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# Uncontrolled hypertension among people with comorbidities in 

Sub-Saharan Africa

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# A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the Health Sciences 

Division of Health Sciences, Warwick Medical School, The University of Warwick

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## Declarations

This thesis presents the work of Shukri Mohamed in collaboration with her advisors, Professors Paramjit Gill, Olalekan A. Uthman and invited co-authors. This work is in support to my application for a Doctor of Philosophy Degree at the University of Warwick. This work has not been submitted elsewhere for a degree. The author has published the following articles as a result of this thesis:

## List of Publications

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## Abstract

Aim and objectives: The aims were to address the gaps in knowledge about (i) the scope in the burden of uncontrolled hypertension among adults with comorbidities residing in subSaharan Africa and (ii) the factors associated with uncontrolled hypertension in these individuals.

Methods: A mixed methods approach was used including: (1) a systematic review and metaanalysis to synthesize evidence on uncontrolled hypertension among patients with comorbid conditions and to estimate the prevalence of uncontrolled hypertension among patients with comorbid conditions in sub-Saharan Africa; (2) analysis of nationally representative individual level participant data from 20 sub-Saharan African countries; (3) cross-sectional household level data from two slums in Kenya and (4) a qualitative study exploring facilitators and barriers to blood pressure control among patients with comorbid conditions in two slums in Kenya.

Key findings: The prevalence of uncontrolled hypertension is high and it is higher among people with comorbidities. There were regional differences in the prevalence of uncontrolled hypertension in general and uncontrolled hypertension among individuals with comorbidities. The meta-analysis of the individual WHO STEPwise approach to surveillance (STEPS) data further showed significant associations between comorbidities and uncontrolled hypertension. The cross-sectional study in Nairobi slums, showed that the prevalence of single and multimorbidity was high and hypertension was among the most frequently co-occurring conditions. The main barriers to blood pressure control identified in the qualitative study include: poverty, adherence, unsupportive families, limited access to medications, limited health care staffing, major issues with supply chain management system, and guidelines for treatment and lack of resources allocated to hypertension care.

Conclusion: The burden of uncontrolled hypertension is high among individuals with comorbidities in sub-Saharan Africa. Often, hypertension does not present in isolation and most clinicians fail to recognize the importance of assessing patients' comorbidities along with managing patient blood pressures mainly because they are accustomed to the single disease framework that most healthcare delivery systems have. An epidemiologic transition is already occurring in sub-Saharan African countries and hypertension is a major risk factor that needs addressing. Hypertension and comorbidities need to be closely monitored and managed for improved outcomes in SSA.

## Abbreviations

APHRC - African Population and Health Research Center
AWI-Gen - Africa Wits-INDEPTH Partnership for the Genomic Research
BMI - Body mass index
BP - Blood pressure
CHW - Community health worker
CVDs - Cardiovascular diseases
DBP - Diastolic blood pressure
FGDs - Focus group discussions
HICs - High income countries
HTN - Hypertension
IDIs - In-depth interviews
KIIs - Key informant interviews
LMICs - Low-and-middle-income-countries
NUHDSS - Nairobi Urban Health Surveillance System
UHTN - Uncontrolled hypertension
STEPS - WHO STEPwise approach to surveillance
SBP - Systolic blood pressure
SSA - Sub-Saharan Africa
WHO - World Health Organization

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## 1. Introduction

1.1 General overview

This chapter provides an overview of hypertension and the role of comorbidities in uncontrolled hypertension. The chapter begins with an overview on hypertension in general while providing global estimates and estimates for other regions including sub-Saharan Africa (SSA). This is followed by a definition of hypertension, uncontrolled hypertension and comorbidities; a synopsis of barriers to blood pressure control in SSA and factors known to be associated with blood pressure control. The conceptual framework for the thesis is also discussed. Also presented are the study rationale, research aim, objectives and questions.

Uncontrolled hypertension (UHTN) is one of the most important risk factors for cardiovascular diseases (CVDs) and a leading contributor to death (Forouzanfar et al., 2016). Globally, in 2010, an estimated 1.39 billion people had hypertension and the global prevalence of hypertension was $31.5 \%$ among adults aged $\geq 20$ years (Mills et al., 2016). The highest proportion (1.04 billion - 75\%) of people with hypertension were from low-and-middle-income-countries (LMICs) while 25\% (349 million) were from high-income-countries (HICs). Between 2000 and 2010, there was a much higher increase in the burden of hypertension (7.7\% - 440 million) in LMICs compared to the increase observed in HICs ( $2.6 \%-27$ million) in the same period (Mills et al., 2016) (Figure 1). The highest prevalence (30\%) of hypertension is in the African region compared to $18 \%$ in the Americas region among those aged 18 years and over (World Health Organization, 2014). It is projected that the number of people with hypertension globally will increase to 1.56 billion by 2025 and a large proportion of this increase will continue to occur in LMICs in SSA (Kearney et al., 2005). The increasing trend and high burden of hypertension in LMICs is worrisome particularly because most of the limited resources for healthcare spending is allocated to managing infectious disease burden in these countries.


Figure 1: Worldwide age- and sex-standardized prevalence of hypertension in adults 20 years and older by country (the lighter shade depict lower prevalence and the darker shade depicts higher prevalence).

Reprinted from "Global Disparities of Hypertension Prevalence and Control: A Systematic Analysis of Population-based Studies from 90 Countries," by Mills, K. T., Bundy, J. D., Kelly, T. N., Reed, J. E., Kearney, P. M., Reynolds, K., Chen, J., \& He, J., 2016, Circulation, 441(6), 441-450. Copyright (2016).

According to the Global Burden of Disease (GBD) report, hypertension was responsible for over 9 million deaths in 2010 (13\% of all global deaths) (Lim et al., 2012). Uncontrolled hypertension is an established risk factor for life-threatening cardiovascular complications such as stroke and heart disease (World Health Organization, 2013b). Antihypertensive treatment substantially reduces the risk of morbidity and mortality related to uncontrolled hypertension (Psaty et al., 1997, Chalmers and Zanchetti, 1996, SPRINT Research Group, 2015). Hypertension care is a challenge in SSA particularly due to weak healthcare systems characterized by extreme shortages of health workers, unreliable medical supply systems, and wide variances in quality and safety, among other factors (Kirigia and Barry, 2008).

Communicable diseases still contribute significantly to disease burden in SSA thus creating a double burden of communicable and non-communicable disease to the healthcare system. In view of the economic and public health implications uncontrolled hypertension poses on the healthcare systems in SSA, it is important that robust interventions are developed.

The most recent systematic review and meta-analysis on hypertension in SSA reported a low level of hypertension treatment (18\%) and controlled rate (7\%) (Ataklte et al., 2015). In SSA, several studies on hypertension have been published and most of the earlier studies were small scale localized studies that are not generalizable nationally. For example, hypertension studies conducted in Kenya have focused mainly on urban slums or specific rural communities (Hendriks et al., 2012, Jenson et al., 2011, Joshi et al., 2014, Mathenge et al., 2010, Ongeti et al., 2013, Van de Vijver et al., 2013). In the last decade more national level research providing information on hypertension across SSA have become available. The WHO STEPs surveys (Riley et al., 2015) and some of the Demographic and Health Surveys (DHS) provide data on hypertension that are nationally representative. The availability of these datasets now provide an opportunity to investigate the relationship between uncontrolled hypertension and patient comorbidities (such as obesity, diabetes and hypercholesterolemia) in sub-Saharan African populations.

As the healthcare systems in SSA continue to grapple with communicable diseases they are also faced with an urgent need to reorient in order to manage the growing burden of noncommunicable diseases. Urbanization is thought to be a key driver for the rise in hypertension in SSA (Poulter et al., 1985) and with urbanization, more and more people are moving to cities and living in slums or slum like conditions with limited health-services available. Currently more than half (55\%) of the global population live in urban areas. The UN predicts that this proportion will rise to $68 \%$ by 2050 (United Nations Department of Economic and Social

Affairs (UNDESA), 2018). In 2017, a Lancet article reported intense urban growth over the last 50 years with more than half of city populations living in slums (Ezeh et al., 2017).

Certain comorbidities are known to affect the control of hypertension. Recent research conducted in LMICs show that hypertension co-exists with comorbidities such as chronic kidney disease, diabetes and hypercholesterolemia among others (Hendriks et al., 2012, Jenson et al., 2011, Joshi et al., 2014, Mathenge et al., 2010, Mohamed et al., 2021, Nimako et al., 2013a). Further, studies conducted in Europe and the US found that patients with diabetes mellitus had significantly increased risk of uncontrolled blood pressure (Degli Esposti et al., 2004, Liu and Song, 2013). Similarly, excess weight is an established risk factor for hypertension. Even though under-nutrition is still common in Africa, current estimates show a rise in the prevalence of overweight and or obesity among poor urban residents and this has been associated with lifestyle changes (Ziraba et al., 2009). These conditions that often coexist with hypertension can have an effect on blood pressure control among patients on antihypertensive treatment and may partly explain the inadequate control of blood pressure despite advances made in hypertension care and treatment.

Regarding the relationships between certain comorbidities and blood pressure control, studies have shown mixed results between body mass index and blood pressure control. One study conducted in China (Linderman et al., 2018) assessing the association between body mass index (BMI) and blood pressure found a positive relationship while Cappuccio and colleagues (2008) found a wide variation in the relationship between blood pressure and BMI.

Successful management of uncontrolled hypertension requires that healthcare providers understand the magnitude of the problem and contextual factors associated with it. Quantifying the burden of uncontrolled hypertension among adults in SSA and investigating the contextual factors shaping the distribution of uncontrolled hypertension across countries are needed for policymakers and programme implementers to support actions to achieve the WHO global
target of lowering blood pressure by $25 \%$ by 2025 in SSA (World Health Organization, 2013b).

### 1.2 Definitions

1.2.1 High blood pressure (Hypertension - (HTN)

Until recently, hypertension was globally defined as systolic blood pressure (SBP) $\geq 140 \mathrm{~mm}$ Hg or diastolic blood pressure $(\mathrm{DBP}) \geq 90 \mathrm{~mm} \mathrm{Hg}$, or taking antihypertensive medication (Benjamin et al., 2017). The definition of high blood pressure has been changing over time. The cut off blood pressure values vary for different regions and countries as shown in Table 1. For the US, the American College of Cardiology and the American Heart Association updated their hypertension guidelines (Whelton et al., 2017) by lowering the limits to $130 / 80 \mathrm{~mm} \mathrm{Hg}$ (stage 1) rather than the previous $140 / 90 \mathrm{~mm} \mathrm{Hg}$ (stage 2). This new definition has an impact on the number of people classified as having hypertension and it has implications on treatment and control of blood pressure.

In 2018, the European Society of Hypertension/European Society of Cardiology (ESH/ESC) hypertension guideline maintained the current thresholds of $140 / 90 \mathrm{mmHg}$ among adults (Williams et al., 2018). In SSA, hypertension is defined as per the JNC 8 guidelines (Armstrong, 2014) with threshold of systolic and diastolic blood pressure of greater than $140 / 90 \mathrm{mmHg}$ in adults (Seedat et al., 2014).

The more stringent blood pressure cut off values are based on evidence from large scale prospective studies as well as clinical trials that showed intense ( $\mathrm{SBP}<120 \mathrm{mmHg}$ ) blood pressure lowering significantly reduces cardiovascular disease mortality compared to the standard blood pressure lowering target (SBP $<140 \mathrm{mmHg}$ ) (Guo et al., 2013, SPRINT Research Group, 2015, Bundy et al., 2017). If the new US hypertension guidelines were to be applied globally, hypertension prevalence in LMIC would be very high and the differences between hypertension prevalence in HICs and LMICs would be much higher. Yet, according
to Dzudie and colleagues (2018), only $26 \%$ of countries in Africa had traceable guidelines for hypertension management in 2015.

Table 1: A summary of guidelines for high blood pressure in adults from different organizations.

| Organization | Year | Hypertension definition |
| :--- | :--- | :--- |
| Eighth Report of the Joint <br> National Committee on <br> Prevention, Detection, <br> Evaluation, and Treatment <br> of High Blood Pressure <br> (JNC 8) (James et al., <br> 2014b) | 2014 | $\mathrm{BP} \geq 140 / 90 \mathrm{~mm} \mathrm{Hg}$ |
| American Diabetes <br> Association (ADA) <br> (Association, 2017) | 2017 | $\mathrm{BP} \geq 140 / 90 \mathrm{~mm} \mathrm{Hg}$ |
| American College of <br> Cardiology and the <br> American Heart Association <br> (Whelton et al., 2017) | 2017 | $\mathrm{BP} \geq 130 / 80 \mathrm{~mm} \mathrm{Hg}$ |
| European Society of <br> Hypertension/European <br> Society of Cardiology <br> (ESH/ESC) (Williams et al., <br> 2018) | 2018 | $\mathrm{BP} \geq 140 / 90 \mathrm{~mm} \mathrm{Hg}$ |
| NICE guidelines (National <br> Institute for Health and Care <br> Excellence. NICE guidelines <br> [NG136], 2019) | 2019 | $\mathrm{BP} \geq 140 / 90 \mathrm{~mm} \mathrm{Hg}$ |
| International Society of <br> Hypertension (ISH) (Unger <br> et al., 2020) | 2020 | $\mathrm{BP} \geq 140 / 90 \mathrm{~mm} \mathrm{Hg}$ |
| Kenya (Division of Non- <br> Communicable Diseases - <br> Ministry of Health, 2019) | 2019 | $\mathrm{BP} \geq 140 / 90 \mathrm{~mm} \mathrm{Hg}$ |
| South Africa (Seedat et al., <br> 2014) | 2014 | $\mathrm{BP} \geq 140 / 90 \mathrm{~mm} \mathrm{Hg}$ |

### 1.2.2 Uncontrolled hypertension

Uncontrolled hypertension (UHTN) in this thesis is defined as systolic blood pressure of $\geq 140 \mathrm{mmHg}$ and/or diastolic blood pressure of $\geq 90 \mathrm{mmHg}$ in a patient taking anti-hypertensive medication. Reasons for the high uncontrolled rates especially among those on treatment are not fully understood in SSA. Controlling SBP and DBP is associated with reduction in
cardiovascular complications and premature deaths thus impacting the global burden of disease (Czernichow et al., 2011, James et al., 2014a).

### 1.2.3 Comorbidities

This area forms the cornerstone of this thesis. Comorbidity is the occurrence of medical conditions additional to an index disease (Feinstein, 1970). Feinstein coined the term comorbidity and described it as 'any distinct additional entity that has existed or may occur during the clinical course of a patient who has the index disease under study'. In order words, it assumes an additional disorder to an index disease. However, some authors have used it to imply the coexistence of disease.

### 1.3 Overview of potential barriers to hypertension care in SSA

The inability to achieve blood pressure control despite the known and effective treatments among patients on treatment is a result of many factors including limited access to hypertension care. In Africa, due to shortage of trained health professionals, screening and treatment of hypertension is also limited. No user fees at the point of care can encourage many to seek healthcare services. With many countries across SSA looking into providing their citizens with universal healthcare, hypertension care could improve if user fees are eliminated or minimized. While patient adherence to treatment is important, equally important is the intensity of clinical management provided by healthcare providers (Rose et al., 2007a). A study conducted by Rose et al (2007b) concluded that inadequate treatment regimens are to blame for a majority of uncontrolled hypertension. For persistent hypertension, combination therapies are required to achieve blood pressure control (Cushman et al., 2002). Results from a multinational study revealed that LMICs had the lowest use of antihypertensive drugs and the use of combination antihypertensives was significantly lower in these countries compared to the HICs (Chow et al., 2013).

Another barrier is the use of counterfeit drugs. These are common in SSA but the burden of counterfeit drugs in SSA is very variable and hard to estimate mainly due to its illegal nature.

Most published estimates vary from $1 \%$ to $50 \%$ of all pharmaceuticals (Li, 2014). WHO (2013a) has estimated that $50 \%$ of essential drugs in Africa are counterfeit. This may explain the low control rates among individuals on anti-hypertensive treatment.

### 1.4 Factors associated with uncontrolled hypertension

Factors affecting uncontrolled hypertension among patients on treatment can be categorized into four categories using an adapted socio-ecological framework (Centers for Disease Control Prevention, 2015b); i.e. individual, family and community, health system, and policy level (Table 2).

Table 2: Factors associated with uncontrolled hypertension categorized using the socioecological model

| Individual level | Family and <br> community level | Health system level | Policy level |
| :--- | :--- | :--- | :--- |
| Non-modifiable | Relationships | Service delivery | Guidelines |
| Age | Culture | Health workforce | Policies |
| Sex | Traditional beliefs | Access to essential <br> Environment <br> Genetics | Directives <br> Femily support |
| Modicines | Health information | Laws |  |
| Behavioural | Community | Financing |  |
| Adherence | resources and | Leadership |  |
| Smoking | activities | governance |  |
| Alcohol use |  |  |  |
| Unhealthy diet |  |  |  |
| Weight control |  |  |  |
| Biological |  |  |  |
| Comorbidities |  |  |  |

### 1.4.1 Individual/patient factors

These are categorized as non-modifiable and modifiable.

### 1.4.1.1 Non-modifiable factors

### 1.4.1.1.1 Genetic factors

The wealth of genetic information collected over the years has provided insights into the genetic aetiology of many conditions including hypertension. Environmental exposures during the life-course and genetics contribute to diseases including high blood pressure (Muñoz et al., 2016). Findings from a recent analysis involving over one million people identified over 500
new loci associated with blood pressure traits (Evangelou et al., 2018). These findings provide new pathways to regulate blood pressure control that could prevent and reduce cardiovascular disease burden.

### 1.4.1.1.2 Age

The aging process has been linked to hypertension. As one ages, blood vessels narrow causing a higher risk of hypertension. Studies conducted in LMIC have consistently found that the prevalence of hypertension increases with age (Van de Vijver et al., 2013, Son et al., 2012, Dzudie et al., 2012, Mathenge et al., 2010, Mohamed et al., 2018).

### 1.4.1.1.3 Sex

Studies have associated both sexes to hypertension. For instance, earlier studies have shown that premenopausal women have lower blood pressures compared to men but this trend is reversed after menopause; women have a higher prevalence than men (Lima et al., 2012).

### 1.4.1.2 Modifiable factors

1.4.1.2.1 Behavioral factors
1.4.1.2.1.1 Adherence to treatment

Adherence to antihypertensive treatment is important in management of hypertension and in achieving optimal blood pressure. Non-adherence to antihypertensives is an important cause of uncontrolled hypertension. A systematic review (Abegaz et al., 2017) found $45 \%$ of patients were non-adherent with a higher proportion (84\%) being among those with uncontrolled blood pressures. Barriers to adherence are mainly related to medication side effects, low perception of the risks involved with having uncontrolled blood pressure and out-of-pocket costs. In SSA, access to medication is a major barrier to adherence.

### 1.4.1.2.1.2 Smoking

There is evidence to show that tobacco use increases blood pressure (Gao et al., 2017). However, literature on the link between blood pressure and hypertension is inconclusive. A study looking at the effects of cigarette on blood pressure and hypertension found that smoking
was associated with lowering of blood pressure (Gumus, 2013). Hansen et.al (1994) also found lower blood pressure among diabetic smokers compared to non-smoking diabetics.

### 1.4.1.2.1.3 Alcohol intake

Harmful use of alcohol has been linked to hypertension despite the known beneficial effects that moderate alcohol consumption has on ischemic heart diseases (Roerecke and Rehm, 2014). In 2017, a meta-analysis assessing the effect of reducing alcohol consumption on change in blood pressure found that reducing alcohol consumption lowers blood pressure in a dosedependent manner (Roerecke et al., 2017). SSA is characterised as having high proportion of abstainers but also a high proportion of heavy episodic drinkers among drinkers (Morojele et al., 2021) possibly explaining the high uncontrolled rates that are observed.

### 1.4.1.2.1.4 Unhealthy diets

Many LMICs are experiencing an epidemiological transition, described as a move from a high burden of infectious diseases, to a high prevalence of chronic diseases (Olshansky and Ault, 1986). This transition is largely as a result of various lifestyle changes, including shifts in dietary patterns. Sugar-sweetened beverages (SSB) such as carbonated soft drinks and fruit juices, high salt foods such as salty snacks and processed foods, and foods high in saturated and trans fats are increasingly forming a significant proportion of diets for many people living in LMICs (Popkin, 2004, Popkin et al., 2012). High consumption of these food items have been associated with obesity and other chronic health conditions (Malik et al., 2010, Malik et al., 2006), which can contribute to poor blood pressure control.

### 1.4.1.2.1.5 Weight control

The Framingham study demonstrated that overweight men and women had higher blood pressure compared to their normal weight counterparts (Higgins et al., 1987). Weight reduction has been shown to be associated with reduced blood pressure (Neter et al., 2003). While most countries in SSA have a growing threat of obesity (Agyemang et al., 2016), South Africa has a huge burden of obesity with $70 \%$ (aged15+) of women and $39 \%$ (aged $15+$ ) of men being
either obese or overweight. In 2018 South Africa was the only country in Africa to levy a tax on sugar-sweetened beverages among other beverages with added sugars in order to curb this challenge.

### 1.4.1.3 Biological Factors

### 1.4.1.3.1 Comorbidities

Hypertension co-exists with comorbidities such as chronic kidney disease, diabetes and hypercholesterolemia (Hendriks et al., 2012, Jenson et al., 2011, Joshi et al., 2014, Mathenge et al., 2010, Mohamed et al., 2021, Nimako et al., 2013a). These comorbidities could explain part of the inadequacy in blood pressure control seen among patients on treatment. Studies conducted in Europe and the US found that patients with diabetes mellitus had significantly increased risk of uncontrolled blood pressure (Degli Esposti et al., 2004, Liu and Song, 2013). Overweight and obesity are also known to be risk factor for hypertension. Due to urbanization and lifestyle changes associated with that, current estimates suggest a rise in the prevalence of overweight and or obesity especially among urban residents (Ziraba et al., 2009).

### 1.4.2 Family and community level factors

The family and community level factors describe the relationships that individuals have with friends, families and traditions. Family and community level factors play an important role in the creation of awareness in the community while bridging the gap between the patients and the clinicians. For instance, the elderly or patients who require support need to have a family or a support system that can assist the patient to get the care they need. A study among older adults showed that older adults with support from family and friends had better blood pressure control compared to those without this support (Pirkle et al., 2018). Other studies have also reported that patients with uncontrolled hypertension had their management of hypertension care facilitated by family members who remind them to take their medications and attend doctor visits and help them with meal preparations (Flynn et al., 2013, Gebrezgi et al., 2017). Many countries in SSA use community health workers (CHW) to bridge the gap between
clinicians and the community (Pascal Saint-Firmin et al., 2021, Center for Sustainable Development et al., Africa Renewal, 2021).

### 1.4.3 Health system related factors

Health systems are expected to promote health in the individuals they serve. In SSA, health systems have been characterized as being weak and unable to provide quality care to the populations they serve. Mendis et al (2012) identified gaps in capacity for implementation of essential non-communicable disease (NCD) intervention in low resource settings. For instance, major gaps were noted in the access to essential drugs and simple technologies. The same study also identified a shortage of health care personnel and the need to train lower cadre staff to deliver simple essential NCD interventions such as CVD risk assessment. Further reduction of medication cost, especially in countries without universal health coverage, is associated with improved hypertension care (Maimaris et al., 2013). This finding is particularly important for SSA, where universal coverage is not common. Healthcare provider related barriers also contribute to blood pressure control. Guidelines have been changing therefore healthcare providers need to keep abreast with newer guidelines in order to provide their patients with optimum care. Provider lack of adherence to hypertension guidelines in regards to dose escalation and use of multiple drug regimens are a barrier to hypertension control. Chow et al revealed the use of multiple drug regimens to treat hypertension was lower in low-income countries compared the higher-, upper middle- or the lower middle-income countries (Chow et al., 2013).

### 1.4.4 Policy level related factors

Policy level factors includes the laws or policies and guidelines both at the local and at a national level that influence hypertension control. Hypertension guidelines have evolved as more data have become available. As earlier stated, the American College of Cardiology and the American Heart Association updated their hypertension guidelines. These stricter guideline have implications for care and treatment. In SSA, the guidelines have not changed much and
the use of the JNC 8 is still currently in use. As more data becomes available in SSA, the guidelines should be improved.

### 1.5 Conceptual framework

This thesis was explored using the Social Ecological Model (SEM) framework adapted from the Centers for Disease Control and Prevention (Centers for Disease Control Prevention, 2015a) to understand the multiple levels of factors associated with uncontrolled hypertension and the interactions between the different levels within this system. This framework was originally developed by Bronfenbrenner in the 70 's and it has undergone many changes until his death in 2005 (Eriksson et al., 2018). There are four levels in this adapted SEM: Individual, family and community, health system, and policy/enabling environment (Figure 2). This model takes into account the complex interplay between the different levels. This model allows for the understanding of the range of factors that put people at risk for uncontrolled hypertension or protects them from having uncontrolled blood pressure. The overlapping levels in the model show how factors at the different levels influence each other. The solutions and gaps in hypertension care can be investigated by assessing these factors at these levels.


Figure 2: Factors affecting uncontrolled hypertension at the different levels

[^0]The individual level factors identify biological and personal history factors that increase the likelihood of one having uncontrolled hypertension. These factors include non-modifiable factors (age, sex,), modifiable factors (behavioural factors such as substance use, physical activity, unhealthy diets, harmful use of alcohol, and tobacco use), patient comorbidities (such as diabetes, chronic kidney disease, obesity among others) and socio-demographics (marital status, education, wealth status). Strategies for prevention at the individual level are expected to promote attitudes and behaviours that can improve uncontrolled hypertension. The family and community level factors describe the relationships that individuals have with friends, families, traditions, and the environment they live in. Strategies at this level include the promotion of healthy relationships, promotion of healthy living behaviours and access to healthy living spaces. The health system factors identify the health system building blocks that can influence hypertension care. These factors include service delivery, health workforce, access to essential medicines, health information system, finance leadership and governance. The final outer ring level (policy level) identifies the laws or policies and guidelines both at the local and at a national level that influence hypertension control. This study examined all the four levels in the SEM framework to understand the multiple levels of factors associated with uncontrolled hypertension. The use of this framework provides a holistic approach in looking at barriers that can provide information for the design of a multi-level intervention to uncontrolled hypertension.

### 1.6 Research gaps

Hypertension disproportionately affects people living in LMIC, especially in SSA where the prevalence is the highest and treatment and control rates are low. More concerning are the high uncontrolled rates observed among individuals on treatment. Previous research from HICs have been shown that comorbidities increases the risk of uncontrolled hypertension (Degli Esposti et al., 2004, Liu and Song, 2013). However the burden of uncontrolled hypertension among individuals with comorbidities in SSA is unknown. The availability of nationally representative
data across SSA has provided an opportunity to estimate this burden and examine the association between uncontrolled hypertension with comorbidities such as diabetes, dyslipidemia, obesity and abdominal obesity among adults in sub-Saharan Africa.

With the current intense urban growth occurring across SSA, the earlier benefits associated with urban living such as improved access to health care are not as apparent. There is now increased recognition that urban slum residents are highly vulnerable and are an underserved community. In Nairobi, Kenya's capital city, an estimated $60 \%$ of the population live in slums or slum-like conditions (Candiracci S and Syrjänen R, 2007). Nairobi's slum dwellers face all the conditions that make slums vulnerable to emergencies such as disease outbreaks, natural i.e. floods and human induced i.e. fires disasters. Studies conducted in SSA have revealed that the prevalence of hypertension is higher in urban areas compared to rural areas (Joshi et al., 2014, Van de Vijver et al., 2013, Seedat, 2000, Addo et al., 2007) but the extent of having two or more chronic condition (multimorbidity) in the slums of Nairobi is not known. Using data from two slums in Nairobi, the prevalence and factors associated with multimorbidity in two slums of Nairobi was estimated.

There is a dearth of information on what is driving the large uncontrolled hypertension rates in general in urban slum settings. Apart from multimorbidity, there are other factors such as access to healthcare, poverty, unsupportive families and communities that may contribute to the burden of uncontrolled hypertension. It was therefore important to use a systemic approach to explore more in-depth, the patient, provider, and health system factors driving uncontrolled hypertension in slums and why treated patients with hypertension still have uncontrolled blood pressures.

### 1.7 Aim, Objectives, and Research Questions

1.7.1 Overall aim

The aims of this research are to address major gaps in knowledge about (i) the scope in the burden of uncontrolled hypertension among adults with comorbidities residing in sub-Saharan Africa and (ii) the factors associated with uncontrolled hypertension. The results will inform debates on policy and programming to improve uncontrolled hypertension related care and service provision for populations in SSA. This research used a mixed methods approach that combined the strength of qualitative and quantitative research methods for the purposes of obtaining a richer and deeper understanding of uncontrolled hypertension (Zhang and Creswell, 2013). The current research aimed to give a clearer picture of uncontrolled hypertension in SSA hence the approach of integration was deemed most appropriate. In this approach, both the qualitative and quantitative data were analysed separately but the results were integrated during interpretation.

### 1.7.2 Specific objectives

The objectives are to:

1. Estimate the prevalence of uncontrolled hypertension among individuals with comorbidities in SSA
2. Estimate the prevalence of uncontrolled hypertension among individuals with diabetes, dyslipidemia, obesity and abdominal obesity in SSA.
3. Examine the association between uncontrolled hypertension with diabetes, dyslipidemia, obesity and abdominal obesity among adults in sub-Saharan Africa
4. Estimate the prevalence of multimorbidity and its determinants in two informal settlements in Nairobi (Kenya) - Korogocho and Viwandani.
5. Explore facilitators and barriers to hypertension control among patients with comorbid conditions in Korogocho and Viwandani at a patient, family/community, health system and policy level.

### 1.7.3 Research Questions

1. What is the prevalence of uncontrolled hypertension among people with comorbid conditions in sub-Saharan Africa?
2. What is the prevalence of uncontrolled hypertension overall and the prevalence of uncontrolled hypertension among individuals with diabetes, dyslipidemia, obesity and general obesity conditions in sub-Saharan Africa?
3. What is the relationship between uncontrolled hypertension with being obese, having abdominal obesity, diabetes, and dyslipidemia?
4. What is the prevalence of multimorbidity and what are the factors associated with multimorbidity in slum communities?
5. What are the patient, family/community, health system and policy level facilitators and barriers to blood pressure control in the slum communities?

