by the team optometrist or optometry technician, with no direct sunlight or glare in the direction of the participant or the VA test chart. The vision testing protocol is summarised diagrammatically in *Extended data*[17].

Distance visual acuity: Monocular distance visual acuity (uncorrected and wearing available correction) was measured using Peek Acuity – a validated Android-deployed 'tumbling E' visual acuity test – on the tablet devices[21]. All participants whose uncorrected (or corrected, if wearing spectacles) visual acuity was less than 6/12 in either eye underwent 1) a pinhole test in the eye(s) less than 6/12 (Lorgnette multi 17 occluder) and 2) objective and subjective refraction of both eyes using a trial lens set and fixed wall chart (3 metre Snellen chart, Sussex Vision). Monocular best corrected visual acuity (BCVA) was measured with Peek Acuity following refraction.

Near vision screening: Binocular near vision screening was carried out with participants wearing near correction, if available (i.e. presenting near vision). A binary outcome of can (at least 4/5 optotypes correct), or cannot, read an N8 crowded tumbling E optotype at 40cm was recorded. If participants could not see N8 with presenting near vision they were corrected with age-appropriate near addition lenses in a trial frame and retested at the same threshold.

Contrast sensitivity: Monocular and binocular contrast sensitivity was measured using the smartphone-based Peek Contrast test deployed on a Sony Z3 smartphone[22]. The test presented successively lower contrast tumbling E optotypes until they were no longer distinguishable from the background. The test provided a contrast sensitivity measure calibrated to the Pelli-Robson contrast sensitivity test, and an average measure of the ambient light in lux.

Intraocular pressure: Intraocular pressure (IOP) was measured by the team's SOMA using an iCare ic100 tonometer according to device specifications. Time of testing was recorded, and the first eye measured was alternated between participants to avoid operator bias. Unless contra-indicated by current corneal infection, each iCare probe tip was disinfected and used six times before disposal[23].

Ocular examination and imaging: The team's ophthalmologist examined both eyes. First, the standard RAAB examination procedure was completed. This included undilated direct ophthalmoscopy examination of the anterior segment and fundus and a lens status screen with pen torch. The RAAB algorithm, whereby the most readily treatable condition only is recorded, was applied to categorise the main cause of VI (presenting <6/12) per eye and per person[9]. This was undertaken to allow the RAAB methodology-derived diagnosis of cause of VI to be compared with the findings of the subsequent detailed and dilated examination.

The eyelids and anterior segment of the eye (conjunctiva, sclera, cornea, iris and lens) were then examined in detail using a slit-lamp, to document presence of anterior segment eye disease and trachomatous trichiasis using a standardised eye health survey examination form comparable to the 1996 survey methodology. Table 1 describes the study's outcome measures, including where specific, published grading protocols for classifying particular eye diseases were followed.

Table 1. Definitions for the study's primary and secondary outcome measures.

Primary Outcome Measures		
Measure	**Category**	**Definition**
Distance Vision Impairment	Any Vision Impairment	Presenting distance visual acuity (PVA, with available correction if worn) <6/12 in the better seeing eye
	No Vision Impairment	PVA ≥ 6/12 in the better seeing eye
	Mild Vision Impairment	PVA <6/12 and ≥ 6/18 in the better seeing eye
	Moderate Vision Impairment	PVA <6/18 and ≥6/60 in the better seeing eye
	Severe Vision Impairment	PVA <6/60 and ≥3/60 in the better seeing eye
	Blind	PVA <3/60 in the better seeing eye
Sub-categories of blindness	Not blind	PVA ≥ 3/60in the better seeing eye
	<3/60 – 1/60	PVA <3/60 and ≥ 1/60 in the better seeing eye
	<1/60 – Light Perception	PVA ≥ 1/60 and light perception in the better seeing eye
	No Light Perception	No light perception in the better seeing eye
Low Vision (1996 paper comparison)	Low Vision	PVA <6/18 and ≥3/60 in the better seeing eye

Primary Outcome Measures		
Measure	**Category**	**Definition**
Near Vision Impairment	Presenting Near Vision Impairment	Cannot see N8 (binocular), with available correction if worn
	Corrected Near Vision Impairment	Cannot see N8 (binocular), whilst wearing near correction
Secondary Outcome Measures (ocular, per eye)		
Anterior Segment Eye Disease	Any Refractive Error	Uncorrected visual acuity (UCVA) <6/12 improving to ≥ 6/12 with available correction, pinhole or refraction
	Vision Impairing Refractive Error	Presenting visual acuity (PVA) <6/12 improving to ≥ 6/12 with pinhole or refraction
	Cataract[24]	Any grade 1 - 3 of nuclear, cortical or posterior capsular cataract or, if ungradable, any cataract marked mature or hypermature using WHO Cataract Grading Tool
	Cataract Surgical Complications	Aphakia, posterior capsular opacification, aphakic bullous or pseudophakic bullous keratopathy identified on ophthalmic examination
	Trachoma corneal opacity[25,26]	Current trichiasis (defined using WHO 2019 definition), or evidence of prior trichiasis surgery alongside corneal scarring (C2a – C4 only) in the same eye
	Other corneal opacity[26]	Corneal scarring but no prior trichiasis or prior trichiasis surgery in the same eye (C2a – C4 only)
	Other anterior segment eye disease	Presence of at least one of the below pre-coded diseases, identified on slit lamp examination: pterygium (cornea involved), band keratopathy, corneal ulcer, uveitis, or other anterior segment ocular disease ***or*** other anterior segment disease described in open text
Posterior Segment Eye Disease	Age-related maculopathy and degeneration (ARMD)	Any ARMD including: drusen or hypo/hyper pigmentation without degeneration, dry or geographic, or wet/neovascular or disciform
	Glaucoma[27]	99.5% percentile of cup-disc ratio or asymmetry (Category 2), based on field grading. If optic disc not visible: PVA <3/60 and IOP in the 99.5% percentile
	Any diabetic retinopathy[28]	Any diabetic retinopathy at least R1 or M1 using the Scottish Grading System, based on dilated ocular photograph grading
	Sight-threatening diabetic retinopathy (STDR)[29]	Proliferative Retinopathy (R4) or Referable Maculopathy (M2) using the Scottish Grading System, based on dilated ocular photograph grading
	Optic disc atrophy	Optic disc atrophy marked as present but does not meet glaucoma definition
	Other posterior segment eye disease	Presence of pseudo-exfoliation, identified on slit lamp examination ***or*** other posterior segment disease described in open text
	Main cause of distance vision impairment	In all eyes with PVA<6/12, disease presence as above. If more than one of the above definitions are met in one eye using the definitions above, the main cause will be listed as the highest ranking in order of: 1. Refractive Error 2. Cataract 3. Other Anterior Segment 4. Posterior segment 5. Globe 6. Unknown If more than one of the above definitions is met in one person, the main cause at the person level will be listed as the highest ranking in this order. Participants with PVA<6/12 with no reported anterior or posterior segment disease as defined above were categorised as unknown. A known limitation of this hierarchical approach to determining the "main cause" is that it will lead to under estimation of posterior segment causes. The proportion of people with comorbidities will be reported, and manuscripts detailing prevalence and associations of specific eye diseases will provide further detailed breakdown on anterior and posterior causes of VI.

A complete assessment at the central location took roughly 1.5 hours, but varied depending on the participants' health status and according to how many other participants were attending the central location at the time.

Unless contra-indicated (IOP ≥35mmHg or van Herrick's grade 2 or 1 was recorded), all participants were then dilated in both eyes using the short-acting mydriatic eye drop tropicamide 1%. A slit lamp and a 90D fundus lens, were used to complete a comprehensive examination and grade predetermined lens, retinal and optic disc disease.

Imaging was completed by the team's SOMA. The anterior segment of both eyes was photographed using a Nikon D5600 Digital Single Lens Reflex (SLR) camera with macro lens and flash. The posterior segment was photographed (disc centred and macula centred images) using the Remidio Retinal Camera imaging system[35].

Other impairment and functioning assessment

Self-reported functioning: The team general nurse used the Washington Group Short Set to measure self-reported functional limitations in seeing, hearing, walking/climbing, remembering/concentrating, understanding/being understood and selfcare[36]. Mental Health was assessed by the mental health nurse using two well-established tools: The Patient Health Questionnaire 9 (PHQ 9) for measuring depression[37], and the Generalised Anxiety Disorder 7 item tool (GAD-7)[38], for anxiety.

Self-reported assistive product use and need: The general nurse asked reported need for, use of and barriers to access to assisted products (including glasses) using a modified version of the World Health Organisation (WHO) rapid assistive technology assessment (rATA)[39].

Musculoskeletal impairment: The general nurse used the six screening questions from the Rapid Assessment of Musculoskeletal impairment to screen for musculoskeletal impairment (MSI)[40].

Hearing impairment: In the team measuring hearing impairment, an audiology nurse screened for hearing impairment using HearTest, a validated mobile pure tone audiometry application deployed on a Samsung Galaxy A3 Smartphone together with calibrated, noise-cancelling Sennheiser HD280 pro circumaural headphones[41]. Hearing tests were completed in a separate and private area, and ambient noise levels were automatically recorded by the device, which flagged a warning when these reached unacceptable levels. Following the Rapid Assessment of Hearing Loss (RAHL) methodology, all participants screened for hearing impairment also had their ears briefly examined by the team audiology nurse to assess ear health, and if applicable determine cause of hearing loss and appropriate referral mechanisms[16].

Diagnoses and referrals

Survey teams carried basic first aid kits and medicines for treating common illnesses, and referral letters for onward services. Referrals for eye conditions were made to the Sheikh Zayed Regional Eye Care Centre in Kanifing, close to the capital city Banjul. Participants with blood pressure readings above 95 mm/Hg diastolic or 150 mm/Hg systolic, alongside participants judged by the team general nurse to require follow up services for other reasons (including emergencies) were referred to relevant primary health services. The team mental health nurses made referrals to relevant mental health services as per their clinical judgement following screening. Any participant with hearing impairment ≥35 dBA in the better ear or who was otherwise considered in need of referral by the audiology nurse was referred to the relevant ENT services.

Data management

Data collection forms were built using Open Data Kit (ODK) software[42]. Tablets were password protected and team leaders used data SIM cards to transfer the encrypted data to a secure ODK server held at the London School of Hygiene & Tropical Medicine (LSHTM) daily. Electronic data support was provided by LSHTM Global Health Analytics (odk.lshtm.ac.uk). During data collection, anterior segment images were stored locally on password-protected laptop computers and backed up weekly to password-protected storage drives. After data collection, all images were transferred to a secured LSHTM server.

Anonymised posterior segment images were transferred via WiFi daily to a secured cloud-based platform. Fundus image grading for diabetes, AMD and glaucoma will be performed remotely by trained ophthalmologists, following a formal training and inter-observer variation test.

Data preparation

Data collection was completed between March and July 2019. Raw data were exported from the secure server and imported into STATA version 14.0. Data were merged into a single database and anonymised.

Data completeness. To prevent listwise deletion, all data were checked for completeness. Figure 2 summarises this process.

Sample characteristics. Table 2 presents the final sample population characteristics, compared with the characteristics of the population in the 2013 Census[12]. The survey oversampled women compared to men (70.3% female vs. 29.7% male). Additionally, selection probabilities were lower than expected in several age groups (5-year band) and in clusters.

Poststratification sample weights were calculated to account for the disproportionate age-sex sampling by 5-year band. Two sample weights were created, one to generalize the findings to the 2013 Gambia Census[12], and one to the WHO Standard Population[43]. All weights were then multiplied with the cluster selection probabilities.

Defining outcome measures. Table 1 describes the definitions for the study's primary and secondary outcome measures.

Primary Outcome Measures		
Measure	**Category**	**Definition**
Service Coverage	Cataract Surgical Coverage (CSC)	Proportion of people with operated cataract (pseudophakia/aphakia) as a proportion of all people with operated cataract or operable cataract (defined at different thresholds of BCVA)
	Refractive Error Coverage (REC)	Proportion of people with refractive error (UCVA<6/12 in the better eye, correctable to 6/12 or better) with refractive error correction
Effective Service Coverage	Effective Cataract Surgical Coverage (eCSC)[30]	Proportion of people with operated cataract (pseudophakia/aphakia) and good postoperative presenting visual acuity (VA 6/12 or better) as a proportion of all people with operated cataract or operable cataract (defined at different thresholds of BCVA)
	Effective Refractive Error Coverage (eREC)[31]	Proportion of people with refractive error (UCVA<6/12 in the better eye, correctable to 6/12 or better) with refractive error correction and a good outcome (CVA 6/12 or better)
Secondary Outcome Measures (non-ocular)		
Hypertension		Average systolic blood pressure values across two readings of ≥140 mmHg and/or diastolic values of ≥90 mmHg and/or taking antihypertensive medication and/or reported history of hypertension
Diabetes	Diabetic	Reported history of diabetes (told by healthcare worker and/or on diabetic treatment), fasting blood glucose (FBG) ≥7mmol/L or random blood glucose (RGB) ≥11mmol/L
	Pre-diabetic	FBG >5.6 <7, or RBG ≥7.8 <11
	Not diabetic	No reported history of diabetes and neither impaired FBG or RBG
Obesity	Underweight	Body Mass Index (BMI) under 18
	Normal	BMI ≥18 and <25
	Overweight	BMI ≥25 and >30
	Obese	BMI ≥30
Hearing Impairment[32]	None	>19 decibels hearing level (dbHL) jn either ear
	Mild	20 to <35 dBHL in the better hearing ear
	Moderate	35 to <50 dBHL in the better hearing ear
	Moderately Severe	50 to <65 dBHL in the better hearing ear
	Severe	65 to <0 dBHL in the better hearing ear
	Profound	80 to <95 dBHL in the better hearing ear
	Complete/ total	95 dBHL or greater in the better hearing ear
	Binary Classification	20dbHL or greater in the better hearing ear
Anxiety[33]	None	Score of 0-4 on GAD-7
	Mild	Score of 5-9 on GAD-7
	Moderate	Score of 10-14 on GAD-7
	Severe	Score of ≥15- on GAD-7
	Binary Classification	Score of ≥ 10 on GAD-7
Depression[34]	None	Score of 0-4 on PHQ-9
	Mild	Score of 5-9 on PHQ-9
	Moderate	Score of 10-14 on PHQ-9
	Moderately Severe	Score of 15-19 on PHQ-9
	Severe	Score of 20-27 on PHQ-9
	Binary Classification	Score of ≥ 10 on PHQ-9
Disability		Any of the 6 Washington Group Short Set Functional Domains reported "a lot of difficulty" or "cannot do"

A complete assessment at the central location took roughly 1.5 hours, but varied depending on the participants' health status and according to how many other participants were attending the central location at the time.