### 1.8 Structure of the thesis

The thesis begins with an overview of the definition and epidemiology of hypertension and it provides a general overview of blood pressure control in people with comorbidities. Chapter 2 is a systematic review and meta-analysis of uncontrolled hypertension in sub-Saharan Africa among patients with comorbidities. Chapter 3 examines the relationship between general obesity, abdominal obesity, diabetes and dyslipidemia and uncontrolled hypertension using nationally representative individual participant data. Chapter 4 is a cross-sectional quantitative study exploring multimorbidity of chronic diseases and its determinants in a slum set up. Chapter 5 explores the reasons why blood pressure is not controlled in individuals on treatment for hypertension and have comorbidities. This is a qualitative study conducted in two slum communities in Nairobi. Chapter 6 provides overall discussions, recommendations and conclusion.

## 2. Uncontrolled hypertension among people with comorbidities in sub-Saharan Africa; a systematic review and meta-analysis

### 2.1 Introduction

This chapter synthesizes all the available evidence on uncontrolled hypertension among individuals with comorbidities in SSA. The pooled prevalence of uncontrolled hypertension among individuals with comorbidities in general and among individuals with diabetes using aggregate data is estimated. Lastly, the implications of these findings and recommendations are discussed.

Uncontrolled hypertension in SSA is a challenge despite increasing knowledge of hypertension care and the availability of low cost medications. The previous chapter highlighted the high burden of uncontrolled hypertension in SSA. High uncontrolled rates have economic and public health implications. Morbidities, such as stroke, associated with uncontrolled hypertension are costly to treat and pose a burden to health care systems in SSA that are already weak and strained (WHO Africa, 2011).

Previous reviews conducted in SSA have focused on hypertension prevalence, awareness, treatment and control (Ataklte et al., 2015, Dzudie et al., 2012). However, as previously noted, hypertension does not present in isolation-it co-exists with comorbidities (Wong et al., 2007). Having comorbidities is associated with poorer health outcomes for patients (Fortin et al., 2007a) and it is complex and expensive to manage (Wolff et al., 2002). However, there is a dearth of literature on the impact of comorbidities on uncontrolled hypertension in SSA and uncontrolled hypertension among people with comorbid conditions is poorly understood. This chapter presents results of a systematic review and meta-analyses conducted to estimate the burden of uncontrolled hypertension among patients with comorbidities in SSA.

### 2.2 Method:

2.2.1 Protocol and registration

This review was undertaken and reported in accordance with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). The protocol is published (Mohamed et al., 2020) and registered in PROSPERO International Prospective Register of Systematic reviews (CRD42019108218).

### 2.2.2 Eligibility criteria

### 2.2.2.1 Inclusion criteria

Studies were included if they fulfilled the following criteria:

- Use of cohort, cross-sectional and baseline data from randomised control trials from sub-Saharan Africa (published and unpublished) on high blood pressure/hypertension/uncontrolled hypertension among individuals on antihypertensive treatment as a primary or secondary outcome.
- Participants had hypertension and were on treatment for hypertension and had one of the following comorbid conditions (table 3); type 2 diabetes mellitus, dyslipidemia, obesity, chronic kidney disease, stroke and or transient ischemic attack, coronary heart disease, heart failure, peripheral vascular disease, atrial fibrillation, depression or HIV. Comorbid conditions were selected that commonly co-exist with hypertension and these conditions were identified from Barnett and colleagues (2012).
- Participants were individuals older than 15 years
- The studies were in any language.
- The study was based in a community or hospital setting.
- Published between Jan 1, 2000 and June 30, 2019.


### 2.2.2.2 Exclusion criteria

The following studies were excluded:

- Systematic reviews, case-control studies, qualitative studies, commentaries, editorials, letters, and studies without primary data or explicit description of methods, or both.
- Studies that do not report uncontrolled hypertension among patients with comorbidities of interest.
- Studies that lacked sufficient data to calculate the outcome of interest (uncontrolled hypertension).
- Studies with participants younger than 15 years of age.
- Studies on pregnancy related hypertension

Table 3: List of 11 conditions included as comorbidity

|  | Conditions |
| :--- | :--- |
| 1 | Diabetes |
| 2 | Dyslipidemia |
| 3 | Obesity |
| 4 | Chronic kidney disease |
| 5 | Stroke and transient Ischemic attack |
| 6 | Coronary heart disease |
| 7 | Heart failure |
| 8 | Peripheral vascular disease |
| 9 | Atrial fibrillation |
| 10 | Depression |
| 11 | HIV |

### 2.2.3 Information sources

The literature search strategy was developed using medical subject headings (MeSH) and key text words such as hypertension, high blood pressure, uncontrolled hypertension, uncontrolled blood pressure, each of the comorbidities of interest, and sub-Saharan Africa. Three databases (MEDLINE via OVID, Embase, and Web of Science) were searched to identify papers from January 1, 2000 to June 30, 2019. Abstracts of published literature with relevant information on the prevalence of uncontrolled hypertension in adults with comorbid conditions on antihypertensive therapy residing in SSA were identified. Further, the reference list of all the included relevant articles identified through the search were scanned to identify additional relevant articles. In addition, grey literature such as reports were searched using OpenSIGLE and the WHO websites.

### 2.2.4 Search Strategy

A specific search strategy was developed with guidance from a librarian with expertise in systematic review searching (Appendix 1). The MEDLINE search strategy was adapted to the syntax and subject headings for the other two databases.

### 2.2.5 Study records

Based on the inclusion and exclusion criteria, a tool was developed a priori to guide the screening process. The search results were uploaded to EndNote software to remove duplicates. Then the remaining articles were uploaded to Rayyan, a mobile and a web-based software program (Ouzzani et al., 2016). This is a free program that facilitates collaboration among the reviewers involved in the screening and selection of studies.

### 2.2.6 Selection process

Two investigators—Shukri F Mohamed (SFM) and Mustapha S Abba (MSA) —independently screened the titles and abstracts of articles retrieved from the literature search against the eligibility criteria. Full texts for the eligible titles and/or abstracts including those where there was uncertainty were obtained for further assessment on whether to include in the study or not. For studies that were multi-national, we used estimates at country level. We resolved our disagreements through discussion and when that was not possible we invited a third reviewerOlalekan A Uthman (OAU)-to arbitrate.

### 2.2.7 Data extraction process

Data were extracted using a standardised data extraction form. From the studies included, MSA and I independently extracted data using the predefined standardised extraction form. Disagreements were resolved through discussion and when needed we involved a third reviewer (OAU) to arbitrate the disagreement.

### 2.2.8 Data items

From the studies retrieved, we extracted data on general information (first author name, year of publication, country, language,), study characteristics (study design, setting, sample size, study period, mean or median age, data source and male proportion), data on type of
comorbidity present (diabetes, atrial fibrillation, stroke, chronic kidney disease and HIV), use of comorbidity specific hypertension values cut-offs, and prevalence of uncontrolled hypertension among those on treatment.

### 2.2.9 Outcomes and prioritization

The primary outcome in this study was the prevalence of uncontrolled hypertension among people who report taking antihypertensive treatment and have a comorbid condition of interest in SSA. If the primary outcome measure was not specifically stated, it was calculated so long as the necessary items needed to calculate it were available in the study. Hypertension cut-off values differed depending on the comorbid conditions. For instance, in the general population, uncontrolled hypertension is defined as either having a systolic blood pressure (SBP) equal to or greater than 140 mmHg and/or a diastolic blood pressure (DBP) equal to or greater than 90 mmHg and while on antihypertensive treatment. Target blood pressure measurements for patients with hypertension and comorbid conditions such as diabetes are usually lower; systolic blood pressure (SBP) equal to or less than 130 mmHg and/or a diastolic blood pressure (DBP) equal to or greater than 85 mmHg (Passarella et al., 2018). Thus studies that reported using the comorbid condition specific target blood pressure cut-off values when categorizing patients as hypertensive were recorded to have used comorbidity specific hypertension cut-off values.

### 2.2.10 Risk of bias in individual studies

The tool developed by Hoy et.al (Appendix 2) for prevalence studies was used to assess the methodological quality of the included studies (Hoy et al., 2012). The tool has nine items to assess the internal and external validity of studies while the tenth item is a summary risk by the reviewer based on the responses to the 9 items that were scored 1 if yes and 0 if no. Studies were classified as having a low (>8), moderate (6-8), or high ( $\leq 5$ ) risk of bias. Two reviewersSFM and Martin K Mutua (MKM)—independently scored the papers and disagreements were resolved by discussion and where necessary a third reviewer- OAU -resolved the disagreement.

### 2.2.11 Data synthesis

Random-effects meta-analysis was performed to pool the prevalence estimates that were similar across the included studies to determine the pooled estimate of the prevalence of uncontrolled hypertension among individuals with comorbidities overall and also among those with diabetes, stroke and HIV separately while on treatment across the included studies in SSA. Prevalence estimates were further summarized by age, gender, comorbidities, sample size, year of publication, study setting, risk of bias, and geographic region. The standard errors for the study-specific prevalence estimates were determined from the reported prevalence and sample size for each study. In order to reduce the influence of studies with extreme prevalence estimates, variances of the study-specific estimates were first stabilized using the double arcsine transformation (Barendregt et al., 2013).

Heterogeneity (as measured by $I^{2}$ statistics) was explored using Cochrane's Q and quantified by $I^{2}$ statistics (Higgins and Thompson, 2002, Higgins et al., 2003) and where substantial heterogeneity ( $I^{2}$ values greater than $60 \%$ ) were noted; subgroup analyses based on the following; patient characteristics (age, sex), patient comorbidities, study setting, sample size, study design, use of comorbidity specific blood pressure cut-off values, countries, geographic regions, and by gross national income (GNI) were performed to identify the possible sources of heterogeneity. Further, sensitivity analyses excluding studies with high risk of bias were performed to assess the robustness of the findings.

The presence of publication bias was assessed using the Egger's test and funnel plots asymmetry (Egger et al., 1997). Inter-rater agreement for studies included and to identify risk of bias was assessed using Kappa statistics (Viera and Garrett, 2005). All proportions and 95\% CIs were calculated using Stata Version 16.1.

### 2.3 Results

### 2.3.1 Study selection

A total of 7365 records (figure 3) were identified through the electronic database search. Using other sources and reference tracing we identified an additional 35 articles. Following duplicate removal, 4776 records remained for title and abstract screening. After title and abstract screening, we found 4267 records to be irrelevant and excluded them. The remaining 509 articles' full-text were retrieved and further assessed for inclusion. Of the 509 articles, 14 articles were excluded as they were duplicates that were not identified in the first round of screening and 25 articles were case-control studies. Six articles were not based on SSA residents and two articles were among children younger than 15 years of age so they were excluded. Two articles were reviews while another eight were abstracts only which lacked sufficient information on the study outcomes so they were excluded. A total of 88 articles lacked the outcome of interest and another 344 articles had information on hypertension but lacked information on uncontrolled hypertension thus they were excluded. A further two articles were excluded as they were published outside the 2000-2019 time period. A total of 491 articles were excluded resulting in the inclusion of 18 studies for this meta-analysis. More detail of this process can be found in figure 3 below. The inter-rater agreement for study selection for inclusion was 0.77 suggesting substantial agreement (Viera and Garrett, 2005).

Figure 3: Study selection flow diagram


### 2.3.2 Sample characteristics

In total, 18 studies with 3,469 participants from eight countries in SSA were included (Abboud et al., 2013, Abera and Woldemichael, 2016, Adeniyi et al., 2016, Agaba et al., 2009, Babua et al., 2015, Choukem et al., 2007, Cohen et al., 2010, Hyle et al., 2019, Jardine et al., 2014, Muddu et al., 2019, Mwita et al., 2012, Pinchevsky et al., 2017, Pinchevsky et al., 2013, Rotchford and Rotchford, 2002, Soetedjo et al., 2018, Steffen et al., 2017, Wahab et al., 2017, Yaméogo et al., 2012). Most of the studies were from South Africa ( $\mathrm{n}=8,44.4 \%$ ) (Abboud et al., 2013, Adeniyi et al., 2016, Hyle et al., 2019, Jardine et al., 2014, Pinchevsky et al., 2017, Pinchevsky et al., 2013, Rotchford and Rotchford, 2002, Soetedjo et al., 2018). Uganda (Babua et al., 2015, Muddu et al., 2019), Malawi (Cohen et al., 2010, Steffen et al., 2017) and Nigeria (Agaba et al., 2009, Wahab et al., 2017) represented $11.1 \%$ each of the studies included while Ethiopia (Abera and Woldemichael, 2016), Tanzania (Mwita et al., 2012), Cameroon (Choukem et al., 2007) and Senegal (Yaméogo et al., 2012) represented 5.6\% of the studies included. The reported mean age of the participants ranged from 36 to 67 years. Most of the studies were published in English (17, 94\%), cross-sectional (17, 94\%), used consecutive sampling $(14,78 \%)$, were hospital-based $(11,61 \%)$ and collected data prospectively $(12,67 \%)$. The sample sizes ranged from 35 to 567 participants. The proportion of male participants in the included studies ranged from $25.5 \%$ (Yaméogo et al., 2012) to $60.9 \%$ (Wahab et al., 2017). Of the included studies, diabetes was reported as a comorbidity in the majority ( $61.1 \%$ ) of the studies (Abera and Woldemichael, 2016, Adeniyi et al., 2016, Agaba et al., 2009, Choukem et al., 2007, Cohen et al., 2010, Mwita et al., 2012, Pinchevsky et al., 2017, Pinchevsky et al., 2013, Rotchford and Rotchford, 2002, Soetedjo et al., 2018, Yaméogo et al., 2012). Three of the studies reported on HIV (Babua et al., 2015, Hyle et al., 2019, Muddu et al., 2019, Steffen et al., 2017), two studies reported on stroke (Abboud et al., 2013, Wahab et al., 2017), and one study each reported on chronic kidney disease (Babua et al., 2015) and atrial fibrillation (Jardine et al., 2014). Obesity, dyslipidaemia, coronary heart disease, heart failure, peripheral
heart disease, and depression were not reported in the included studies. Table 4 and Table 5 provide more detailed information on the included studies. Of the 18 included studies, 14 ( $77.8 \%$ ), had low risk of bias, 2 (11.1\%) had moderate risk, and 2 (11.1\%) had high risk (Table 6).

Table 4: Characteristics of studies in the prevalence of uncontrolled hypertension in subSaharan Africa

| Year of publication ( $\mathrm{n}=18$ ) | 2002-2019 |
| :---: | :---: |
| Period of inclusion ( $\mathrm{n}=18$ ) | 2000-2019 |
| Mean age, years ( $\mathrm{n}=18$ ) | 56.7( $\pm 0.11$ ) |
| \% of males ( $\mathrm{n}=18$ ) | 46.9( $\pm 0.18)$ |
| Comorbidities | N (\%) studies |
| Diabetes | 11 (61.1\%) |
| HIV | 3 (16.7\%) |
| Stroke | 2 (11.1\%) |
| Atrial fibrillation | 1 (5.6\%) |
| Chronic Kidney Disease (CKD) | 1 (5.6\%) |
| Countries |  |
| South Africa | 8 (44.4\%) |
| Uganda | 2 (11.1\%) |
| Malawi | 2 (11.1\%) |
| Nigeria | 2 (11.1\%) |
| Ethiopia | 1 (5.6\%) |
| Tanzania | 1 (5.6\%) |
| Cameroon | 1 (5.6\%) |
| Senegal | 1 (5.6\%) |
| sub-Saharan African regions |  |
| Eastern Africa | 4 (22.2\%) |
| Western Africa | 3 (16.7\%) |
| Central Africa | 1 (5.6\%) |
| Southern Africa | 10 (55.5\%) |
| Study design |  |
| Cross sectional | 17 (94.4\%) |
| Not reported | 1 (5.6\%) |
| Sampling |  |
| Consecutive | 14 (77.8\%) |
| Random | 2 (11.1\%) |
| Not reported | 2 (11.1\%) |
| Timing of data collection |  |
| Retrospectively | 5 (27.8\%) |
| Prospectively | 12 (66.7\%) |
| Not reported | 1 (5.6\%) |
| Data sources |  |
| Medical records | 5 (27.8\%) |
| Participants | 9 (50\%) |
| from both medical records and participants | 3 (16.7\%) |
| Not reported | 1 (5.6\%) |
| Study site |  |
| Hospital | 11 (61.1\%) |
| Health center | 7 (38.9\%) |

Table 5: Characteristics of the Included Studies

| Study | Country | Age <br> (Mean/Median) | Study period | Study site | Sampling | Male \% | Sample size | UHTN\% | Risk of bias |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Atrial Fibrillation |  |  |  |  |  |  |  |  |  |
| Jardine et.al,2014 | South Africa | $67 \pm 13$ | Feb 2010 - Mar 2011 | Health center | Consecutive | 59.9 | 198 | 100.0 | High |
| Chronic Kidney Disease |  |  |  |  |  |  |  |  |  |
| Babua et.al 2015 | Uganda | 42.8 | Jun - Feb 2013 | Hospital | Consecutive | 51.2 | 191 | 76.0 | Low |
| Diabetes |  |  |  |  |  |  |  |  |  |
| Abera et.al, 2016 | Ethiopia | $56.3 \pm 10$ | Aug - Jan 2015 | Hospital | Consecutive | 59.9 | 382 | 85.0 | Low |
| Adeniyi et.al, 2016 | South Africa | $61.3 \pm 11.8$ | Jul to Nov 2013 | Hospital | Consecutive | 28.3 | 265 | 75.5 | Low |
| Agaba et.al, 2009 | Nigeria | $51 \pm 12$ | Jun - Sept 2004 | Hospital | Consecutive | 40.2 | 79 | 70.9 | Moderate |
| Choukem et.al 2006 | Cameroon | $56.6 \pm 13.3$ | 6 months | Hospital | Consecutive | 50.5 | 98 | 79.6 | Low |
| Cohen et.al, 2010 | Malawi | $53.2 \pm 14.0$ | Mar - Jun 2007 | Hospital | Consecutive | 39.8 | 253 | 72.7 | Low |
| Mwita et.al, 2012 | Tanzania | $51.6 \pm 11.2$ | Feb - Sep 2010 | Health center | Consecutive | 38.0 | 67 | 66.0 | Low |
| Pinchevsky et.al, 2017 | South Africa | $53.9 \pm 11.5$ | May - Aug 2015 | Health center | Consecutive | 46.1 | 459 | 78.0 | Low |
| Pinchevsky et.al, 2013 | South Africa | $63 \pm 11.9$ | July 2008-2009 | Hospital | Random | 44.6 | 567 | 54.2 | Low |
| Rotchford,2002 | South Africa | $56.5 \pm 10.4$ | 2 months in 1999 | Hospital | Consecutive | 26.9 | 129 | 86.0 | Low |
| Soetedjo et.al 2018 | South Africa | $53 \pm 9.9$ | Dec 2013 - Jun 2016 | Health center | Consecutive | 35.9 | 48 | 66.7 | Low |
| Yameogo et.al,2012 | Senegal | $58.2 \pm 9.2$ | Mar 2007-Jul 2008 | Hospital | NR | 25.5 | 52 | 80.8 | High |
| HIV |  |  |  |  |  |  |  |  |  |
| Hyle et.al, 2019 | South Africa | $38.4 \pm 8.3$ | 2015 | Health center | Consecutive | 33.0 | 54 | 83.0 | Low |
| Muddu et.al, 2019 | Uganda | $43.6 \pm 11.5$ | Jan 2014 - Jan 2017 | Health center | Consecutive | 39.4 | 91 | 41.8 | Low |
| Steffen et.al, 2017 | Malawi | $36 \pm 9.3$ | Not indicated | Health center | NR | 42.8 | 35 | 77.1 | Moderate |
| Stroke |  |  |  |  |  |  |  |  |  |
| Abboud et.al, 2013 | South Africa | $63.5 \pm 11.3$ | Jan 2007 - Dec 2008 | Hospital | Random | 58.5 | 217 | 88.0 | Low |
| Wahab et.al, 2017 | Nigeria | $59 \pm 13.1$ | Feb 2009-Apr 2011 | Hospital | Consecutive | 60.9 | 284 | 60.2 | Low |
| NR=Not reported | UHTN - Unco | rolled hypertensi |  |  |  |  |  |  |  |

Table 6: Risk of bias assessment

| Author \& Publication Date | External Validity Questions |  |  |  | Internal Validity Questions |  |  |  |  | Total Score | Risk of Bias |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |  |  |
| Atrial Fibrillation |  |  |  |  |  |  |  |  |  |  |  |
| Jardine et.al, 2014 | $\chi$ | $\chi$ | $\chi$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 5 | High |
| Chronic Kidney Disease |  |  |  |  |  |  |  |  |  |  |  |
| Babua et.al, 2015 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 9 | Low |
| Diabetes |  |  |  |  |  |  |  |  |  |  |  |
| Abera et.al, 2016 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\sqrt{ }$ | 8 | Low |
| Adeniyi et.al, 2016 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 9 | Low |
| Agaba et.al, 2009 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 7 | Moderate |
| Choukem et.al, 2006 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 8 | Low |
| Cohen et.al, 2010 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 9 | Low |
| Mwita et.al, 2012 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 9 | Low |
| Pinchevsky et.al, 2017 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 8 | Low |
| Pinchevsky et.al, 2013 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 8 | Low |
| Rotchford et.al, 2002 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 9 | Low |
| Soetedjo et.al 2018 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 9 | low |
| Yameogo et.al, 2012 | $\chi$ | $\chi$ | $\chi$ | $\chi$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 4 | High |
| HIV |  |  |  |  |  |  |  |  |  |  |  |
| Hyle et.al, 2019 | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 8 | Low |
| Muddu et.al, 2019 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 7 | Low |
| Steffen et.al, 2017 | $\checkmark$ | $\checkmark$ | $\chi$ | $\chi$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | 6 | Moderate |
| Stroke |  |  |  |  |  |  |  |  |  |  |  |
| Abboud et.al, 2013 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\chi$ | $\checkmark$ | $\checkmark$ | 8 | Low |
| Wahab et.al, 2017 | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | $\checkmark$ | 9 | Low |

2.3.3 Burden of uncontrolled hypertension among individuals with comorbidities and on antihypertensive treatment
Meta-analysis results for the prevalence of uncontrolled hypertension among individuals with comorbidities and on antihypertensive treatment are shown on Table 7 and figure 5. The prevalence of uncontrolled hypertension among individuals with comorbidities and on antihypertensive treatment ranged from $41.8 \%$ ( $95 \%$ CI, $32.2 \%-52.0 \%$ ) in Uganda (Muddu et al., 2019) to $100 \%$ ( $95 \%$ CI, $98.1 \%-100.0 \%$ ) in South Africa (Jardine et al., 2014). From the random effects meta-analysis, the estimated pooled prevalence of uncontrolled hypertension among individuals with comorbidities and on antihypertensive treatment was 75.9\% (95\% CI, $67.9 \%-83.0 \%)$ with evidence of statistically significant substantial $\left(I^{2}=96.1 \% ; \mathrm{p}<0.0001\right)$ heterogeneity. There was no evidence of publication bias through the inspection of the funnel plot (figure 4) and this finding was confirmed by the Egger's test ( $\mathrm{p}=0.623$ ).

Table 7: Meta-analysis results for the prevalence of uncontrolled hypertension in people with comorbidities and on antihypertensive treatment in sub-Saharan Africa

|  | Prevalence $(95 \% \mathrm{CI})$ | No of studies | Number of Participants | $\begin{gathered} \mathbf{I}^{2} \\ (95 \% \mathrm{CI}) \end{gathered}$ | $\mathbf{P}^{\text {heterogeneneity }}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Overall | 75.9 (67.9-83.0) | 18 | 3469 | 96.1 | $<0.0001$ |
| By comorbidity |  |  |  |  |  |
| Atrial fibrillation | 100.0 (98.1-100.0) | 1 | 198 | - | - |
| Chronic kidney disease | 75.9 (69.4-81.4) | 1 | 191 | - | - |
| Diabetes | 74.5 (67.1-81.3) | 11 | 2399 | 93.1 | $<0.001$ |
| HIV | 66.2 (38.3-89.3) | 3 | 180 | - | - |
| Stroke | 73.1 (69.1-76.9) | 2 | 501 | - | - |
| By region |  |  |  |  |  |
| Eastern | 68.4 (49.7-84.4) | 4 | 731 | 95.6 | <0.001 |
| Western | 69.8 (57.0-81.2) | 3 | 415 | - | - |
| Central | 79.6 (70.6-86.4) | 1 | 98 | - | - |
| Southern | 79.8 (68.1-89.4) | 10 | 2225 | 97.3 | $<0.001$ |
| By risk of bias |  |  |  |  |  |
| Low | 72.9 (65.7-79.5) | 14 | 3105 | 94.5 | $<0.001$ |
| Moderate | 72.0 (63.3-80.0) | 2 | 114 | - | - |
| High | 99.0 (97.1-100.0) | 2 | 250 | - | - |
| By study size |  |  |  |  |  |
| Small studies | 70.4 (60.1-79.8) | 8 | 524 | 83.4 | $<0.001$ |
| Large studies | 79.5 (69.0-83.0) | 10 | 2945 | 97.7 | <0.001 |
| By period of publication |  |  |  |  |  |
| Before 2015 | 79.4 (66.5-89.9) | 10 | 1851 | 97.3 | $<0.001$ |
| After 2015 | 71.1 (61.6-79.8) | 8 | 1618 | 93.1 | <0.001 |
| By gender proportion |  |  |  |  |  |
| More females | 71.0 (63.3-78.1) | 12 | 2099 | 91.9 | $<0.001$ |
| More males | 84.1 (69.5-94.7) | 6 | 1370 | 97.6 | <0.001 |
| By sampling |  |  |  |  |  |
| Consecutive | 76.1 (67.6-83.7) | 14 | 2598 | 95.6 | $<0.001$ |
| Random | 64.5 (61.1-67.9) | 2 | 784 | - | - |
| By setting |  |  |  |  |  |
| Hospital | 75.5 (67.7-82.3) | 11 | 2517 | 94.7 | $<0.001$ |
| Health center | 76.0 (55.7-91.6) | 7 | 952 | 97.3 | <0.001 |
| By comorbidity HTN target |  |  |  |  |  |
| Comorbidity target used | 70.7 (61.3-79.2) | 11 | 1735 | 93.3 | $<0.001$ |
| Comorbidity target not used | 83.0 (72.4-91.4) | 7 | 1734 | 96.3 | <0.001 |
| By Gross National Income |  |  |  |  |  |
| Below SSA Average | 72.7 (63.4-81.0) | 8 | 1169 | 97.5 | $<0.001$ |
| Above SSA average | 78.3 (66.1-88.4) | 10 | 2300 | 90.2 | $<0.001$ |

[^1]

Figure 4: Pooled prevalence of uncontrolled hypertension in people with comorbidities and on antihypertensive treatment in sub-Saharan Africa, by comorbidities.
$\mathrm{CKD}=$ chronic kidney disease; $\mathrm{AF}=$ Atrial fibrillation


Figure 5: Funnel plot of the prevalence of uncontrolled hypertension in people with comorbidities on antihypertensive treatment in sub-Saharan Africa

Subgroup analysis showed differences in the prevalence of uncontrolled hypertension among people with comorbidities and on antihypertensive treatment (Table 7). With regards to comorbidities, the highest uncontrolled hypertension estimate (100.0\% [95\% CI, 98.1\%$100.0 \%$ ]) was noted for adults with atrial fibrillation, this was followed by adults with chronic kidney disease ( $75.9 \%$ [ $95 \% \mathrm{CI}, 69.4 \%-81.4 \%$ ]). The lowest pooled uncontrolled hypertension prevalence estimate was found in adults with $\operatorname{HIV}$ ( $66.2 \%$ [ $95 \% \mathrm{CI}, 38.3 \%-89.3 \%]$ ). Variations were noted with regards to geographic regions; the Southern (79.8\% [95\% CI, 68.2\%-89.3\%]) and Central regions ( $79.6 \%$ [ $95 \%$ CI, $70.6 \%-86.4 \%]$ ) reported higher prevalence's compared to studies conducted in the Eastern ( $68.4 \%$ [ $95 \%$ CI, $49.7 \%-84.4 \%$ ]) and Western regions (69.8\% [95\% CI, 57.0\%-81.2\%]). With regards to sample size; larger studies reported a higher prevalence ( $79.5 \%$ [ $95 \% \mathrm{CI}, 69.1 \%-88.2 \%]$ ) compared to small studies ( $70.4 \%$ [ $95 \% \mathrm{CI}$, $60.1 \%-79.8 \%]$ ). A higher pooled prevalence of uncontrolled hypertension was reported in studies published before 2015 (79.1 [95\% CI, 66.5-89.9]) compared to studies published after

2015 (71.1 [95\% CI, 61.6-71.8]). Studies that used the recommended hypertension control value for each comorbidity reported lower pooled prevalence of uncontrolled hypertension (70.1 [95\% CI, 57.4-81.5]) compared to those that did not use the recommended comorbidity specific blood pressure control value (78.2 [95\% CI, 73.1-82.9]). Studies reporting on countries that had a GNI below the average GNI for sub-Saharan Africa reported a lower prevalence of uncontrolled hypertension ( 72.7 [ $95 \% \mathrm{CI}, 63.4-81.0]$ ) compared to studies reporting on countries with a GNI above the regional average ( 78.3 [ $95 \%$ CI, 66.1-88.4]). However, most of the differences were not statistically significant except for differences noted by comorbidity and risk of bias. The prevalence of uncontrolled hypertension was statistically higher in people with atrial fibrillation and in the studies with high risk of bias compared to other comorbidities and low or medium risk studies respectively.

In the univariable analysis (table 8 ), heterogeneity was explained by being female ( $14.5 \%$ ), risk of bias (19.8\%), by regions ( $15.8 \%$ ), comorbidities ( $14.4 \%$ ), using target blood pressure (26.5\%) and mean age (19.0\%). However only comorbidities and the use of target blood pressure were significant and these were added to the multivariable meta-regression analysis. Comorbidities and the use of the recommended blood pressure explained $32.4 \%$ of between studies heterogeneity, however, these were not statistically significant. Sensitivity analysis conducted by excluding studies that had high risk of bias from the analysis did not show any influence on the robustness of the findings in the pooled analyses.