Unless contra-indicated (IOP ≥35mmHg or van Herrick's grade 2 or 1 was recorded), all participants were then dilated in both eyes using the short-acting mydriatic eye drop tropicamide 1%. A slit lamp and a 90D fundus lens, were used to complete a comprehensive examination and grade predetermined lens, retinal and optic disc disease.

Imaging was completed by the team's SOMA. The anterior segment of both eyes was photographed using a Nikon D5600 Digital Single Lens Reflex (SLR) camera with macro lens and flash. The posterior segment was photographed (disc centred and macula centred images) using the Remidio Retinal Camera imaging system[35].

Other impairment and functioning assessment

Self-reported functioning: The team general nurse used the Washington Group Short Set to measure self-reported functional limitations in seeing, hearing, walking/climbing, remembering/concentrating, understanding/being understood and selfcare[36]. Mental Health was assessed by the mental health nurse using two well-established tools: The Patient Health Questionnaire 9 (PHQ 9) for measuring depression[37], and the Generalised Anxiety Disorder 7 item tool (GAD-7)[38], for anxiety.

Self-reported assistive product use and need: The general nurse asked reported need for, use of and barriers to access to assisted products (including glasses) using a modified version of the World Health Organisation (WHO) rapid assistive technology assessment (rATA)[39].

Musculoskeletal impairment: The general nurse used the six screening questions from the Rapid Assessment of Musculoskeletal impairment to screen for musculoskeletal impairment (MSI)[40].

Hearing impairment: In the team measuring hearing impairment, an audiology nurse screened for hearing impairment using HearTest, a validated mobile pure tone audiometry application deployed on a Samsung Galaxy A3 Smartphone together with calibrated, noise-cancelling Sennheiser HD280 pro circumaural headphones[41]. Hearing tests were completed in a separate and private area, and ambient noise levels were automatically recorded by the device, which flagged a warning when these reached unacceptable levels. Following the Rapid Assessment of Hearing Loss (RAHL) methodology, all participants screened for hearing impairment also had their ears briefly examined by the team audiology nurse to assess ear health, and if applicable determine cause of hearing loss and appropriate referral mechanisms[16].

Diagnoses and referrals

Survey teams carried basic first aid kits and medicines for treating common illnesses, and referral letters for onward services. Referrals for eye conditions were made to the Sheikh Zayed Regional Eye Care Centre in Kanifing, close to the capital city Banjul. Participants with blood pressure readings above 95 mm/Hg diastolic or 150 mm/Hg systolic, alongside participants judged by the team general nurse to require follow up services for other reasons (including emergencies) were referred to relevant primary health services. The team mental health nurses made referrals to relevant mental health services as per their clinical judgement following screening. Any participant with hearing impairment ≥35 dBA in the better ear or who was otherwise considered in need of referral by the audiology nurse was referred to the relevant ENT services.

Data management

Data collection forms were built using Open Data Kit (ODK) software[42]. Tablets were password protected and team leaders used data SIM cards to transfer the encrypted data to a secure ODK server held at the London School of Hygiene & Tropical Medicine (LSHTM) daily. Electronic data support was provided by LSHTM Global Health Analytics (odk.lshtm.ac.uk). During data collection, anterior segment images were stored locally on password-protected laptop computers and backed up weekly to password-protected storage drives. After data collection, all images were transferred to a secured LSHTM server.

Anonymised posterior segment images were transferred via WiFi daily to a secured cloud-based platform. Fundus image grading for diabetes, AMD and glaucoma will be performed remotely by trained ophthalmologists, following a formal training and inter-observer variation test.

Data preparation

Data collection was completed between March and July 2019. Raw data were exported from the secure server and imported into STATA version 14.0. Data were merged into a single database and anonymised.

Data completeness. To prevent listwise deletion, all data were checked for completeness. Figure 2 summarises this process.

Sample characteristics. Table 2 presents the final sample population characteristics, compared with the characteristics of the population in the 2013 Census[12]. The survey oversampled women compared to men (70.3% female vs. 29.7% male). Additionally, selection probabilities were lower than expected in several age groups (5-year band) and in clusters.

Poststratification sample weights were calculated to account for the disproportionate age-sex sampling by 5-year band. Two sample weights were created, one to generalize the findings to the 2013 Gambia Census[12], and one to the WHO Standard Population[43]. All weights were then multiplied with the cluster selection probabilities.

Defining outcome measures. Table 1 describes the definitions for the study's primary and secondary outcome measures.

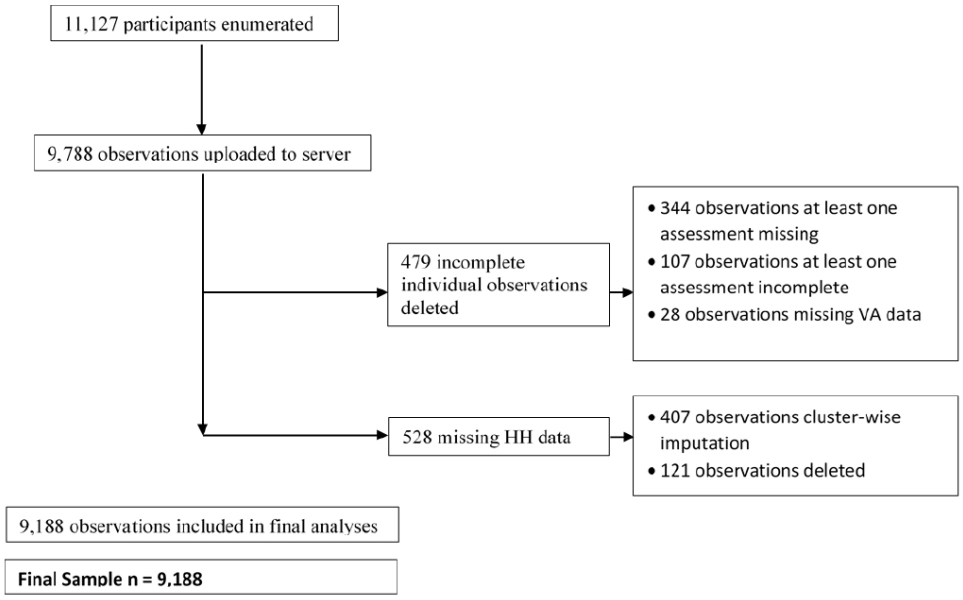

Figure 2. Flow chart of data completeness.

Socio-economic position imputation. Quintiles based on the Gambia Demographic and Health Survey 2013 were established following EquityTool procedures. To improve the integrity of socioeconomic position (SEP) data, all 12 EquityTool questions were checked for completeness. Preliminary analysis revealed that among all 360 clusters, 67 had at least one participant with one or more questions unanswered. Missing data were handled by re-approaching non-respondents of 23 clusters where more than half of its participants had incomplete SEP data.

For the remaining observations missing data, mean imputation was used in which the most frequent value of a cluster filled the missing attribute's value. Each of the EquityTool questions was treated independently of other questions and of other clusters. Missing values were not substituted if there was more than a single most frequent response observed for that attribute.

Ethics

Ethical approval for the study was granted in 2019 by the Gambia Government/MRC Joint Ethics Scientific Coordinating Committee (SCC, Ref 1635) and the LSHTM Observational/Interventions Ethics Committee (Ref 16172).

Dissemination, engagement and data availability

A summary of survey findings will be shared with relevant stakeholders through the Directorate of Planning and Information (DPI) of the Ministry of Health. Study results will be published in a suite of peer-reviewed manuscripts later in 2021 and beyond. The study team includes the National Eye Health Coordinator in the Gambia (AH), ensuring that results will feed directly into population eye health service planning. The anonymised dataset will be made available on reasonable request from the study team.

Study status

Data has been collected and prepared for analysis. Data analysis is ongoing across different study objective areas.

Strengths and limitations

The data from the Gambia National Eye Health Survey 2019 will provide valuable, robust data on population eye health and comorbidities in a nationally representative sample of the population of the Gambia 35 years and older. We used validated tools and collected data in line with international priorities and the Universal Health Coverage agenda, and maximised comparability to the previous survey by using similar screening and examination tools. The inclusion of modules on disability, hearing, musculoskeletal impairment, mental health and NCDs will support evidence-based service provision and greater understanding of comorbidities. The phenotyping and sample adjustment to support establishment of a cohort study may provide powerful data on the incidence and progression of disease.

Table 2. Sample characteristics.

	Sample, n (%)	Census 2013, n (%)
Age Group		
35 – 44	4,102 (44.7)	167,595 (43.7)
45 – 54	2,061 (22.4)	101,183 (26.4)
55 – 64	1,444 (15.7)	56,894 (14.8)
65 – 74	1,018(11.1)	33,755 (8.8)
75 – 84	441 (4.8)	16,521 (4.3)
85+	122 (1.3)	7779 (2.0)
Mean (SD)	49.6 (13.4)	
Sex		
Male	2,710 (29.5)	192,969 (50.3)
Female	6,478 (70.5)	190,758 (49.7)
Region		
Central	1,476 (16.1)	301,122 (16.2)
East	2,087 (22.7)	459,127 (24.7)
West	5,625 (61.2)	1,096,932 (59.1)
Location		
Rural	4,149 (45.2)	783,884 (42.2)
Urban	5,039 (54.8)	1,073,297 (57.8)
Ethnicity		
Mandinka/Jahanka	3,564 (38.8)	120,000 (34.9%)
Wollof	1,365 (14.9)	50,494 (14.7%)
Jola/Karoninka	1,079 (11.7)	41,820 (12.1%)
Fula/Tukulur/ Lorobo	1,847 (20.1)	76,753 (22.3%)
Serere	287 (3.1)	11,570 (3.4%)
Serahuleh	677 (7.4)	25,442 (7.4%)
Creole and AkuMarabo	22 (0.2)	2,570 (0.7%)
Manjago	171 (1.9)	7,095 (2.1%)
Bambara	69 (0.8)	3,822 (1.1%)
Other ethnic group	103 (1.1)	4,653 (1.3%)
Non-Gambian	4 (0.0)	
Socio-economic position (SEP) quintile		
1st (Poorest)	853 (9.3)	
2nd	1,313 (14.3)	
3rd	2,251 (24.5)	
4th	2,121 (23.1)	
5th (Richest)	2,650 (28.8)	

There were also limitations. The comprehensive nature of the protocol led to higher than expected incomplete examinations and non-response rates, requiring sampling weights to be applied. The 2019 survey fieldwork did not include visual fields testing unlike the 1996 survey that used the Henson Visual Fields Analyzer. While we took advantage of newer hand-held techniques where appropriate, it was logistically challenging to set up central locations in each cluster without electricity to power table-top/table-mounted equipment, quiet areas for hearing testing and a food preparation area for participant lunches; all of which contributed to occasional delays for participants. Further, conditions did not allow us to proceed with HbA_{1c} testing, and human resource constraints did not permit continuity of examiners, potentially leading to measurement bias. Two teams had high turnover of ophthalmologists at various stages of the data collection. These human resource challenges meant some clusters had to be revisited in order to examine 80% or more listed participants.

The period April to July in The Gambia coincides with the pre-rainy and rainy/farming season, which sees most rural Gambian men 35 years and older spending more time in their farms. This social pattern skewed the population that was available on the morning of examination towards females, leading to a requirement for poststratification weighting of the sample results in all analyses.

Conclusion

The Gambia National Eye Health Survey 2019 will provide data to support eye health and broader health service planning in The Gambia and allow critical appraisal of changes in the population's eye health needs in comparison to earlier national surveys of 1986 and 1996. This survey shall provide a basis to explore the broader understanding of the evolution of chronic and blinding eye diseases and other co-morbid health conditions in a rapidly increasing West African population.

Data availability

Underlying data

No data were associated with this article.

Extended data

Open Science Framework: Gambia National Eye Health Survey 2019 Study Documents, https://doi.org/10.17605/OSF.IO/EKCDT[17].

This project contains the following extended data:

- Study questionnaire
- Informed consent sheet
- Vision testing protocol

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Open Peer Review

Current Peer Review Status: ✔ ✔

Version 2

Reviewer Report 11 November 2021

https://doi.org/10.21956/wellcomeopenres.19114.r46435

✔ **Ling Lee**
[1] University of New South Wales, Sydney, NSW, Australia
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[3] University of Melbourne, Melbourne, Vic, Australia

My sincerest apologies for the delay. Thank you for your considerate responses, I have no further comments to make.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health services research and evaluation, Quality of refractive error care, Ocular Epidemiology, Genomic secondary and incidental findings.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 21 October 2021

https://doi.org/10.21956/wellcomeopenres.19114.r46436

✔ **Srinivas Marmamula**
Brien Holden Institute of Optometry and Vision Science, Gullapalli Pratibha Rao International Centre for Advancement of Rural Eye care, L V Prasad Eye Institute, Hyderabad, Telangana, India

Thank you for revising the manuscript based on my comments. Congratulations on this great work. I have no further comments to make.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: public eye health specialist; optometrist

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 17 June 2021

https://doi.org/10.21956/wellcomeopenres.18215.r44224

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Srinivas Marmamula
Brien Holden Institute of Optometry and Vision Science, Gullapalli Pratibha Rao International Centre for Advancement of Rural Eye care, L V Prasad Eye Institute, Hyderabad, Telangana, India

It is a well-written paper vividly describing the study protocol. I have a few comments to improve the manuscript.

1. Mention of age groups 35 and older and 50 and older are confusing. As the protocol is the same for all age groups, suggest using 35 years and older in the objectives and elsewhere in the manuscript instead of both the age groups.

2. Four teams were used in the survey. On average, how many participants were examined on each day by a single team?

3. How was the quality of eye examinations in the field monitored?

4. What was the time taken for the assessment of each participant in the central location?

5. What was the purpose of the genetic sample?

6. Lower participation of men is a matter of concern and authors should discuss the implications of this on the extrapolation of the results to the population. Also, the reasons for this large difference should be presented though authors describe harvesting season as one reason.

Is the rationale for, and objectives of, the study clearly described?
Yes

Is the study design appropriate for the research question?

Yes

Are sufficient details of the methods provided to allow replication by others?
Yes

Are the datasets clearly presented in a useable and accessible format?
Not applicable

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: public eye health specialist; optometrist

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 08 Oct 2021

Islay Mactaggart, London School of Hygiene & Tropical Medicine, London, UK

It is a well-written paper vividly describing the study protocol. I have a few comments to improve the manuscript.

Response: We thank Dr. Marmamula for their consideration of our manuscript and helpful comments below.