Table 8: Meta-regression analysis for the variation of uncontrolled hypertension in people with comorbidity in SSA

| Variables (reference) | Univariable analysis |  |  |  | Multivariable analysis |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N studies | P value | Odds ratio (95\% CI) | $\mathrm{R}^{2}$, \% | P-value | Odds ratio (95\% CI) |
| Year of publication (after 2015) | 18 | 0.402 | 0.94 (0.81; 1.09) | 0.00 |  |  |
| More females | 18 | 0.114 | 1.12 (0.97; 1.28) | 14.45 |  |  |
| Risk of bias (low) | 18 |  |  | 19.80 |  |  |
| Moderate |  | 0.990 | 1.00 (0.76; 1.30) |  |  |  |
| High |  | 0.067 | 1.23 (0.98; 1.55) |  |  |  |
| Sample size (small studies) | 18 |  |  | 0.00 |  |  |
| Large studies |  | 0.328 | 1.08 (0.922; 1.26) |  |  |  |
| SSA regions (Eastern) | 18 |  |  | 0.00 |  |  |
| Western |  | 0.929 | 0.997 (0.77; 1.27) |  |  |  |
| Central |  | 0.572 | 1.11 (0.76; 1.61) |  |  |  |
| Southern |  | 0.381 | 1.08 (0.89; 1.31) |  |  |  |
| Comorbidities (atrial fibrillation) | 18 |  |  | 14.44 |  |  |
| Chronic kidney disease |  | 0.205 | 0.78 (0.53; 1.16) |  | 0.483 | 0.87 (0.58; 1.31) |
| Diabetes |  | 0.073 | 0.77 (0.58; 1.03) |  | 0.110 | 0.80 (0.61; 1.06) |
| HIV |  | 0.036 | 0.68 (0.49; 0.97) |  | 0.136 | 0.76 (0.53; 1.10) |
| Stroke |  | 0.106 | 0.76 (0.55; 1.07) |  | 0.340 | 0.85 (0.60; 1.21) |
| Setting (Health center) | 18 |  |  | 0.00 |  |  |
| Hospital |  | 0.974 | 1.00 (0.85; 1.17) |  |  |  |
| Sampling (Consecutive) | 16 |  |  |  |  |  |
| Random |  | 0.614 | 0.95 (0.76; 1.18) | 0.00 |  |  |
| BP target used (recommended comorbidity target not used) | 18 |  |  | 26.48 |  |  |
| Recommended BP control used |  | 0.064 | 0.88 (0.77; 1.01) |  | 0.190 | 0.90 (0.76; 1.06) |
| GNI (Below SSA average) | 18 |  |  |  |  |  |
| Above SSA average |  | 0.675 | 1.03 (0.89; 1.20) | 0.00 |  |  |

$\mathrm{BP}=$ Blood pressure
2.3.4 Burden of uncontrolled hypertension among individuals with diabetes and on antihypertensive treatment
There were 11 studies with a total of 2399 participants reporting on the prevalence of uncontrolled hypertension among individuals with diabetes (Abera and Woldemichael, 2016,

Adeniyi et al., 2016, Agaba et al., 2009, Choukem et al., 2007, Cohen et al., 2010, Mwita et
al., 2012, Pinchevsky et al., 2017, Pinchevsky et al., 2013, Rotchford and Rotchford, 2002, Soetedjo et al., 2018, Yaméogo et al., 2012). The overall pooled estimate for uncontrolled hypertension among participants with diabetes and on antihypertensive treatment was $74.5 \%$ $(95 \% \mathrm{CI}, 67.1 \%-81.3 \%)$ and the prevalence ranged from $54 \%(95 \% \mathrm{CI}, 50 \%-58 \%)$ to $85 \%$ ( $95 \%$ CI, $78 \%-90 \%$ ) (Table 5). The included studies had substantial heterogeneity $\left(\mathrm{I}^{2}=93.1 \%\right.$; $\mathrm{P}<.001$ ) (Figure 4). There was no evidence of publication bias from the visual inspection of the funnel plot (Figure 6).


Figure 6: Funnel plot of the prevalence of uncontrolled hypertension in people with diabetes in sub-Saharan Africa

Subgroup analysis showed differences in the prevalence of uncontrolled hypertension among people with diabetes and on antihypertensive treatment (Table 9). There were differences observed by gender, sample size, geographic regions, use of the recommended blood pressure
targets and the year the study was conducted. Studies that had included more male participants had higher pooled prevalence estimates ( $83.9 \%$ [ $95 \% \mathrm{CI}, 80.4 \%-87.1 \%]$ ) compared to studies that included more female participants ( $72.5 \%$ [ $95 \%$ CI, $64.4 \%-79.9 \%]$ ). Studies with large sample sizes reported higher prevalence ( $75.5 \%$ [ $95 \% \mathrm{CI}, 67.1 \%-81.3 \%]$ ) compared to studies with smaller sample sizes ( $73.3 \%$ [ $95 \%$ CI, $68.2 \%-79.3 \%]$ ) (table 7). Studies conducted in the Eastern region reported the highest pooled prevalence ( $82.5 \%$ [ $95 \%$ CI, $80.4 \%-87.1 \%$ ]) while studies in conducted in the Southern region reported the lowest pooled prevalence (72.5\% [95\% CI, $62.0 \%-81.8 \%]$ ). Studies that used the recommended diabetes hypertension cut-off for diabetes $(\mathrm{BP}<130 / 85 \mathrm{mmHg})$ to define blood pressure control reported lower uncontrolled hypertension prevalence compared to those that did not use the recommended hypertension control value for diabetes. Higher pooled prevalence of uncontrolled hypertension among people with diabetes were reported in studies conducted after 2015 compared to studies conducted before 2015. Variations were also noted in average GNI. Studies from countries with a GNI that was below the SSA average had a higher pooled prevalence of uncontrolled hypertension (77.3 [95\% CI, 69.7-84.2]) compared to studies that had reported on countries with GNIs that were above the average for SSA (72.3 [95\% CI, 61.0-82.3]). However, most of the noted differences in prevalence of uncontrolled hypertension were not statistically significant except by gender proportions and by sampling methods. Studies with higher male proportions and consecutive sampling methods had significantly higher UHTN prevalence compared to those among more women and with random sampling procedures respectively.

Table 9: Meta-analysis results for the prevalence of uncontrolled hypertension in people with diabetes and on antihypertensive treatment in sub-Saharan Africa

|  | Prevalence (95\%CI) | No of studies | Number of Participants | $\begin{array}{r} I^{2} \\ (95 \% \mathrm{Cl}) \end{array}$ | Pheterogeneneity |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Overall | 74.5 (67.1-81.3) | 11 | 2399 | 93.1 | <0.001 |
| By region |  |  |  |  |  |
| Eastern | 82.5 (78.8-85.9) | 2 | 449 | - | - |
| Western | 75.0 (67.1-82.1) | 2 | 131 | - | - |
| Central | 79.6 (70.6-86.4) | 1 | 98 | - | - |
| Southern | 72.5 (62.0-81.8) | 6 | 1721 | 94.9 | <0.001 |
| By risk of bias |  |  |  |  |  |
| Low | 74.2 (65.8-81.9) | 9 | 2268 | 94.4 | <0.001 |
| Moderate | 70.9 (60.1-78.8) | 1 | 79 | - | - |
| High | 80.8 (68.1-89.2) | 1 | 52 | - | - |
| By study size |  |  |  |  |  |
| Small studies | 73.25 (66.8-79.3) | 5 | 344 | 40.6 | 0.15 |
| Large studies | 75.5 (64.82-84.8) | 6 | 2055 | 96.4 | <0.001 |
| By period of publication |  |  |  |  |  |
| Before 2015 | 72.9 (62.4-82.3) | 4 | 1245 | 92.4 | <0.001 |
| After 2015 | 78.0 (71.9-83.6) | 7 | 1154 | 79.6 | <0.001 |
| By gender proportion |  |  |  |  |  |
| More females | 72.5 (64.4-79.9) | 9 | 1919 | 92.2 | <0.001 |
| More males | 83.9 (80.4-87.1) | 2 | 480 | - | - |
| By sampling |  |  |  |  |  |
| Consecutive | 76.7 (72.3-80.9) | 9 | 1780 | 75.2 | <0.001 |
| Random | 54.1 (50.0-58.2) | 1 | 567 | - | - |
| By setting |  |  |  |  |  |
| Hospital | 75.7 (66.0-84.3) | 8 | 1825 | 94.9 | <0.001 |
| Health center | 71.6 (61.5-80.8) | 3 | 574 | - | - |
| By comorbidity HTN target |  |  |  |  |  |
| Comorbidity target used | 70.1 (57.4-81.5) | 5 | 863 | 90.1 | <0.001 |
| Comorbidity target not used | 78.2 (73.1-82.9) | 6 | 1536 | 79.3 | <0.001 |
| By Gross National Income |  |  |  |  |  |
| Below SSA Average | 77.3 (69.7-84.2) | 5 | 852 | 81.1 | <0.001 |
| Above SSA average | 72.3 (61.0-82.3) | 6 | 1547 | 94.9 | <0.001 |

[^2]In the univariable meta-regression analysis, the use of the recommended hypertension control value for diabetes explained most of the heterogeneity ( $56.7 \%$ ) observed while the sampling method explained $100 \%$ of the heterogeneity (Table 10). However, in the multivariable metaregression analysis, only the sampling method used was associated with uncontrolled hypertension and this explained most of the heterogeneity observed.

Table 10: Meta-regression analysis for the variation of uncontrolled hypertension in people with diabetes and on antihypertensive treatment in sub-Saharan Africa

| Variables (reference) | Univariate analysis |  |  |  | Multivariate analysis |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | N studies | $\mathbf{P}$ value | Odds ratio (95\% CI) | R ${ }^{2}$ \% | $P$ value | Odds ratio (95\% CI) |
| Year of publication (after 2015) | 11 | 0.274 | 1.08 (0.93; 1.26) | 18.20 |  |  |
| More females | 11 | 0.205 | 1.12 (0.93; 1.36) | 16.26 |  |  |
| Risk of bias (low) | 11 |  |  | 0.00 |  |  |
| Moderate |  | 0.858 | 0.97 (0.69; 1.38) |  |  |  |
| High |  | 0.688 | 1.07 ( 0.72; 1.59) |  |  |  |
| Sample size (small studies) | 11 |  |  | 0.00 |  |  |
| Large studies |  | 0.890 | 1.01 (0.84; 1.21) |  |  |  |
| SSA regions (Eastern) | 11 |  |  | 0.00 |  |  |
| Western |  | 0.815 | 0.97 (0.69; 1.35) |  |  |  |
| Central |  | 0.953 | 1.01 (0.69; 1.48) |  |  |  |
| Southern |  | 0.500 | 0.93 (0.73; 1.18) |  |  |  |
| Setting (Health center) | 11 |  |  | 0.00 |  |  |
| Hospital |  | 0.860 | 1.02 (0.83; 1.24) |  |  |  |
| Sampling (Consecutive) | 10 |  |  |  |  |  |
| Random |  | 0.001 | 0.79 (0.71; 0.88) | 100.00 | 0.043 | 0.83 (0.69; 0.99 ) |
| BP target used (recommended diabetes BP target not used) | 11 |  |  | 56.66 | 0.439 | 0.94 (0.80; 1.11) |
| Recommended diabetes BP control target used |  | 0.054 | 0.88 (0.76; 1.00) |  |  |  |
| GNI (Below SSA average) | 11 |  |  |  |  |  |
| Above SSA average |  | 0.401 | 0.94 (0.80; 1.10) | 3.10 |  |  |
| BP=Blood pressure |  |  |  |  |  |  |

### 2.4 Discussion

To the best of my knowledge, this is the first systematic review and meta-analysis reporting on the pooled prevalence estimate of uncontrolled hypertension among individuals with comorbidities and on antihypertensive treatment in SSA. The limited number of studies demonstrate the paucity of research on this issue. Yet, findings from the review suggest a high burden of uncontrolled hypertension among people with comorbidities while on antihypertensive treatment with three out of four people with comorbidities reporting uncontrolled hypertension. The findings underscore the need to consider patient comorbidities as a core aspect of the care and support offered to patients with hypertension.

Findings from this study show that the prevalence of uncontrolled hypertension varied with the type of comorbidity that was present. Individuals with HIV (100\%), chronic kidney disease ( $75.9 \%$ ) and diabetes ( $74.5 \%$ ) were noted to have the highest estimates for uncontrolled hypertension while on antihypertensive treatment. Our findings are similar to findings from elsewhere. A study conducted in the UK found that reduced hypertension risk associated with diabetes was observed in people who achieved optimal blood pressure (U. K. Prospective Diabetes Study Group, 1998). Another study by Githinji and colleagues conducted in Kenya found that $80 \%$ of diabetic patients from rural and semi-urban areas had hypertension (Githinji et al., 2018). Since hypertension is common among people with diabetes, there is need to focus on integrated care for diabetes and hypertension.

The sensitivity analysis stratified for year of publication showed a decline in uncontrolled hypertension rates. In particular, the prevalence of uncontrolled hypertension in studies published after $2015(71.1 \%)$ declined significantly compared to those published before 2015 (79.1\%). These differences are probably due to adherence to the changing guidelines promoting tighter blood pressure control for people with hypertension in general or among those with comorbidities. However, despite the observed decline, the prevalence of uncontrolled
hypertension among people with comorbidities is very high and warrants further research to understand the impact of comorbidities on blood pressure control to help tailor interventions that can reduce the uncontrolled hypertension among individuals with comorbidities.

Apart from comorbidities, other factors affecting blood pressure control need to be considered among patients on treatment and taken into account. The cornerstone to achieving blood pressure control is adherence to anti-hypertensive medication. A recent systematic review and meta-analysis looking at non-adherence to antihypertensive medication found that $45 \%$ of patients on treatment for hypertension were non-adherent with higher proportions being among women (53.9\%), those with uncontrolled blood pressures (83.7\%), Africans (62.5\%) and those with comorbidities (31.6\%) (Abegaz et al., 2017). Non-adherence to hypertension treatment in people with comorbidities can be detrimental as it increases their risk of experiencing a cardiovascular event. Several barriers to adherence to hypertension medications exist in SSA and they are mainly due to adverse effects from medications, out-of-pocket payments for medication, pill burden and low perception of the risks associated with uncontrolled blood pressure.

Clinicians also have a role to play in blood pressure control. For instance, according to hypertension guidelines, dose escalation and the use of multi-dose regimens are required in patients with uncontrolled hypertension. Rose and colleagues found that the majority of patients with uncontrolled hypertension were a result of inadequate treatment (Rose et al., 2007b). Chow et al also found the use of multi-dose regimens for blood pressure control was lower in low-income countries (Chow et al., 2013). This is an area of research that requires further attention in SSA.

This study has both some strengths and limitations. Results from this review should be interpreted in the context of the following limitations. First, in most of the studies assessed, the main outcome (uncontrolled hypertension among those on antihypertensive treatment) was not
the main focus of the articles, rather this was computed from the information provided in the study. Secondly, among the studies that were included, some of the comorbidities of interest were only reported in single studies limiting the generalizability of the findings. Third, the majority of the studies included were hospital based studies that used non-random sampling procedures. Fourth, most of the heterogeneity observed was not explained by the metaregressions conducted. It is possible that the lack of uniformity and the variance in blood pressure cut-off points may have resulted in the heterogeneity observed.

However, this is the first systematic review and meta-analysis examining uncontrolled hypertension among individuals with comorbidities in SSA while focusing only on those on treatment for hypertension. A major strength is the use of a rigorous process that entailed the use of a peer-reviewed protocol (Mohamed et al., 2020), the use of multiple electronic databases, the use of grey literature, contacting experts in this field for additional data to reduce selection bias, the use of the PRISMA guidelines for reporting, not having a language restriction for articles included and exploring heterogeneity by sub-group and sensitivity analysis to generate evidence on uncontrolled hypertension from sub-Saharan Africa. Assessor bias was also reduced by the use of two independent reviewers in data extraction and in the risk of bias assessment.

### 2.5 Chapter summary

This review provides evidence on uncontrolled hypertension among patients with comorbid conditions while on treatment for hypertension. This review also provides prevalence of uncontrolled hypertension among patients with comorbidities while on antihypertensive treatment in general and also separately for diabetes in SSA. The following chapter describes data meta-analysis using individual participant level data.

## 3. Uncontrolled hypertension and comorbidities: a pooled metaanalysis of individual participant data from 20 sub-Saharan Africa countries with 4245 individuals

3.1 Background

This chapter uses individual participant data (IPD) to estimate the pooled prevalence of uncontrolled hypertension (UHTN) overall and the prevalence of UHTN among individuals with comorbidities (diabetes, dyslipidemia, obesity and abdominal obesity). The relationships between UHTN and comorbidities are also explored.

Despite the numerous studies on hypertension care and management, the current literature reveals that relatively little is known about the relationship between patient comorbidities and uncontrolled hypertension in sub-Saharan Africa (SSA). Most of the studies looking at the relationship between hypertension and comorbidities have been conducted outside of Africa and those done in Africa have been small scale (Joshi et al., 2014, Mathenge et al., 2010). Also, most of these studies have not focussed on the treatment for hypertension rather they look at the general population with hypertension. More recent national level studies are now being conducted in SSA that provide information on hypertension treatment status and comorbidities where measurements have been collected in a similar way. Therefore, these national level studies from SSA provide an opportunity to investigate the relationship between uncontrolled hypertension and patient comorbidities (such as diabetes, dyslipidemia, obesity, and abdominal obesity) in SSA populations. Also from a policy perspective, it is better to deal with national level data for representation of the continent.

For objective two in this thesis, a meta-analysis of individual participant data (IPD) were conducted. Compared to meta-analysis of aggregate data, the meta-analyses of the IPD data gives a researcher more control of the data and analysis, heterogeneity is reduced by data standardisation, selection of the same effect estimates and covariates, it has potential to give more outcomes that may not have been considered in the original studies, it increases the
statistical power to investigate outcomes and has the ability to detect important differences in effect sizes that are not otherwise detected by the traditional aggregate data meta-analyses (Riley et al., 2010). Therefore, this study investigated the relationship between comorbidities (diabetes, dyslipidemia, general obesity and central obesity) and uncontrolled hypertension in order to inform programs and policies.

To the best of our knowledge, no studies have investigated the association between uncontrolled hypertension among patients with comorbidities while on blood pressure treatment in SSA. Therefore, it is unclear whether certain comorbidities might explain the disparities seen in uncontrolled hypertension rates observed in patients with hypertension while on treatment. The current research study hypothesised that comorbidities in patients would lead to poor blood pressure control even when the patient is on treatment than if the patient had hypertension without comorbidities. In this chapter, we estimate the prevalence of uncontrolled hypertension among individuals with specific comorbidities (diabetes, dyslipidemia, obesity and abdominal obesity) in SSA; and examine the association between specific comorbidities and uncontrolled hypertension among adults in SSA.

### 3.2 Methods

3.2.1 Data source and design

Data from the WHO-STEPwise approach to Surveillance (STEPS) surveys conducted in SSA between 2000 and 2019 was used (Riley et al., 2015). STEPS surveys, are usually nationally representative surveys conducted to assess the risks of NCD among individuals aged 15 years and above in LMICs. They take a cross-sectional approach and are conducted after every 5-10 years (Riley et al., 2015). The survey collects data on the risk factors that estimate the disease burden using a standardized procedure across countries with modifications to suit each country's context. In this study, the most recent nationally representative WHO STEPS survey for each country done since 2000 was used.

According to the World Bank, there are 49 countries in SSA however, there were only 41 countries that had collected the STEPS data by 2019. The countries that did not collect data were Angola, Burundi, Djibouti, Equatorial-Guinea, Guinea-Bissau, Somalia, South Africa and South Sudan. Among the 41 countries with data, six countries did not have publicly accessible data (Burkina Faso, Democratic Republic of Congo (DRC), Mauritius, Nigeria, Senegal and Zimbabwe) leaving 35 countries with available data for use. The available data were collected between 2003 and 2017. For Tanzania, there were two separate data sources with independent samples; one for Zanzibar (Island) and the other for the mainland Tanzania. This left 36 datasets thus we will refer to Tanzania and Zanzibar as separate countries for this analysis. Table 11 provides more details on the countries with WHO STEPS data in SSA.

Table 11: Countries in sub-Saharan Africa with WHO steps data available

|  | Countries (year data collected) | Collected WHO <br> STEPS data | National <br> level data | Publicly <br> accessible |
| :--- | :--- | :---: | :---: | :---: |
| 1 | Angola | No | - | - |
| 2 | Benin (2015) | Yes | Yes | Yes |
| 3 | Botswana (2014) | Yes | Yes | Yes |
| 4 | Burkina Faso (2013) | Yes | Yes | No |
| 5 | Burundi | No | - | - |
| 6 | Cape Verde (2007) | Yes | Yes | Yes |
| 7 | Cameroon (2003) | Yes | Yes | Yes |
| 8 | Central African Republic (2017) | Yes | Yes | Yes |
| 9 | Chad (2008) | Yes | No | Yes |
| 10 | Comoros (2011) | Yes | Yes | Yes |
| 11 | Congo (Brazzaville) (2004) | Yes | No | Yes |
| 12 | Congo (Democratic Republic) | Yes | No | No |
| 13 | Côte d'Ivoire (2005) | Yes | No | Yes |
| 14 | Djibouti | No | - | - |
| 15 | Equatorial Guinea | No | - | - |
| 16 | Eritrea (2010) | Yes | Yes | Yes |
| 17 | Eswatini (2014) | Yes | Yes | Yes |
| 18 | Ethiopia (2015) | Yes | Yes | Yes |
| 19 | Gabon (2009) | Yes | No | Yes |
| 20 | The Gambia (2010) | Yes | Yes | Yes |
| 21 | Ghana (2006) | Yes | No | Yes |
| 22 | Guinea (2009) | Yes | No | Yes |
| 23 | Guinea-Bissau | No | - | - |
| 24 | Kenya (2015) | Yes | Yes | Yes |
| 25 | Lesotho (2012) | Yes | Yes | Yes |


| 26 | Liberia (2011) | Yes | Yes | Yes |  |
| :---: | :--- | :---: | :---: | :---: | :---: |
| 27 | Madagascar (2005) | Yes | No | Yes |  |
| 28 | Malawi (2017) | Yes | Yes | Yes |  |
| 29 | Mali (2013) | Yes | No | Yes |  |
| 30 | Mauritania (2006) | Yes | No | Yes |  |
| 31 | Mauritius (2004) | Yes | Yes | No |  |
| 32 | Mozambique (2005) | Yes | Yes | Yes |  |
| 33 | Namibia (2005) | Yes | Yes | Yes |  |
| 34 | Niger 2007) | Yes | Yes | Yes |  |
| 35 | Nigeria (2003) | Yes | No | No |  |
| 36 | Rwanda (2012-2013) | Yes | Yes | Yes |  |
| 37 | Sao Tome and Principe (2008/09) | Yes | Yes | Yes |  |
| 38 | Senegal (2015) | Yes | Yes | No |  |
| 39 | Seychelles (2004) | Yes | Yes | Yes |  |
| 40 | Sierra Leone (2009) | Yes | Yes | Yes |  |
| 41 | Somalia | No | - | - |  |
| 42 | South Africa | No | - | - |  |
| 43 | South Sudan | Yes | Yes | - |  |
| 44 | Sudan (2016) | Yes | Yes | Yes |  |
| 45 | Tanzania (2012)* | Yes | Yes | Yes |  |
| 46 | Togo (2010-2011) | Yes | Yes | Yes |  |
| 47 | Uganda (2014) | Yes | Yes | Yes |  |
| 48 | Zambia (2017) | Yes | No | No |  |
| 49 | Zimbabwe (2005) | Yes | Yes | Yes |  |
|  | Zanzibar (2011)** |  |  |  |  |
| *Tanzania data only has mainland data. |  |  |  |  |  |
| **Zanzibar data only has data from the island. |  |  |  |  |  |

### 3.2.2 Data inclusion and exclusion criteria

We broadly classified the inclusion and exclusion criteria into two stages; the first step involved the selection of eligible countries while the second involved the selection of participants into the study. In the first step, countries were eligible for inclusion if they: (1) participated in the WHO STEPS survey between 2000 and 2019 and the data were publicly accessible; (2) the data were nationally representative; and (3) collected key variables UHTN, age, sex, education, marital status, occupation, harmful use of alcohol, current smoking, unhealthy diet, and physical inactivity. For the key comorbidities (diabetes, obesity (using BMI), central obesity and dyslipidemia), each was assessed separately and countries were examined case by case depending on missingness of the comorbidities. For instance, for diabetes we excluded
countries that had more than $20 \%$ or more missing in the diabetes variable; for dyslipidemia we excluded countries that did not collect any information on dyslipidemia.

In the second stage, participants were eligible for inclusion if they met the following criteria: (1) had hypertension and were on treatment; (2) were not pregnant, and 3) had data on the uncontrolled hypertension variable. Figure 6 shows a study flow diagram describing how the final analysis sample was arrived at.

After the first inclusion criteria were implemented, there were 36 countries with 147,587 participants who participated in the WHO STEPS survey between 2000 and 2019. The second inclusion criteria involved having national level datasets. This criterion resulted in nine countries (Guinea, Congo, Cote de Ivory, Ghana, Gabon, Chad, Mali, Madagascar and Mauritania) being excluded with a total of 26,937 participants, leaving behind 27 countries with 120,650 participants. The last step in stage one was to exclude countries that did not collect the key study variables. In this study, we had identified nine key study variables for a country to be considered eligible for inclusion. This exclusion process further excluded seven more countries (Cameroon, Cape Verde, Mozambique, Namibia, Niger, Sao Tome, and Seychelles) with a total of 24,511 participants with missing data on the following key variables; marital status, occupation, harmful use of alcohol, smoking, unhealthy diet and physical inactivity. This concluded the first step leaving behind 20 countries with a total of 96,139 participants. In the second stage, study participants needed to be hypertensive and on treatment. This process excluded no countries but 91,731 participants were excluded leaving 4,408 participants. The next step involved the exclusion of participants who were pregnant and those missing data on uncontrolled hypertension. This process further excluded 84 and 79 participants who were pregnant and with missing data on uncontrolled hypertension respectively. The base analysis dataset following the above inclusion criteria included 20 countries from SSA with 4,245 participants. Figure 7 describes how the final analysis sample was arrived at.

Figure 7: Flow Diagram describing the process to the final analysis sample


### 3.2.3 Missing data

Missing data were present in all datasets with Benin having the lowest ( $0.63 \%$ ) to Gambia and Sierra Leonne having complete missing data on key independent variables. Table 12 presents the distribution of missing data in the final dataset.

Most of the socio-demographic variables (age ( $0 \%$ ), sex ( $0 \%$ ), education ( $0.85 \%$ ), occupation ( $0.24 \%$ ), and marital status ( $0.16 \%$ )) had none to minimal missing data. Similarly, the behavioural factors (harmful use of alcohol ( $0.97 \%$ ), current smoking ( $0.02 \%$ ), unhealthy diet ( $0 \%$ ) and physical inactivity $(0.09 \%$ ) also had very minimal missing data. The few missing cases for each of these variables were imputed to the mean of each variable which was also the category with the highest proportion of individuals.

The diabetes variable had $17.5 \%$ of missing data and this was mainly due to the high proportion of missingness in Gambia (71.6\%), Sierra Leone (77.5\%) and Comoros (37.9\%). For the analysis involving diabetes, the three countries (Gambia, Sierra Leone and Comoros) were further excluded with a total of 1,032 participants. Thus, the final sample for uncontrolled hypertension and diabetes analysis included 17 countries with 3,213 participants.

The dyslipidemia variable had $8.57 \%$ missing data and this was due to two countries (Gambia and Sierra Leone) that did not collect any data for dyslipidemia. For the analysis involving dyslipidemia, the two countries (Gambia and Sierra Leone) with a total of 364 participants were excluded. Thus the final sample for uncontrolled hypertension and dyslipidemia analysis included 18 countries with 3,881 participants.

For the analysis involving general obesity and abdominal obesity, all 20 countries were included since they all had data on the two variables. However, specific cases of participants that had missing data in the two variables were excluded. The proportions missing were very minimal 79 ( $1.86 \%$ ) and $40(0.94 \%)$ respectively. The final sample for general obesity and abdominal obesity had 4,166 and 4,205 participants respectively.