Mention of age groups 35 and older and 50 and older are confusing. As the protocol is the same for all age groups, suggest using 35 years and older in the objectives and elsewhere in the manuscript instead of both the age groups.

Response: Objective 7 is relevant to the population 50+ only. We have revised Objective 1 in the revised manuscript, in hope that this reduces any confusion.

Four teams were used in the survey. On average, how many participants were examined on each day by a single team?

Response: Each team completed one cluster of 30 per day. We have described this in the sample frame and size section. Unfortunately we do not have additional data on the average number actually seen per team per day beyond this.

How was the quality of eye examinations in the field monitored?

Response: Team ophthalmologists were trained in the conduction of eye examinations according to protocol by the study PI, a senior consultant ophthalmologist. The study PI continued to observe the teams regularly throughout data collection, to ensure that protocol was being followed. We have clarified as such in the "Team composition and training" section of the revised manuscript.

What was the time taken for the assessment of each participant in the central location?

Response: A complete assessment at the central location took roughly 1.5 hours, but varied depending on the participants' health status and according to how many other participants were attending the central location at the time. We have included this at the end of the section "Data collection at the central location" in the revised manuscript.

What was the purpose of the genetic sample?

Response: The genetic sample was taken for archiving and future genetic testing. The scope of future testing (including depth and breadth of analyses) will be conditional on further funding. We have clarified as such in the revised manuscript.

Lower participation of men is a matter of concern and authors should discuss the implications of this on the extrapolation of the results to the population. Also, the reasons for this large difference should be presented though authors describe harvesting season as one reason.

Response: We are unable to determine explicitly whether other reasons contributed to the low participation of men in the study, as we did not capture data on this. We believe this to be associated with harvesting season. We describe the post-stratification weighting of the sample to account for this, which supports us in being able to extrapolate from the sample to the population. We have clarified this in the Strengths and Limitations section of the revised manuscript.

Competing Interests: No competing interests were disclosed.

Reviewer Report 01 March 2021

https://doi.org/10.21956/wellcomeopenres.18215.r42596

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Ling Lee
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This method article aims to investigate the prevalence of vision impairment, blindness and associated comorbidities in a population-based cohort of adults aged 35 years and older in The Gambia. Overall, it is well written, and largely, a well-considered protocol with all the different components of data collection that draw upon validated tools/measures, yet still remain relatively

practical. With a large cohort recruited, there is great opportunity to assess the information with various perspectives, enables at least some comparison to 1996 data, to rapid methodology and provides a good baseline for future national surveys.

A few areas that would benefit from clarification:

- Why was a genetic sample taken? It does not appear to be associated with any of the objectives. Is it to develop a genotype-phenotype baseline?

- I can see in the Extended data, you mention genetic testing for associated ocular conditions, would this be single gene testing, or would it be wider panels/exome/genome sequencing? Is there a risk of incidental findings? If so, there does not appear to be appropriate information considering the potential ethical implications of genetic testing even for research purposes.

- For study objective 3, it is unclear which outcome measures are used to measure/evaluate the impact of Gambia NEHP activities such as cataract and refractive error services. I wonder whether prevalence of VI or blindness is enough. There does not appear to be the inclusion of cataract surgical outcomes and only presenting distance and near VA with correction might be possible to measure refractive error services (that does not take into account those who purchase readymade spectacles from elsewhere).

- With newer technology and up to date validated techniques used for the primary and secondary outcome measures, how comparable will these outcomes be to 1996 Survey data?

- Minor edit: Please spell out or provide a footnote for the socioeconomic position in Table 2.

Congratulations on completing the data collection. I look forward to seeing the outcomes from this Survey.

Is the rationale for, and objectives of, the study clearly described?
Yes

Is the study design appropriate for the research question?
Partly

Are sufficient details of the methods provided to allow replication by others?
Yes

Are the datasets clearly presented in a useable and accessible format?
Not applicable

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health services research and evaluation, Quality of refractive error care, Ocular Epidemiology, Genomic secondary and incidental findings.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 08 Oct 2021

Islay Mactaggart, London School of Hygiene & Tropical Medicine, London, UK

This method article aims to investigate the prevalence of vision impairment, blindness and associated comorbidities in a population-based cohort of adults aged 35 years and older in The Gambia. Overall, it is well written, and largely, a well-considered protocol with all the different components of data collection that draw upon validated tools/measures, yet still remain relatively practical. With a large cohort recruited, there is great opportunity to assess the information with various perspectives, enables at least some comparison to 1996 data, to rapid methodology and provides a good baseline for future national surveys.

Response: We thank Dr. Lee very much for this positive and helpful feedback on the manuscript, and respond to their specific comments further below.

A few areas that would benefit from clarification:
Why was a genetic sample taken? It does not appear to be associated with any of the objectives. Is it to develop a genotype-phenotype baseline?

I can see in the Extended data, you mention genetic testing for associated ocular conditions, would this be single gene testing, or would it be wider panels/exome/genome sequencing? Is there a risk of incidental findings? If so, there does not appear to be appropriate information considering the potential ethical implications of genetic testing even for research purposes.

Response: The genetic sample was taken for archiving and future genetic testing. The scope of future testing (including depth and breadth of analyses) will be conditional on further funding. We have clarified as such in the revised manuscript.

For study objective 3, it is unclear which outcome measures are used to measure/evaluate the impact of Gambia NEHP activities such as cataract and refractive error services. I wonder whether prevalence of VI or blindness is enough. There does not appear to be the inclusion of cataract surgical outcomes and only presenting distance and near VA with correction might be possible to measure refractive error services (that does not take into account those who purchase readymade spectacles from elsewhere).

Response: We omitted to describe cataract surgical coverage and refractive error coverage (plus effective [quality-corrected] measures of the above) as outcome measures in Table 1. These have been included in in the revised manuscript and will be explored in the relevant results papers to evaluate the impact of the NEHP on these service outcome indicators.

With newer technology and up to date validated techniques used for the primary and

secondary outcome measures, how comparable will these outcomes be to 1996 Survey data?

Response: We used Peek Acuity to test visual acuity, which has been shown to be comparable with Snellen optotypes, as used in the previous study. Indirect ophthalmoscopy and slit lamp examination were included in 1996 as in 2019 and epidemiological definitions remain similar. Combined, we believe these attributes support comparability between the primary outcomes of both surveys. We have clarified this in strengths and limitations in the revised manuscript.

Minor edit: Please spell out or provide a footnote for the socioeconomic position in Table 2.

Response: we have made this change

Competing Interests: No competing interests were disclosed.

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Supplementary appendix 1

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplement to: Jobe M, Mactaggart I, Bell S, et al. Prevalence of hypertension, diabetes, obesity, multimorbidity, and related risk factors among adult Gambians: a cross-sectional nationwide study. *Lancet Glob Health* 2024; **12:** e55–65.

SUPPLEMENTAL APPENDIX

Accompanying the manuscript

Prevalence of hypertension, diabetes, obesity, multimorbidity and related risk factors among adult Gambians: a nationwide survey

Modou Jobe FWACP[1,*], Islay Mactaggart PhD[2], Suzannah Bell MBChB[3], Min J Kim MPH[2], Abba Hydara M Med Opthalmol[4], Covadonga Bascaran MSc[2], Modou Njai MSc[5], Omar Badjie MSc[5], Pablo Perel PhD[6], Andrew M Prentice PhD[1], Matthew J Burton PhD[2,7]

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[5] Directorate of Health Promotion & Education, Ministry of Health, The Gambia
[6] Department of Non-communicable Disease Epidemiology, London School of Hygiene & Tropical Medicine, London, UK
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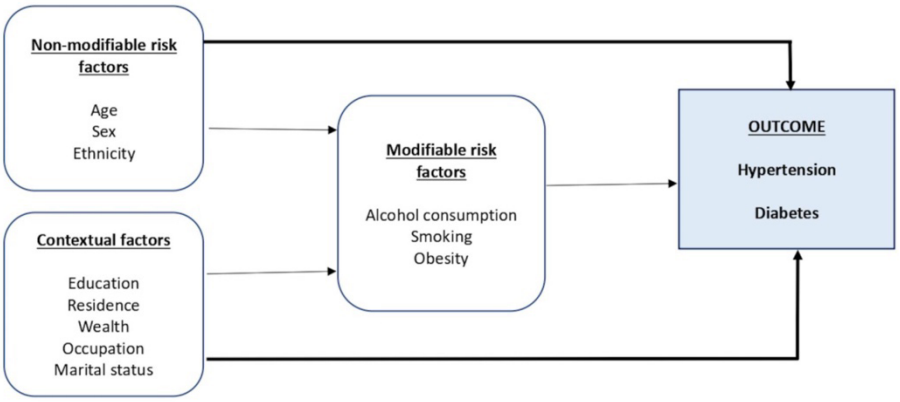
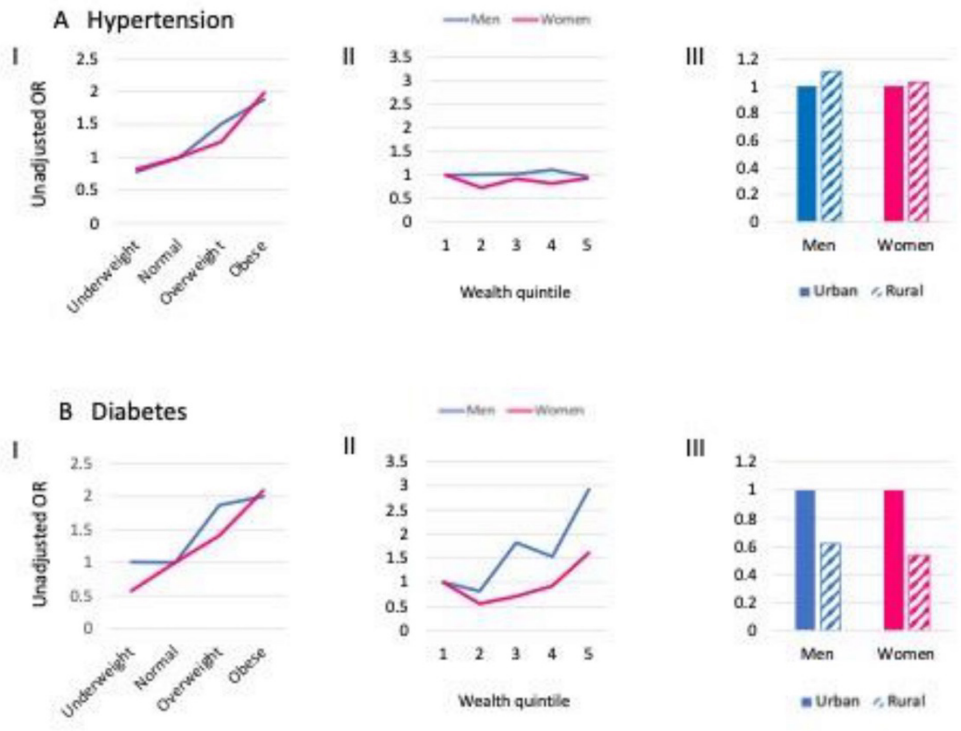
Table of Content

Supplementary Figure 1: Conceptual Framework of risk factors for outcomes of diabetes and hypertension



Supplementary Figure 2: Unadjusted odds of hypertension and diabetes in men and women by I) body mass index category (normal weight as reference group) and II) Wealth Quintile (quintile 1 as reference group) III) Odds ratio of hypertension (A) and diabetes (B) in men compared to women by residence



Supplementary Table 1: Sensitivity analysis of socio-economic position and vision impairment before and after imputation

		All surveyed (9788)		WITHOUT IMPUTATION				AFTER IMPUTATION			
				Dataset without imputation		Excluded		Final dataset*		Excluded	
All		9,309		8,790		519		9,188		121	
Presenting vision (corrected)											
	1: can see 6/12	7,977	85.7%	7,530	85.7%	447	86.1%	7,861	89.4%	116	22.4%
	2: cannot see 6/12, but can see 6/18	326	3.5%	316	3.6%	10	1.9%	326	3.7%	0	0.0%
	3: cannot see 6/18, but can see 6/60	728	7.8%	687	7.8%	41	7.9%	726	8.3%	2	0.4%
	4: cannot see 6/60, but can see 3/60	173	1.9%	164	1.9%	9	1.7%	171	1.9%	2	0.4%
	5: cannot see 3/60, but can see 1/60	105	1.1%	93	1.1%	12	2.3%	104	1.2%	1	0.2%
Age categories (years)											
	35-44	4,154	44.6%	3,930	44.7%	224	43.2%	4,102	46.7%	52	10.0%
	45-54	2,095	22.5%	1,978	22.5%	117	22.5%	2,061	23.4%	34	6.6%
	55-64	1,462	15.7%	1,389	15.8%	73	14.1%	1,444	16.4%	18	3.5%
	65-74	1,031	11.1%	956	10.9%	75	14.5%	1,018	11.6%	13	2.5%
	75-84	444	4.8%	422	4.8%	22	4.2%	441	5.0%	3	0.6%
	85+	123	1.3%	115	1.3%	8	1.5%	122	1.4%	1	0.2%
Sex											
	Men	2,753	29.6%	2,593	29.5%	160	30.8%	2,710	30.8%	43	8.3%
	Women	6,556	70.4%	6,197	70.5%	359	69.2%	6,478	73.7%	78	15.0%

*final dataset obtained after exclusion of 479 participants with incomplete/missing/inaccurate core variables. Follow-up data collection was then conducted after which we excluded another 121 that have no socio-economic status variables.