Table 12: Distribution of missing data

| Countries | N | Age | Sex | Education | Marital Status | Occupation | Alcohol | Smoking | Diet | Physical activity | Obesity | Central Obesity | Dsylipe | Diabetes | UHTN |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Benin | 158 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.63 | 1.27 | 0 | 0 | 0 |
| Botswana | 481 | 0 | 0 | 0 | 0 | 0.21 | 0.62 | 0 | 0 | 0 | 1.04 | 0.42 | 0 | 9.98 | 0 |
| CAR | 306 | 0 | 0 | 5.23 | 1.63 | 1.31 | 1.96 | 0 | 0 | 0 | 0.65 | 0.65 | 0 | 17.97 | 0 |
| Cameroon | 240 | 0 | 0 | 0 | 0 | 0 | 54.17 | 0 | 100 | 0.83 | 2.08 | 1.25 | 100 | 2.08 | 0 |
| CapeVerde | 148 | 0 | 0 | 0 | 100 | 0.68 | 100 | 0 | 0 | 0 | 2.7 | 0.68 | 0 | 44.59 | 0 |
| Comoros | 319 | 0 | 0 | 0.31 | 0 | 0.31 | 0 | 0 | 0 | 0 | 2.51 | 1.57 | 0 | 37.93 | 0 |
| Eritrea | 190 | 0 | 0 | 0.53 | 0 | 0 | 0.53 | 0 | 0 | 0 | 0.53 | 0.53 | 0 | 3.68 | 0 |
| Eswatini | 288 | 0 | 0 | 0 | 0 | 0 | 1.74 | 0 | 0 | 0 | 2.78 | 1.39 | 0 | 12.85 | 0 |
| Ethiopia | 151 | 0 | 0 | 0 | 0 | 0 | 0.66 | 0 | 0 | 0 | 0.66 | 0 | 0 | 2.65 | 0 |
| Gambia | 155 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.52 | 3.23 | 100 | 71.61 | 0 |
| Kenya | 131 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.76 | 0.76 | 0 | 8.4 | 0 |
| Lesotho | 228 | 0 | 0 | 0 | 0 | 0.44 | 2.19 | 0.44 | 0 | 0.44 | 3.51 | 2.63 | 0 | 9.21 | 0 |
| Liberia | 133 | 0 | 0 | 0 | 0 | 0 | 2.26 | 0 | 0 | 0 | 10.53 | 2.26 | 0 | 9.02 | 0 |
| Malawi | 182 | 0 | 0 | 0 | 0 | 1.1 | 0.55 | 0 | 0 | 0 | 1.1 | 0 | 0 | 9.34 | 0 |
| Mozambique | 125 | 0 | 0 | 1.6 | 100 | 0 | 100 | 0 | 0 | 0 | 1.6 | 1.6 | 0 | 11.2 | 0 |
| Namibia | 318 | 0 | 0 | 0.31 | 100 | 100 | 100 | 100 | 100 | 100 | 0.94 | 0 | 100 | 100 | 0 |
| Niger | 38 | 0 | 0 | 0 | 100 | 0 | 5.26 | 0 | 0 | 0 | 0 | 0 | 100 | 13.16 | 0 |
| Rwanda | 67 | 0 | 0 | 0 | 0 | 0 | 1.49 | 0 | 0 | 0 | 0 | 0 | 0 | 5.97 | 0 |
| SaoTome | 218 | 0 | 0 | 0 | 100 | 0 | 70.18 | 0 | 0 | 0 | 4.59 | 3.21 | 0 | 2.75 | 0 |
| Seychelles | 362 | 0 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SierraLeone | 209 | 0 | 0 | 6.22 | 0.48 | 0 | 4.31 | 0 | 0 | 1.44 | 3.83 | 1.44 | 100 | 77.51 | 0 |
| Sudan | 521 | 0 | 0 | 0.58 | 0 | 0 | 0.38 | 0 | 0 | 0 | 1.15 | 0.77 | 0 | 8.06 | 0 |
| Tanzania | 191 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.52 | 0 | 0 | 16.75 | 0 |
| Togo | 81 | 0 | 0 | 0 | 0 | 0 | 3.7 | 0 | 0 | 0 | 1.23 | 0 | 0 | 8.64 | 0 |
| Uganda | 111 | 0 | 0 | 1.8 | 0 | 0 | 0.9 | 0 | 0 | 0 | 0.9 | 0.9 | 0 | 7.21 | 0 |
| Zambia | 198 | 0 | 0 | 0 | 0.51 | 0.51 | 0 | 0 | 0 | 0 | 1.01 | 0.51 | 0 | 16.16 | 0 |
| Zanzibar | 145 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.38 | 0 | 0 | 8.28 | 0 |
| Total | 5694 | 0 | 0 | 0.68 | 21.36 | 5.78 | 22.46 | 5.6 | 9.8 | 5.69 | 1.81 | 0.93 | 16.86 | 20.32 | 0 |
|  |  |  |  | Completely excluded from analysis because the countries lacked key variables |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  | Excluded only from analysis for diabetes and dyslipidemia respectively |  |  |  |  |  |  |  |  |  |  |  |

### 3.2.4 Measures and definition

The outcome of interest in this study was uncontrolled hypertension, which is defined as being on treatment for hypertension and having either a systolic blood pressure (SBP) greater than or equal to 140 mmHg and/or a diastolic blood pressure greater than or equal to 90 mmHg . For each participant, the mean of the last two measurements was used for this analysis.

The main independent variables of interest were comorbidities namely diabetes, dyslipidemia, general obesity and central obesity. Diabetes was defined as a fasting blood glucose of $7 \mathrm{mmol} / \mathrm{l}$ or more or a self-report of a previous diagnosis of diabetes by a health care professional or currently receiving diabetes treatment using WHO guidelines (World Health Organization, 2006a). All fasting glucose levels were converted to mili-moles per litre (mmol/L).

Dyslipidemia was defined as total cholesterol levels of above $5 \mathrm{mmol} / \mathrm{l}$ and/or LDL cholesterol above $2.5 \mathrm{mmol} / \mathrm{l}$, and $/$ or HDL cholesterol below $1.0 \mathrm{mmol} / \mathrm{l}$ for men and below $1.2 \mathrm{mmol} / \mathrm{l}$
for women or on treatment or they have been previously diagnosed by a healthcare professional to have dyslipidemia. All lipid levels were converted to mili-moles per litre ( $\mathrm{mmol} / \mathrm{L}$ ).

General obesity was calculated using body mass index (BMI) and it was computed following the WHO BMI cut-off points (World Health Organization, 2000). It was calculated as body weight in kilogram divided by the height in meters squared $(\mathrm{kg} / \mathrm{m} 2)$ and categorized into 2 groups (in which a BMI $<30 \cdot 0 \mathrm{~kg} / \mathrm{m}^{2}$ was defined as not obese while a BMI of $\geq 30 \cdot 0 \mathrm{~kg} / \mathrm{m}^{2}$ was defined as being obese using the WHO BMI. Abdominal obesity was computed using the WHO guidelines and it was defined as having a waist circumference greater or equal to 94 cm for men and greater than or equal to 80 cm for women (World Health Organization, 2000, World Health Organization, 2011).

The following demographic characteristics were considered for inclusion in the multivariate analysis; age, sex, education level, occupation status and marital status. The age variable was recoded into four categories (15-34, 35-44, 45-54 and 55+) so all countries had a uniform age category. The level of education was categorized into no schooling, primary level, and secondary or above level, while occupation was categorized into employed and unemployed.

Behavioral factors considered for inclusion in the analysis were harmful use of alcohol, tobacco use, consumption of healthy diets and physical activity status. Tobacco use was defined as selfreported current use of smoked tobacco or smokeless tobacco products. Harmful use of alcohol was defined as the consumption of more than 1 standard drink per day for females and more than 2 standard drinks for males (Centers for Disease Control and Prevention, Drug and Alcohol Rehab in Thailand, 2018). An unhealthy diet was defined as an insufficient fruit and vegetable intake which was assessed using self-reported consumption of fewer than 5 servings/day of fruit and vegetables for 5 days (World Health Organization, 2003). The STEPS survey used the WHO Global Physical Activity Questionnaire (World Health Organization) to assess self-reported physical activity. Physical inactivity was defined as self-reports of less
than 150 minutes of moderately intensive activity or less than 75 minutes of vigorous intensity physical activity per week.

Countries were grouped into regions using the United Nations regional classification for SSA; Eastern, West, Southern and Central (UN Statistic Division). Regions were further grouped into two; Eastern and Southern Africa (ESA) and Western and Central Africa (WCA) using the United Nations regional classification for SSA (UN Statistic Division).

### 3.2.5 Statistical analysis

Descriptive statistics (percentage, medians and IQR) were used to describe survey participants. Individual level data from all countries were pooled together using a two-step approach for all analyses. In the first step, raw data from each country were analysed using logistic regression to estimate the odds ratio (OR) and the corresponding 95\% confidence interval (CI) for the relationship between uncontrolled hypertension (UHTN) and each comorbidity (diabetes, dyslipidemia, obesity and abdominal obesity) separately. Prior knowledge of the relationship between hypertension and comorbidities was used to select covariates adjusted for in these models; age, sex, education and occupation while accounting for the clustering in the sample design. All variables with p-values $<0.20$ from the bivariable analysis were considered for inclusion in the multivariable regression model. Some key variables which are already known to be associated with hypertension were retained in the model regardless of statistical significance. In the second step, the odds ratios and $95 \%$ confidence intervals were pooled together to compute regional estimates first by stabilizing the variances of the raw country proportions using a double arcsine transformation (Barendregt et al., 2013) to minimise the effect of countries with very small or very large estimates on the overall estimate then the DerSimonian-Laid random effects model was applied (DerSimonian and Laird, 1986).

In the meta-analysis, countries with very low prevalence's for comorbidities (diabetes, dyslipidemia, obesity and central obesity) did not allow computation of their corresponding
odds ratios thus they were excluded from the meta-analysis. Sensitivity analysis excluding countries with wide confidence intervals were conducted to test the robustness of the study findings. Further, heterogeneity among the study specific estimates was explored using the Cochrane's Q and quantified by $\mathrm{I}^{2}$ statistics (Higgins and Thompson, 2002, Higgins et al., 2003). Low, medium and substantial heterogeneity are reported by $\mathrm{I}^{2}$ values of $25 \%, 50 \%$ and $75 \%$ respectively. Analyses were therefore complete case analyses. Analyses were performed using "ipdmetan" routine on Stata (version 16.1) for Windows (StataCorp, 2019). Statistical significance was defined by a P-value $<0.05$.

### 3.2.6 Ethical Approval

The STEPS survey datasets (Riley et al., 2015) used for this analysis are publicly available on the World Health Organization (WHO) NCD Microdata repository site. Formal written consent was obtained from the WHO for all the surveys included. Once permission was granted to use the data, no additional ethical institutional review board approval was required since approvals were obtained by the respective countries and all participants provided written informed consent before the data were collected.

### 3.3 Results

3.3.1 Sample characteristics

The country level characteristics of study participants on treatment for hypertension from 20042017 in SSA by country (percentages) and regions (medians) are presented in Table 13. The total number of participants included were 4,245 overall and ranged from 67 to 521 individuals from 20 countries. Of the 4,245 participants included in this analysis, [median $66.7 \%$ (IQR; 57.7, 73.0) were females, [median $32.2 \%$ (IQR: 27.6, 37.1)] were aged 55 years and above, [median 39.4\% (IQR; 27.8, 48.4)] had primary level of education, [median 66.6\% (IQR; 59.4, 69.0)] were employed, [median 6.7\% (IQR; 3.6, 9.3)] were smokers, [median 9.6\% (IQR: 5.2, 14.8)] consumed harmful levels of alcohol, [median $87.5 \%$ (IQR; 84.5, 91.1)] consumed unhealthy diets and [ $0.8 \%$ (IQR; 0.0, 2.3)] had insufficient levels of physical activity. For body
size, [median $27.1 \%$ (IQR; 16.7, 31.5)] had general obesity while [median $61.2 \%$ (IQR; 49.2, 69.2)] had abdominal obesity. In regards to other comorbidities, [median $16.0 \%$ (IQR; 11.0, 21.6)] had diabetes and [median $40.2 \%$ (IQR; 29.2, 56.0)] had dyslipidemia.

The diabetes prevalence ranged from $3.9 \%$ in Rwanda to $34.6 \%$ in Gambia. For dyslipidemia, the lowest prevalence was observed in Togo (16.5\%) while the highest prevalence was in Sudan (81.6\%). Obesity and central obesity prevalence was lowest in Ethiopia (6\% and 28.7\% respectively) and highest in Eswatini (54.3\% and 83.7\% respectively).

In regards to regions, the median UHTN prevalence was highest in the Western region [72.3\% (IQR: 64.0, 73.1)] and lowest in the Eastern Africa region [59.0\% (IQR: 47.7, 62.2)] and these differences were statistically significant. Significant differences were also observed in median prevalence for diabetes with the highest median estimate observed in the Central African region [22.6\% (22.6 22.6)] and the lowest rate was in Eastern Africa [15.3\% (IQR: 9.1, 20.1)]. The median prevalence for dyslipidemia, obesity and abdominal obesity were highest in the Southern Africa region. The median prevalence for dyslipidemia was highest in the Southern African region [56\%, (IQR; 51.2, 56)] compared to the Western Africa region [16.5\%, (IQR: $0,34)]$ and this difference was statistically significant. Significant difference were noted in abdominal obesity with Western Africa recording the lowest prevalence [53.2\%, (IQR: 51.4, 54.2)] compared to the Southern Africa region which had the highest prevalence of central obesity [78.4\% (IQR: 67.4, 83.6)]. Significant differences in obesity estimates were noted by regions; with Southern Africa region recording the highest median prevalence for obesity [43.2\% (IQR: 34.7, 54.2)] compared to the Eastern African region with the lowest median prevalence [17.2\% (IQR: 16.2, 28.3)].

Table 13: Sample characteristics of included studies

| Countries | Men | Women | $\begin{aligned} & 15-34 \\ & \text { years } \\ & \hline \end{aligned}$ | $\begin{aligned} & 35-44 \\ & \text { years } \\ & \hline \end{aligned}$ | $\begin{aligned} & 45-54 \\ & \text { years } \end{aligned}$ | $55+$ years | No education | Primary level | Secondary and above | Unemployed | Smoker | Harmful use of alcohol | Unhealthy diet | Physical inactivity | UHTN | Diabetes | Dyslipidemia | $\begin{aligned} & \text { Obese } \\ & \text { (BMI) } \\ & \hline \end{aligned}$ | $\begin{aligned} & \text { Central } \\ & \text { Obesity } \\ & \hline \end{aligned}$ | N |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Benin | 43.5 | 56.5 | 19.4 | 17.1 | 26.6 | 36.9 | 47.5 | 27.8 | 24.8 | 30.7 | 1.6 | 10.3 | 81.8 | 0 | 72.3 | 10.6 | 34 | 26.2 | 53.3 | 158 |
| Botswana | 36.5 | 63.5 | 15.3 | 22.4 | 24.9 | 37.4 | 16.1 | 36.8 | 47.1 | 58.1 | 16.4 | 10.4 | 91.4 | 0.8 | 58.8 | 15.7 | 56.1 | 34.7 | 67.4 | 481 |
| CAR | 37 | 63 | 12.5 | 26.4 | 28.8 | 32.3 | 14.1 | 36.4 | 49.5 | 21.6 | 3.6 | 32.1 | 64.4 | 3 | 67 | 22.6 | 29.3 | 22.1 | 69 | 306 |
| Comoros | 30.8 | 69.2 | 13.5 | 19.7 | 37.8 | 29.1 | 56.4 | 20.3 | 23.3 | 54.2 | 8 | 0.4 | 84.4 | 0.6 | 63 | 20.1 | 15.7 | 30.8 | 69.5 | 319 |
| Eritrea | 24.4 | 75.6 | 3.9 | 20.7 | 25.2 | 50.2 | 44.8 | 43.8 | 11.5 | 67.7 | 1.9 | 7.9 | 99.6 | 0 | 59 | 20.6 | 61 | 10.4 | 62.9 | 190 |
| Eswatini | 27.1 | 72.9 | 16.8 | 13.4 | 20.9 | 48.9 | 14.5 | 48.4 | 37.1 | 55.1 | 1.9 | 5.1 | 88.2 | 0.6 | 60.6 | 27.7 | 56 | 54.2 | 83.7 | 288 |
| Ethiopia | 57.4 | 42.6 | 34.5 | 14.4 | 16.1 | 34.9 | 44.3 | 39.1 | 16.6 | 24.9 | 4.8 | 26.9 | 96.4 | 0 | 60.1 | 8.2 | 44.6 | 6.6 | 28.7 | 151 |
| Gambia | 26.6 | 73.4 | 11.4 | 25.9 | 31.6 | 31.1 | 73 | 11.5 | 15.5 | 62.8 | 8.2 | 0 | 85.3 | 0 | 77 | 34.6 |  | 32.2 | 43.4 | 155 |
| Kenya | 30.2 | 69.8 | 13.6 | 28.7 | 27.5 | 30.2 | 11.3 | 47.8 | 40.9 | 32.7 | 10.5 | 17.8 | 87.3 | 2 | 56.8 | 13.3 | 48.1 | 28.4 | 65.6 | 131 |
| Lesotho | 19.2 | 80.8 | 11.9 | 21.3 | 26.9 | 39.9 | 7.1 | 65.2 | 27.7 | 70.9 | 3.2 | 10.4 | 89.8 | 5.2 | 69.4 | 17.7 | 51.3 | 43.2 | 78.4 | 228 |
| Liberia | 44.5 | 55.5 | 13.8 | 17.9 | 36.1 | 32.3 | 39.8 | 14.2 | 45.9 | 34.2 | 11.7 | 9.2 | 91 | 0.8 | 73.2 | 12.1 | 0 | 32.8 | 51.4 | 133 |
| Malawi | 26.7 | 73.3 | 18.7 | 12.8 | 28.1 | 40.4 | 18.2 | 67.5 | 14.4 | 61.3 | 6.8 | 5.8 | 85.8 | 2.6 | 47.7 | 11 | 34.9 | 16.3 | 45.1 | 182 |
| Rwanda | 44.8 | 55.2 | 49.5 | 15.3 | 21.3 | 13.9 | 15.4 | 59.2 | 25.4 | 17.3 | 6.8 | 5.3 | 96.3 | 3.9 | 25.9 | 3.9 | 73.3 | 16.7 | 32.1 | 67 |
| SL | 39 | 61 | 13.6 | 24 | 36.7 | 25.6 | 46.3 | 27.9 | 25.8 | 50.3 | 20.9 | 12 | 88.7 | 2.1 | 63.9 | 25.4 |  | 12.3 | 61.2 | 209 |
| Sudan | 40.9 | 59.1 | 18.5 | 19 | 27.4 | 35.1 | 36.2 | 25.5 | 38.4 | 53.5 | 9.1 | 0 | 86.6 | 0.7 | 63.9 | 26.8 | 81.6 | 29.4 | 72.4 | 521 |
| Tanzania | 28.3 | 71.7 | 10.3 | 33.4 | 31.3 | 25 | 13.4 | 71.9 | 14.7 | 29.5 | 6.6 | 10.1 | 92.1 | 0.6 | 59.6 | 15.4 | 35.9 | 28.1 | 71 | 191 |
| Togo | 27.2 | 72.8 | 9.5 | 27 | 30.8 | 32.6 | 31.3 | 41.4 | 27.3 | 21.2 | 3.6 | 28.4 | 84.6 | 2.6 | 64.1 | 11.1 | 16.5 | 29.5 | 54.3 | 81 |
| Uganda | 25.3 | 74.7 | 14.4 | 20.9 | 34.6 | 30.1 | 20.3 | 39.8 | 39.9 | 36.3 | 3.8 | 22.4 | 79.8 | , | 62.2 | 16.3 | 65.5 | 16.9 | 57.1 | 111 |
| Zambia | 35.7 | 64.3 | 27 | 20.6 | 26.3 | 26.1 | 10.1 | 36.5 | 53.4 | 49.6 | 4.7 | 8.5 | 87.9 | 0 | 55.2 | 18.4 | 18.5 | 24.5 | 61.4 | 198 |
| Zanzibar | 52.2 | 47.8 | 31.1 | 18.6 | 29.9 | 20.4 | 23.2 | 48.5 | 28.3 | 27 | 9.4 | 0 | 82.1 | 0 | 46.1 | 9.1 | 30.3 | 17.3 | 47.1 | 145 |
| Regions |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Central Africa | $37(37,37)$ |  | 12.5 | 26.3 | 28.7 | 32.2 | $\begin{array}{r} 14.1 \text { (14.1, } \\ 14.1) \end{array}$ | $\begin{array}{r} 36.4(36.4, \\ 36.4) \end{array}$ | $\begin{array}{rrr}49.5(49.5, & 71.5(69, \\ 49.5) & 73.9)\end{array}$ |  | 3.59 | $\begin{array}{r} 32(32, \\ 32) \end{array}$ | $\begin{array}{r} 64.4(64.4, \\ 64.4) \end{array}$ |  |  | 22.6 |  | 22.1 | $\begin{array}{r} 69(69, \\ 69) \end{array}$ |  |
|  |  | 63 (63, | (12.5, | (26.3, | (28.7, | $\begin{gathered} (32.2, \\ 32.2) \end{gathered}$ |  |  |  |  | (3.59, |  |  | $3(3,3)$ | $67(67$, (22.6, <br> $67)$ $22.6)$ |  | $\begin{array}{r} 29.2(29.2, \\ 29.2) \end{array}$ | $\begin{aligned} & (22.1, \\ & 22.1) \end{aligned}$ |  | 306 |
|  |  | 63) | 12.5) | 26.3) | 28.7) |  |  |  |  |  | 3.59) |  |  |  |  |  |  |  |  |  |
|  |  | 69.1 | 18.5 | 19.7 | 27.5 |  |  |  |  |  | 6.8 |  |  |  | 59 |  |  | 17.2 |  |  |
| EasternAfrica | 30.7 (26.7,$44.7)$ | (55.2, | (13.5, | (15.3, | (25.2, | 30.1 (25, | $\begin{array}{r} 20.2(13.3, \\ 44.2) \end{array}$ | $\begin{gathered} 43.7(36.5, \\ 59.2) \end{gathered}$ | $\begin{array}{r} 25.3 \text { (14.6, } \\ 39.9) \end{array}$ | $\begin{array}{r} 60.9(59.4, \\ 67) \end{array}$ | (4.69, | 7.9 (.4, | $\begin{array}{r} 87.3 \text { (84.4, } \\ 96.3) \end{array}$ | . $6(0,2)$ | (47.7,$62.2)$ | $\begin{array}{r} 15.3 \text { (9.1, } \\ 20.1) \end{array}$ | $\begin{array}{r} 44.5(30.2, \\ 65.5) \end{array}$ | (16.2, | $61.4(45$,$69.5)$ | 1826 |
|  |  | 73.3) | 31.1) | 20.8) | 31.2) | 35) |  |  |  |  | 9.1) | 17.7) |  |  |  |  |  | 28.3) |  |  |
|  | 27.1 (19.2,$36.5)$ | 72.9 | 15.3 | 21.2 | 24.8 | 39.9 |  |  |  |  | 3.2 | 10.3 |  |  | 60.5 | 17.7 |  | 43.2 | 78.4 |  |
| Southern Africa |  | $\begin{gathered} (63.5, \\ 80.8) \end{gathered}$ | (11.8, | $\begin{aligned} & (13.3, \\ & 22.3) \end{aligned}$ | $\begin{gathered} (20.8, \\ 26.8) \end{gathered}$ | (37.4, | $\begin{array}{r} 14.5(7.09, \\ 16.1) \end{array}$ | $\begin{array}{r} 48.4 \text { (36.7, } \\ 65.1) \end{array}$ | $37(27.7 .47)$ | $\begin{array}{r} 67 \text { (57.2, } \\ 69.4) \end{array}$ | (1.89, | (5.09, | $\begin{array}{r} 89.8(88.1, \\ 91.4) \end{array}$ | $\begin{aligned} & 8 \text {. } 8 \text { (6, } \\ & 5.19) \end{aligned}$ | $\begin{gathered} (58.7, \\ 69.4) \\ \hline \end{gathered}$ | $\begin{aligned} & (15.6, \\ & 27.7) \end{aligned}$ | $56(51.2,56)$ | $\begin{aligned} & (34.7, \\ & 54.2) \end{aligned}$ | (67.4, <br> 83.6) | 1377 |
|  |  |  | 16.7) |  |  | 48.9) |  |  |  |  | 16.3) | 10.3) |  |  |  |  |  |  |  |  |
|  |  |  | 13.6 |  |  | 32.2 |  |  |  |  | 8.19 | 10.3 |  |  | 72.3 | 12.1 |  | 29.5 | 53.2 |  |
| Western Africa | $\begin{array}{r} 39(27.2, \\ \quad 43.5) \\ \hline \end{array}$ | $\begin{array}{r} 61(56.5, \\ \quad 72.8) \\ \hline \end{array}$ | $\begin{gathered} (11.3, \\ 13.8) \end{gathered}$ | $\begin{array}{r} 24(17.8, \\ \quad 25.8) \\ \hline \end{array}$ | $\begin{array}{r} 31.6 \\ (30.7,66) \end{array}$ | (31.1, | $\begin{array}{r} 46.2(39.7, \\ 47.5) \\ \hline \end{array}$ | $\begin{array}{r} 27.7 \text { (14.1, } \\ 27.8) \\ \hline \end{array}$ | 25.7 (24.7, | $\begin{array}{r} 68 \text { (54.9, } \\ 85.3) \\ \hline \end{array}$ | (3.59, | (9.19, | 85.3 (84.5, $88.6)$ | $\begin{aligned} & .8(0, \\ & 2.09) \end{aligned}$ | $\begin{array}{r} (64, \\ 73.1) \end{array}$ | $\begin{aligned} & (11.1, \\ & 25.3) \\ & \hline \end{aligned}$ | $16.5(0,34)$ | (26.2, | $(51.4,$ | 736 |
|  | $\begin{array}{r} 30.5 \text { (26.7, } \\ 40.9) \end{array}$ | $\begin{array}{r} 69.5(59, \\ 73.3) \end{array}$ | $\begin{array}{r} 16 \text { (13.5, } \\ 27) \end{array}$ | 20.1 | 27.1 | 32.5 | $\begin{array}{r} 17.1(13.3, \\ 36.2) \end{array}$ | $\begin{array}{r} 45.7 \text { (36.7, } \\ 59.2) \end{array}$ | $\begin{array}{r} 28(16.6, \\ 39.9) \end{array}$ | $\begin{array}{r} 62.9(58.7, \\ 67.8) \end{array}$ | 6.69 | 8.19 | $\begin{gathered} 88(85.8, \\ 92) \\ 9 \end{gathered}$ |  | 59.2 |  |  | 64.2 | 26.2 |  |
| ESA |  |  |  | (15.3, | (24.8, | (26.1, |  |  |  |  | (3.79, | (5.09, |  | . $649(0,2)$ | (55.2, | 16 (11, | 49.7 (34.9, 61) | $\begin{aligned} & (47,2, \\ & 71) \end{aligned}$ | $\begin{aligned} & (16.7, \\ & 30.7) \\ & \hline \end{aligned}$ | 3203 |
|  |  |  |  | 21.2) | 29.8) | 39.9) |  |  |  |  | 9.1) | 10.3) |  |  | 62.2) | 20.1) |  |  |  |  |
|  |  |  |  | 24.9 |  | 32.2 |  |  |  |  | 5.9 | 11.1 |  |  | 69.6 | 17.3 |  | 53.7 | 27.8 |  |
| WCA | $\begin{array}{r} 38(27.2, \\ 43.5) \\ \hline \end{array}$ | $\begin{array}{r} 62(56.5, \\ 72.8) \\ \hline \end{array}$ | $\begin{array}{r} 13 \text { (11.3, } \\ 13.8) \\ \hline \end{array}$ | (17.8, |  | (31.1, | $\begin{array}{r} 43(31.2, \\ 47.5) \\ \hline \end{array}$ | $\begin{array}{r} 27.8(14.1, \\ 36.4) \\ \hline \end{array}$ | $\begin{array}{r} 26.5(24.7, \\ 45.9) \\ \hline \end{array}$ | $69(63.2,77)$ | (3.59, | (9.19, | $\begin{array}{r} 84.9(81.8, \\ 88.6) \\ \hline \end{array}$ | $\begin{array}{r} 1.45(0, \\ 2.59) \\ \hline \end{array}$ | (64, | (11.1, | $\begin{array}{r} 22.8(8.25, \\ 31.6) \\ \hline \end{array}$ | $\begin{array}{r} (51.4, \\ 61.2) \\ \hline \end{array}$ | $\begin{aligned} & (22.1, \\ & 32.2) \\ & \hline \end{aligned}$ | 1042 |
|  |  |  |  | 26.3) | $(28.7,36)$ | 32.5) |  |  |  |  | 11.6) | 28.3) |  |  | 73.1) | 25.3) |  |  |  |  |
|  | $\begin{array}{r} 33.2(26.8, \\ 42.2) \\ \hline \end{array}$ | $\begin{array}{r} 66.7 \\ (57.7, \\ 73) \\ \hline \end{array}$ | $\begin{array}{r} 14.1 \\ (12.1,19) \\ \hline \end{array}$ | 20.6 |  | 32.2 | $\begin{array}{r} 21.7 \text { (14.3, } \\ 44.5) \\ \hline \end{array}$ | $\begin{array}{r} 39.4(27.8 \\ \quad 48.4) \\ \hline \end{array}$ | $\begin{array}{r} 27.5(19.9 \\ 40.4) \\ \hline \end{array}$ | $\begin{array}{r} 66.6(59.4, \\ 69) \\ \hline \end{array}$ | 6.69 | 9.64 | $\begin{array}{r} 87.5(84.5, \\ 91.1) \\ \hline \end{array}$ | $\begin{array}{r} .75(0, \\ 2.34) \\ \hline \end{array}$ |  | $\begin{array}{r} 16(11, \\ 21.6) \\ \hline \end{array}$ | $\begin{array}{r} 40.2(29.2, \\ 56) \\ \hline \end{array}$ | $\begin{array}{r} (49.2, \\ 69.2) \\ \hline \end{array}$ |  | 4245 |
|  |  |  |  | (17.5, | (25.7, | (27.6, |  |  |  |  | (3.59, | (5.19, |  |  | $\begin{aligned} & \text { (57.7, } \\ & \text { 65.5) } \\ & \hline \end{aligned}$ |  |  |  | $\begin{aligned} & (16.7, \\ & 31.5) \end{aligned}$ |  |
| SSA |  |  |  | 24.9) | 31.4) | 37.1) |  |  |  |  | 9.25) | 14.8) |  |  |  |  |  |  |  |  |

### 3.3.2 Prevalence of hypertension, treatment and control among individuals with comorbidities in SSA

The prevalence of hypertension and comorbidities is presented in appendix table s1. The overall median prevalence of hypertension in SSA was [28.0\% (IQR; 23.0, 29.7)]. The estimated prevalence of hypertension was highest in the Southern [33.7\% (IQR; 28.1, 34.2)] and lowest in the Eastern region [25.3\% (IQR; 17.1, 28.2)] of Africa. Overall, hypertension prevalence was higher among individuals with diabetes [59.5\% (IQR; 47.2, 69.3)], central obesity [38.5\% (IQR; 33.0, 41.9)], general obesity [49.0\% (IQR; 44.8, 52.7)], and those with dyslipidemia [36.0\% (IQR; 26.7, 43.2)] compared to those without these conditions. However, statistical significant differences were not seen among those with dyslipidemia.

The prevalence of treatment and comorbidities is presented in appendix table s2. The overall median prevalence of hypertension in SSA was [15.3\% (IQR; 9.69, 18.7)]. The estimated prevalence of treatment was highest in the Southern region [23.5\% (IQR; 18.7, 24.7)] and lowest in the Western region $[10.1 \%$ (IQR; 9.69, 10.5)] of Africa. Overall, treatment prevalence was higher among individuals with diabetes [40.2\% (IQR; 33.1, 60.4)], central obesity [20.7\% (IQR; 13.7, 28.4)], general obesity [24.2\% (IQR; 16.8, 31.5)], and those with dyslipidemia [19.7\% (IQR; 11.3, 25.7)] compared to those without these conditions. However, statistical significant differences were only noted in those with diabetes and central obesity compared to their counterparts without these conditions.
3.3.3 Prevalence of uncontrolled hypertension among individuals with comorbidities and on antihypertensive treatment in SSA
The overall median prevalence of uncontrolled hypertension in SSA was [61.4\% (IQR; 57.8, 65.5)]. Figure 8 is a graphical representation of the prevalence of uncontrolled hypertension in the included countries. The prevalence ranged from $25.9 \%$ in Rwanda to $77.0 \%$ in Gambia. Most countries had uncontrolled hypertension prevalence of more than 50\% except for Rwanda and Zanzibar.

Figure 8: Prevalence of uncontrolled hypertension by countries


With regards to regions (figure 9), the highest estimated median prevalence for uncontrolled hypertension was in the Western Africa region [72.1 \% (IQR; 64.0, 73.1)] while the lowest pooled median prevalence was in the Eastern African region [59.0\% (IQR; 47.7, 62.2)] and these differences were statistically significant.

Figure 9: Prevalence of uncontrolled hypertension by regions


Table 14 provides the prevalence of uncontrolled hypertension by socio-demographic factors. Overall, there were more men [median $62.4 \%$ (IQR; 55.3, 66.3) with uncontrolled hypertension compared to women $[61.3 \%$ (IQR; 54.2, 68.1)] in SSA. The highest estimated pooled prevalence was among the participants aged 55 and above [ $75 \%$ (IQR; 68.5, 84.6)], those with no education [64.6\% (IQR; 57.7, 74.1)], and those who were unemployed [67\% (IQR; 59.5, 70.4)]. However, significant differences were only observed in the prevalence of uncontrolled hypertension among individuals aged 55 year and above [75\% (IQR; 68.5, 84.6)] compared to individuals aged 15-34 years [37\%, (IQR; 25.6, 49.2)] and those aged 35-44 years [54.3\% (IQR; 46.4, 59.2)].

The prevalence of UHTN and behavioural factors is presented in table 15. Overall, uncontrolled hypertension prevalence was higher among non-smokers [68.8\% (IQR; 46.2, 79.2)], those who didn't consume harmful levels of alcohol [63.2\% (IQR; 57.7, 71.1)], those who consumed healthy diets [69.1\% (IQR; 39.1, 74.8)], and those who had sufficient physical activity [64\% (IQR; 60, 100)]. However, all these differences were not statistically significant.

Table 14: Prevalence of uncontrolled hypertension by socio-demographic variables, countries and region

| Countries | Men | Women | $15-34 \mathrm{yrs}$. | 35-44 yrs. | 45-54 yrs. | $55+\mathrm{yrs}$. | No education | Primary level | Secondary Plus | Employed | Unemployed |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| West | 69.5 (66.9, 73.0) | 76.0 (62.0, 78.0) | 40.5 (37.4, 49.0) | $57.7(53.9,60.7)$ | 69.9 (65.4, 74.0) | 86.5 (83.9, 88.4) | 74.3 (67.1, 75.8) | 64.3 (61.9, 67.3) | 74.9 (67.4, 75.8) | 66.4 (66.0, 74.4) | 70.9 (64.4, 77.9) |
| Benin | 64.0 (48.0, 77.4) | 78.5 (66.3, 87.2) | 49.0 (24.4, 74.1) | 60.8 (40.9, 77.6) | 74.0 (54.1, 87.3) | 88.4 (76.4, 94.7) | 79.0 (66.7, 87.6) | $67.3(42.9,85.0)$ | 64.5 (42.1, 82.0) | 66.1 (52.6, 77.4) | 85.9 (72.0, 93.5) |
| Gambia | $74.4(59.8,85.0)$ | 78.0 (66.3, 86.5) | 73.4 (43.9, 90.7) | 79.2 (54.9, 92.3) | 69.9 (53.4, 82.4) | 83.9 (69.3, 92.3) | 75.8 (65.0, 84.1) | 86.6 (62.2, 96.2) | 75.8 (55.6, 88.7) | 75.6 (62.7, 85.1) | $77.9(64.6,87.2)$ |
| Liberia | 69.5 (58.5, 78.7) | 76.1 (64.5, 84.8) | 36.7 (19.6, 58.1) | 53.9 (34.2, 72.5) | 81.8 (64.8, 91.6) | 89.8 (72.4, 96.7) | 74.3 (60.8, 84.4) | 64.3 (34.9, 85.8) | 74.9 (65.0, 82.8) | 74.4 (66.7, 80.8) | 70.9 (48.4, 86.3) |
| Togo | 73.1 (45.0, 90.0) | 60.7 (44.4, 75.0) | 37.4 (10.4, 75.4) | 57.7 (29.1, 81.9) | $65.2(45.5,80.8)$ | 76.2 (48.8, 91.5) | 64.1 (39.4, 83.1) | $61.9(44.1,77.0)$ | $67.4(38.9,87.1)$ | $66.4(48.8,80.4)$ | 55.6 (29.9, 78.6) |
| SL | 66.9 (51.4, 79.5) | 62.0 (47.6, 74.6) | 40.6 (20.6, 64.3) | 50.8 (34.1, 67.4) | 65.4 (44.9, 81.5) | 86.6 (74.3, 93.5) | $67.2(41.8,85.4)$ | 45.4 (30.0, 61.7) | 78.1 (66.5, 86.4) | 63.5 (47.4, 77.0) | $64.4(47.9,78.1)$ |
| Central | $61.0(61.0,61.0)$ | 70.5 (70.5, 70.5) | 28.3 (28.3, 28.3) | 56.0 ( $56.0,56.0)$ | 76.6 (76.6, 76.6) | 82.3 (82.3, 82.3) | 75.8 (75.8, 75.8) | $62.9(62.9,62.9)$ | 67.5 (67.5, 67.5) | 64.6 (64.6, 64.6) | 75.5 (75.5, 75.5) |
| CAR | $61.1(38.7,79.6)$ | 70.6 (55.6, 82.1) | 28.4 (11.3, 55.3) | 56.0 (32.6, 77.0) | 76.7 (61.7, 87.1) | 82.3 (77.8, 86.1) | 75.8 (54.7, 89.0) | 62.9 (51.0, 73.4) | 67.6 (47.7, 82.7) | $64.7(48.5,78.2)$ | 75.5 (55.9, 88.2) |
| Eastern | 59.0 (45.0, 65.5) | 56.0 (47.4, 66.5) | 33.9 (17.7, 40.9) | 52.5 (34.4, 56.7) | 67.8 (45.9, 71.4) | 73.5 (64.9, 82.0) | 60.0 (49.2, 65.0) | 58.0 (44.2, 62.5) | 49.2 (46.5, 61.0) | 51.5 (41.5, 55.7) | 66.0 (59.5, 69.4) |
| Comoros | 53.5 (36.7, 69.5) | 67.3 (60.5, 73.4) | 49.5 (30.1, 69.1) | 54.6 (38.2, 70.1) | 65.9 (51.3, 78.0) | 71.3 (61.0, 79.8) | 68.1 (59.7, 75.5) | 67.8 ( $52.5,80.0$ ) | 46.5 (29.8, 64.0) | 55.6 (42.3, 68.0) | $69.4(62.3,75.6)$ |
| Eritrea | 63.5 (50.2, 75.0) | $57.5(46.6,67.7)$ | 49.8 (14.9, 84.9) | $62.1(31.6,85.3)$ | $45.9(30.8,61.9)$ | $64.9(55.0,73.8)$ | 64.3 (54.0, 73.4) | 58.1 (44.8, 70.3) | 41.6 (19.6, 67.5) | 41.6 (29.0, 55.3) | 67.3 (55.6, 77.1) |
| Ethiopia | 65.7 (49.4, 79.1) | 52.6 (36.3, 68.3) | 33.9 (16.2, 57.7) | 52.6 (26.9, 76.9) | 75.6 (50.9, 90.2) | 82.1 (67.4, 91.0) | $60.2(38.6,78.4)$ | 60.4 (41.2, 76.9) | $59.4(27.3,85.1)$ | $58.2(43.5,71.5)$ | 66.0 (47.9, 80.5) |
| Kenya | 59.1 (33.5, 80.5) | 56.0 ( $35.5,74.7$ ) | 40.9 (14.1, 74.4) | 47.0 (16.4, 80.1) | $64.9(38.0,84.8)$ | 66.2 (50.4, 79.1) | 56.3 (31.3, 78.5) | $65.4(44.9,81.5)$ | 47.1 (22.1, 73.6) | $55.7(34.7,74.8)$ | 59.5 (39.5, 76.8) |
| Rwanda | $19.4(6.50,45.5)$ | 31.1 (19.3, 46.2) | $16.2(5.20,40.5)$ | 13.8 (3.00, 45.3) | 24.6 (10.0, 49.0) | 75.7 (47.3, 91.5) | 40.2 (17.5, 67.9) | 22.3 (9.70, 43.6) | 25.5 (10.5, 50,0) | 27.3 (16.1, 42.4) | 18.9 (4.80, 51.9) |
| Sudan | 60.1 (51.7, 67.9) | 66.6 (59.0, 73.4) | $31.2(18.6,47.4)$ | 71.8 (60.0, 81.2) | 68.3 (57.9, 77.2) | 73.5 (65.0, 80.5) | 74.1 (65.6, 81.0) | 53.1 (41.2, 64.7) | 61.6 (50.9, 71.3) | 60.4 (51.7, 68.6) | 67.0 (60.1, 73.2) |
| Tanzania | 65.5 (46.4, 80.6) | 57.3 (49.0, 65.2) | 19.3 (7.50, 41.4) | $41.5(20.2,66.7)$ | 71.4 (47.6, 87.3) | 85.4 (73.0, 92.7) | 42.1 (21.5, 65.8) | $62.5(52.6,71.5)$ | $61.1(36.6,81.1)$ | 55.3 (39.8, 69.8) | $69.9(45.3,86.7)$ |
| Uganda | 42.9 (24.7, 63.2) | 68.7 (56.0, 79.1) | $17.8(5.90,42.7)$ | 55.5 (32.6, 76.3) | 74.3 (58.8, 85.4) | 74.3 (52.8, 88.2) | 65.0 (42.9, 82.2) | $51.7(35.0,68.0)$ | 71.3 (55.2, 83.3) | 51.5 (38.7, 64.0) | $81.0(61.5,92.0)$ |
| Zanzibar | 45.0 (23.7, 68.3) | 47.4 (31.2, 64.1) | 7.80 (2.20, 24.6) | 29.3 (12.8, 53.8) | 67.8 (48.7, 82.4) | 88.3 (56.0, 97.8) | 49.3 (29.0, 69.7) | 43.8 (24.9, 64.7) | 47.5 (26.6, 69.4) | 40.4 (24.0, 59.2) | 61.6 (39.7, 79.7) |
| Southern | $61.4(56.2,76.5)$ | 62.2 (57.2, 67.6) | 56.7 (22.7, 73) | 54.0 (45.9, 64.0) | 69.6 (63.5, 73.5) | 70.9 (59.4, 72.0) | 66.4 (34.0, 85.0) | 57.7 (56.4, 67.9) | 57.2 (56.5, 81.9) | 60.4 (49.4, 74.6) | $67.1(57.7,69.8)$ |
| Lesotho | 76.6 (51.5, 91.0) | $67.7(59.8,74.7)$ | 73.0 (46.8, 89.3) | 64.1 (39.0, 83.2) | 69.7 (55.2, 81.1) | 70.9 (59.9, 79.9) | 34.1 (11.8, 66.7) | 67.9 (58.8, 75.9) | 81.9 (68.6, 90.4) | 74.7 (57.2, 86.7) | $67.2(59.1,74.4)$ |
| Botswana | 61.4 (46.0, 74.9) | 57.3 (50.4, 64.0) | 56.8 (37.6, 74.1) | 54.1 (34.0, 73.0) | 63.5 (52.1, 73.6) | 59.4 (48.9, 69.0) | 66.4 (51.2, 78.7) | $57.7(46.8,67.8)$ | 57.2 (44.7, 68.8) | $60.4(50.7,69.4)$ | 57.7 (46.7, 67.9) |
| Malawi | 54.4 (31.0, 76.0) | 45.2 (30.5, 60.8) | 39.0 (17.6, 65.7) | 34.4 (13.8, 63.3) | 41.5 (15.4, 73.4) | 60.2 (39.4, 77.9) | 59.2 (36.0, 78.9) | 44.2 (27.0, 62.9) | 49.2 (25.4, 73.4) | 48.9 (26.6, 71.7) | 46.9 (32.5, 61.8) |
| Eswatini | 56.3 (42.0, 69.6) | $62.2(50.9,72.3)$ | 22.8 (11.2, 41.0) | $45.9(24.6,68.8)$ | 73.5 (60.1, 83.6) | 72.1 (58.4, 82.6) | 85.1 (71.3, 92.9) | $56.4(40.9,70.7)$ | 56.6 (43.2, 69.0) | $49.4(34.5,64.3)$ | $69.8(57.8,79.6)$ |
| Zambia | 65.8 (47.2, 80.6) | 49.4 (40.8, 58.0) | 36.6 (18.1, 60.1) | $56.7(35.5,75.8)$ | 68.4 (51.6, 81.4) | 60.1 (46.8, 72.0) | 60.0 (37.7, 78.9) | 62.3 (49.4, 73.7) | 49.5 (37.9, 61.1) | 50.9 (40.1, 61.7) | 59.6 (47.5, 70.7) |
| ESA | 59.5 (53.5, 65.5) | 57.2 (49.4, 66.5) | 35.2 (19.2, 49.5) | 53.3 (41.5, 56.7) | 68.0 (63.5, 71.4) | 71.6 (64.9, 75.6) | 60.0 (49.2, 66.4) | 57.9 (51.7, 62.5) | $53(47.0,61.0)$ | 53.4 (48.9, 58.2) | 66.5 (59.5, 69.4) |
| WCA | 68.1 (64.0, 73.0) | 73.3 (62.0, 78.0) | 39.0 (36.7, 49.0) | 56.8 (53.9, 60.7) | $71.9(65.4,76.6)$ | $85.2(82.3,88.4)$ | 75.0 (67.1, 75.8) | 63.5 (61.9, 67.3) | $71.2(67.4,75.8)$ | $66.2(64.6,74.4)$ | 73.1 (64.4, 77.9) |
| SSA | $62.4(55.3,66.3)$ | 61.3 (54.2, 68.1) | 37.0 (25.6, 49.2) | 54.3 (46.4, 59.2) | 68.3 (65.0, 73.7) | 75.0 (68.5, 84.6) | 64.6 (57.7, 74.1) | $61.1(52.4,64.8)$ | 60.2 (48.3, 69.4) | 56.9 (50.1, 65.4) | 67.0 (59.5, 70.4) |

Table 15: Prevalence of uncontrolled hypertension by behavioural variables, countries and regions

|  | \% (IQR) | \% (IQR) | \% (IQR) | \% (IQR) | \% (IQR) | \% (IQR) | \% (IQR) | \% (IQR) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Countries | No alcohol | Harmful use of alcohol | Smoker | Non-smoker | Unhealthy diet | Healthy diet | Sufficient PA~ | Insufficient PA~ |
| West | $71.3(64,73.6)$ | 63.7 (58.7, 66.1) | 71.6 (63.5, 73.8) | 69.3 (68.3, 78.1) | 72.1 (67.5, 72.5) | 73 (71.9, 75.5) | 73.8 (64.4, 100) | $0(0,50.7)$ |
| Benin | 73.7 (63.5, 81.9) | $58.8(29.8,82.8)$ | $71.7(61.4,80.2)$ | 100 (., .) | $72.2(60.8,81.4)$ | $71.9(51.8,86)$ | 100 (., .) | 0 (., . ) |
| Gambia | 100 (., .) | 0 (., .) | 78.3 (68.1, 85.9) | 63.1 (41.5, 80.5) | $77.7(68.3,85)$ | 73 (51.4, 87.3) | 100 (., .) | 0 (., . ) |
| Liberia | 71.3 (62.2, 79) | 91.5 (67.2, 98.3) | 73.8 (65.3, 80.9) | 68.3 (48.6, 83) | 72.6 (64.7, 79.4) | 78.9 (64.5, 88.5) | $73.8(65.6,80.5)$ | 0 (., .) |
| SL | $64(49.5,76.3)$ | 63.7 (26.7, 89.4) | $62.5(48.2,75)$ | 69.3 (45.5, 85.9) | $62.5(49.3,74)$ | 75.6 (44.9, 92.2) | $63.5(50.7,74.6)$ | 85.7 (31.5, 98.7) |
| Togo | 63.3 (46.3, 77.5) | $66.2(40.3,85)$ | $63.6(47.6,77)$ | $78.2(30.3,96.7)$ | $67.5(50.3,81)$ | 45.5 (22.6, 70.4) | $64.4(48.8,77.5)$ | $50.7(5.7,94.6)$ |
| Central | 69.9 (69.9, 69.9) | $60.9(60.9,60.9)$ | 66.4 (66.4, 66.4) | 83.5 (83.5, 83.5) | $67.4(67.4,67.4)$ | $66.5(66.5,66.5)$ | $66.1(66.1,66.1)$ | $95(95,95)$ |
| CAR* | 69.9 (55.9, 81) | 60.9 (39.4, 78.9) | $66.4(52.6,77.9)$ | 83.6 (60.7, 94.4) | $67.4(50.7,80.5)$ | 66.5 (54.1, 76.9) | $66.2(53.3,77.1)$ | $95(85.5,98.4)$ |
| Eastern | $59.5(53,67.8)$ | $49(0,68.9)$ | 59.2 (50.5, 61.7) | 46.7 (35.5, 72.3) | $58.7(50.2,61)$ | $62.2(31.3,74)$ | $63.2(56,100)$ | $0(0,54.7)$ |
| Comoros | 63.3 (55.6, 70.3) | 0 (., .) | $61.7(54.1,68.6)$ | 78.9 (54.6, 92.1) | $61(52.3,69)$ | $74(56.7,86.1)$ | $63.2(55.7,70.1)$ | $41(3.8,92.4)$ |
| Eritrea | 59.8 (50.4, 68.6) | $49.1(26.8,71.7)$ | 58.7 (49.8, 67.1) | 72.3 (19.8, 96.5) | 58.8 (49.9, 67.2) | 100 (., .) | 100 (., .) | 0 (., .) |
| Eswatini | $61.5(51.8,70.3)$ | $44.4(19,73.2)$ | 59.9 (50.9, 68.2) | 100 (., .) | $57.8(48.6,66.4)$ | $81.9(62.7,92.4)$ | $60.4(51.5,68.6)$ | 100 (., .) |
| Ethiopia | $53(37.9,67.5)$ | 79.5 (50.6, 93.6) | 59.2 (46.9, 70.4) | 79.6 (36, 96.4) | $62.2(49.8,73.3)$ | 3.8 (.4, 28.2) | 100 (., .) | 0 (., . ) |
| Uganda | 67.8 (56.4, 77.4) | $42.9(22.3,66.2)$ | 62.6 (52.2, 71.9) | 53.3 (19.3, 84.5) | 59.6 (47.8, 70.3) | 72.6 (47.8, 88.5) | 62.8 (52.7, 71.9) | 0 (., . . |
| Kenya | 56.4 (41.1, 70.6) | $59.2(22.4,88)$ | 59.4 (41.4, 75.2) | 35.6 (9.2, 75) | 53.2 (36.2, 69.4) | 82.4 (59.1, 93.8) | $56.1(39.8,71.1)$ | 100 (., .) |
| Zanzibar | 100 (., .) | 0 (., .) | 50.6 (37, 64.1) | $3.5(.3,29.7)$ | 49.3 (33.4, 65.4) | $31.4(13.7,56.8)$ | 100 (., .) | 0 (., .) |
| Rwanda | 25.5 (14.8, 40.3) | 32.8 (4.5, 83.5) | $26.2(15.4,41)$ | 21.6 (2.7, 72.9) | $25.9(15.4,40.1)$ | 25.4 (2.7, 80.4) | 26.9 (16.2, 41.3) | 0 (., . ) |
| Sudan | 100 (., .) | 0 (., .) | 65.7 (59.9, 71.1) | $45.9(24.8,68.6)$ | 65.2 (59.1, 70.8) | $55.8(37.5,72.6)$ | $63.7(57.9,69.1)$ | 100 (., .) |
| Southern | $61.5(59,71)$ | 55.9 (44.4, 57.2) | 59.9 (56.4, 68.4) | $100(70.9,100)$ | $61.2(57.7,69)$ | 72.3 (32.7, 81.9) | 60.4 (59.2, 69.6) | $63.5(0,100)$ |
| Lesotho | $71(63,77.8)$ | 55.9 (29.5, 79.4) | 68.4 (60.7, 75.2) | 100 (., .) | 69.1 (60.7, 76.3) | 72.3 (49.4, 87.5) | 69.7 (62.1, 76.4) | 63.6 (19.6, 92.6) |
| Botswana | $59(51.3,66.3)$ | 57.3 (35.9, 76.3) | $56.4(49.6,63.1)$ | 70.9 (43.8, 88.4) | $61.3(54,68.1)$ | 32.8 (15.7, 55.9) | 59.3 (51.9, 66.2) | 0 (., .) |
| Malawi | 44.7 (30.7, 59.7) | 95.3 (82.9, 98.8) | 46.7 (32.6, 61.3) | $61.4(21.3,90.4)$ | 50.2 (35.2, 65.2) | 32.6 (12.4, 62.3) | $47.7(33.2,62.5)$ | 46.9 (6.5, 91.8) |
| Zambia | $54(45.1,62.6)$ | 68.9 (35.9, 89.8) | $55.8(47.6,63.7)$ | $43.9(14,79)$ | $54.3(45.8,62.6)$ | $62.2(40.4,80)$ | 100 (., .) | 0 (., . . |
| ESA | $59.7(54,67.8)$ | $52.5(32.7,59.5)$ | 59.2 (55.7, 61.7) | 57.3 (43.9, 78.9) | $59(53.2,61.2)$ | $62.5(32.5,74)$ | $63(59.2,100)$ | $20.5(0,63.5)$ |
| WCA | $70.5(64,73.6)$ | $62.2(58.7,66.1)$ | $69(63.5,73.8)$ | $73.7(68.3,83.5)$ | $69.8(67.4,72.5)$ | $72.4(66.5,75.5)$ | 70 (64.4, 100) | $25.3(0,85.6)$ |
| SSA | $63.2(57.7,71.1)$ | 58 (37.8, 64.9) | $61(57.5,66)$ | 68.8 (46.2, 79.2) | $61.1(56,67.4)$ | 69.1 (39.1, 74.8) | $64(60,100)$ | $20.5(0,74.6)$ |

[^3]Regarding comorbidities the estimated pooled median prevalence for uncontrolled hypertension was highest among study participants with diabetes [66.1\% (IQR; 60.2, 80.6)], obesity using BMI [68.4\% (IQR; 64.5, 77.9)], central obesity [69.1\% (IQR; 62.5, 72.5)] and those with dyslipidemia [66.4\% (IQR; 57.4, 73.8)] respectively (Table 16). However with regards to comorbidities, among individuals with uncontrolled hypertension significant differences were only noted between participants with obesity [68.4\%, (IQR; 64.5, 77.9)] compared to those without obesity 59.5 (IQR; 50.5, 63.2)] and those with abdominal obesity [69.1\%, (IQR; 62.5, 72.5)] compared to those without central obesity [49.5\%, (IQR; 42.2, 56.2)].

Table 16: Prevalence (\%) of uncontrolled hypertension by comorbidities and regions

| Countries | Non-diabetic | Diabetes | No central obesity | Centrally obese | Not obese | Obese | No Dyslipidemia | Dyslipidemia |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| West | 69.1 (68.6, 70.1) | 92.6 (84.1, 95.1) | 57.5 (54.2, 66.9) | 74.4 (70.6, 77.8) | $69(63.2,70)$ | 79.1 (66.8, 81) | 65.9 (62.2, 100) | $73.8(0,84.4)$ |
| Benin | 69.2 (58.1, 78.4) | 97.6 (84.7, 99.7) | 54.3 (39.4, 68.5) | 87 (76.1, 93.4) | 69.1 (56.6, 79.4) | 85.4 (63.5, 95.1) | 65.9 (52.5, 77.1) | 84.4 (66.7, 93.6) |
| Gambia | 72.7 (50.9, 87.2) | 84.2 (57.9, 95.4) | 79.1 (65.5, 88.3) | 74.4 (61.5, 84.1) | $77.2(67.3,84.8)$ | 79.2 (61.3, 90.2) |  |  |
| Liberia | $70.2(58.7,79.6)$ | 92.7 (54.5, 99.3) | 66.9 (55.4, 76.6) | 77.8 (65.4, 86.7) | 70.1 (59.6, 78.9) | $81(67.8,89.6)$ | 100 (., .) | 0 (., . $)$ |
| Togo | $68.7(52,81.6)$ | 48.5 (14.5, 83.9) | 57.5 (35.9, 76.6) | $69.6(51.8,83)$ | 63.3 (43.3, 79.6) | 65.6 (44.3, 82.1) | $62.2(47.3,75.1)$ | 73.8 (37.3, 93) |
| SL | 58.3 (34.1, 79.1) | $95.2(68.3,99.5)$ | $54.3(33.5,73.8)$ | $70.7(59,80.3)$ | 63.2 (48.9, 75.5) | 66.8 (45.9, 82.7) |  |  |
| Central | $67.6(67.6,67.6)$ | $62.2(62.2,62.2)$ | 61.2 (61.2, 61.2) | 70.4 (70.4, 70.4) | 66.4 (66.4, 66.4) | $70.8(70.8,70.8)$ | $64.1(64.1,64.1)$ | 73.9 (73.9, 73.9) |
| CAR* | 67.7 (57.1, 76.7) | 62.3 (42.4, 78.7) | 61.3 (34.1, 82.9) | 70.4 (56.4, 81.3) | 66.4 (49.8, 79.8) | 70.8 (56.1, 82.1) | 64.2 (43.5, 80.7) | 73.9 (53.3, 87.5) |
| Eastern | 57.5 (43.5, 61.5) | 63.4 (60, 75.1) | 45.2 (35.7, 51.5) | 62.9 (60.5, 70.3) | 53.2 (45.9, 59.7) | $67(44.9,73)$ | $50.5(42,61)$ | $62.9(56.9,69.8)$ |
| Comoros | 61.5 (50.7, 71.3) | 61.1 (41.5, 77.7) | 45.3 (33.5, 57.8) | 69.8 (61.9, 76.7) | 59.5 (50.7, 67.7) | 67.1 (54.7, 77.5) | 61.8 (53.2, 69.6) | 69.8 (52.7, 82.7) |
| Eritrea | 57.5 (47.2, 67.2) | $63.4(42.5,80.2)$ | $54.9(43,66.2)$ | $61(48.6,72.1)$ | 60.6 (51.7, 68.9) | 43.6 (21.9, 68) | $61.4(44.3,76.2)$ | $57.4(47.7,66.5)$ |
| Ethiopia | $64.8(52,75.9)$ | 45.3 (17.8, 75.9) | $51.8(37.6,65.8)$ | 80.8 (67.5, 89.5) | $59.7(46.8,71.4)$ | 67.3 (43.1, 84.8) | $50.1(34.6,65.7)$ | 72.6 (56.6, 84.3) |
| Kenya | 54.4 (35.7, 71.9) | 66.6 (37.1, 87.1) | 47.6 (23.8, 72.6) | 60.6 (38.6, 79) | 53.2 (36.2, 69.6) | 63.6 (35.5, 84.7) | $52.7(32.5,72.1)$ | 61.5 (41.7, 78.2) |
| Rwanda | $26.9(16,41.5)$ | $41.5(5.6,89.5)$ | 19.4 (8.6, 38.1) | 39.6 (22.3, 59.9) | 23 (12.4, 38.4) | 40.5 (19.9, 65.1) | $17.9(6.3,41.3)$ | 28.8 (16.4, 45.5) |
| Sudan | 63.7 (56.8, 70.1) | $72(61.6,80.4)$ | 46.9 (36.7, 57.4) | 70.3 (63.9, 76.1) | $61(54.6,67.1)$ | $70.7(60,79.6)$ | $50.3(35.6,64.8)$ | 67 (60.6, 72.9) |
| Tanzania | 58.9 (49.4, 67.7) | $77.2(49.6,92.1)$ | $51.5(33.6,69)$ | $62.9(52.8,72)$ | 50.8 (36.2, 65.3) | $81.9(62.4,92.5)$ | $61.1(50.4,70.8)$ | 56.9 (44.6, 68.5) |
| Uganda | 59.5 (47, 70.9) | 75.2 (43.5, 92.3) | 43.4 (29.1, 58.9) | $75.4(61.3,85.6)$ | 56.4 (45.3, 66.9) | 90.2 (58.4, 98.4) | $60.9(40.3,78.3)$ | $62.9(50.5,73.8)$ |
| Zanzibar | 40.1 (26.4, 55.5) | 100 (., .) | 34.5 (18.6, 54.8) | 59.2 (41.7, 74.7) | 45.9 (30.2, 62.5) | $44.9(22.7,69.2)$ | $42(27.5,58)$ | 55.7 (33.2, 76.1) |
| Southern | $59.4(53.7,69.4)$ | 65.6 (53.2, 73.3) | 43.5 (41, 70.5) | 66.4 (63.2, 68.6) | $53.5(47,62.5)$ | 69.3 (67.5, 76.6) | $54(53.5,63.5)$ | 65.8 (62.9, 74.9) |
| Lesotho | $69.4(60,77.5)$ | 65.7 (48.5, 79.6) | 70.6 (49.7, 85.4) | $68.7(60.3,76)$ | 62.6 (51.1, 72.8) | 76.7 (65.3, 85.2) | 63.6 (50.5, 75) | 74.9 (65.1, 82.6) |
| Botswana | 59.4 (51.1, 67.2) | 53.2 (35.3, 70.3) | 43.6 (30.6, 57.5) | 66.4 (59.5, 72.6) | $53.5(44.2,62.6)$ | 67.5 (57.1, 76.4) | 53.6 (44.4, 62.5) | $62.9(52.3,72.4)$ |
| Malawi | $43.5(29.8,58.3)$ | 60.5 (29.1, 85.1) | $35.7(20.6,54.2)$ | 62.3 (42.3, 78.8) | 45.5 (29.9, 62) | 58.6 (35.7, 78.3) | 36.8 (22.9, 53.4) | $67.9(46.8,83.6)$ |
| Eswatini | 53.7 (41.8, 65.2) | 73.3 (55.8, 85.7) | $41(23.5,61.2)$ | 63.3 (51.4, 73.8) | 47.1 (36.3, 58.1) | 69.3 (57.5, 79.1) | 54.1 (43.8, 63.9) | $65.8(53,76.6)$ |
| Zambia | 48.9 (38.8, 59.1) | $60.1(35.3,80.6)$ | 39.2 (25.9, 54.3) | 66.1 (55.4, 75.3) | 50.3 (41.5, 59.1) | $73(57,84.6)$ | 50.5 (40.9, 59.9) | 76.3 (60.7, 87) |
| ESA | 58.2 (48.9, 61.5) | $64.5(60,73.3)$ | 44.4 (39.2, 51.5) | 64.6 (61, 69.8) | 53.3 (47, 59.7) | $67.4(58.5,73)$ | $53.1(50,61)$ | 64.3 (57.4, 69.8) |
| WCA | 68.9 (67.6, 70.1) | 88.4 (62.2, 95.1) | 59.4 (54.2, 66.9) | 72.5 (70.4, 77.8) | 67.7 (63.2, 70) | $75(66.8,81)$ | 65 (63.2, 82.9) | 73.8 (36.9, 79.1) |
| SSA | $59.4(54,68.1)$ | 66.1 (60.2, 80.6) | 49.5 (42.2, 56.2) | 69.1 (62.5, 72.5) | 59.5 (50.5, 63.2) | 68.4 (64.5, 77.9) | 57.5 (50.2, 62.2) | 66.4 (57.4, 73.8) |

*CAR -Central African Republic, ~PA -Physical Activity, ESA - Eastern and Southern Africa, WCA - Western and Central Africa, SSA - sub-Saharan Africa

### 3.3.4 Individual level meta-analysis

In the bivariable model examining the association between uncontrolled hypertension and the key study variables; associations with p-values less than the cut-off were only found with age, education level, occupation, diabetes, dyslipidemia, general obesity and central obesity. Even though sex had a p-value higher than the cut-off, it was added to all the adjusted models because it is a known risk factor for hypertension. Table 17 shows the association between uncontrolled hypertension with diabetes, dyslipidemia, general obesity and central obesity.