Supplementary Table 2: Unadjusted and non-weighted socio-demographic characteristics of study participants

	Total			Urban (N=5039)		Rural (N=4149)	
	All (N=9188)	M (N=2710)	W (N=6478)	M (N=1336)	W (N=3703)	M (N=1374)	W (N=2775)
Age							
Mean (SD)	49.6 (13.4)	54.1 (14.0)	47.7 (12.7)	54.6 (14.0)	47.6 (12.6)	53.6 (14.0)	47.9 (12.8)
Age categories							
35-44	4012 (44.7%)	827 (30.5%)	3275 (50.6%)	400 (29.9%)	1867 (50.4%)	427 (31.1%)	1408 (50.7%)
45-54	2061 (22.4%)	615 (22.7%)	1446 (22.3%)	277 (20.7%)	849 (22.9%)	338 (24.6%)	597 (21.5%)
55-64	1444 (15.7%)	557 (20.6%)	887 (13.7%)	294 (22.0%)	523 (14.1%)	263 (19.2%)	364 (13.1%
65-74	1018 (11.1%)	462 (17.1%)	556 (8.6%)	240 (18.0%)	290 (7.8%)	222 (16.2%)	266 (9.6%)
75-84	441 (4.8%)	185 (6.8%)	256 (4.0%)	96 (7.2%)	139 (3.8%)	89 (6.5%)	117 (4.2%)
85+	122 (1.3%)	64 (2.4%)	58 (0.9)	29 (2.2%)	35 (1.0%)	35 (2.6%)	23 (0.8%)
Level of education attained							
Pre-school/no school	1651 (18.0%)	401 (14.8%)	1250 (19.3%)	186 (13.9%)	711 (19.2%)	214 (15.6%)	539 (19.4%)
Primary	985 (10.7%)	265 (9.8%)	720 (11.1%)	144 (10.8%)	521 (14.1%)	121 (8.8%)	199 (7.2%)
Secondary/ vocational	1316 (14.3%)	547 (20.2%)	769 (11.9%)	371 (27.8%)	616 (16.6%)	176 (12.8%)	153 (5.5%)
Higher	286 (3.1%)	175 (6.5%)	111 (1.7%)	145 (10.9%)	99 (2.7%)	30 (3.2%)	12 (0.4%)
Don't know/other	189 (2.1%)	30 (1.1%)	159 (2.5%)	5 (0.4%)	66 (1.8%)	25 (1.8%)	93 (3.4%)
non-formal/Quranic	4761 (51.8%)	1291 (47.7%)	3469 (53.6%)	485 (36.3%)	1690 (45.6%)	807 (58.7%)	1779 (64.1%)
Ethnicity							
Mandinka	3564 (38.8%)	945 (34.9%)	2619 (40.3%)	559 (41.8%)	1693 (45.7%)	386 (28.1%)	926 (33.4%)
Wollof	1365 (14.9%)	439 (16.2%)	926 (14.3%)	149 (11.2%)	398 (10.8%)	290 (21.1%)	528 (19.0%)
Jola/Karoninka	1079 (11.7%)	312 (11.5%)	767 (11.8%)	181 (13.6%)	524 (14.2%)	131 (9.5%)	243 (8.8%)
Fula/Tukulor/Lorobo	1847 (20.1%)	638 (23.5%)	1209 (18.7%)	256 (19.2%)	554 (15.0%)	382 (27.8%)	655 (23.6%)
Sarahuleh	677 (7.4%)	175 (6.5%)	502 (7.8%)	69 (5.2%)	215 (5.8%)	106 (7.7%)	287 (10.3%)
Others	656 (7.1%)	201 (7.4%)	455 (7.0%)	122 (9.1%)	319 (8.6%)	79 (5.8%)	136 (4.9%)
Marital status							
never married	132 (1.4%)	81 (3.0%)	51 (0.8%)	55 (4.1%)	42 (1.1%)	26 (1.9%)	9 (0.3%)
married/living together	7641 (83.2%)	2573 (94.9%)	5068 (78.2%)	1244 (93.1%)	2835 (76.6%)	1329 (96.7%)	2233 (80.5%)
widowed	1229 (13.4%)	20 (0.7%)	1209 (18.7%)	12 (0.9%)	699 (18.9%)	8 (0.6%)	510 (18.4%)
divorced/separated	186 (2.0%)	36 (1.3%)	150 (2.3%)	25 (1.9%)	127 (3.4%)	11 (0.8%)	23 (0.8%)
Occupation							
Unemployed	1178 (12.8%)	302 (11.1%)	876 (13.5%)	210 (15.7%)	605 (16.3%)	92 (6.7%)	271 (9.8%)
manual	4931 (53.7%)	1193 (44.0%)	3738 (57.7%)	274 (20.5%)	1563 (42.2%)	919 (66.9%)	2175 (78.4%)
Trades	2304 (25.1%)	768 (28.3%)	1536 (23.7%)	571 (42.7%)	1319 (35.6%)	197 (14.3%)	217 (7.8%)
professional	427 (4.7%)	292 (10.8%)	135 (2.1%)	192 (14.4%)	113 (3.1%)	100 (7.3%)	22 (0.8%)
other	108 (1.2%)	83 (3.1%)	25 (0.4%)	41 (3.1%)	17 (0.5%)	42 (3.1%)	8 (0.3%)
retired/old age	240 (2.6%)	72 (2.7%)	168 (2.6%)	48 (3.6)	86 (2.3%)	24 (1.8%)	82 (3.0%)
Wealth quintile							
1 (poorest)	853 (9.3%)	289 (10.7%)	564 (8.7%)	27 (2.0%)	34 (0.9%)	262 (19.1%)	530 (19.1%)
2	1313 (14.3%)	437 (16.1%)	876 (13.%)	75 (5.6%)	165 (4.5%)	362 (26.4%)	711 (25.6%)
3	2251 (24.5%)	729 (26.9%)	1522 (23.5%)	118 (8.8%)	270 (7.3%)	611 (44.5%)	1252 (45.1%)
4	2121 (23.1%)	597 (22.0%)	1524 (23.5%)	458 (34.3%)	1242 (33.5%)	139 (10.1%)	282 (10.2%)
5 (richest)	2650 (28.8%)	658 (24.3%)	1992 (30.8%)	658 (49.3%)	1992 (53.8%)	0	0

Supplementary Table 3: Age and sex-standardised prevalence (95% CI) of hypertension by selected socio-demographic characteristics and risk factors weighted for cluster size

	Total			Urban		Rural	
	All	M	W	M	W	M	W
All	47.0 (45.6-48.5)	44.7 (42.4-47.0)	49.3 (47.8-50.8)	43.5 (40.4-46.6)	49.0 (47.2-50.9)	46.0 (42.6-49.3)	49.7 (47.2-52.2)
Age categories (years)							
35-44	30.5 (28.7-32.4)	28.5 (25.3-31.7)	32.4 (30.6-34.2)	27.3 (22.8-31.7)	31.6 (29.4-33.8)	29.8 (25.2-34.4)	33.5 (30.5-36.5)
45-54	47.9 (45.3-50.5)	43.2 (38.8-47.5)	52.8 (50.0-55.6)	40.4 (34.7-46.1)	53.9 (50.3-57.4)	45.7 (39.3-52.2)	51.2 (46.9-55.6)
55-64	64.8 (62.2-67.3)	64.6 (60.6-68.6)	65.0 (60.6-68.6)	65.4 (59.8-71.0)	66.0 (62.1-69.9)	63.7 (58.0-69.3)	63.4 (58.3-68.5)
65-74	74.9 (72.0-77.7)	73.0 (69.0-77.0)	76.8 (72.8-80.8)	71.1 (65.6-76.6)	74.2 (68.6-79.9)	75.1 (69.2-81.0)	79.7 (74.1-85.2)
75-84	77.3 (73.2-81.4)	74.9 (68.4-81.4)	79.4 (74.4-84.4)	65.5 (55.8-75.2)	79.2 (72.5-85.9)	85.3 (77.9-92.8)	79.7 (72.1-87.3)
85+	78.3 (70.9-85.8)	73.2 (62.1-84.3)	82.1 (72.0-92.2)	73.9 (57.6-90.3)	77.2 (63.3-91.1)	72.3 (57.4-87.6)	90.6 (78.0-1.03)
Level of education attained							
Pre-school/no school	51.0 (47.8-54.3)	48.3 (42.6-54.0)	53.0 (50.1-55.9)	50.5 (42.4-58.5)	55.1 (51.5-58.8)	46.4 (38.2-54.6)	49.9 (45.2-54.5)
Primary	38.5 (34.5-42.5)	36.1 (29.7-42.5)	41.2 (37.0-45.4)	34.7 (26.1-42.2)	42.0 (37.0-46.9)	37.7 (28.0-47.4)	39.0 (31.6-46.4)
Secondary/ vocational	37.8 (34.5-41.0)	37.2 (32.9-41.6)	38.9 (34.9-42.9)	36.4 (31.2-41.7)	39.0 (34.5-43.4)	38.9 (31.2-46.6)	38.8 (29.9-47.8)
Higher	37.6 (31.0-44.1)	36.9 (29.3-44.5)	40.9 (30.8-51.0)	38.0 (29.7-46.3)	40.8 (30.0-51.5)	31.7 (13.4-50.0)	41.8 (13.5-70.2)
Don't know/other	57.9 (49.8-66.0)	62.8 (48.1-77.5)	56.0 (47.1-64.8)	82.7 (51.1-1.14)	56.6 (43.1-70.2)	59.9 (44.5-75.4)	55.5 (43.9-67.1)
non-formal/Quranic	51.1 (49.0-53.1)	50.6 (47.2-54.0)	51.4 (49.3-53.5)	52.5 (47.6-57.5)	51.7 (49.1-54.3)	49.5 (45.0-54.0)	51.2 (47.9-54.4)
Ethnicity							
Mandinka	47.0 (44.9-49.0)	44.9 (41.3-48.5)	48.7 (46.5-50.9)	41.5 (36.8-46.1)	47.9 (45.4-50.4)	50.1 (44.6-55.5)	50.4 (46.1-54.6)
Wollof	44.9 (41.4-48.4)	42.4 (36.9-47.9)	47.8 (43.6-51.9)	44.4 (35.2-53.6)	50.6 (45.4-55.7)	41.3 (34.5-48.1)	45.5 (39.3-51.7)
Jola/Karoninka	44.7 (40.8-48.6)	45.7 (39.0-52.4)	43.7 (39.9-47.6)	49.2 (41.5-56.9)	41.6 (37.4-45.8)	40.9 (29.6-52.3)	48.6 (40.5-56.7)
Fula/Tukulor/Lorobo	45.7 (42.5-49.0)	42.9 (38.2-47.6)	49.5 (46.2-52.9)	43.0 (35.2-50.8)	51.7 (46.5-57.0)	42.9 (37.1-48.6)	47.5 (43.3-51.8)
Sarahuleh	57.2 (52.5-61.8)	56.3 (48.2-64.3)	57.9 (53.8-62.0)	47.8 (36.8-58.7)	55.7 (50.0-61.4)	61.6 (50.7-72.6)	59.4 (53.6-65.3)
Others	48.7 (42.9-54.6)	43.3 (33.9-52.6)	54.3 (49.1-59.4)	42.6 (32.2-53.0)	55.7 (50.0-61.7)	44.4 (26.2-62.7)	50.6 (41.0-60.1)
Marital status							
never married	28.9 (19.7-38.0)	28.3 (18.0-38.6)	32.2 (18.7-45.7)	32.0 (18.9-45.0)	31.1 (16.5-45.7)	20.3 (4.8-35.7)	38.6 (3.4-73.8)
married/living together	44.3 (42.7-45.9)	45.3 (42.9-47.7)	43.1 (41.4-44.9)	44.0 (40.7-47.2)	43.2 (41.0-45.4)	46.6 (43.2-50.0)	43.0 (40.2-45.8)
widowed	72.5 (69.9-75.2)	62.0 (35.2-88.8)	72.9 (70.3-75.5)	62.1 (33.1-91.2)	70.6 (67.3-74.0)	61.9 (11.4-112.3)	76.1 (72.1-80.1)
divorced/separated	45.1 (37.2-52.9)	44.0 (26.6-61.4)	45.8 (38.6-53.0)	45.7 (24.9-66.6)	46.7 (39.1-54.2)	39.2 (7.8-70.6)	40.3 (19.0-61.6)
Occupation							
unemployed	67.6 (64.5-70.3)	67.8 (3.1-73.9)	67.5 (63.8-71.2)	67.2 (59.7-74.7)	66.6 (62.1-71.0)	69.5 (59.8-79.2)	69.7 (63.0-76.4)
manual	46.2 (44.2-48.2)	47.6 (44.3-51.0)	45.1 (43.1-47.2)	46.8 (40.4-53.2)	44.7 (41.8-47.6)	47.9 (44.0-51.8)	45.5 (42.6-48.4)
trades	39.8 (37.4-42.3)	37.4 (33.6-41.2)	43.2 (40.4-46.1)	36.7 (32.1-41.2)	42.6 (39.4-45.7)	39.5 (32.8-46.2)	47.4 (40.6-54.3)
professional	37.6 (32.5-42.7)	36.7 (31.0-42.4)	43.0 (34.4-51.5)	37.6 (30.6-44.6)	41.8 (32.7-51.0)	35.0 (25.2-44.7)	50.1 (25.7-74.5)
other	39.6 (26.4-52.9)	36.6 (22.8-50.5)	64.5 (44.1-84.9)	47.8 (31.1-64.4)	67.3 (42.9-91.7)	26.1 (8.7-43.4)	57.8 (23.3-92.4)
retired/old age	81.3 (76.1-86.4)	77.3 (67.8-86.8)	83.3 (76.8-89.7)	77.0 (65.6-88.5)	82.2 (72.0-92.3)	78.0 (61.0-95.0)	84.6 (77.3-91.8)
BMI							
Underweight	36.9 (32.0-41.8)	35.5 (28.9-42.2)	39.0 (33.1-44.9)	26.4 (17.0-35.8)	42.7 (33.1-52.3)	41.5 (32.7-50.4)	36.8 (29.4-44.2)
Normal	42.5 (40.6-44.4)	41.5 (38.8-44.3)	43.9 (41.8-46.0)	39.8 (36.2-43.5)	41.7 (38.7-44.7)	43.1 (39.1-47.1)	46.0 (43.2-48.9)
Overweight	50.3 (47.6-53.0)	51.7 (46.7-56.7)	49.3 (46.6-51.9)	50.4 (43.4-57.4)	47.5 (44.3-50.6)	53.6 (46.9-60.3)	52.7 (47.9-57.6)
Obese	60.0 (57.2-62.9)	57.1 (47.0-67.3)	60.6 (57.7-63.5)	53.4 (40.5-66.4)	59.5 (56.2-62.8)	62.2 (46.4-78.0)	63.8 (58.1-69.6)
Family history of hypertension[a]							
No	40.5 (38.5-42.6)	40.6 (37.6-43.6)	40.4 (38.1-42.7)	39.7 (35.7-43.8)	39.3 (36.7-41.9)	41.7 (37.2-46.2)	42.1 (38.1-46.0)
Yes	52.0 (49.9-54.1)	46.8 (43.1-50.4)	56.5 (54.5-58.5)	45.2 (40.0-50.5)	57.1 (54.5-59.6)	48.0 (43.0-52.9)	55.7 (52.5-59.0)
Don't know	53.2 (49.9-56.5)	53.8 (48.5-59.0)	52.6 (49.1-56.2)	55.6 (48.7-62.5)	53.3 (48.5-58.1)	52.3 (44.7-60.0)	51.9 (46.7-57.0)
Alcohol consumption[b]							
Never	46.9 (45.5-48.3)	44.6 (42.3-46.8)	49.3 (47.8-50.8)	43.1 (40.1-46.2)	49.0 (47.1-50.9)	46.0 (42.6-49.4)	49.7 (47.1-52.2)