Table 17: Association between uncontrolled hypertension among patients with comorbidities

| Overall effects |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Unadjusted model |  |  |  |  |  | Adjusted model* |  |  |  |  |  |
|  | OR | 95\%CI |  | $I^{2}$ | pvalue | Countries | OR | 95\%CI |  | $I^{2}$ | pvalue | Countries |
| Diabetes | 1.29 | 0.97 | 1.72 | 17.2\% | 0.082 | 16 | 1.12 | 0.84 | 1.48 | 0.0\% | 0.435 | 14 |
| Dyslipidemia | 1.62 | 1.32 | 1.99 | 2.3\% | 0.000 | 17 | 1.59 | 1.27 | 1.98 | 0.0\% | 0.000 | 16 |
| General obesity | 1.64 | 1.35 | 1.98 | 0.0\% | 0.000 | 20 | 1.54 | 1.27 | 1.86 | 0.0\% | 0.000 | 19 |
| Abdominal Obesity | 2.23 | 1.83 | 2.73 | 13.5\% | 0.000 | 20 | 2.04 | 1.56 | 2.68 | 38.3\% | 0.000 | 18 |

*Model adjusted for age, sex, education, occupation.

In the unadjusted model for diabetes, participants with diabetes were 1.29 times more likely to have UHTN compared to those without diabetes though this estimate was not statistically significant [1.29, (95\% CI $0.97-1.72)$ ]. Additionally, in both unadjusted and adjusted model, Zanzibar was excluded from the analysis because none of the participants with UHTN had diabetes. After adjusting for other factors, there still was a higher risk of UHTN [1.18, (95\% CI 0.90-1.56)] among participants with diabetes but this was not significant. Sensitivity analysis excluding Benin and Liberia due to their very wide confidence intervals did not show a major difference in the multivariate analysis [1.12, ( $95 \% \mathrm{CI} 0.85-1.48$ )]. Figure 10 is a forest plot showing the association between UHTN and diabetes in SSA. Increased risk of UHTN among participants with diabetes were noted in majority of the countries. The highest risk of UHTN was observed in Tanzania while the lowest risk was noted in Rwanda.


Figure 10: Forest plot of association between uncontrolled hypertension and diabetes
Compared to those without dyslipidemia, participants with dyslipidemia had a $62 \%$ ( 1.62 ( $95 \%$ CI 1.32-1.99) higher odds of having uncontrolled hypertension. This estimate was similar after adjusting for confounders [1.61 (95\% CI 1.29-2.01)]. Exclusion of countries with large confidence intervals (Rwanda) did not result in a major difference in the estimate [1.59, (95\% CI 1.27-1.98)] in the multivariate analysis. Figure 11 is a forest plot showing the association between UHTN and dyslipidemia in SSA. All countries except Eritrea and Tanzania showed
higher risk of UHTN among participants with dyslipidemia though significant association were only in few countries; Ethiopia, Malawi and Zambia.


Figure 11: Forest plot of association between uncontrolled hypertension and dyslipidemia
Participants with general obesity were $64 \%$ more likely to have UHTN compared to those without general obesity and this estimate was statistically significant (OR; 1.64 (95\% CI 1.351.98). After adjusting for confounders, the association between uncontrolled hypertension and general obesity was still statistically significant (OR; 1.56 (95\% CI 1.29-1.89). Sensitivity analysis excluding Uganda due to its large confidence interval showed no difference in the overall estimate [OR; 1.54 (95\% CI 1.27-1.86)]. Figure 12 is a forest plot showing the association between UHTN and general obesity in SSA. Most of the countries showed
increased risk of UHTN among obese participants though significant associations were only noted in few countries; Botswana, Eswatini, Lesotho, and Tanzania.


Figure 12: Forest plot of association between uncontrolled hypertension and obesity
Compared to non-centrally obese individuals, participants with central obesity had a 2.23 (OR; 2.23 ( $95 \%$ CI 1.83-2.73) higher risk of having UHTN. The estimate remained similar after the model was adjusting for age, sex, education and occupation [OR; 2.24 (95\% CI 1.68-2.99)]. Sensitivity analysis excluding countries with large confidence intervals (Benin, and Ethiopia) showed a slightly reduced overall estimate which was also statistically significant (OR; 2.04 ( $95 \%$ CI 1.56-2.68). Medium level heterogeneity was also observed in the adjusted model $\left(I^{2}=38.3 \%\right)$. Figure 13 is a forest plot showing the association between UHTN and general obesity in SSA. All countries except the Central African Republic and Gambia showed that
participants with central obesity had higher risk for UHTN and significant association were noted in several countries.


Figure 13: Forest plot of association between uncontrolled hypertension and central obesity

### 3.4 Discussion

This is the first study in SSA to examine the relationship between uncontrolled hypertension and comorbidities; providing important insights into the state of uncontrolled hypertension and comorbidities in SSA. Previous national level studies conducted in SSA focused mainly on hypertension in general but not among those on treatment and with comorbidities. Using IPD from 20 countries with a total of 4,245 individuals, this meta-analysis provides evidence that the level of uncontrolled hypertension is related to the presence of comorbidities (dyslipidemia, obesity and abdominal obesity). The results show a high burden of uncontrolled hypertension
with close to two thirds (61.4\%) of the study population having uncontrolled hypertension and the burden is higher among those with comorbidities.

Uncontrolled hypertension among people with comorbidities was estimated in 20 countries in SSA from 2009 to 2017. Our high UHTN estimate (61.4\%) for SSA is similar to the global estimate (62.9\%) (Mills et al., 2016) and estimates from Iran (61\%) (Mirzaei et al., 2020). Our findings further highlight a high burden of UHTN among people with comorbidities in SSA with age and regional differences. The differences observed are somewhat expected in line with previous evidence showing that older individuals tend to have higher levels of uncontrolled hypertension probably due to having underlying conditions compared to younger individuals. However, the regional differences are surprising and it suggests that there are differences in hypertension services, policies, guidelines and interventions in the different regions contributing to these observed differences highlighting the need to have targeted comorbidity care integrated into hypertension management in these regions.

Often, clinicians fail to recognize the importance of assessing patients’ comorbidities along with managing patient blood pressures mainly because they are accustomed to the single disease framework that most healthcare delivery systems have. As sub-Saharan Africa undergoes an epidemiological transition, hypertension and comorbidities need to be closely managed for better control of blood pressure in the continent. Dyslipidemia, obesity and abdominal obesity were all positively associated with uncontrolled hypertension in the current study. Dyslipidemia and hypertension have been shown to often coexist and this combination can contribute to cardiovascular disease consequences in patients. A recent systematic review and meta-analysis by Noubiap and colleagues reported a high burden of dyslipidemia among Africans which was comparable to estimates from other regions (Noubiap et al., 2018). This finding raises concern considering the significant association found between dyslipidemia and the risk for UHTN in the current study. The observed association is consistent with findings
from other studies (Halperin et al., 2006, Hunt et al., 1991). Literature has shown that there are different mechanisms by which the relationship between dyslipidemia and hypertension have been shown. Dyslipidemia, causes endothelial damage that results in loss of physiological vasomotor activity that is thought to manifest as high blood pressure (Nickenig, 2002, Nickenig and Harrison, 2002). There is evidence also suggesting a genetic association between blood pressure and dyslipidemia. A study conducted in 58 Utah families found lipid abnormalities to be one of the biochemical correlates of early familial hypertension (Williams et al., 1988). Another study found that $68 \%$ of carriers of a specific mutation (lipoprotein lipase) that causes lipid abnormalities had hypertension (Williams et al., 1992). Spannella and colleagues also found that very few patients with hypertension were on therapy for dyslipidemia (Spannella et al., 2019) and this also may explain the uncontrolled blood pressures observed. However, the majority of studies report the association between hypertension in general among individuals with dyslipidemia who are not on treatment for hypertension. Nonetheless, these findings suggest the need for clinicians to pay attention to patients' lipid levels when assessing blood pressure control among individuals already on treatment for hypertension.

The high prevalence of UHTN (68.4\%) found among individuals with obesity is higher than findings from the US that found among obese individuals 42.5\% had hypertension (Wang and Wang, 2004). However it is important to note that the use of antihypertensive medication was not reported in Wang's study and in most of the articles reviewed for this study. Another study by Lv and colleagues (Lv et al., 2018) found that obese individuals had a higher UHTN (81.1\%) prevalence compared to the current study.

The current study found general obesity and abdominal obesity were also significantly associated with higher risk of UHTN and this relationship remained unchanged when confounders were included in the adjusted model. Our results are similar to a recent study by Akpa and colleagues (Akpa et al., 2020) conducted in 13 African countries which found obese
individuals were twice likely to be hypertensive compared to non-obese individuals though this study also did not focus on individuals on treatment for hypertension.

Although many studies have been conducted on hypertension in SSA, data on the association between hypertension and obesity have provided inconsistent findings. For instance a large cross-sectional study by Lindeman and colleagues found a positive association between BMI and blood pressure even among individuals on treatment for hypertension (Linderman et al., 2018). Weight reduction can independently reduce blood pressure. Trials have shown that reduction in weight by $10 \%$ can produce significant reductions in blood pressure which in turn will reduce mortality from cardiovascular disease (Appel et al., 2006). Thus strategies that involve weight reduction would be important to assist in the reduction of uncontrolled hypertension.

Abdominal obesity is a recognized independent risk factor for cardio-metabolic diseases and it is associated with higher risk of cardiovascular disease mortality (Sun et al., 2019). As a result research on abdominal obesity has gained prominence worldwide. In this study having abdominal obesity was positively associated with having UHTN. The results from our study are similar to what other studies found (Wang et al., 2014, Zhou, 2002) though these studies also did not focus on individuals on antihypertensive medications. Nonetheless, this information will be important for healthcare providers to assess abdominal obesity in their patients when assessing their blood pressure control levels. Assessment of abdominal obesity is simple and it is recommended in clinical settings and it should form the basis of health advice given to individuals with uncontrolled hypertension.

Results from our survey can inform the need for further research, to explore why certain regions have high uncontrolled hypertension rates.

## Strengths and limitations

This study has both strengths and limitation. First, a major strength of this study is the use of individual participant level data. Second the use nationally representative multicounty data obtained from 20 countries across SSA. Third, using the World Health Organizations STEPs survey for comparability of the data across a wide range of sub-Saharan African countries. This enabled the representation of many different cultures. Fourth this is the only and largest national level and multi-country study in SSA to examine the association between UHTN and specific comorbidities making the results somewhat generalizable to SSA while contributing new knowledge on the burden and association of UHTN and comorbidities. However, there are some limitations to note. An important limitation of this study is the cross-sectional nature of the study thus causal association cannot be inferred. Secondly, a major study limitation was the level of missingness in important study variables in the country datasets which necessitated the exclusion of countries thus limiting the representativeness of the dataset for SSA. The exclusion criteria chosen for this study may have further limited the representativeness of the dataset for SSA. Adherence to blood pressure medication plays an important role in determining blood pressure control but the available data in this study did not allow us to investigate this important aspect of blood pressure control. Despite these limitations, this study provides useful information on the state of uncontrolled hypertension among individuals with comorbidities in sub-Saharan countries, which are usually not well represented or included in individual participant data analysis.

### 3.5 Chapter summary

In this chapter I examined the role of comorbidities in uncontrolled hypertension. This study has provided important evidence on the impact of comorbidities on uncontrolled hypertension among individuals on treatment for hypertension in sub-Saharan Africa. It shows that the burden of UHTN in individuals with specific comorbidities is high in sub-Saharan Africa. This study also confirms the contribution of these comorbidities to uncontrolled hypertension.

Interventions that aim at eliminating or controlling these comorbidities may help reduce the burden of uncontrolled hypertension among patients on treatment for hypertension in subSaharan Africa. Healthcare providers, program implementers and policy makers should prioritize preventive and control strategies as well as good clinical management for individuals with comorbidities with a particular focus on those with lipid abnormalities, obesity and abdominal obesity.

The vast majority of the research examining the association between hypertension and the above comorbidities have not focussed on individuals on treatment for hypertension. Thus more large scale longitudinal research with sufficient inclusion of this group are needed to understand the casual relationship between UHTN and comorbidities in SSA. Expanding the body of knowledge on research on uncontrolled hypertension and comorbidities is needed in development of policies and interventions that will promote blood pressure control among individuals on treatment for hypertension.

The next chapter involves analysis of primary data from two urban study sites. This chapter aims to estimate the prevalence of multimorbidity and its determinants. A further aim was to identify the most prevalent occurring conditions involved in instances of single- and multimorbidity.

## 4. Multimorbidity among adults in two slums of Nairobi: a crosssectional study

4.1 Background

Previous chapters have shown that comorbidities are associated with uncontrolled hypertension. This chapter estimates multimorbidity at a population level and to understand the magnitude of the problem. Primary data collected in two slums of Nairobi is used to estimate the prevalence of single morbidity, multimorbidity, and determinants of multimorbidity differentials while identifying the most common chronic condition present in the slum population. Multimorbidity is described as any co-occurrence of medical conditions within a person. The term comorbidity and multi-morbidity have been used interchangeably in the literature. Some studies use multimorbidity to mean 'the co-occurrence of several chronic or acute diseases'. A systematic review conducted in 2013 to explore the definition of multimorbidity in the literature with a focus on roles of diseases, risk factors and symptoms in the definition found that the definition of multimorbidity is heterogeneous and risk factors are more often included than symptoms while severity of conditions is seldom included (Willadsen et al., 2016).

Managing multiple morbidities has implications for patients especially since the therapies can interact positively, negatively or they can counteract the therapeutic effect of a co-existing condition. Multi-morbidity research is important particularly as sub-Saharan Africa goes through the epidemiologic transition. Research on multimorbidity has gained traction in high income countries and countries in low-and-middle-income countries have also started providing some evidence of the existence of multimorbidity (Alaba and Chola, 2013, Hien et al., 2014, Nimako et al., 2013b, Pefoyo et al., 2015). The Sustainable Development Goal 3 aims to 'ensure healthy lives and promote well-being for all at all ages' by 2030. However, if governments do not prioritize and plan for the health needs of their citizens, this SDG may not be achieved. Knowledge of multimorbidity is important for clinicians and program
implementers as it helps with decision making. However, seldom do you find studies looking at multimorbidity in low resourced settings. This study aims to estimate the prevalence of multimorbidity and its determinants in two Nairobi slums.

### 4.2 Methods

4.2.1 Data source, design and study population

The data used in this study were from the AWI-Gen study (Africa Wits-INDEPTH Partnership for the Genomic Research) - Human Heredity and Health in Africa (H3Africa) study. This was a cross-sectional household survey involving several demographic surveillance sites (DSS) in four countries; Kenya, South Africa, Ghana, and Burkina Faso. The aim of the main study was to identify the environmental and genetic factors to body composition and susceptibility to cardio-metabolic disease (de Vries et al., 2015, Ramsay et al., 2014, Ramsay and Sankoh, 2016). The main study protocol is available elsewhere with detailed information on the recruitment of the participants, sample sizes for each site as well as the inclusion and exclusion criteria (de Vries et al., 2015, Ramsay and Sankoh, 2016). The analyses for this study only focuses on the population from the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) (Beguy et al., 2015b) which is managed by the African Population and Health Research Center. The NUHDSS consists of two slum setting; Korogocho and Viwandani. Since 2002, APHRC has followed over 90,000 people in two Nairobi informal settlements every 4-6 months to update residence status, births and deaths including verbal autopsies (Wamukoya et al., 2020). In 2014, the most recent NUHDSS database was used to randomly select approximately 2,000 adults aged 40-60 years with a fairly equal representation of males and females.

### 4.2.2 Data collection and measurements

Data was collected between 2014 and 2016 using an interviewer administered questionnaire by trained field staff. Data was collected in clinics within the two slums due to the sample collection. The questionnaire had four sections: socio-demography data, past health history,
anthropometry data, and sample collection (blood and urine). Some chronic conditions were computed using anthropometry and key biomarker values while others were recorded from self-report.

Weight in kilogram ( Kg ) and height in centimeter were measured using a validated SECA $874^{\mathrm{TM}}$ weighing machine and a portable stadiometer (Seca $213^{\mathrm{TM}}$ ), respectively.

For blood pressure measurements, Omron ${ }^{\mathrm{TM}} \mathrm{M} 10-\mathrm{IT}$ validated blood pressure machine were used. Three blood pressure measurements were taken while the participant was seated. These measurements were taken five minutes apart and the average of the last two measurements were used in the final analyses for this study.

For this study, 16 conditions were identified. These conditions included chronic diseases, metabolic abnormalities and lifestyle disorders. The majority of these conditions were selfreported and the rest were from direct measurements. Table 18 below presents the 16 conditions and the assessment method used for each.

Table 18: Chronic diseases and their assessment method in the study

|  | Disease condition | Measurement |
| :--- | :--- | :--- |
| $\mathbf{1}$ | Tuberculosis | Self-report: Ever been told that you have TB? |
| $\mathbf{2}$ | HIV infection | Self-report \& test: Tested HIV+ |
| $\mathbf{4}$ | Diabetes | Self-report: Ever been told that you have diabetes? |
| $\mathbf{5}$ | Stroke | Self-report: Ever been told that you had a stroke? |

### 4.2.3 Definitions

Lifetime morbidity was defined as the proportion of individuals who have had two or more of the identified 16 conditions at some point in their life. In other words, it is the occurrence of two or more of the chronic conditions in their lifetime. Multimorbidity in this study was defined as the co-occurrence of two or more of the 16 chronic conditions in an individual (Fortin et al., 2007b).

### 4.2.4 Data analysis

All data were analysed using the Stata software. The prevalence of multimorbidity, single conditions and several conditions was computed using proportions. In addition, study participants with none up to nine conditions as a proportion of the total sample was calculated. The prevalence of multimorbidity against sex (males and females) and age in five-year categories (40-45, 46-50, 51-55, and 56-60) was computed. Lifetime prevalence was assessed for individual chronic conditions as well as combinations of the conditions. Multinomial logistic regression models were used to describe the association between lifetime multimorbidity and basic sociodemographic characteristics. The final model had the following variables; age, sex, education level, employment status, ethnicity, wealth index, current smoking status, work that involves sitting and unhealthy diets

### 4.3 Results

4.3.1 Characteristics of the study population

Table 19 presents the background characteristics of the study population. This study included 2003 individuals aged between 40 and 60 years. The majority of the study participants were females (54\%), aged 40-45 (36.1\%), and had up to primary level of education (57.5\%). Close to half (47.3\%) of the study population were self-employed while a third (31.1) were engaged in informal employment.

Table 19: Background characteristics of the study population

|  |  |  |  |
| :--- | :--- | :---: | :---: |
|  | Categories | $\%$ | Total (N) |
|  |  |  |  |
| Sex | Men | $46.0 \%$ | 922 |
|  | Women | $54.0 \%$ | 1081 |
|  | $40-45$ years | $36.1 \%$ | 724 |
|  | $46-50$ years | $26.5 \%$ | 530 |
|  | 51-55 years | $21.8 \%$ | 436 |
|  | 56-60 years | $15.6 \%$ | 313 |
|  | No formal education | $7.7 \%$ | 154 |
|  | Primary education | $57.5 \%$ | 1,151 |
|  | Secondary education | $33.5 \%$ | 672 |
|  | Tertiary education | $1.3 \%$ | 26 |
|  | Self-employed | $47.2 \%$ | 946 |
|  | Full-time employed | $13.3 \%$ | 267 |
|  | Part-time employed | $2.3 \%$ | 45 |
|  | Informal employment | $31.1 \%$ | 623 |
|  | Unemployed | $5.9 \%$ | 119 |
|  | Missing | $0.2 \%$ | 3 |
|  | Poorest | $12.0 \%$ | 241 |
|  | second | $22.5 \%$ | 451 |
|  | Wealth status | Third | 464 |
|  | Fourth | $20.2 \%$ | 405 |
|  | Richest | $22.1 \%$ | 442 |
|  | Total | 2,003 |  |

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### 4.3.2 Prevalence of individual chronic conditions

This population had a total of 2081 episodes of chronic conditions. Among the most prevalent conditions were hypertension (22.9\%), obesity (19.9\%), drug use (12.8\%), HIV (12.1\%), tuberculosis (10.9\%) and alcohol disorders (10.9\%). These six conditions together accounted for $89.5 \%$ of the total conditions identified. Diabetes, asthma, angina and kidney disease accounted for $1.8 \%-3.1 \%$ of the total conditions identified. Stroke, cancer, thyroid disease, heart attack, congestive heart failure and high cholesterol accounted for $<1 \%$ each of the 16 identified conditions. Table 20 provides more details of the lifetime prevalence's' of the 16 identified conditions.

Table 20: Lifetime prevalence of having individual chronic conditions

| $\mathbf{1}$ | Disease condition | \# | \% |
| ---: | :--- | :---: | :---: |
| $\mathbf{2}$ | Obpertension | 458 | 22.9 |
| $\mathbf{3}$ | Drug use | 398 | 19.9 |
| $\mathbf{4}$ | HIV | 257 | 12.8 |
| $\mathbf{5}$ | Tuberculosis | 243 | 12.1 |
| $\mathbf{6}$ | Alcohol disorder | 219 | 10.9 |
| $\mathbf{7}$ | Diabetes | 219 | 10.9 |
| $\mathbf{8}$ | Asthma/reactive air disease | 62 | 3.1 |
| $\mathbf{9}$ | Angina | 63 | 3.1 |
| $\mathbf{1 0}$ | Kidney disease | 50 | 2.5 |
| $\mathbf{1 1}$ | Stroke | 37 | 1.8 |
| $\mathbf{1 2}$ | Cancer | 17 | 0.8 |
| $\mathbf{1 3}$ | Thyroid disease | 13 | 0.7 |
| $\mathbf{1 4}$ | Heart attack | 11 | 0.6 |
| $\mathbf{1 5}$ | Congestive heart failure | 11 | 0.5 |
| $\mathbf{1 6}$ | High cholesterol | 9 | 0.4 |
|  |  | 2081 |  |

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4.3.3 Prevalence of a single chronic condition

Out of 2081 episodes of chronic conditions identified, 726 (36.2\%) occurred in isolation. Women had a higher ( $54.7 \%$ ) prevalence of single morbidity than men ( $45.3 \%$ ). Similarly, the youngest age group (40-45 years) had the highest single morbidity ( $35.8 \%$ ) compared to the other age groups. A further look into the 726 identified single morbidities showed that obesity $25.2 \%$, hypertension $24.2 \%$, drug use (12.0\%), HIV (12.3\%) and alcohol disorders (9.9\%) were the top prevalent single chronic conditions (Table 22). Figure 14 shows the prevalence of single chronic morbidity by age and gender.

Figure 14: Prevalence of single chronic condition by age and gender


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4.3.4 Prevalence of ever having at least one chronic condition

Majority (65\%) of the study population had at least one of the chronic conditions identified in this study. The prevalence of the at least one chronic condition was higher among women ( $68.4 \%$ ) compared to men ( $61.1 \%$ ), higher among those who attained primary level education (67.2\%) compared to those with tertiary level of education (53.8\%) and higher among unemployed participants (76.5\%) compared to those in full-time employment (52.8\%). Participants in the lowest wealth category had the highest prevalence (70.5\%) of having at least one chronic condition compared to those in the other wealth status category. Table 21 has more information on the prevalence of having at least one chronic condition in the study.

Table 21: Prevalence of having at least one chronic condition by study characteristics

|  | Categories | Have at least one <br> chronic condition? | Total (N) |
| :--- | :--- | :---: | :---: |
| Sex | Men | $61.1 \%$ | 922 |
|  | Women | $68.4 \%$ | 1081 |
|  | 40-45 years | $63.7 \%$ | 724 |
|  | 46-50 years | $62.4 \%$ | 530 |
|  | 51-55 years | $69.0 \%$ | 436 |
|  | 56-60 years | $66.8 \%$ | 313 |
|  | No formal education | $66.9 \%$ | 154 |
|  | Primary education | $67.2 \%$ | 1,151 |
|  | Secondary education | $61.3 \%$ | 672 |
|  | Tertiary education | $53.8 \%$ | 26 |
|  | Self-employed | $67.4 \%$ | 946 |
|  | Full-time employed | $52.8 \%$ | 267 |
|  | Part-time employed | $66.7 \%$ | 45 |
|  | Informal employment | $64.2 \%$ | 623 |
|  | Unemployed | $76.5 \%$ | 119 |
|  | Poorest | $70.1 \%$ | 241 |
|  | Second | $62.1 \%$ | 451 |
|  | Third | $64.4 \%$ | 464 |
|  | Fourth | $68.6 \%$ | 405 |
|  | Richest | $62.4 \%$ | 442 |
|  | Total | $\mathbf{6 5 . 0 \%}$ | $\mathbf{2 , 0 0 3}$ |

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### 4.3.5 Prevalence of multimorbidity

Figure 15 presents the prevalence of co-existing chronic conditions. A total of 576 study participants had multimorbidity (two or more of the 16 identified chronic conditions). This worked out to lifetime morbidity of $28.7 \%$. The prevalence of having two and three conditions simultaneously was $20.8 \%$ and $6.1 \%$ respectively. A maximum of nine chronic condition combinations were identified and this was only present in one individual ( $0.05 \%$ ).

Figure 15: Prevalence of co-existing chronic conditions


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Out of 2081 episodes of chronic conditions identified, 1355 (65.1\%) instances of chronic multimorbidity conditions were identified in this population. The top six chronic conditions identified in the multimorbidity combinations were hypertension (20.8\%), obesity ( $15.9 \%$ ), drug use (12.5\%), TB (11.6\%), HIV (11.4\%) and alcohol disorder (10.8\%). These six chronic conditions accounted for $83.0 \%$ of the total number of chronic multimorbidity conditions identified. Table 22 presents the chronic conditions involved in instances of single and multimorbidity.

Table 22: Chronic conditions involved in instances of single- and multi-morbidity

| Single morbidity |  |  |  | Multimorbidity |  |  |
| :--- | :---: | :---: | :--- | :--- | :---: | :---: | :---: |
| Chronic conditions | $\#$ | \% |  | Chronic conditions | $\#$ | \% |
| Obesity | 183 | 25.2 |  | Hypertension | 282 | 20.8 |
| Hypertension | 176 | 24.2 |  | Obesity | 215 | 15.9 |
| Drug use | 87 | 12.0 |  | Drug use | 170 | 12.5 |
| HIV | 89 | 12.3 |  | TB | 157 | 11.6 |
| Alcohol disorder | 72 | 9.9 |  | HIV | 154 | 11.4 |
| TB | 62 | 8.5 |  | Alcohol disorder | 147 | 10.8 |
| Asthma | 18 | 2.5 |  | Diabetes | 53 | 3.9 |
| Angina | 9 | 1.2 |  | Asthma | 45 | 3.3 |
| Diabetes | 9 | 1.2 |  | Angina | 41 | 3.0 |
| Kidney disease | 10 | 1.4 |  | Kidney disease | 27 | 2.0 |
| Stroke | 5 | 0.7 |  | Cancers | 14 | 1.0 |
| Thyroid | 3 | 0.4 |  | Stroke | 12 | 0.9 |
| Heart Failure | 2 | 0.3 |  | Heart attack | 10 | 0.7 |
| Heart attack | 1 | 0.1 |  | Thyroid | 10 | 0.7 |
| Cholesterol | - |  |  | Heart Failure | 9 | 0.7 |
| Cancers | - |  |  | Cholesterol | 9 | 0.7 |
| Total | $\mathbf{7 2 6}$ | $\mathbf{1 0 0 . 0}$ |  | Total | $\mathbf{1 , 3 5 5}$ | $\mathbf{1 0 0 . 0}$ |

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### 4.3.6 Differentials of multimorbidity

Table 23 shows the prevalence of having no condition, single condition and multimorbidity by study background characteristics. Among those with no chronic conditions, there were more men compared to women ( $38.9 \%$ vs $31.4 \%$ ), participants aged less than 50 years compared to those older than 50 years ( $36.8 \%$ vs $31.9 \%$ ), participants who attained tertiary level of education compared to those who attained primary level of education ( $46.1 \%$ vs $32.8 \%$ ), participants in full-time employment compared to those who are unemployed ( $47.2 \%$ vs $\mathbf{2 3 . 5 \%}$ ) and those in the second poorest wealth category compared to those in the poorest wealth category ( $37.9 \%$ vs $29.9 \%$ ).

For participants with multimorbidity, women had higher levels of multimorbidity compared to men ( $31.6 \%$ vs $25.4 \%$ ). Similarly, participants aged 50 years and older had multimorbidity compared to those age less than 50 years ( $32.5 \%$ vs $26.5 \%$ ). Participants in the poorest wealth
category had the highest level of multimorbidity compared to participants in the other wealth categories.