Ever	56.3 (46.9-65.8)	55.3 (43.1-67.4)	59.5 (45.8-73.1)	61.5 (45.0-78.0)	64.0 (39.1-88.9)	45.4 (26.8-64.0)	57.5 (41.6-73.4)
Smoking status[c]							
Current smoker	33.7 (29.1-38.3)	33.7 (29.1-38.3)	29.9 (-5.2-65.0)	33.6 (26.7-40.5)	0.00	33.8 (27.7-39.8)	39.5 (-4.4 - 83.5)
Never smoked	48.4 (46.9-49.9)	47.0 (44.4-49.7)	49.3 (47.8-50.9)	44.9 (41.4-48.5)	49.1 (47.2-50.9)	49.0 (45.2-52.9)	49.7 (47.2-52.2)
Previous smoker	49.0 (43.1-54.9)	48.9 (43.0-54.8)	0.00	50.3 (41.4-59.2)	0.00	47.4 (40.0-54.8)	0.00
Wealth quintile							
1 (poorest)	47.9 (43.2-52.6)	44.2 (37.5-50.8)	52.6 (47.6-57.7)	44.0 (22.5-65.5)	43.1 (22.1-64.2)	44.2 (37.2-51.1)	53.4 (48.2-58.5)
2	44.7 (41.4-47.9)	44.5 (39.2-49.7)	44.9 (41.0-48.8)	39.0 (26.9-51.1)	43.7 (35.8-51.7)	45.7 (39.9-51.5)	45.2 (40.8-49.7)
3	47.5 (44.6-50.4)	44.7 (40.4-49.0)	50.6 (47.5-53.6)	40.6 (31.9-49.3)	50.7 (44.6-56.9)	45.6 (40.7-50.5)	50.5 (47.0-54.0)
4	47.2 (44.5-50.0)	46.8 (42.4-51.2)	47.7 (44.8-50.6)	45.4 (40.3-50.4)	46.9 (43.7-50.2)	51.4 (42.6-60.1)	51.1 (44.2-58.0)
5 (richest)	47.5 (45.2-49.8)	43.3 (39.2-47.4)	50.7 (48.3-53.2)	43.3 (39.2-47.4)	50.7 (48.3-53.2)	0.00	0.00
Diabetes status[d]							
No	45.7 (44.2-47.3)	43.7 (41.3-46.1)	47.8 (46.3-49.4)	42.3 (39.0-45.5)	47.0 (45.1-48.9)	45.1 (41.7-48.5)	49.0 (46.4-51.5)
Yes	66.1 (61.7-70.4)	62.2 (54.7-69.8)	69.1 (64.5-73.8)	60.1 (50.0-70.2)	71.0 (65.5-76.5)	65.6 (54.5-76.6)	64.5 (55.9-73.1)

[a] self-report; [b] self-report of any alcohol consumption in the past 12 months; [c] self-reported tobacco use; [d] defined as a fasting blood glucose level ≥7mmol/L or random blood glucose of ≥11.1mmol/L and/or self-reported history of health personnel diagnosis of diabetes and/or currently receiving treatment for diabetes

Abbreviations: M=men; W=women

Supplementary Table 4: Age and sex-standardised prevalence (95% CI) of diabetes by selected socio-demographic characteristics weighted for cluster size

	Total			Urban		Rural	
	All	M	W	M	W	M	W
All	6.3 (5.7-6.9)	5.6 (4.6-6.5)	7.0 (6.3-7.7)	6.8 (5.3-8.2)	8.6 (7.6-9.6)	4.3 (3.1-5.5)	4.8 (4.0-5.7)
Age categories							
35-44	3.8 (3.1-4.6)	2.5 (1.4-3.6)	5.1 (4.3-5.9)	2.2 (0.8-3.6)	5.9 (4.8-7.0)	2.8 (1.0-4.5)	4.1 (3.0-5.3)
45-54	7.8 (6.5-9.2)	7.4 (5.3-9.7)	8.2 (6.7-9.7)	10.5 (6.7-14.4)	9.8 (7.7-12.0)	4.8 (2.6-7.0)	5.7 (3.8-7.6)
55-64	8.9 (7.2-10.5)	8.5 (6.0-11.0)	9.3 (7.3-11.2)	10.7 (6.9-14.5)	11.9 (9.1-14.7)	5.9 (2.9-8.9)	5.4 (3.1-7.6)
65-74	9.1 (7.2-10.9)	8.7 (6.1-11.3)	9.5 (6.9-12.1)	9.8 (5.9-13.6)	13.0 (8.8-17.2)	7.5 (3.9-11.0)	5.5 (2.8-8.2)
75-84	7.8 (5.1-10.5)	6.5 (2.9-10.1)	9.0 (5.4-12.7)	7.2 (2.0-12.5)	12.6 (6.8-18.5)	5.6 (0.8-10.5)	4.5 (1.0-8.0)
85+	4.0 (0.4-7.6)	4.6 (-0.5-9.8)	3.6 (-1.3-8.6)	6.7 (-2.4- 15.8)	2.8 (-2.7-8.3)	2.8 (-2.6-8.2)	4.9 (-4.5- 14.2)
Level of education attained							
Pre-school/no school	7.3 (6.0-8.7)	6.9 (4.5-9.2)	7.6 (6.1-9.2)	9.3 (5.8-12.8)	9.2 (7.1-11.4)	4.8 (1.7-7.9)	5.3 (3.3-7.3)
Primary	6.3 (4.7-7.8)	3.3 (1.2-5.4)	9.5 (7.1-11.9)	3.2 (0.5-5.8)	10.9 (7.9-13.9)	3.4 (0.1-6.7)	5.3 (2.0-8.6)
Secondary/ vocational	6.4 (4.9-7.9)	5.4 (3.4-7.3)	8.7 (6.5-10.8)	6.4 (3.9-9.0)	9.7 (7.2-12.2)	3.1 (0.5-5.8)	4.1 (1.0-7.4)
Higher	9.4 (4.9-13.9)	9.9 (4.6-15.2)	7.1 (1.3-12.9)	10.5 (4.4-16.6)	7.8 (1.4-14.1)	7.1 (-2.1-16.4)	0
Don't know/other	6.1 (2.2-10.0)	8.3 (-1.3-18.0)	5.2 (1.6-8.8)	0	9.6 (1.9-17.2)	9.5 (-1.7-20.8)	2.1 (-0.8-4.9)
non-formal/Quranic	5.6 (4.8-6.4)	5.0 (3.8-6.2)	6.1 (5.2-6.9)	6.1 (3.9-8.3)	7.3 (6.0-8.5)	4.4 (3.0-5.8)	4.9 (3.8-6.0)
Ethnicity							
Mandinka	6.7 (5.7-7.6)	6.1 (4.6-7.7)	7.1 (6.0-8.1)	7.0 (4.9-9.1)	8.1 (6.7-9.5)	4.9 (2.5-7.3)	5.2 (3.8-6.6)
Wollof	7.3 (5.8-8.9)	6.2 (3.9-8.5)	8.6 (6.6-10.6)	5.4 (2.3-8.6)	11.2 (7.7-14.7)	6.6 (3.5-9.8)	6.6 (4.4-8.8)
Jola/Karoninka	5.0 (3.4-6.6)	4.6 (2.3-7.0)	5.4 (3.5-7.2)	6.6 (2.9-10.4)	6.5 (4.0-9.0)	1.9 (-0.07-3.9)	2.7 (1.0-4.4)
Fula/Tukulor/Lorobo	5.4 (4.1-6.7)	5.2 (3.4-7.0)	5.7 (4.1-7.4)	7.3 (4.0-10.6)	7.3 (4.9-9.6)	3.6 (1.7-5.5)	4.4 (2.1-6.6)
Sarahuleh	5.7 (3.7-7.7)	5.3 (1.4-9.1)	6.0 (3.9-8.1)	6.9 (-0.7-14.6)	8.3 (4.2-12.4)	4.2 (-0.05-8.5)	4.4 (2.3-6.5)
Others	7.4 (5.1-9.8)	4.3 (1.3-7.2)	10.7 (7.2-14.1)	6.4 (2.0-10.8)	13.7 (9.4-18.0)	0.6 (-0.6-1.8)	2.9 (-0.04-5.8)
Marital status							
never married	2.4 (-0.07-4.9)	1.3 (-1.2-3.9)	8.7 (0.4-17.0)	1.9 (-1.8-5.6)	10.2 (0.6-19.9)	0	0
married/living together	6.0 (5.4-6.7)	5.7 (4.7-6.7)	6.5 (5.7-7.3)	6.9 (5.4-8.5)	7.8 (6.7-8.9)	4.5 (3.2-5.7)	4.7 (3.7-5.8)
widowed	8.2 (6.6-9.8)	5.5 (-5.5-16.2)	8.3 (6.7-9.8)	9.3 (-8.1-26.7)	10.3 (8-12.5)	0	5.4 (3.7-7.2)
divorced/separated	11.0 (6.1-15.8)	8.1 (6.7-17.2)	12.9 (7.2-18.5)	11.1 (-1.1-23.4)	14.4 (7.9-20.8)	0	3.6 (-3.4-10.7)
Occupation							
unemployed	8.5 (6.8-10.2)	8.1 (4.8-11.4)	8.7 (6.8-10.5)	8.7 (4.5-12.8)	9.7 (7.3-12.0)	6.7 (1.6-11.8)	6.3 (3.8-8.8)
manual	4.9 (4.3-5.6)	4.1 (3.0-5.2)	5.6 (4.7-6.5)	3.7 (1.6-5.8)	6.9 (5.5-8.4)	4.2 (2.9-5.5)	4.6 (3.6-5.6)
trades	7.3 (6.0-8.5)	6.2 (4.4-8.0)	8.7 (7.1-10.4)	6.9 (4.7-9.1)	9.2 (7.4-10.9)	4.1 (0.8-7.4)	6.0 (1.9-10.1)
professional	7.0 (3.9-10.0)	7.0 (3.6-10.3)	7.1 (2.6-11.7)	7.7 (3.3-12.1)	7.6 (2.5-12.7)	5.5 (0.7-10.2)	4.3 (-4.1-12.7)
other	6.5 (1.6-11.4)	3.7 (-0.3-7.6)	30.1 (13.2-47.1)	6.0 (-1.2-13.3)	39.1 (17.7-60.5)	1.4 (-1.5-4.3)	9.0 (-6.1-24.1)
retired/old age	9.6 (5.5-13.8)	11.4 (4.0-18.8)	8.8 (3.9-13.6)	14.4 (4.6-24.3)	13.5 (4.6-24.3)	13.5 (5.1-21.8)	3.1 (-0.3-6.5)
BMI							
Underweight	4.0 (2.1-5.9)	4.6 (1.7-7.4)	3.2 (1.3-5.0)	5.5 (-0.2-11.2)	5.1 (1.1-9.2)	3.9 (1.1-6.8)	2.0 (2.7-3.7)
Normal	4.9 (4.1-5.7)	4.5 (3.4-5.6)	5.4 (4.5-6.3)	5.2 (3.4-6.9)	7.0 (5.5-8.4)	4.0 (2.6-5.3)	3.9 (2.8-5.0)
Overweight	7.8 (6.5-9.1)	8.2 (5.8-10.6)	7.5 (6.1-8.9)	9.5 (6.2-12.9)	7.9 (6.1-9.7)	6.2 (2.9-9.4)	6.6 (4.6-8.7)
Obese	10.4 (8.5-12.2)	8.7 (2.9-14.5)	10.7 (8.9-12.5)	10.4 (2.2-18.6)	12.0 (9.8-14.2)	6.3 (-1.1-13.8)	6.7 (4.0-9.4)
Family history of hypertension[a]							
No	5.1 (4.3-5.9)	5.2 (3.9-6.5)	4.9 (4.1-5.8)	6.0 (4.1-7.9)	5.4 (4.3-6.5)	4.2 (2.6-5.8)	4.3 (3.0-5.6)
Yes	7.5 (6.5-8.5)	6.0 (4.4-7.5)	8.9 (7.7-10.0)	7.4 (4.8-10.1)	11.2 (9.6-12.9)	4.8 (2.9-6.7)	5.7 (4.3-7.0)
Don't know	6.4 (4.9-7.9)	5.6 (3.4-7.7)	7.2 (5.3-9.0)	8.5 (4.7-12.3)	10.1 (7.2-13.0)	3.3 (1.0-5.6)	3.9 (1.9-5.9)
Alcohol consumption[b]							
Never	6.3 (5.7-6.9)	5.6 (4.7-6.6)	7.0 (6.3-7.7)	6.8 (5.4-8.3)	8.5 (7.5-9.6)	4.4 (3.1-5.6)	4.9 (4.0-5.8)
Ever	4.1 (-1.3-9.5)	2.6 (-2.2-7.4)	8.4 (-7.6-24.4)	4.2 (-3.1-11.5)	27.4 (-4.4-59.3)	0	0

Smoking status[c]							
Current smoker	2.8 (1.3-4.3)	2.9 (1.4-4.3)	0	3.3 (1.0-5.5)	0	2.4 (0.4-4.4)	0
Never smoked	6.7 (6.0-7.3)	6.1 (4.9-7.3)	7.0 (4.9-7.3)	7.4 (5.6-9.2)	8.6 (7.6-9.6)	4.9 (3.2-6.5)	4.9 (4.0-5.7)
Previous smoker	6.5 (4.0-9.1)	6.6 (4.0-9.1)	0	8.7 (4.6-12.8)	0	4.1 (1.2-7.1)	0
Wealth quintile							
1 (Poorest)	4.8 (3.3-6.4)	3.3 (0.7-5.8)	6.8 (4.9-8.7)	2.1 (-1.9-6.1)	8.4 (0.2-16.5)	3.4 (0.6-6.1)	6.7 (4.7-8.7)
2	3.2 (2.1-4.4)	2.7 (1.2-4.2)	3.9 (2.4-5.5)	2.2 (-2.1-6.4)	5.9 (1.9-9.9)	2.8 (1.2-4.4)	3.5 (1.8-5.1)
3	5.4 (4.2-6.5)	5.8 (3.9-7.6)	4.9 (3.8-6.1)	4.2 (0.8-7.6)	4.3 (1.7-7.0)	6.1 (4.0-8.2)	5.1 (3.8-6.3)
4	5.7 (4.5-6.8)	4.9 (2.9-6.9)	6.4 (5.1-7.7)	5.6 (3.1-8.0)	6.9 (5.4-8.4)	2.8 (0.7-4.9)	4.1 (2.1-6.1)
5 (richest)	9.8 (8.5-11.2)	9.0 (6.6-11.3)	10.5 (9.1-11.9)	9.0 (6.6-11.3)	10.5 (9.1-11.9)	0	0

[a] self-report; [b] self-report of any alcohol consumption in the past 12 months; [c] self-reported tobacco use
Abbreviations: M=men; W=women

Supplementary Table 5: Age and sex-standardised prevalence (95% CI) of obesity by selected socio-demographic characteristics and risk factors weighted for cluster size

	Total			Urban		Rural	
	All	M	W	M	W	M	W
All	12.0 (11.1-12.9)	3.9 (3.0-4.8)	20.2 (18.8-21.5)	4.5 (3.2-5.8)	25.8 (23.8-27.7)	3.3 (2.0-4.6)	12.3 (10.6-14.0)
Age categories							
35-44	12.0 (10.8-13.2)	3.2 (2.0-4.5)	20.4 (18.7-22.1)	4.1 (2.0-6.2)	25.9 (23.5-28.4)	2.4 (0.9-3.8)	12.7 (10.5-14.9)
45-54	13.0 (11.4-14.7)	3.7 (1.9-5.4)	22.7 (20.0-25.3)	3.4 (0.9-5.8)	28.9 (25.1-32.7)	4.0 (1.4-6.5)	13.3 (10.3-16.4)
55-64	13.4 (11.5-15.3)	5.7 (3.4-8.1)	21.9 (18.9-24.9)	6.1 (3.1-9.1)	27.1 (22.7-31.5)	5.3 (1.6-8.9)	14.0 (10.3-17.8)
65-74	10.8 (8.6-13.0)	5.9 (3.5-8.4)	16.1 (12.7-19.5)	7.7 (4.0-11.4)	21.7 (16.5-27.0)	3.9 (0.9-7.0)	9.7 (5.9-13.5)
75-84	6.0 (3.4-8.5)	1.9 (-0.2-4.0)	9.5 (5.2-13.8)	2.5 (-0.9-6.0)	12.5 (5.7-19.3)	1.3 (-1.2-3.8)	6.0 (1.3-10.7)
85+	1.5 (-1.4-4.4)	0	2.7 (-2.4-7.9)	0	4.0 (-3.5-11.5)	0	0
Level of education attained							
Pre-school/no school	12.0 (10.0-14.0)	3.3 (1.4-5.2)	18.2 (15.3-21.0)	3.3 (0.8-5.8)	23.3 (19.6-27.0)	3.3 (0.5-6.2)	10.4 (7.2-13.7)
Primary	16.7 (14.2-19.3)	3.4 (0.9-5.9)	31.2 (27.3-35.2)	4.3 (0.4-8.3)	36..2 (31.6-40.9)	2.3 (-0.4-5.1)	16.1 (10.2-21.9)
Secondary/ vocational	11.6 (9.8-13.4)	3.0 (1.4-4.7)	29.5 (26.1-33.0)	3.4 (1.2-5.6)	32.4 (28.5-36.4)	2.3 (-0.1-4.8)	16.8 (11.0-22.7)
Higher	11.9 (8.0-15.9)	6.7 (2.8-10.6)	36.6 (27.5-45.8)	6.5 (2.3-10.8)	37.0 (27.3-46.6)	7.5 (-2.7-17.8)	32.7 (6.1-59.2)
Don't know/other	15.8 (9.9-21.8)	4.1 (-3.7-11.9)	20.3 (13.0-27.6)	0	21.0 (10.6-31.4)	4.8 (-4.3-13.9)	19.8 (9.9-29.8)
non-formal/Quranic	11.0 (9.8-12.2)	4.2 (2.8-5.6)	16.4 (14.8-18.0)	5.4 (3.1-7.7)	21.1 (18.7-23.5)	3.5 (1.8-5.2)	11.7 (9.7-13.7)
Ethnicity							
Mandinka	13.6 (12.0-15.2)	5.2 (3.3-7.2)	20.8 (18.7-22.9)	4.6 (2.5-6.7)	24.7 (22.1-27.4)	6.2 (2.4-9.9)	13.3 (10.5-16.0)
Wollof	10.4 (8.2-12.6)	2.8 (1.2-4.3)	19.0 (15.2-22.8)	3.5 (0.6-6.3)	29.9 (24.1-35.7)	2.4 (0.5-4.3)	9.9 (6.7-13.1)
Jola/Karoninka	14.0 (11.5-16.5)	3.2 (0.9-5.5)	23.9 (20.4-27.5)	4.5 (0.9-8.2)	27.8 (23.7-31.9)	1.5 (-0.4-3.5)	15.2 (9.8-20.7)
Fula/Tukulor/Lorobo	8.7 (7.0-10.3)	3.3 (1.8-4.7)	16.0 (13.3-18.8)	5.4 (2.4-8.3)	21.5 (17.7-25.3)	1.7 (0.4-2.9)	11.0 (7.3-14.6)
Sarahuleh	10.4 (7.8-13.0)	2.2 (-0.003-4.3)	16.9 (12.8-21.1)	2.0 (-0.9-4.9)	24.3 (17.6-30.9)	2.3 (-0.7-5.3)	11.7 (7.1-16.3)
Others	15.9 (12.9-18.9)	4.8 (1.9-7.7)	27.6 (22.5-32.6)	4.3 (0.4-8.3)	31.5 (25.6-37.3)	5.7 (1.8-9.6)	17.8 (9.4-26.2)
Marital status							
never married	7.7 (3.0-12.3)	3.7 (-0.6-8.0)	29.8 (16.7-43.0)	5.5 (-0.8-11.8)	29.3 (14.8-43.7)	0	33.6 (3.0-64.2)
married/living together	11.4 (10.5-12.3)	3.9 (2.9-4.8)	20.5 (19.0-21.9)	4.4 (3.1-5.8)	26.3 (24.3-8.3)	3.3 (2.0-4.6)	12.7 (10.9-14.6)
widowed	16.3 (13.8-18.8)	10.3 (-6.5-27.2)	16.5 (13.9-18.9)	0	20.7 (17.1-24.4)	23.3 (-4.2-50.8)	10.1 (7.2-13.0)
divorced/separated	25.0 (17.8-32.3)	3.7 (-3.5-10.9)	38.7 (29.8-47.6)	5.3 (-4.8-15.3)	42.3 (32.5-52.0)	0	16.0 (5.2-31.5)
Occupation							
unemployed	13.6 (11.3-15.9)	3.6 (1.4-5.9)	18.7 (15.7-21.8)	3.9 (1.2-6.6)	21.8 (17.9-25.6)	2.8 (-1.2-6.9)	11.8 (6.9-16.5)
manual	10.3 (9.2-11.5)	3.2 (1.8-4.5)	15.6 (14.2-17.1)	3.6 (1.3-6.0)	21.6 (19.2-24.0)	3.0 (1.4-4.6)	11.1 (9.5-12.8)
trades	16.3 (14.5-18.0)	5.0 (3.3-6.7)	31.9 (28.9-34.8)	5.1 (3.1-7.2)	32.5 (29.2-35.7)	4.5 (1.8-7.2)	28.0 (21.9-34.1)
professional	8.1 (5.6-10.6)	4.5 (2.0-6.9)	3.1 (23.2-39.6)	4.8 (1.6-8.0)	33.7 (24.7-42.7)	3.8 (-0.04-7.7)	16.9 (0.4-33.3)
other	5.0 (1.9-8.1)	2.6 (-0.3-5.6)	25.8 (6.5-45.2)	2.1 (-1.9-6.2)	31.5 (7.2-55.8)	3.0 (-1.1-7.2)	11.2 (-10.9-33.3)
retired/old age	7.4 (3.8-11.0)	0	11.1 (6.0-16.3)	0	16.8 (9.0-24.6)	0	3.7 (-1.5-9.0)
Family history of hypertension[a]							
No	10.4 (9.3-11.6)	3.7 (2.5-4.9)	18.3 (16.5-20.2)	5.0 (3.2-6.9)	22.5 (20.1-25.0)	2.1 (0.8-3.3)	11.9 (9.5-14.4)
Yes	14.7 (13.3-16.1)	4.3 (2.7-5.8)	23.6 (21.6-25.6)	3.8 (1.8-5.8)	30.4 (27.7-33.2)	4.7 (2.4-7.0)	14.2 (11.8-16.6)
Don't know	9.0 (7.0-11.0)	3.3 (1.2-5.4)	14.6 (11.5-17.8)	3.9 (0.3-7.6)	20.6 (15.8-25.4)	2.9 (0.5-5.3)	7.5 (4.6-10.4)
Alcohol consumption[b]							
Never	12.1 (11.1-13.0)	3.9 (3.0-4.8)	20.2 (3.0-21.5)	4.5 (3.1-5.8)	25.8 (23.8-27.7)	3.3 (2.0-4.6)	12.3 (10.6-14.0)
Ever	8.0 (3.0-13.0)	4.5 (-0.9-9.8)	19.6 (10.5-28.7)	4.5 (-3.1-12.0)	23.9 (2.8-44.9)	4.5 (-1.9-10.9)	17.9 (8.4-27.4)
Smoking status[c]							
Current smoker	1.8 (0.5-3.0)	1.8 (0.5-3.0)	0	0.4 (-0.1-0.9)	0	3.3 (0.8-5.8)	0
Never smoked	14.0 (12.9-15.0)	4.4 (3.3-5.6)	20.2 (18.8-21.6)	5.6 (3.8-7.5)	25.8 (23.9-27.7)	3.3 (1.9-4.7)	12.3 (10.6-14.0)
Previous smoker	4.3 (2.2-6.5)	4.4 (2.2-6.5)	0	5.1 (1.9-8.3)	0	3.5 (0.7-6.4)	0

Wealth quintile							
1 (poorest)	7.7 (5.6-9.7)	2.5 (0.5-4.5)	14.0 (10.1-17.8)	0	13.7 (2.6-24.7)	2.7 (0.5-5.0)	14.0 (9.9-18.0)
2	7.0 (5.5-8.5)	2.3 (0.9-3.7)	13.1 (10.2-15.9)	0.8 (-0.7-2.3)	22.5 (15.5-29.4)	2.6 (0.9-4.3)	10.7 (7.8-13.6)
3	8.4 (7.0-9.8)	4.1 (2.3-5.9)	13.2 (11.0-15.3)	3.8 (-0.5-8.1)	18.0 (12.4-23.5)	4.2 (2.2-6.2)	12.1 (9.8-14.3)
4	13.6 (11.8-15.5)	4.3 (2.3-6.2)	22.5 (19.9-25.2)	4.8 (2.5-7.2)	24.3 (21.3-27.4)	2.5 (-0.4-5.5)	14.5 (11.1-17.8)
5 (richest)	18.2 (16.2-20.1)	5.0 (3.0-7.1)	28.3 (25.9-30.7)	5.0 (3.0-7.1)	28.3 (25.9-30.7)	0	0
Diabetes status[d]							
No	11.5 (10.6-12.4)	3.8 (2.8-4.7)	19.4 (18.0-20.7)	4.3 (3.0-5.6)	24.8 (22.8-26.8)	3.2 (1.9-4.6)	12.1 (10.4-13.8)
Yes	20.1 (16.6-23.6)	6.2 (2.1-10.3)	31.1 (26.7-35.5)	7.1 (1.3-13.0)	36.5 (31.1-41.8)	4.7 (-0.4-9.9)	17.6 (10.8-24.3)

[a] self-report; [b] self-report of any alcohol consumption in the past 12 months; [c] self-reported tobacco use; [d] defined as a fasting blood glucose level ≥7mmol/L or random blood glucose of ≥11.1mmol/L and/or self-reported history of health personnel diagnosis of diabetes and/or currently receiving treatment for diabetes
Abbreviations: M=men; W=women

Supplementary Table 6: Age and sex-standardised prevalence (95% CI) of multimorbidity by selected socio-demographic characteristics and risk factors weighted for cluster size