Table 23: Prevalence of chronic conditions by study background characteristics

| Factors | Categories | No condition <br> $\%$ | Single <br> condition | Multimorbidity <br> $\%$ | Total <br> $(\mathrm{N})$ |
| :--- | :--- | :---: | ---: | :---: | :---: |
| Sex | Men | 38.9 | 35.7 | 25.4 | 922 |
| Age | Women | 31.4 | 36.7 | 31.6 | 1081 |
|  | $\leq 50$ years | 36.8 | 36.7 | 26.5 | 1254 |
| Education | $>50$ years | 31.9 | 35.5 | 32.6 | 749 |
|  | No formal | 33.1 | 38.3 | 28.6 | 154 |
|  | education | 32.8 | 36.7 | 30.4 | 1,151 |
|  | Primary | 38.7 | 34.8 | 26.5 | 672 |
|  | Secondary | 46.1 | 38.5 | 15.4 | 26 |
|  | Tertiary | 32.6 | 38.2 | 29.3 | 946 |
| Employment | Self-employed | 47.2 | 33.7 | 19.1 | 267 |
|  | Full-time | 33.3 | 40.0 | 26.7 | 45 |
|  | Part-time | 35.8 | 33.9 | 30.3 | 623 |
|  | Informal | 23.5 | 38.7 | 37.8 | 119 |
|  | Unemployed | 29.9 | 39.0 | 31.1 | 241 |
| Wealth | Poorest | 37.9 | 32.4 | 29.7 | 451 |
| status | Second | 35.6 | 37.7 | 26.7 | 464 |
|  | Third | 31.4 | 38.5 | 30.1 | 405 |
|  | Fourth | 37.6 | 35.1 | 28.8 | 442 |

Reprinted from "Multimorbidity from Chronic Conditions among Adults in Urban Slums: The AWI-Gen Nairobi Site Study Findings." by Mohamed, S.F., Haregu, T.N., Uthman, O.A., Khayeka-Wandabwa, C., Muthuri, S.K., Asiki, G., Kyobutungi, C. and Gill, P., 2021, Global Heart, 16(1), p.6. Copyright (2021).

### 4.3.7 Determinants of multimorbidity differentials

The factors associated with 'single morbidity' against 'no morbidity' (model 1) and 'multimorbidity' against 'single morbidity' (model 2) are summarized in Table 24. In model 1 the base outcome is 'no morbidity' while in model 2 the base outcome is 'single morbidity'. The results of the two models show that women had higher odds of single morbidity (OR 1.23; p value $<0.01$ ) and multimorbidity ( OR 1.76 ; p value $<0.001$ ) compared to their male counterpart after controlling for confounding variables. Increased odds of single morbidity and multimorbidity among those aged 50 years and above were noted though significant associations were only noted among those with multimorbidity (OR 1.44; p value < 0.01 ) compared to those aged less than 50 years. Employment status was significantly associated
with multimorbidity. Study participants in full-time employment compared to those who were self-employed were less likely to have multimorbidity (OR 0.65 ; p value $<0.05$ ). Conversely, study participants who were unemployed compared to those who were self-employed had significantly higher odds of multimorbidity (OR 1.90; p value < 0.05 ). With regards to behavioural risk factors, current smoking was significantly associated with multimorbidity. Current smokers were more likely to have multimorbidity (OR 3.59; p value $<0.05$ ) compared to those not currently smoking. Education level, wealth status, unhealthy diet and work that involving sitting were not associated with single morbidity or multimorbidity.

Table 24: Multinomial logistic regression model for differentials of multimorbidity


### 4.4 Discussion

This study sought to estimate multimorbidity and its determinants in two Nairobi slums. This is the first study in a slum context to estimate multimorbidity and its determinants. The results of this study showed that multimorbidity is prevalent (28.7\%) in slums of Kenya. Study findings further revealed age, gender, ethnicity, employment status and behavioural risk factors are associated multimorbidity of chronic conditions. These findings add to the evidence base from sub-Saharan Africa particularly from a slum set up. Most chronic diseases such as tuberculosis and HIV have been set up as vertical programs but the results from this study suggest many individuals present with more than one chronic condition. Thus the findings call for the design of integrated chronic care models.

The high prevalence of multimorbidity in this study, is higher than what has been reported in high income countries (Freid et al., 2012, Pefoyo et al., 2015). Within the SSA region, this study's' estimate was slightly higher than what was reported in South Africa (22.5\%) (Phaswana-Mafuya et al., 2013) but lower than what has been reported in Ghana (38.8\%) (Nimako et al., 2013b). This finding is concerning because the study populations are in a slum set up and are an economically disadvantaged population (African Population \& Health Research Center (APHRC), 2012, African Population \& Health Research Centre (APHRC), 2002).

With the advancement of healthcare provision across the world, more and more people are living into old age. Advanced nations have focussed on improving their health systems to cater for the growing number of their aged population however, very little consideration has been given to reorient the healthcare system to cater to older populations in the African continent. Even though SSA has the youngest population, it is currently undergoing a demographic transition and there is evidence of unpreparedness for the older populations and the resulting emerging health trends. Among these health trends is multimorbidity which will pose a huge
economic burden to the region's health systems and economic well-being (African Population \& Health Research Center (APHRC), 2012, African Population \& Health Research Centre (APHRC), 2002, Fortin et al., 2007b). In this study, the most prevalent co-occurring condition was hypertension (23\%). Studies on multimorbidity from South Africa and Ghana (Nimako et al., 2013b, Phaswana-Mafuya et al., 2013) had similar finding which suggests an entry point to integrated care for people with hypertension.

Older age in this study was associated with both single chronic condition and multimorbidity. This finding is similar to findings from elsewhere (Marengoni et al., 2011, Marengoni et al., 2009, Nimako et al., 2013b). This finding is expected as one gets older they tend to have more comorbidities possibly due to increased exposure to lifestyle risk factors such as reduced physical activity and obesity.

In this study population, women were also more likely to have single conditions and multimorbidity compared to men. This has also been reported in other studies (Afshar et al., 2015, Barnett et al., 2012, Nimako et al., 2013b). Changes in women during their reproductive years and their physiologic make may predispose them to some chronic conditions such as obesity and hypertension (Gunderson and Clinics, 2009). A recent study done in the current study setting found that women were mostly engaged in more sedentary type of employment and they had higher levels of obesity and normal-weight central obesity compared to their male counterparts (Haregu et al., 2016, Mohamed et al., 2019). Women compared to men have an increased chance to be diagnosed early with illness because of their greater interaction with the health system (Bertakis et al., 2000, Mustard et al., 1998).

Higher levels of education in the current study was associated with lower odds of multimorbidity. This is consistent with what has been reported in other studies (Afshar et al., 2015, Barnett et al., 2012, Nimako et al., 2013b). Higher levels of education has the potential
to improve understanding of health messages which may in turn influence healthy behaviors (Scuteri et al., 2008).

Being unemployed was associated with higher odds of single morbidity and multimorbidity. Likely reasons for this finding could be that unemployed individuals do not have health insurance and hence they may have limited access to health information on the prevention of chronic conditions. It could also mean that unemployed individuals are less likely to keep jobs due to their illnesses. Further research is needed to understand this finding.

Smoking and alcohol consumption were positively associated with both single morbidity and multimorbidity. These findings are somewhat expected as both of these are known risk factors to many illnesses and are among the leading causes of death globally (World Health Organization., 2008). These behaviours are also rampant in informal settlements.

## Strengths and limitations

A strength of this study is that it uses data from an urban slum setting to estimate the prevalence of multimorbidity and its determinants. It therefore adds to the evidence base on multimorbidity from slum settings and it can be used a baseline against which future progress for multimorbidity interventions can be measured.

A major limitation was the use of self-reported chronic conditions. This is likely to have introduced bias whereby socially desirable conditions could have been over-reported and the undesirable conditions or behaviours were under-reported thus introducing some errors. The study population for this study was aged 40-60 years thus we can't make inferences beyond this age group. Given that the multimorbidity measure was a count, it did not consider the severity of the disease because having more than one condition does not necessarily translate to poor outcomes especially if the conditions are under control. Despite these limitations, this study has provided important information on the prevalence and determinants of
multimorbidity which can be used to inform the design of integrated programs for chronic care management.

### 4.5 Chapter summary

This chapter used primary data from two slums in Nairobi to estimate the prevalence of multimorbidity and its determinants. It shows that a substantial proportion of urban slum dwellers have multimorbidity. This study further highlighted age, sex, employment and behavioural risk factor differences in multimorbidity in adults in urban slums which can guide targeted interventions. Multimorbidity has huge public health implication due to the high cost it poses on the healthcare systems and individuals, increased risk of mortality, disability, and poor quality of life. This study has potential to inform public health approaches for the planning, prevention and management of modifiable risk factors that drive the high prevalence of multimorbidity. More efforts should also be placed in designing integrated chronic care models.

The next chapter will explore findings from a qualitative study addressing the reasons why blood pressure control is not achieved in current two urban slums in Nairobi, Kenya.

## 5. A socio-ecological framework examination to blood pressure control among patients with comorbidities and on treatment in two Nairobi slums; a qualitative study

### 5.1 Introduction

This chapter explores why blood pressure is not controlled among individuals with comorbidities in two urban slum settings in Nairobi, Kenya. An adapted socio-ecological model (SEM) was used to identify barriers and facilitators at the patient/individual, family and community, health system and policy level.

Previous literature has shown that economic constraints have been cited as a major barrier to blood pressure control at the individual level while having knowledge and understanding of ones' own condition are thought to be an important facilitator at this level (Gebrezgi et al., 2017). There is also literature to support the importance of family and community in hypertension management. A study conducted by Flynn and colleagues (2013) reported that family members of individuals with hypertension usually helped them with meal preparations, taking their medications and attending appointments. Similarly, another study conducted in Eritrea reported that patients with hypertension highly valued the support they received from their families and community in hypertension care (Gebrezgi et al., 2017). Health systems in SSA are already overburdened with communicable diseases. Gaps in capacity for implementation of essential non-communicable disease (NCD) intervention have been identified in low resource settings (Mendis et al., 2012). A study conducted in the slums of Nairobi also found major gaps in staffing, equipment and drugs for handling chronic diseases (Kyobutungi et al., 2010). Despite the known and effective treatments to control high blood pressure, there is a dearth of information on the drivers of large uncontrolled hypertension rates in urban slum settings (Hulzebosch et al., 2015, Olack et al., 2015, Joshi et al., 2014, Van de Vijver et al., 2013). In the previous chapters, quantitative methods were used to show how comorbidities have an effect on blood pressure control and how there is a high burden of
multimorbidity in the slums. However, apart from having comorbidities there are other barriers to blood pressure control in the slums. The use of qualitative data in this chapter will complement the quantitative data and further enrich our understanding on the facilitators and barriers to blood pressure control among people with comorbidities that exist at different levels of the socio-ecological model. This chapter will also explore why treated patients with hypertension still have uncontrolled blood pressures.

### 5.2 Methods

5.2.1 Conceptual framework

Using the socio-ecologic framework as a guiding framework, this study examined the multiple levels of factors associated with uncontrolled hypertension. The use of this framework provided a wholesome approach in looking at barriers that can provide information for the design of multi-level interventions to manage uncontrolled hypertension.

### 5.2.2 Study site and participants

The study was conducted in two informal settlements or slums in Nairobi (Kenya) namely, Korogocho and Viwandani (figure 16). The two slums are located on the outskirts of Nairobi City about 10 km from the city center. The study sites were chosen as the African Population and Health Research Center (APHRC) has been running the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) in these two slums since 2003. The NUHDSS captures routine information on births, deaths and migration from households three times a year. In 2018, the NUHDSS covered 88,798 individuals in 33,462 households (APHRC 2018). The NUHDSS (Beguy et al., 2015a) provides a sampling frame for many nested studies including AWI-Gen study (Ali et al., 2018) from which this current study drew its study participants from. Briefly, the AWI-Gen study collected data on sociodemographic, anthropometric, biomedical and genetic information from 2003 study participants between the ages of 40 and 60 years in the NUHDSS using a cross-sectional survey.


Figure 16: Map with the location of the Nairobi Urban Health and Demographic Surveillance System (NUHDSS) sites (Korogocho and Viwandani).

Reprinted from "Health \& demographic surveillance system profile: the Nairobi urban health and demographic surveillance system (NUHDSS)." by Beguy, D., Elung'ata, P., Mberu, B., Oduor, C., Wamukoya, M., Nganyi, B. and Ezeh, A., 2015, International journal of epidemiology, 44(2), pp.462-471. Copyright (2015).

The AWI-Gen sample described above was used to purposively sample residents of the two slums with uncontrolled hypertension and comorbid conditions using the participants' most recent blood pressure measurements (collected in 2018). All participants from the community were adults aged 45 years and older, previously diagnosed with hypertension, and had at least one of the following comorbidities; diabetes, dyslipidemia and overweight/obesity in 20142015 AWI-Gen survey, and were receiving care for uncontrolled hypertension. Healthcare providers in the community and relevant decision/policymakers at county and national level were also approached.

### 5.2.2.1 Description of the health system

The health sector in Kenya comprises the public system and the private sector (Muga et al., 2005). Kenya's health sector is defined by six levels of preventive and curative health service provision ranging from level I-VI. Most of the Kenyan health system is devolved and it is
managed by the county governments as stipulated in the 2010 Constitution. Level 1-V are managed by the counties while level VI is managed by the national government. Level I are community facilities that provide very basic services. They provide the first contact with patients at the lowest level of the public health system. These facilities are manned by medical clinical officers and they provide services such as home visits, treatment of minor ailments like diarrhoea, Tuberculosis (TB) and HIV screening, screening of malnutrition, blood pressure and blood sugar testing. Level II are health dispensaries run by clinical officers. They provide services such as outpatient services, well baby clinics, laboratory services, curative treatment, pharmacy, antenatal and postnatal services, and counselling services. Level III are health Centers also considered to be small hospital. The day to day activities of these facilities are run by at least one doctor, clinical officers and nurses. In addition to providing level II services, they also provide maternity in-patient services, dental care services, TB clinics, HIV clinics, and hypertension and diabetes clinics. Level IV are County hospitals that offer a wide range of services. They are ran by a director who is should be a healthcare professional. In addition to providing all Level III services, they also provide X-Ray services. Level V are the county referral hospitals. They are run by Chief Executive Officers who are health profession. These facilities have at least an in-patient capacity of over 100 beds. They provide specialized services such as ultrasound, CT-Scan, Surgery, physiotherapy, orthopaedics and occupational therapy. Level VI are three Teaching and Research referral hospitals. In addition to Level V services, they also provide specialised treatments to patients.

Korogocho and Viwandani slums have limited access to healthcare. Most of the facilities in the two slums range from Level I-III. Both of the two slums have only one public health center and numerous private pharmacies (Ahmed et al., 2020). The majority of facilities offering healthcare are private facilities that charge for healthcare services.

### 5.2.3 Study design

Qualitative studies can provide more understanding and meaning of local context while generating knowledge that can contribute to understanding of an issue by delving deeper into the issues (Petty et al., 2012a). They also provide rich perspectives and experiences of study participants (Gill et al., 2008). This study used a phenomenology approach to gain an in-depth understanding of the facilitators and barriers in controlling blood pressure among patients who are on treatment for hypertension and have a comorbid condition. A phenomenological approach is a form of qualitative enquiry that emphasizes lived experiences of individuals by exploring the meaning of a phenomenon while gaining a deeper understanding of the phenomenon (Petty et al., 2012b). The main goal of this approach is to identify a phenomena by how it is perceived by those with the lived experiences (Lester, 1999). The consolidated criteria for reporting qualitative research (COREQ) was adopted in this study.

Data were collected via focus group discussions (FGDs) and individual interviews. In-depth interviews were used because they provide rich participant views and allow for issues to be explored in more depth (Gill et al., 2008, Kvale, 1996). FGDs were used to supplement the interviews because they give participants an opportunity to reflect on other participants' views while building on their views and they give a good understanding about participants' views on the topic of interest (Gill et al., 2008, Kitzinger, 2005, Petty et al., 2012a). The combination of methods were chosen because they provide different aspects of participants' and stakeholders' views on facilitators and barriers of blood pressure control in the study population. In-depth interviews (IDIs) and FGDs were conducted among people with uncontrolled hypertension and comorbidities while on hypertension treatment. Key informant interviews (KIIs) were conducted among key actors shaping hypertension care (healthcare providers, and decision/policy makers).

### 5.2.4 Characteristics of study participants

As shown in table 25 , a total of 57 people participated in the study. There were slightly more females 30 (53\%). Thirty-one IDIs (15 in Korogocho and 16 in Viwandani) were conducted. Two FGDs were also conducted; one in each of the two slums.

Eleven KIIs were conducted among healthcare providers in service provision for hypertension in the two study communities. Another five key stakeholder interviews were also conducted with representation from the ministry of health; two from the national level and three others were from the sub-county health levels.

Table 25: Sample characteristics

| Interview type |  | Participants |
| :--- | :--- | :--- |
| Site 1: Korogocho |  | Number |
| In-depth interviews (IDIs) | Males | 6 |
|  | Females | 9 |
|  | Males | 4 |
|  | Females | 1 |
| Focus group discussions <br> (FGDs) | Males | 3 |
|  | Females | 2 |
| Site 2: Viwandani |  | 5 |
| In-depth interviews (IDIs) | Males | 10 |
|  | Females | 3 |
|  | Males | 3 |
|  | Females | 3 |
| Focus group discussions <br> (FGDs) | Males | 3 |
|  | Females | 3 |
| Site 3: National/county level |  | 2 |
| KIIs - Decision and policy <br> makers | Males | 57 |
|  | Females |  |

### 5.2.4.1 In-depth interviews and focus group discussions

Both IDIs and FGDs were conducted among participants with uncontrolled hypertension and have also comorbidities to understand their experiences and views about their hypertension care. They were also asked about facilitators and barriers to blood pressure control and solutions to the barriers mentioned at each of the SEM levels. The sample size was determined
by theoretical saturation (Sebele-Mpofu, 2020). Once no new information was emerging from the interviews, data collection was stopped.

### 5.2.4.2 Key informant interviews with key stakeholders

For the key stakeholders' interviews (policy/decision-makers and healthcare providers), an initial list of purposively selected study participants was generated with varying representation in sectors. Their selection was based on their role in hypertension care provision in the community or their ability to influence policy and decision making for hypertension care. Snowballing (Boyatzis, 1998) was also used to identify additional key informants during interviews with the initial key informants selected. Key informant interviews were conducted with decision/policymakers to get their views on the challenges in the access and uptake of hypertension care in the study community and what can be done to improve access and uptake of hypertension care while interviews with healthcare providers sought to ascertain the healthcare providers' prescription practices, conformity and knowledge of national guidelines, and how they treat patients with comorbidities. Both categories of the key stakeholders further provided their views on factors associated with uncontrolled hypertension in the community using the different levels in the SEM framework as a guide. Sample size was determined by theoretical saturation (Sebele-Mpofu, 2020). There were five and six interviews held with health care providers from Korogocho and Viwandani respectively while a total five interviews were held with policy/decision makers at the national level and sub-county levels.

### 5.2.5 Guide development, training of interviewers and pilot study

The initial topic guides were developed from the literature review informed by the conceptual framework. All study participants were asked to describe facilitators, barriers and solutions to blood pressure control at different levels of the adapted SEM (patient, family or community, health system and policy level). These guides were further revised following the pilot study. Three guides were developed (Appendix 2).

Two female interviewers from the community collected the data for this study. Both had previous experience working in the community and had prior experience conducting qualitative interviews. They were conversant with the local language (Swahili) and the cultural nuances in the community. The team were trained on the study rationale, objectives, study approach, the data collection procedures to be employed, note-taking during interviews and phone based interviews. They were further trained on research ethics and the study's informed consent process. The team also reviewed the guides to understand the purpose of each question and the objective it answered. The training involved presentations, open discussions, demonstrations and role plays.

Following the training exercise, a virtual pilot study was conducted. The pilot study was undertaken outside the study areas to test all the study guides. A debriefing session was held following the pilot exercise to discuss questions that were unclear, had wrong instructions, questions respondents struggled with or questions that were difficult for the participant to understand in all the developed guides. The guides were then revised accordingly before the actual the data collection.

### 5.2.6 Data collection

Due to the COVID-19 pandemic, most of the interviews were conducted on phone. The FGDs were conducted in a face-to-face set up that adhered to COVID-19 measures. In the original data collection plan, blood pressure measurements were to be confirmed from the second round of data collection for the AWI-Gen study, which was to start in first quarter of 2020. However, due to the COVID-19 pandemic, the AWI-Gen team were unable to start their data collection hence we were unable to get blood pressure measurements to confirm the blood pressure control status of the study participants. We therefore resorted to using the return of results blood pressure recordings from 2018 for selection into the study and also asked the participants during the interview to share their most recent blood pressure recordings.

Before the interviews begun, all study participants were asked to complete a brief questionnaire to provide their demographic information. During data collection, the data collectors submitted their daily summary notes and several debriefing sessions were held with the interviewers to assess the quality of data that were collected. Data collection took place from June to August 2020. The interviews took 45-120 min to complete. Data collection was stopped when theoretical saturation was reached - no new information was being generated from the interviews (Sebele-Mpofu, 2020).

### 5.2.7 Analysis

All interviews were recorded. Audio-recordings were first transcribed verbatim by a professional. These transcripts were then translated into English by an independent translator. Transcripts were reviewed daily by myself (SFM) as soon as they were ready to get a sense of theoretical saturation. All the transcripts were imported into NVivo software (version 12, QSR International) for coding and further analysis.

The analysis was guided by Braun and Clarke's six steps to conduct thematic analysis (Braun and Clarke, 2006). Table 26 gives a description of the steps involved. These steps are there as a guide and they can be used in a non-linear way to analyse data. Coding and identification of quotes to go with each theme was done by two independent researchers (myself and TNM). The initial process involved immersion in the data to get a deeper understanding of the data and codes/themes emerging while increasing the inter-coder reliability and validity (Campbell et al., 2013). From this process, a codebook with codes that correspond to facilitators, barriers and solutions to blood pressure control was initially developed. This codebook was further revised to add themes and sub-themes that corresponded to different levels of the socioecological model (individuals/patients, family and community, health system, and policy level) to guide analysis using a thematic analysis method (Clarke and Braun, 2013). Many sub-themes were identified along with relevant quotes to match each code. Codes were further collapsed
to form themes and sub-themes. Several analysis iterations of the interviews and FGDs were done in the development of the main themes and sub-themes. Following back and forth discussions among the two researchers (myself and TRM), a consensus was reached on the final set of themes and sub-themes (saturation point) from the coding process when no new sub-themes were identified. Due to limited resources, we were unable to present the research findings to the participants to ensure the participants' perceptions were represented and not the researchers' perspective.

Table 26: Description of the six steps involved in thematic analysis

| Steps | Description of the steps |
| :---: | :--- |
| 1. Familiarising oneself with the data | This step requires full immersion into the <br> data. This involves reading and re-reading <br> the transcripts and listening to the audio- <br> recording to familiarise oneself with the data. |
| 2. Identifying initial codes | This step involves the identification of <br> preliminary data. These codes are elements <br> of the data that are important. |
| 3. Identifying emerging themes | This step is the start of interpretive analysis <br> of collating the codes. This involves <br> collapsing the codes to form overarching <br> themes. |
| 4. Reviewing the themes | This step requires a deeper review of the <br> identified themes. It involves decisions of <br> whether to split, combine or form new <br> themes. The themes formed at this stage need <br> to be distinctly different. |
| 5. Definition and naming of the themes | This step involved defining and naming the <br> themes and subthemes from the data. |
| 6. Writing up the report | This is the final stage that brings the story <br> together. It involves interpretive writing that <br> uses extracts that illustrate the themes and <br> research questions |

All the data were analysed and integrated together in the presentation of the themes. Eight major themes were developed. These were facilitators and barriers to blood pressure control at the 1) patient/individual level, 2) family and community level, 3) health system level and 4) policy level. The solutions to the above barriers are also presented as separate themes.

### 5.2.8 Ethics

This research study was approved both by the AMREF and University of Warwick ethical review boards. Informed consent was collected from all participants in accordance with approved ethical procedures and guidelines. All the interviewees were aware and gave consent to have the sessions audio-recorded.

### 5.2.9 Reflexivity

Reflexivity has been describes as a process of a continual acknowledgement, recognition and self-evaluation of one's positionality and how this may affect the entire research process (Berger, 2015). In the current study, I needed to consider the ways in which my interactions with participants might influence my interaction with them given my background, experience and prior assumptions. I have a background in pharmacy and I have worked in public health research for the last 10 years. I therefore continually reflected on how my professional and research background may have impacted on the study participants' interaction with me, their willingness to be free and have open discussion and how this would shape the research. My hope was that study participants would be comfortable discussing all aspects of hypertension care from different perspectives and not to focus on what they perceive I would be more interested in hearing about.

Prior to commencing my PhD , I was working and still continue to work at a research organization that implements several research studies in the two sites. I had therefore interacted with the study community as a healthcare professional and at a project management capacity. Based on my positionality in the community, I felt that the participants would not openly discuss their experiences and views with me. So in order to preserve the rigor in my research, I made the decision not to be the one collecting this data to avoid the assumptions the study participants may form with me collecting this data. While I recognize there are advantages to having me as an insider collecting this data, there are also advantages to having an outsider (someone else) collect this data. Some of the advantages of using an insider to collect this data
include having a connection with the study participants, participants' being motivated to be in the research and having knowledge which comes with experience. Advantages of having an outsider collect this data include being more balanced, being less emotionally involved and being less threatening to the study participants.

Throughout the study processes, I continued to acknowledge and reflect on my assumptions, beliefs and personal experience by keeping notes on the different processes of the study. In qualitative research, researchers need to continually evaluate their subjectivity in the research process and how this may assist or challenge the process of creating true representation (Finlay, 2002). It was important that I understand my role in creating knowledge on uncontrolled hypertension while acknowledging my subjective bias in the topic (Berger, 2015, Finlay, 2002). To ensure researcher reflexivity, I made notes after reading each transcript because I also wanted to make sure I provided a true representation of the data rather than providing my assumptions based on my beliefs or personal experience with the topic. I then had several debrief sessions with the study team to understand what their thoughts and perspectives were in the data that was collected. In addition, the coding of the data was done by myself and an independent researcher. I held several discussions with the independent researcher (TRM) on the selected themes and sub-themes until a consensus was reached on the final set of themes and sub-themes. The additional use of an independent researcher who is a nutritionist also conducting duplicate data analysis was important in providing a range of different expertise in the analysis of this research. The decision to have a data collection team, the engagement with the data collection team, the use of an additional experienced independent coder, the meetings with the data coder, keeping notes throughout the research process all helped me in maintaining reflexivity.

### 5.2.10 COVID-19 implications

Planning data collection for my PhD research during the COVID-19 pandemic was overwhelming. Several regulations and restrictions including lockdowns, banning of
gatherings, closure of learning institutions, remote working among others were imposed by the Government of Kenya as I was about to start my data collection. To enable me to continue with data collection, I had to reapply for both the University of Warwick and the local IRB ethical approval to demonstrate how I was going to protect the target respondents and field staff. This involved redesigning my data collection methods to include remote data collection and adherence to the COVID-19 protocols. Data collection was also very challenging as I was also balancing my work with caring responsibilities and forced home schooling. Despite all these challenges data collection continued.

### 5.3 Results

5.3.1 Organisation of the results

The results from this research are organized to match the various levels of the study's conceptual framework. The first section provides integrated results from the interviews and FGDs looking at the facilitators, barriers and solutions to blood pressure control at the patient, family and community, health system and policy levels according to the SEM framework. This is followed by a discussion of the findings and a conclusion of this chapter with recommendations.

### 5.3.2 Patient level facilitators and barriers

Knowledge, behaviour, practices, and healthcare experiences of residents who had uncontrolled hypertension living in the selected study sites were explored. The findings showed that patient's blood pressure control was facilitated by having a fair understanding of what they needed to do. They mentioned adherence to medication, frequent monitoring of BP , salt reduction, physical activity, diet control, weight control and lowering of alcohol consumption as key facilitating components of hypertension management. Monitoring of blood pressure regularly was mentioned and the monitoring ranged from daily, every three days to every three months. A good number of respondents recorded their readings for future reference. Respondents also noted that they knew what their target blood pressure was supposed to be.
> "When we go for clinics we are told to be walking for long on foot and not just sit in the house, we are also advised not to [take] motorbikes every now and then. We are told to do exercise by walking because walking for long distance helps in lowering the blood pressure...High blood pressure entails the use of things that are supposed to be used like fruits, medicine and one to follow what the doctor advices him or her to do... [IDI (Korogocho), UHTN participant, 200712-001, female, 54]
> "I was told that I am not supposed to take a lot of salt and again I used to love meat so much but nowadays I do vegetables a lot but just a little meat because meat is good but not too much of it. I used to take a lot of salt and I think that's what was affecting me so much" [IDI (Viwandani), UHTN participant, 200715_005, female 56].

Respondents mentioned managing stress as a facilitator in controlling their blood pressure.
They felt it improved their emotional and physical health, which ultimately lowered their high blood pressure. Stress management techniques mentioned included exercising, listening to music, focusing on something calm or peaceful and talking to their friends.

R1: "My experience is staying away from many issues that can make me get angry or make me think a lot.... You also need to commit yourself or avoid them because this condition [HTN] gets worse when you engage yourself in many thoughts. It becomes worse when you come across something that annoys you" [FGD (Korogocho), UHTN participant (R1), Male 61].

Despite the patients' experiences of how to manage their blood pressure, study participants frequently reported poverty because it restricted their access to medication. This was a significant barrier to blood pressure control in their communities. The majority of the participants repeatedly reported not getting medicine at the health facilities they visited and that unaffordability of hypertension medications affected their adherence to blood pressure medications. The situation during the data collection period was worsened by the COVID-19 pandemic with many people losing their jobs. Given the reality of low financial resources in the study area where sources of income were limited and wealth status was low, high costs of the medicine were felt to constrain the success of medication adherence. Respondents noted that they would only buy the medications that they could afford and stay without medications on the days they could not afford. Concerns about the cost of hypertension care went beyond
the cost of medication to include other associated costs including consultation, testing and transport.
"The problems that I face is like sometimes I don't have money to buy drugs and when I go to the hospital I am told that the drugs are not available and the doctor directs you to go buy the drugs at the chemist yet you don't have money. You will just have to stay with your high blood pressure condition because you don't have money. That's one of the challenges that we face" [FGD (Korogocho), UHTN participant (R1), Male 61]
"I think the drugs are very expensive and sometimes you go to the hospital but you don't find drugs and when you go to the chemist you find that the drug that can last you at least for one month goes at 5000 shillings and maybe you need two types. Someone is forced to by a quarter dose instead of buying the whole dose." [IDI (Korogocho), UHTN Participant, 200712_2239, Male 58].

Having some sort of health insurance coverage was mentioned as providing access to healthcare. Patients reported getting treatment in some health facilities was facilitated by having health insurance.