	Total			Urban		Rural	
	All	M	W	M	W	M	W
All	10.7 (9.9-11.5)	5.5 (4.6-6.4)	15.9 (14.7-17.2)	5.8 (4.6-7.1)	19.7 (18.0-21.5)	5.1 (3.8-6.4)	10.6 (9.0-12.1)
Age categories							
35-44	6.9 (6.0-7.6)	1.9 (0.9-2.8)	11.6 (10.3-12.8)	1.5 (0.3-2.7)	14.2 (12.4-15.9)	2.2 (0.8-3.7)	8.0 (6.2-9.8)
45-54	12.9 (11.4-14.4)	6.3 (4.4-8.2)	19.8 (17.3-22.2)	6.1 (3.5-8.7)	24.2 (20.7-27.6)	6.4 (3.7-9.2)	13.1 (10..0-16.2)
55-64	16.4 (14.2-18.5)	10.7 (7.6-13.8)	22.7 (19.6-25.7)	12.7 (8.2-17.3)	28.2 (23.9-32.5)	8.3 (4.3-12.2)	14.4 (4.3-12.2)
65-74	15.1 (12.6-17.6)	11.7 (8.7-14.8)	18.8 (15.1-22.6)	12.7 (8.5-16.9)	24.4 (18.4-30.3)	10.7 (6.3-15.1)	12.5 (8.5-16.6)
75-84	9.5 (6.4-12.7)	5.2 (1.7-8.8)	13.3 (8.4-18.1)	6.5 (0.9-12.1)	18.0 (10.2-25.7)	4.0 (-0.4-8.4)	7.8 (2.6-13.0)
85+	7.2 (1.1-13.4)	5.0 (-1.8-11.7)	9.1 (-0.6-18.7)	7.3 (-6.5-21.1)	8.5 (-2.5-19.5)	3.6 (-3.4-10.6)	10.2 (-8.7-29.0)
Level of education attained							
Pre-school/no school	12.2 (10.2-14.1)	7.0 (4.5-9.4)	15.8 (13.3-18.4)	9.4 (5.4-13.4)	20.2 (16.8-23.5)	4.8 (1.8-7.8)	9.4 (6.3-12.4)
Primary	12.6 (10.4-14.8)	3.8 (1.5-6.1)	22.2 (18.7-25.7)	4.5 (1.0-8.0)	25.2 (20.8-29.5)	3.0 (0.1-5.9)	13.2 (8.5-17.9)
Secondary/ vocational	8.7 (7.1-10.3)	4.2 (2.5-5.9)	18.1 (15.1-21.1)	4.0 (2.0-5.9)	19.9 (16.5-23.4)	4.8 (1.4-8.2)	10.0 (5.1-14.8)
Higher	9.7 (6.3-13.1)	6.6 (2.9-10.4)	24.2 (14.9-33.4)	6.5 (2.4-10.6)	24.6 (14.8-34.4)	7.3 (-2.1-16.7)	19.0 (-3.1-41.2)
Don't know/other	14.9 (8.8-21.1)	9.4 (-1.6-20.4)	17.0 (10.4-23.6)	0	22.9 (12.1-33.7)	11.0 (2.0-24.0)	13.1 (5.3-20.9)
non-formal/Quranic	10.4 (9.3-11.5)	5.8 (4.5-7.1)	14.0 (12.6-15.5)	6.4 (4.2-8.6)	17.5 (15.4-19.7)	5.4 (3.8-7.0)	10.6 (8.6-12.5)
Ethnicity							
Mandinka	11.7 (10.4-13.1)	6.2 (4.6-7.9)	16.5 (14.7-18.3)	5.3 (3.4-7.3)	19.1 (16.8-21.5)	7.5 (4.6-10.4)	11.4 (8.8-14.0)
Wollof	10.2 (8.4-12.0)	5.6 (3.6-7.6)	15.4 (12.5-18.4)	4.9 (1.8-8.0)	23.2 (18.4-27.9)	6.0 (3.4-8.6)	8.9 (6.1-11.8)
Jola/Karoninka	11.0 (8.6-13.3)	4.2 (2.0-6.5)	17.2 (13.9-20.4)	6.0 (2.5-9.4)	19.6 (15.6-23.6)	2.0 (-0.3-4.3)	11.7 (6.7-16.7)
Fula/Tukulor/Lorobo	7.8 (6.3-9.3)	4.4 (2.9-5.9)	12.5 (10.1-14.8)	6.4 (3.4-9.3)	15.0 (1.4-4.4)	2.9 (1.4-4.4)	10.1 (6.8-13.3)
Sarahuleh	10.7 (8.0-13.4)	6.5 (2.3-10.8)	14.0 (10.4-17.7)	8.4 (-0.1-16.8)	17.9 (12.2-23.6)	5.3 (0.8-9.8)	11.2 (6.7-15.8)
Others	14.5 (11.3-17.7)	6.2 (1.7-9.5)	23.3 (18.2-28.3)	6.1 (1.3-10.8)	28.7 (22.6-34.7)	6.3 (2.3-10.3)	9.6 (5.1-14.2)
Marital status							
never married	2.2 (0.3-4.2)	0.8 (-0.8-2.3)	10.5 (1.3-19.6)	1.1 (-1.1-3.4)	10.1 (0.2-20.1)	0.00	12.6 (-10.8-35.9)
married/living together	9.9 (9.1-10.7)	5.7 (4.7-6.6)	15.0 (13.7-16.3)	6.1 (4.7-7.4)	18.5 (16.7-20.4)	5.3 (4.0-6.6)	10.3 (8.6-11.9)
widowed	18.3 (15.6-21.0)	7.4 (-6.8-21.6)	18.6 (15.9-21.3)	13.3 (-11.2-37.8)	23.1 (19.3-26.9)	0.00	11.8 (8.4-15.2)
divorced/separated	18.2 (13.3-23.2)	2.7 (-2.7-8.1)	28.2 (21.6-34.9)	3.9 (-3.7-11.4)	30.6 (23.4-37.8)	0.00	13.1 (-1.4-27.6)
Occupation							
unemployed	16.1 (13.5-18.7)	10.0 (6.0-14.0)	19.2 (16.0-22.4)	10.9 (5.8-16.0)	21.7 (17.6-25.7)	7.7 (1.9-13.5)	13.5 (8.9-18.2)
manual	9.1 (8.1-10.1)	4.6 (3.4-5.8)	12.4 (11.1-13.7)	3.8 (1.8-5.9)	16.3 (14.1-18.5)	4.9 (3.5-6.3)	9.5 (7.9-11.1)
trades	12.4 (10.9-13.9)	5.4 (3.8-7.0)	22.0 (19.4-24.6)	5.6 (3.8-7.5)	22.1 (19.3-24.9)	4.7 (1.5-7.8)	21.4 (15.2-27.7)
professional	7.4 (4.9-9.9)	5.6 (3.0-8.3)	18.6 (11.6-25.7)	5.0 (1.9-8.1)	20.5 (12.7-28.4)	6.9 (1.7-12.0)	6.2 (-5.6-18.1)
other	8.1 (2.7-13.4)	4.9 (0.7-9.0)	35.8 (13.7-58.0)	5.3 (-2.1-12.7)	49.7 (24.3-75.1)	4.5 (0.1-8.8)	0.00
retired/old age	13.6 (8.6-18.6)	9.9 (2.6-17.2)	15.4 (9.4-21.5)	12.1 (2.4-21.8)	24.3 (15.1-33.4)	5.2 (-4.9-15.3)	3.6 (-1.6-8.9)
Alcohol consumption[a]							
Never	10.7 (9.9-11.5)	5.5 (4.6-6.4)	15.9 (14.7-17.2)	5.9 (4.6-7.1)	19.7 (18.0-21.4)	5.1 (3.8-6.4)	10.6 (9.0-12.1)
Ever	7.3 (2.2-12.3)	4.5 (-0.8-9.8)	16.5 (2.6-30.3)	4.5 (-3.1-12.0)	34.5 (14.5-54.5)	4.5 (-1.9-10.9)	9.3 (-0.7-19.4)
Smoking status[b]							
Current smoker	2.2 (1.0-3.4)	2.2 (1.0-3.4)	0.00	1.6 (0.3-3.0)	0.00	2.8 (0.8-4.9)	0.00
Never smoked	12.1 (11.2-13.0)	6.2 (5.0-7.3)	16.0 (14.7-17.2)	6.5 (4.9-8.1)	19.8 (18.0-21.5)	5.8 (4.2-7.4)	10.6 (9.1-12.1)
Previous smoker	6.8 (4.1-9.4)	6.8 (4.1-9.4)	0.00	8.5 (4.4-12.7)	0.00	4.8 (1.8-7.7)	0.00
Wealth quintile							
1 (poorest)	7.7 (5.6-9.8)	2.7 (0.5-4.9)	13.8 (10.1-17.5)	2.2 (-2.0-6.3)	10.7 (1.2-20.2)	2.8 (0.4-5.2)	14.1 (10.1-18.0)
2	6.2 (4.8-7.7)	3.7 (1.8-5.6)	9.5 (7.1-11.9)	0.8 (-0.7-2.3)	16.5 (9.9-23.1)	4.4 (2.1-6.8)	7.7 (5.2-10.1)

3	8.6 (7.1-10.0)	6.3 (4.4-8.3)	11.1 (9.2-13.0)	3.3 (0.4-6.3)	13.5 (8.7-18.3)	7.0 (4.7-9.3)	10.5 (8.5-12.6)
4	10.5 (9.1-12.0)	4.9 (3.1-6.6)	15.9 (13.6-18.2)	5.3 (3.1-7.4)	16.8 (14.2-19.5)	3.5 (1.4-5.7)	11.7 (8.1-15.2)
5 (richest)	16.3 (14.5-18.0)	7.6 (5.6-9.5)	22.9 (20.6-25.2)	7.6 (5.6-9.5)	22.9 (20.6-25.2)	0.00	0.00

[a] self-report of any alcohol consumption in the past 12 months; [b] self-reported tobacco use
Abbreviations: M=men; W=women

Supplementary Table 7: Association of risk factors with hypertension and diabetes in the study population, adjusted for non-modifiable and contextual factors*

	Hypertension		Diabetes	
Variable	Men	Women	Men	Women
Residence				
Urban	1	1	1	1
Rural	1.29 (0.96-1.74)	1.04 (0.85-1.28)	1.23 (0.72-2.09)	0.81 (0.58-1.15)
Age group				
35-44	1	1	1	1
45-54	1.83 (1.46-2.30)	2.21 (1.94-2.52)	3.24 (2.02-6.29)	1.74 (1.32-2.29)
55-64	4.17 (3.30-5.26)	3.29 (2.78-3.90)	3.56 (2.02-6.29)	1.99 (1.46-2.73)
65-74	5.72 (4.40-7.45)	4.78 (3.66-6.25)	3.61 (1.94-6.73)	2.11 (1.35-3.30)
75-84	5.56 (3.77-8.19)	4.82 (3.40-6.83)	2.51 (1.12-5.62)	2.02 (1.12-3.67)
85+	4.47 (2.40-8.32)	5.12 (2.48-10.57)	1.69 (0.42-6.69)	0.71 (0.14-3.56)
Level of education attained				
Pre-school/no school	1	1	1	1
Primary	0.86 (0.60-1.26)	1.01 (0.80-1.28)	0.54 (0.25-1.17)	1.33 (0.91-1.95)
Secondary/vocational)	0.92 (0.67-1.26)	0.95 (0.75-1.21)	0.85 (0.47-1.54)	1.09 (0.73-1.65)
Higher	0.87 (0.55-1.37)	0.93 (0.55-1.56)	1.40 (0.59-3.31)	0.84 (0.28-2.48)
Don't know/other	1.53 (0.67-3.51)	1.19 (0.75-1.89)	1.56 (0.40-6.12)	0.70 (0.30-1.61)
non-formal/Quranic	1.07 (0.82-1.40)	0.95 (0.81-1.12)	0.74 (0.46-1.19)	0.80 (0.59-1.09)
Ethnicity				
Mandinka	1	1	1	1
Wollof	0.85 (0.64-1.13)	1.09 (0.90-1.32)	1.16 (0.71-1.90)	1.40 (1.03-1.90)
Jola/Karoninka	1.02 (0.74-1.41)	0.78 (0.65-0.94)	0.73 (0.40-1.36)	0.74 (0.50-1.09)
Fula/Tukulor/Lorobo	0.94 (0.73-1.21)	1.17 (0.98-1.39)	1.04 (0.64-1.70)	0.95 (0.67-1.35)
Sarahuleh	1.60 (1.10-2.34)	1.53 (1.23-1.91)	1.02 (0.44-2.38)	0.97 (0.64-1.48)
Others	0.94 (0.61-1.45)	1.21 (0.93-1.58)	0.59 (0.27-1.28)	1.43 (0.95-2.17)
Marital status				
never married	1	1	1	1
married/living together	1.20 (0.71-2.04)	1.35 (0.74-2.48)	3.59 (0.54-23.93)	1.00 (0.33-2.99)
widowed	1.64 (0.42-6.46)	2.10 (1.13-3.90)	3.72 (0.21-69.95)	1.01 (0.33-3.08)
divorced/separated	1.43 (0.54-3.77)	1.48 (0.76-2.88)	5.63 (0.53-59.56)	1.46 (0.44-4.80)
Occupation				
unemployed	1.45 (1.04-2.02)	1.41 (1.14-0.75)	1	1
manual	1	1	0.60 (0.33-1.09)	0.79 (0.57-1.10)
trades	0.89 (0.70-1.12)	1.07 (0.92-1.25)	0.97 (0.54-1.74)	0.98 (0.69-1.40)
professional	0.99 (0.70-1.12)	1.38 (0.90-2.10)	0.91 (0.43-1.91)	0.81 (0.33-1.97)
other	0.76 (0.42-1.37)	2.21 (0.72-6.74)	0.63 (0.18-2.21)	4.73 (2.02-11.07)
retired/old age	1.67 (0.86-3.25)	1.67 (1.01-2.74)	1.26 (0.52-3.06)	0.93 (0.45-4.80)
Wealth quintile				
1 (poorest)	1	1	1	1
2	1.17 (0.81-1.69)	0.71 (0.55-0.92)	0.93 (0.37-2.33)	0.54 (0.33-0.88)
3	1.01 (0.71-1.43)	0.89 (0.69-1.13)	1.88 (0.78-4.56)	0.67 (0.46-0.99)
4	1.36 (0.91-2.03)	0.78 (0.59-1.05)	1.55 (0.62-3.86)	0.71 (0.47-1.08)
5 (richest)	1.28 (0.83-1.98)	0.91 (0.68-1.22)	2.98 (1.17-7.56)	1.09 (0.71-1.69)

BMI				
Mean (SD)	1.09 (1.06-1.11)	1.08 (1.06-1.09)	1.05 (1.01-1.10)	1.04 (1.01-1.08)
Underweight	0.61 (0.44-0.85)	0.65 (0.49-0.85)	1.10 (0.55-2.21)	0.56 (0.30-1.07)
Normal	1	1	1	1
Overweight	1.68 (1.32-2.14)	1.47 (1.28-1.69)	1.68 (1.11-2.52)	1.26 (0.95-1.66)
Obese	1.86 (1.21-2.84)	2.58 (2.23-2.98)	1.58 (0.66-3.79)	1.69 (1.30-2.20)
Alcohol consumption[a]				
Never	1	1	1	1
Ever	2.01 (1.08-3.76)	0.72 (0.47-1.12)	0.44 (0.09-2.18)	0.94 (0.12-7.51)
Smoking status[b]				
Current smoker	0.71 (0.55-0.90)	0.57 (0.12-2.62)	0.55 (0.30-1.02)	empty
Never smoked	1	1	1	empty
Previous smoker	1.09 (0.82-1.43)	1 (empty)	1.08 (0.67-1.73)	empty

* Adjusted for age, ethnicity, education, residence, wealth quintile, occupation, marital status

Data are in OR (95% confidence interval); [a] self-report of any alcohol consumption in the past 12 months; [b]self-reported smoking

Supplementary Table 8: Association of risk factors with obesity in the study population, adjusted for non-modifiable and contextual factors*

Variable	Men	Women
Residence		
Urban	1	1
Rural	1.26 (0.63-2.52)	0.71 (0.55-0.92)
Age group		
35-44	1	1
45-54	1.16 (0.62-2.17)	1.25 (1.04-1.49)
55-64	1.88 (1.01-3.49)	1.30 (1.03-1.63)
65-74	2.14 (1.06-4.33)	1.00 (0.75-1.35)
75-84	0.79 (0.21-2.94)	0.56 (0.32-0.99)
85+	empty	0.15 (0.21-1.00)
Level of education attained		
Pre-school/no school	1	1
Primary	0.95 (0.35-2.55)	1.59 (1.23-2.05)
Secondary/vocational)	0.83 (0.35-1.97)	1.35 (1.06-1.72)
Higher	1.95 (0.65-5.83)	1.66 (1.01-2.73)
Don't know/other	1.49 (0.17-12.81)	1.20 (0.73-1.99)
non-formal/Quranic	1.32 (0.67-2.60)	0.90 (0.73-1.11)
Ethnicity		
Mandinka	1	1
Wollof	0.51 (0.24-1.08)	0.94 (0.74-1.19)
Jola/Karoninka	0.59 (0.25-1.39)	1.12 (0.90-1.40)
Fula/Tukulor/Lorobo	0.61 (0.31-1.15)	0.83 (0.66-1.05)
Sarahuleh	0.39 (0.13-1.13)	1.02 (0.76-1.37)
Others	0.93 (0.44-1.97)	1.19 (0.91-1.55)
Marital status		
never married	1	1
married/living together	0.93 (0.26-3.32)	1.02 (0.54-1.93)
widowed	4.44 (0.34-57.20)	0.93 (0.47-1.82)
divorced/separated	1.03 (0.09-11.35)	1.73 (0.83-3.60)
Occupation		
unemployed	1	1
manual	1.16 (0.48-2.85)	0.83 (0.65-1.05)
trades	1.99 (0.87-4.57)	1.48 (1.15-1.89)
professional	1.31 (0.43-3.99)	1.07 (0.64-1.79)
other	1.11 (0.26-4.70)	1.23 (0.44-3.44)
retired/old age	empty	0.93 (0.52-1.65)
Wealth quintile		
1 (poorest)	1	1
2	1.00 (0.37-2.72)	0.91 (0.62-1.33)
3	1.77 (0.73-4.33)	0.89 (0.62-1.28)
4	1.85 (0.70-4.93)	1.11 (0.76-1.60)
5 (richest)	1.97 (0.70-5.55)	1.30 (0.88-1.92)
Alcohol consumption[a]		
Never	1	1
Ever	1.00 (0.26-3.80)	1.14 (0.64-2.01)
Smoking status[b]		
Current smoker	0.39 (0.19-0.82)	empty
Never smoked	1	empty
Previous smoker	0.98 (0.55-1.74)	empty

* Adjusted for age, ethnicity, education, residence, wealth quintile, occupation, marital status

Data are in OR (95% confidence interval); [a] self-report of any alcohol consumption in the past 12 months; [b] self-reported smoking

Appendix 3: Supplementary material to Chapter 5

Evaluating the hypertension care cascade in middle-aged and older adults in The Gambia: Findings from a nationwide survey

Short title: Hypertension care cascade in Gambian adults

Authors: Modou Jobe[1,*], Islay Mactaggart[2], Abba Hydara[3], Min J Kim[2], Suzannah Bell[4], Omar Badjie[5], Mustapha Bittaye[6,7], Andrew M Prentice[1], Matthew Burton[2,8]

Supplementary appendix

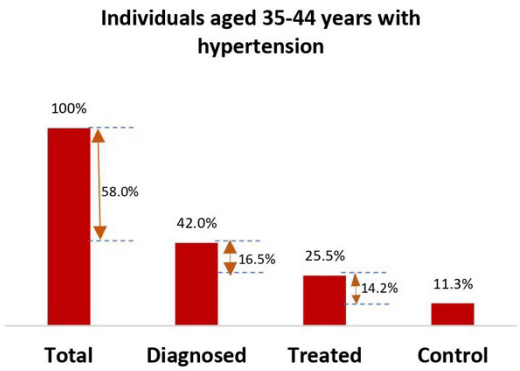
Supplementary Table 1: Age and sex-standardised prevalence, diagnosis, treatment, and control of hypertension by age and sex

						Controlled	
Variable	**Number of participants**	**Number of individuals with hypertension**	**Prevalence of hypertension**	**Proportion with diagnosed hypertension (aware)**	**Proportion of hypertensive patients treated**	**Among all hypertensives**	**Among treated**
Men							
35-44	1952	821	28.5 (25.3-31.7)	23.8 (17.6-30.1)	60.4 (46.4-74.4)	6.7 (3.1-10.2)	41.2 (24.2-58.3)
45-54	1259	419	43.2 (38.3-47.5)	47.3 (40.8-53.8)	65.7 (55.9-75.5)	6.7 (3.7-9.7)	21.6 (12.1-31.1)
55-64	715	149	64.6 (60.6-68.6)	50.2 (44.8-55.6)	71.9 (65.4-78.5)	6.6 (4.0-9.2)	17.5 (11.1-23.9)
65-74	414	66	73.0 (69.0-77.0)	55.1 (49.9-60.3)	75.2 (69.0-82.2)	6.5 (3.9-9.1)	15.3 (9.5-21.2)
75-84	184	27	74.9 (68.4-81.4)	58.0 (49.5-66.6)	73.6 (62.7-84.5)	8.2 (3.4-13.0)	18.3 (8.1-28.5)
85+	74	12	73.2 (62.1-84.3)	53.7 (37.3-70.1)	85.1 (66.4-1.03)	8.2 (0.3-16.1)	21.9 (2.7-16.8)
All	4598	1494	44.7 (42.4-47.0)	43.6 (40.5-46.8)	69.5 (65.1-73.9)	6.8 (5.3-8.2)	21.7 (17.5-25.9)
Women							
35-44	2043	328	32.4 (30.6-34.2)	57.3 (53.8-60.8)	61.1 (56.5-65.6)	15.1 (12.5-17.7)	35.6 (30.5-40.7)
45-54	1203	319	52.8 (50.0-55.6)	64.1 (60.4-67.7)	71.8 (67.5-76.2)	14.5 (11.9-17.0)	28.0 (23.5-32.6)
55-64	635	271	65.0 (61.9-68.1)	69.5 (65.9-73.1)	75.4 (70.6-80.2)	12.9 (10.1-15.7)	23.2 (18.4-28.0)
65-74	393	178	76.8 (72.8-80.8)	72.6 (68.1-77.0)	75.2 (69.5-81.0)	10.6 (7.7-13.6)	19.0 (14.0-24.1)
75-84	209	81	79.4 (74.4-84.4)	70.2 (63.0-77.4)	86.4 (80.3-92.5)	6.7 (3.3-10.1)	11.2 (5.5-16.8)
85+	106	32	82.1 (72.0-92.2)	68.4 (54.1-82.6)	72.6 (56.9-88.2)	6.5 (-0.6-13.7)	12.8 (-1.0-26.5)
All	4589	1209	49.3 (47.8-50.8)	64.8 (62.7-66.9)	71.0 (67.9-74.0)	13.0 (11.7-14.3)	25.6 (23.3-27.9)

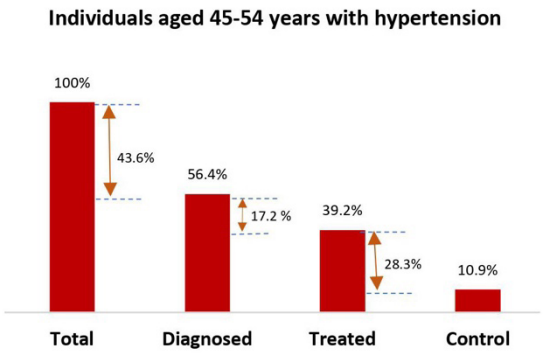
Supplementary Table 2: Age and sex-standardised prevalence, diagnosis, treatment, and control of hypertension by sex and location

	Overall		**Urban**		**Rural**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**
Prevalence	44.7 (42.4-47.0)	49.3 (47.8-50.8)	43.5 (40.4-46.5)	49.0 (47.2-50.9)	46.0 (42.6-49.3)	49.7 (47.2-52.2)
Diagnosed	43.6 (40.5-46.8)	64.8 (62.7-66.9)	43.3 (38.8-47.8)	63.6 (60.9-66.4)	43.9 (39.5-48.4)	66.5 (63.2-69.7)
Treated	73.8 (69.4-78.2)	79.4 (76.6-82.3)	71.1 (64.9-77.3)	77.7 (73.6-81.8)	76.4 (70.1-82.7)	81.7 (77.9-85.6)
Controlled (among hypertensives)	6.8 (5.3-8.2)	13.0 (11.7-14.3)	5.6 (3.9-7.4)	12.5 (10.7-14.2)	7.8 (5.6-10.1)	13.7 (11.7-15.7)
Controlled (among treated)	21.7 (17.5-25.9)	25.6 (23.3-27.9)	18.5 (13.0-24.0)	25.4 (22.3-28.5)	24.6 (18.4-30.8)	25.8 (22.4-29.2)

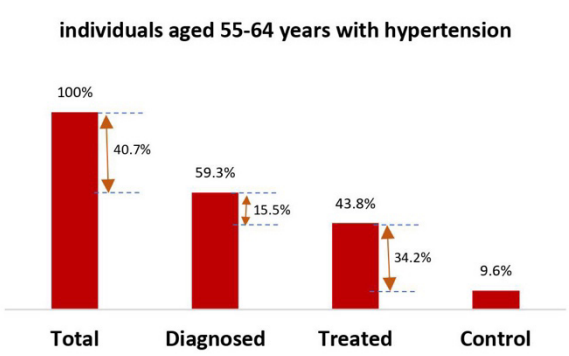
A


Individuals aged 35-44 years with hypertension
100%
58.0%
42.0%
16.5%
25.5%
14.2%
11.3%
Total
Diagnosed
Treated
Control

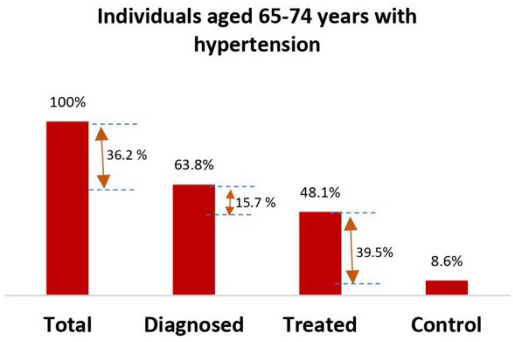
B


Individuals aged 45-54 years with hypertension
100%
43.6%
56.4%
17.2 %
39.2%
28.3%
10.9%
Total
Diagnosed
Treated
Control

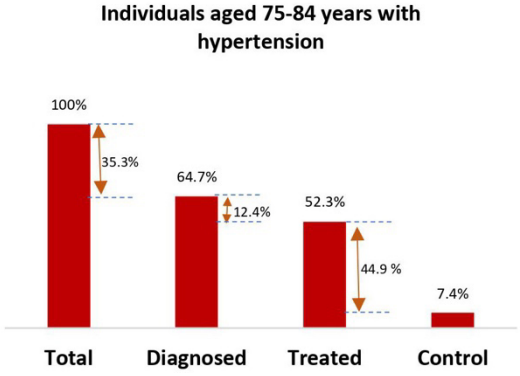
C


individuals aged 55-64 years with hypertension
100%
40.7%
59.3%
15.5%
43.8%
34.2%
9.6%
Total
Diagnosed
Treated
Control

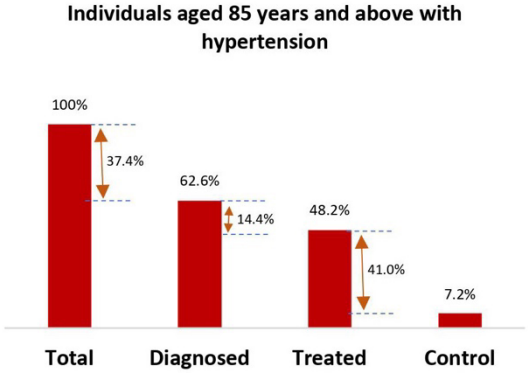
D


Individuals aged 65-74 years with hypertension
100%
36.2 %
63.8%
15.7 %
48.1%
39.5%
8.6%
Total
Diagnosed
Treated
Control

E


Individuals aged 75-84 years with hypertension
100%
35.3%
64.7%
12.4%
52.3%
44.9 %
7.4%
Total
Diagnosed
Treated
Control

F


Individuals aged 85 years and above with hypertension
100%
37.4%
62.6%
14.4%
48.2%
41.0%
7.2%
Total
Diagnosed
Treated
Control

Appendix 4: 2019 Gambia National Eye Health Survey Joint Gambia Government/MRC Ethics Committee approval letter

The Gambia Government/MRCG Joint
ETHICS COMMITTEE

C/o MRC Unit: The Gambia @ LSHTM, Fajara
P.O. Box 273, Banjul
The Gambia, West Africa
Fax: +220 – 4495919 or 4496513
Tel: +220 – 4495442-6 Ext. 2308
Email: ethics@mrc.gm

9 November 2018

Dr. Abba Hydara,
CEO/Senior Consultant Ophthalmologist,
Sheikh Zayed Regional Eye Care Centre, Kanifing.

Dear Dr. Hydara,

SCC 1635, The Gambia National Eye Health Survey 2019

Thank you for submitting your proposal dated 17 September 2018 for consideration by the Gambia Government/MRCG Joint Ethics Committee at its meeting held on 25 October 2018.

Our Committee is pleased to approve your proposed study however you are requested to include Sarjo Kanyi's contact telephone number in the Informed Consent Document.

With best wishes,

Yours sincerely,

[redacted]

Dr. Mohammadou Kabir Cham
Chair, Gambia Government/MRCG Joint Ethics Committee

Documents submitted for review:

- SCC approval letter – 12 October 2018
- SCC reply letter – 4 October 2018
- Cover letter – 17 September 2018
- SCC Application form, version 1.0 – 17 September 2018
- ICD (Adult), version 1.0 – 17 September 2018
- Survey Protocol, version 2.0 – 17 September 2018
- Budget
- CVs: Abba Hydara, Islay Mactaggart, Matthew Burton, Modou Jobe, Omar Badjie, Sarjo Kanyi

Appendix 5: 2019 Gambia National Eye Health Survey London School Of Hygiene And Tropical Medicine Ethics Committee approval letter

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Observational / Interventions Research Ethics Committee

Professor Matthew Burton
LSHTM

14 January 2019

Dear Dr Burton

Study Title: Gambia National Eye Health Survey 2019

LSHTM Ethics Ref: 16172

Thank you for your application for the above research project which has now been considered by the Observational Committee via Chair's Action.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved is as follows:

Document Type	File Name	Date	Version
Investigator CV	Matthew Burton - Short CV - 2017	30/11/2018	1
Investigator CV	Suzannah Bell CV	30/11/2018	1
Investigator CV	CV Islay Mactaggart 2018	30/11/2018	1
Protocol / Proposal	Gambia National Eye Health Survey Protocol v3 Jan 2019	04/01/2019	1
Information Sheet	Gambia Eye Health Survey Info and Consent	04/01/2019	1
Local Approval	SCC MRCG Approval Letter	04/01/2019	1

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

An annual report should be submitted to the committee using an Annual Report form on the anniversary of the approval of the study during the lifetime of the study.

At the end of the study, the CI or delegate must notify the committee using the End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk.

Further information is available at: www.lshtm.ac.uk/ethics.

Yours sincerely,

[redacted]

Professor John DH Porter
Chair

ethics@lshtm.ac.uk
http://www.lshtm.ac.uk/ethics/