Respondent: There are some areas where my insurance card helps me and other places I use cash so if I go there then I will not be assisted the way I am supposed to be assisted [IDI, (Korogocho), UHTN participant, 200712_2239, Male 58].

The few individuals that mentioned having health insurance, mentioned having the National Health Insurance Fund (NHIF). This was reported as the government initiated health insurance that is mainly accepted at government (public) facilities as well as a few other registered health facilities in the community. Even though the public facilities accepted the NHIF, study participants reported that they hardly had medicines in stock. Others also mentioned that the facilities did not accept their insurance because the government was not reimbursing the health facilities for the services they provided. Healthcare providers noted that not having health insurance was a barrier to blood pressure control because the alternative would be to buy the medication though many patients in the community were not be able to afford.
"I tried using it but I was told that they don't take that because they don't get money from insurance. I had to pay with my money to access treatment" [FGD (Viwandani), UHTN participant (R4), Female 57].
".... currently as we talk, patients are really running away from public facilities because
they say even if you are an NHIF if you are not a cash patient you are told even a [pain medicine] go buy. So at times you find that you are told to buy, you don't have that money, yet your NHIF deduction has been made" [KII (Viwandani), Health care provider, 200701-0035, 0426, 0425].
"The most immediate challenge is finance. Funding. You know $\qquad$ (Not clear) conditions they don't have any form of insurances like NHIF that is also a challenge because they can't afford" [KII (Korogocho), Health care provider, 200625_002].

Respondents noted that they were conflicted on whether to spend the little money they had on food or medicine to control their blood pressure. There was a perception among the patients that they had to eat well before taking their medications.
"I went there and I was told to go buy but sometimes I find that I don't have money to buy drugs, I just buy a little flour so that my kids can eat. It is hard to choose whether to buy drugs or food for my kids. That's the challenge that I face [IDI (Korogocho), UHTN participant, 200713_0720, female 55].
..... "I always feel good when I have those drugs even though there is still a challenge sometimes like one feels bad when there is no food. You feel like you are losing sight and the legs become weak so it is always important that you eat foods that give your body energy for you to be able to take drugs" [IDI (Viwandani), UHTN participant, 200715_007, female 53].

Participants also reported that their low economic status inhibited their ability to follow the recommended diet stating that the diet recommendations did not consider their financial status since they could only afford one meal a day. In addition, there was a challenge when only one individual in the family had hypertension or another comorbidity, thus requiring that there are two budgets to cater for food in the family, which was considered unfeasible.
"Feeding is a problem because traditional vegetables are expensive and sometimes we have to eat kales when we can't get traditional vegetables and again we only eat one meal a day" [IDI (Korogocho), UHTN participant, 200710-001, female, 44].
"you go to a seminar where you are taught on what you should eat and the food that you are advised to eat are expensive compared to the food that is prepared for the other people at home and you can't buy your food and let others go without. You are forced to eat what is available because that's what can be used by the majority at home. This endangers you to an extent that it becomes hard to control your blood pressure because you are told to eat traditional vegetables but you end up taking what is available. [FGD (Korogocho), UHTN participant (R4), Female 61].

There were misconceptions and difficulties in implementing physical activity in this community. The most common exercise mentioned was house chores and walking. Some respondents stated that they were too old for exercise and they seemed to understand that exercise was only vigorous activity such as running.

I have not considered doing physical exercise unless I decide to walk for a short distance because at this age I can't engage myself in running. There is this person that was diagnosed with blood pressure and he thought that he could control it by running. He went for a running exercise at Kasarani but I don't know what happened, the guy just fell by the roadside and died...I can't do exercise because of that. Exercising can lead to my death. That's why I don't do exercise" [FGD (Korogocho), UHTN participant (R4), Female 61].
"Lack of exercise and also the work that I do requires me to sit down and I think that contributes a lot. The doctor told me that I should be doing exercise. He also recommended that I be going to the gym but for now it's not possible" [IDI (Viwandani), UHTN participant, 200722_0845, Male 50].
"Am very old, I cannot do exercise, I cannot do many things. I cannot even run" [IDI (Korogocho), UHTN participant, 200712_0542, Male 62].

Age was also mentioned as a barrier. Apart from the fact that it discouraged physical activity, it led to forgetfulness that affected the patients' care in terms of medication adherence and keeping appointments for follow up. Health care providers also noted that it was not easy to care for old patients especially those who lived alone. Elderly patients were described as vulnerable because they relied on other people for their care including food preparation and healthcare. In addition, healthcare providers mentioned that the elderly patients were stubborn and hardly followed instructions.
"My age was ok when I was diagnosed in 2014 because I had 50 something years then but it [HTN] is becoming worse as the age increases. I am 60 years now and that's why I keep forgetting some things. Thing are not doing fine" [IDI (Korogocho), UHTN participant, 200720_001, Male 60].
"There are some, most of the patients who are hypertensive or diabetic, most of them are elderly and sometimes trying to convince an elderly person to take the drugs or do exercises if you are much younger like the way I am, they will pretend to listen but then
again not do as you say, yeah. Again talking to such people is a bit of a problem" [KII (Korogocho), Health Provider, 200627_0158].
"...the other one is the old age. Explaining to that old woman that she is required to take medicine daily because her pressure is high, there are those who will not even remember their return date when they are booked. So that is hectic and when you ask her to come with a guardian or a treatment buddy she will tell you that they are working and they don't have time to come" [KII (Viwandani), Health Care Provider, 200701_0043].

The stresses of daily life and responsibility of taking care of the family were also reported as barriers in blood pressure control. Participants stated that hypertensive patients were prone to stress especially due to their low economic status that hindered their capability to buy medication and provide for their family.
"There are many factors, let's say for example like for us men when you don't have a job and you don't have money, that could be a reason that might lead to high blood pressure because you start thinking of what to tell your wife when you go back home. Children are looking up to you yet you don't have money. There are many reasons that can lead to rise in blood pressure yet it is not your wish but it's because of how life is. Us men go through a lot of issues like not having a job and not having money that lead to rise in our blood pressure" [FGD (Korogocho), UHTN participant (R1), Male 61].
"So in our community maybe hypertension is at high because people from this community are struggling to make a living that leading to stress so most suffer from the same high blood pressure because of being unable to manage stress" [KII (Korogocho), Health Provider, 200531_1126272].

Knowledge on the causes and management of hypertension was limited among the majority of the respondents and this resulted in medication non-adherence. In addition, some of the interviewees were unaware of the asymptomatic nature of hypertension and the rationale for its lifelong treatment. The idea of having to take drugs continuously was also thought to be a burden and some respondents reported that they only took drugs when they felt unwell or when they experienced hypertension side effects. Medication side effects were a significant barrier to blood pressure control in the community. Some respondents reported having to stop taking their medications due to unfavourable side effects.
"when young people have high blood pressure, they become depressed and ask if they will be taking the medication throughout their lifetime. They fear taking the medicine for a long period" [KII (Viwandani), Health Care Provider, 200703_0034].
"The first thing is that my body is weak because there are some tasks that I cannot do, I can't do any heavy task or if I do then I'll be taking rest every now and then and the other thing is like my manhood is not active...not following instruction and not taking medicine though some medicines have side effects, side effects make some people to stop taking medicine like for example the one that I mentioned about my manhood. One decided to stop taking certain types of drugs when he sees such" IDI (Korogocho), UHTN Participant, 200712_2239, Male 58].

While patients possessed some general knowledge of their condition and hypertension, the level of knowledge was limited. Only a few patients were able to recall what their optimal BP was or could identify their target BP as informed by the health care provider and not all could remember their most recent blood pressure measurements.

Behavioural factors such as smoking and alcohol consumption were noted by health care providers to be rampant in the study community and this was a significant barrier to blood pressure control.
"There are some patients especially men who have already been diagnosed and when they come here, maybe it is their first time they come here, some of them don't know if they are hypertensive you see when you are taking history or maybe when they come, they have already taken alcohol. You know you can immediately know someone who is drunk and smelling alcohol. Then when you try to take history you find that he takes alcohol and maybe cigarettes and every time he comes to attend clinic you see that he is drunk. So you see someone is taking drugs when he is taking alcohol and those other cigarettes, it's very hard to control blood pressure" [KII (Korogocho), Health Care Provider, 200709_0207].

Most respondents reported that they also had other comorbidities complicating their management. Comorbidities were mentioned as a barrier to practicing lifestyle changes to control hypertension especially diet modifications. In addition, the comorbidities meant that the number of drugs increased which was a burden to the patient. The most common comorbidity mentioned by respondents was diabetes.
"From the time I was diagnosed in 2001, I only knew because I had another condition and when I saw that the doctor had prescribed HTCZ [drug] for me and when I knew
more about pressure is when I realized that I was given that drug because I had blood pressure" [FGD (Korogocho), UHTN participant (R3), Male 61].
"For me am both diabetic and hypertensive so I think I have two challenges, one comes from the way am supposed to manage diabetes and the way am supposed to take antihypertensive [medications] to control my blood pressure but the biggest challenge that I have is to control diabetes that is causing high blood pressure" [IDI (Korogocho), UHTN participant, 200712_2239, Male 58].

In addition, denial and use of herbs was mentioned as a barrier by both healthcare providers and participants with uncontrolled hypertension.
"I can say is the denial because some of them they don't accept at all and also herbal because others have myths that if you take $A B C D$ you should. For example if you take lemons or those ABCD they can heal" [KII - Health care provider, 200630-0306].

Respondent: they decide to just either use herbal medicine or just staying and just hope that the blood pressure will lower on its self. [KII (Korogocho), Health care provider, 200627_0158].

### 5.3.3 Proposed patient-level solutions

Most of the solutions recommended at this level were around securing resources to enable the patients to access hypertension care. Patients recommended income generating activities to enable them buy medications and cater for their other expenses. Patients also reported that if they could get free medication, then that would reduce their stress and in turn their blood pressure would be controlled. Others thought a change in their environment would help control their blood pressures. Some knew they needed to take their medications in order to control their blood pressure and so they felt it was important to work hard in order to pay for their medications.
"for me I would really be happy if I can get someone to finance me get those drugs and food, change my current way of life, the place where am staying so that I can stay at a place with some fresh air and clean environment" - [IDI (Korogocho), UHTN participant, 200711_001, Female 58].
"The solution would be finding ways in which we can be getting money so that we can be able to get drugs and food easily. If you have money then you will be able to eat as the doctor wants you to eat and you will be able to get drugs" - [IDI (Korogocho), UHTN participant, 200720_001, Male 60].

Policymakers felt it was important for patients to be educated on their condition and how they can manage themselves well. Patients with hypertension felt that getting advice from the health care providers was important for their care. Health care providers suggested using community health volunteers (CHVs) with similar characteristics as the patients (e.g., an elderly CHV to pass the message to the patients in a language they understood).
> "Most important for me is education. If we have education for the clients to understand what they are going through and how it can be managed. We need to empower them with information. You know if we demystify the disease at their level, teach them how to control so that they take care of their generations". [KII policy/decision maker, 200629_2302].

> My doctor should advise me on what I should eat and what I should not eat" [FGD (Viwandani), UHTN Participant (R6), Male 56].
> "As for those, when we are giving health talks, I can also get a CHV who is elderly maybe to also talk at the same time. With that they will be convinced that someone experienced is also talking about the same thing. I can be doing health talks with a community health worker who is also elderly then that will solve that issue" [KII Health care provider, 200627_0158].

### 5.3.4 Family and community-level facilitators and barriers

The availability of CHVs who work in the community was seen as a facilitator for blood pressure control in the community. The CHVs were credited for supporting the elderly in taking medication, giving hypertension information to the community members and referring patients to the hospitals for further care. In addition, the CHVs supported the health providers in reaching those who did not come for the BP clinics
"Sometimes I am helped by those people who bring medical services here [CHVs]. At this moment there is one called [name] who comes to help me...we are advised on how we can live with this condition, how we can be eating or drinking" [IDI (Korogocho), UHTN participant, 200710_002, Female 56].
"As for now there are many programs that are addressing hypertension in the community... We've had some CHVs who give health talks to the community... Who are referring patients to us from the community. They were given some blood pressure machines to be going around taking the blood pressures then they refer those that have high blood pressure to the facility". [KII - Health care provider, 200627-0158]

Ok, here at [place] we have community health volunteers and most of them are in contact with the clients and sometimes they trace the patients who have been absconders of the clinic. [KII - Health care provider, 200531-1126272]

In addition, having social and physical support from family members to help the elderly clients was mentioned as an important facilitator. These family members were reported to provide health care assistance including accompanying the elderly to the health facilities for their regular appointments, supporting them in adhering to medication use as advised, and reminding them of the appointment dates.
$\qquad$ If at all an old lady comes and you ask her to bring along the her guardian and [the guardian/care provider] agrees to bring them and they agree that they stay together and she will be giving her the medicine as you have instructed, she will be attending her clinics, if they do the investigations like the ones that are supposed to be done after every six months then it becomes nice but if the patient comes alone and she is old, then there is nothing that you can do". [KII - Health Provider, 200701_0043].

Most participants reported having easy access to clinics where they went for screening and medication. They reported these clinics to be near their homes and therefore did not require a lot of resources to get to them. The community was reported to have both public and private health facilities. The community members went outside their community when they needed specialised care and when referred.

Some patients reported their neighbourhoods as supportive environments for blood pressure control. They noted getting support from neighbours with regards to food and money to buy medicines when they could not afford to buy for themselves. The community environment was also described by some respondents as an avenue to de-stress. Respondents noted that they would assist their friends and neighbours when they felt stressed for social support. The friends and community members also tried not to stress the patients.
"There are mothers who assist me when I don't have food to eat. They bring me food or even bananas and they tell me to cook because my son is not capable. He was stopped from working after cases of COVID-19 were identified in Kenya." [IDI (Korogocho), UHTN participant, 200710_002, Female 56].
"I just go to the chemist and buy the medicine when I have money and if I don't have money sometimes I cry so much that a neighbor gets money to go buy me the drugs" [IDI (Korogocho), UHTN participant,200711_004, Male 56].
"Respondent: I go meet my fellow women where we share ideas to avoid thinking so much or I can to a noisy place like where I was then and try to think of good things" [IDI (Korogocho) UHTN participant,200710_002, Female 56].

Despite the aforementioned facilitators, many barriers were mentioned at this level. Even though many patients reported accessing care in the community, other patients had to go far from their homes when they needed specialised care, which was a barrier as they needed to have transport. In addition, patients who wanted to avoid the stigma associated with having hypertension opted to seek care far from their homes.
"Transport to come to the facility. Maybe [it] is their due date [appointment] to come to the facility, someone doesn't have means to get to the facility". [KII - Health Provider, 200531-1126272].

An unsupportive family environment was noted as a barrier in the community. Participants with hypertension reported not being able to eat different foods as required for their condition from those consumed in the house. Patients also reported that the foods they were expected to consume were expensive for them to buy. Some respondents also noted that there was no one to accompany the elderly patients for their appointments and language was sometimes an issue. Others mentioned the noisy community environment also meant that it was not conducive for blood pressure control. Since family members are involved in influencing the lifestyle of the patients, including the food they eat and the money and time given to seeking health care and adherence to medication, lack of information among them led to lack of support. Patients also reported a stressful home environment as a barrier. Uncooperative spouses, alcoholic and drug abusing children were among the stresses mentioned.
"Yes, I have a daughter who has been disturbing me and sometimes she makes my blood pressure to rise that's why I told you that family is the main cause" [IDI (Korogocho), UHTN participant, 200721_003, Male 50].
"I think its misunderstanding; maybe your family doesn't know your condition because this condition doesn't want one to be angered, when you are angered then the blood
pressure rises, the other issue is food, maybe they have prepared a different type offood when you are supposed to take a different type so you don't understand each other." [IDI (Korogocho), UHTN Participant, 200712_2239, Male 58].
"Yeah, the other thing is lack of support. Some families don't support their loved ones because you can see an elderly person who has kids but she can't be brought for medication. From the community we can say lack of information the same as ignorance" [KII - Health care provider, 200701_0043].

Participants also reported stigma that they experienced as patients with hypertension. This led to the patients having to travel far to seek medical attention just to conceal their HIV status.

Another barrier identified at the family/community level was the lack of knowledge within the community which has led to myths and misconceptions in the community about hypertension. For instance, some people in the community believed that being diagnosed with hypertension was a death sentence hence there was no need to seek medical care while others thought that once one has hypertension, it is not treatable or manageable. Myths and misconceptions in the community were also reported as barriers.
"[at the] community and family level, you will understand that stigma is one of them ...many [have] stigma and they are in denial...when one is in denial and [have] stigma, you will find out that the stigma from the community will cause it...Or some, some due to those underlying factors that we talked off, they have to travel very far so that the community does not understand them very well...for instance there is one that is HIV positive and also hypertensive...they won't come to the facility around due to stigma" . [KII - Healthcare provider, 200626-001].
"Myths and misconceptions in the community about hypertension... In the community of course people believe that hypertension kills, so someone is not supposed to be stressed when they find out they are hypertensive. So once someone is diagnosed with hypertension and of course he or she has ever heard someone say that if you have pressure then just start counting your number of days to live on this earth.. So someone just have negative attitude towards maybe medication. Even if they come for clinics, back in the community they know that we are caring for the dying even if we are trying our level best" [KII - Healthcare provider, 200531-1126272].

Respondent: "So once someone is diagnosed with hypertension and of course he or she has ever heard someone say that if you have pressure then just start counting your number of days to live on this earth". [KII - Healthcare provider, 200531-1126272].
"And many don't believe that, rarely believe that hypertensive is treatable". [KII Healthcare provider, 200626-001].

Participants noted an increase in number of traditional healers and it was thought that they may be affecting the patients with hypertension adversely.
> "I think traditional doctors are increasing in number and they don't know what they are doing or they are doing some things that might affect other people. There are those people who go to seek care from those people and I think it is not good. The government should create awareness and awareness should be created on hypertensive and diabetic patient so that they can know where they can go to seek care. Some are told that if they eat somethings they will help them in managing their blood pressure and they end up losing their money" [IDI (Korogocho), UHTN participant, 200712_2239, Male 58].

Lastly, the environment where the study was carried out came up as a barrier for a number of reasons. The limited space in the urban informal settlements discouraged exercise and walking due to congestion. In addition, the environment impacted on the foods the patients consumed. Also, it was reported that behavioural factors such as alcohol use and smoking were rampant in the community and this affected blood pressure control in the community.
> "As an individual I am supposed to do exercise but I don't do because of congestion. There is no space to do exercise at the place where I stay especially with this corona and even if it is going to the gym them you have to pay so I don't do exercise. Secondly I don't eat the way I am supposed to eat at home. I have both big and small kids in high school and in primary school. They are big kids so when we talk sometimes I have to be calm so that we can relate well. Avoiding thinking becomes hard because as we are here, I still have to provide food today. I am thinking of what to do after I leave this place yet we are told to avoid thinking" [FGD (Korogocho), UHTN participant (R3), 200807_1015_01, Male 63].
> "In terms of physical and structural we also realize that there is no adequate space for physical activities...and where there's space there is the issue of security...especially in the informal settlements...because you expect them maybe to do a morning jog which might not be very feasible due to safety reasons in those areas...and also the way the settlements are, there are spaces where people can do physical activities. [KII policy makers, 200701-0035, 0426, 0425]
5.3.5 Proposed family and community level solutions to the barriers

Several solutions were suggested at the family and community level. The most mentioned solution was making use of the community health strategy to support continuous monitoring and screening as well adherence to medication and clinic appointments.

Maybe we can use CHVs. When you get a client, first when you diagnose a patient with hypertension, you give then a CHV who will be calling them to know where they stay even locations and even if it's possible they pick up their medicine for them which they are taking and to be reminding them of their clinics. For those who can't make it to the clinic, they can take the medicine to where they can access them" [KII health provider, 200531_1126272]

Another solution was the creation of general awareness in the community about their condition. This involved where patients needed to seek treatment.

The government should create awareness [in the community] and.... hypertensive and diabetic patients [should be educated] so that they can know where they can go to seek care." [IDI (Korogocho), UHTN participant, 200712_2239, Male, 58].

The health care providers who mentioned language barrier as an issue suggested that the patients could come with their care providers for appointments. Health care providers felt that this would help during the clinic appointment and it was hoped that the care provider would support the patient with adherence to the medication due to being present when the information is given to the patients
"One is that they come, for those that have language barrier should come with their care providers so that we are able to relay the information through their care providers" [KII health care provider, 200627_0158].

### 5.3.6 Health system level facilitators and barriers

Health professionals were mentioned to be the key source of information for hypertensive patients. Patients reported having good communication with their doctors and the service providers were generally described to be cooperative. The capacity of the health providers was also reported as a facilitator in that the healthcare providers were able to treat patients who had comorbidities and were able to change the prescription when needed. Some of the facilitators mentioned at the provider level included provider training received and the providers' ability to follow the guidelines for hypertension care in the facility.

According to the study participants, their doctors changed their medication according to their blood pressure measurements. Most patients with uncontrolled hypertension mentioned that
their medications had changed. Some reported taking higher doses while others noted that the number of drugs for hypertension also increased.

Moderator: Have you been taking the same number for the last one year?
Respondent: It depends with the measurement. They change drugs if the blood pressure is very high - [IDI (Korogocho), UHTN participant, 200711_001, Female 58].

Health care providers offering continuous care and following up with their clients was also given as a facilitator. Some health care providers were also working with CHVs to support in follow-up of patients
"By use of CHVs, we give them cards and then TCAs [(to come again (date)/next appointment date)] and then we do follow up by calling them to remind them that they are supposed to come to the clinic as soon as their medicine are done" [KII Health Care Provider, 200531_1126272].

The patients reported that they were happy with the care they were receiving and there seemed to be good rapport between the patients and the health care providers. Some even got financial support from the health care providers who were also described as being friendly.

Respondents further noted many facilitators in regards to health systems. Healthcare providers noted that there were systems in place for following up patients particularly those whose blood pressure have not been controlled. Other respondents also mentioned that systems were in place in their facilities to quantify their needs for medicines for hypertension care even though the shipment for medicines mostly never arrived on time due to various reasons.
"We are able to quantify the needs; we are able to order on time but we are not able to receive supplies on time". [KII - Policy/decision maker, 200629_2302].

Some of the respondents noted they were able to find medications in the facilities they visited and that the medications were offered at no cost. They also mentioned they rarely found stock outs of the medications they needed and in the instances that the facility they used was out of medication, they were given a date to come back for their medication.
"At [facility] drugs are available and if they are no drugs they just tell you to come on a certain day and you will find them. They don't tell you to go and buy drugs like for
my condition. I used to go to cardiac clinic where we were told not to think that we will be treated for free". [IDI (Korogocho, UHTN participant, 200711_004, Male 56].
"It's hard; maybe you can miss drugs once [at the health facility] but not many times". [IDI (Korogocho), UHTN participant, 200711_001, Female 58].
"I have never been told that there are no drugs; I always find them when I go there. I have never been told to go and buy drugs". [IDI (Korogocho), UHTN participant, 200713_0021, Female 47].

A few of the community members seemed to be happy with the care they received at the facilities they visited and how long they took to be treated when they went for care.

Yeah, they serve us well. Hypertensive patients are treated first when we go there. [IDI (Korogocho), UHTN participant, 200710-001, Female 44].

I have no problem with the time because they always attend to us and give us drugs when we go there and then we come back to our normal engagements. [FGD (Korogocho), UHTN participant (R1), Male 61].

Yes, we were not buying and that's why we could always have drugs to take when [facility X] was still operating. [IDI (Korogocho), UHTN participant, 200712-001, Female 54].

Some respondents were happy with the quality of care they received at the facilities. One respondent noted that their blood pressure was stabilized when it was really high while others mentioned that they were also advised on how to manage their blood pressure.
"I told you that they check my blood pressure measurements and if they find that my blood pressure is very high then they ask me to sit down somewhere then they break a tablet and give me to swallow, then I my pressure is measured again after some time then they talk to me on how am supposed to eat to manage my blood pressure, then they give me water". [IDI (Korogocho, UHTN participant, 200713_0305, Female 62].

He measures blood pressure, he prescribes medicine then he tell you to go take the medicine and tells us to come back on Tuesday and when you go back the doctor checks your measurements again. We don't get any other instructions. [IDI (Korogocho), UHTN participant, 200712_0542, Male 62].

Also that you are served better and the doctors at Mareba advise you well on how your blood pressure should be. [IDI (Viwandani), UHTN participant, 200710_0535, Male 57].

Very few participants indicated that the operating hours of the facilities they visit for hypertension care was fine. A few of the respondents mentioned that the facilities they visited
provided 24 hour services while others mentioned specific hours in which hypertensive patients were seen.

Despite the provider-level facilitators reported, many barriers were reported about the healthcare providers in the community. Inability to regularly follow-up and closely monitor patients was described as a significant barrier. Healthcare providers in the community felt their message would have more impact if they were able to follow-up with their patients more frequently. The main barrier to regular follow-up and monitoring was lack of appointments in the facilities they worked in. Other barriers mentioned about the care the providers gave were lack of time due to the providers' heavy workload, lack of training and knowledge or expertise to treat hypertensive patients that had comorbidities.
> "Because of the long queues, you can wait for long and even decide not to attend the next clinic" [IDI (Korogocho), UHTN participant, 200710-0606, Female 62].

The high workload of doctors was noted as a challenge as there was no time for a detailed discussion between the patient and the service providers. From the interviews, it was clear that the respondents were desperate for information on hypertension as they were not getting answers from their health care providers.
"I asked but these doctors from public hospitals don't answer some questions. The just take their pens to write when you try to ask the questions. They just tell us to continue taking drugs and if you tell them that you are tired of taking drugs then they add you other drugs" [FGD (Korogocho), UHTN participant (R3), Male 61].
"This condition is not getting better; he can even see that because he cannot there is no change from the time he checked last month and the current readings. Tell me the problem please because even if it is chest problems then there are places that people go to be treated. Why it that this condition is never treated? That is the question that I always ask myself. Can you use medicine for 5 years on a condition that is not getting treated?" [FGD (Korogocho), UHTN participant (R3), Male 61].

The expertise of the healthcare providers was also mentioned as a barrier. Some patients did not trust the care they received so they either stopped seeking care and only went to buy medication from chemists or changed hospitals.
" [It] reached a time that I lost trust with the doctors that were treating me at [name of hospital] because they were just checking my blood pressure and gave me prescriptions in case they found that it was high but at [national referral hospital] I would say they are more active, they check what could be wrong with the patient, my liver was checked at [name of referral hospital] but at [name of hospital] I was just going to collect drugs and go back home" [IDI (Viwandani), UHTN participant, 200722_0058, Male 52].

Another barrier mentioned by patients with hypertension was that providers were noted to offer the patients only what was in stock, which was particularly challenging for those patients on multi-drug regimens.

Health facilities were also described to have a poor supply management system as medication stock outs were mentioned repeatedly as a major barrier to blood pressure control. Patients and health care providers alike mentioned this to be a problem. Patients reported that even if the medications were free in public facilities, these facilities often lacked the medications and patients had to purchase the medication elsewhere. This was particularly challenging for those patients who were on multi-drug regimens for their hypertension treatment. In addition, due to the inefficient supply system, it was noted that when some medicines arrived, some were expired and patients were using them before they realized they were expired.

Respondent: "I can say that they get good care but the only problem that they have is drugs. When we go to the hospital, like for me I only get one type of drug and I don't get the other one so there is that problem of getting drugs...We have stayed for long without getting drugs. We have been buying all the drugs from last year August. We had a one problem, this drug called...6:26-6:30(Not clear) came in late and they came when they were already expired. We only used them for one month and realized that they were expired we were not getting any drugs at that time. [IDI (Viwandani), UHTN participant, 200621_002, Female 63].

A surprising finding in regards to out of stock medicines at the public facilities is that patients reported that they were always asked to purchase the medications from elsewhere and that the medications were always available in pharmacies yet they were unavailable at the facilities in which they sought care where they expected to receive the medications for free. It also emerged that facilities purposely did not stock all types of medications for hypertension - they only stocked the cheaper medications.

R1: They should also consider the drugs because if you go to the hospital and you are told that there are no drugs and so you will be given one type and asked to go and buy the other one. That one also contributes. They should make sure that hypertensive and diabetic drugs are available at the hospital. It really surprises me that you don't get some drugs at the hospital but when you go to the chemist you find them there yet a chemist is privately owned. Who is more powerful between the government and the private chemist owners? The government should be having everything and personally I think there is a challenge there - [FGD (Korogocho), UHTN participant (R1), Male 61].
"Currently what I can say about that our facility does not stock all the hypertensive drugs. They only stock the ones that are cheaper to the patients which sometimes is not effective to the patient" - [KII - Health care provider, 200627_0158].

Medication stock out was a common feature in most public facilities regardless of where the facility was located. In addition to not stocking medications, a near absence of public facilities was mentioned in the community. In each of the two study communities, respondents mentioned that there was only one facility in each of the study sites and that they almost always didn't not have medications. Healthcare providers at the facilities also advised the patients to buy medications that were out of stock in other public facilities.

Respondent: In Korogocho it's like we don't have a public facility, its only one and it's like it is never stocked with drugs. It's at the chief's camp but the problem is that there are no drugs there and when you go there you are told to go buy - [IDI (Korogocho), UHTN participant, 200710-0606, Female 62].

Respondent: I told you that I go to a hospital managed by the city council called [public facility name]. This is a public dispensary and I am not charged when I go there but we are asked to buy if there other drugs that are not available. [IDI (Viwandani), UHTN participant, 200710_0535, Male 57].

Respondent: Another factor is the absence of drugs, sometimes we ran out of drugs and if you advise a client to get drugs maybe they ran out of money." - [KII - health care provider, 200531_1126272].

Facility hours of operation was cited by many as a barrier to blood pressure control. The government owned facilities did not operate beyond the normal working hours (8am to 5pm) or on the weekend thus limiting care to those who have to work and need care outside those working hours. The clinic days for hypertension care was also reported to be once a week and the hours to be seen were also short.
"So this complications may come at night so the success is limited. So access on time can only be from 8-5 and Monday to Friday, outside those hours you may not get access to care" - [KII - Policy/decision maker, 200701_2332].
"Yeah it's a challenge. For example you have a hypertensive client who is working and in our facility we attend to these clients in the morning hours, one to two. A patient comes at two when there is no caregiver. Maybe yeah. She is told to come tomorrow because there is no caregiver because he or she is late. And maybe the patient was at work and he or she decided to pass by to check her level at the facility. So it's also a challenge". - [KII - Healthcare provider, 200531_1126272].

Another major barrier mentioned was that the facilities were short staffed; this shortage of staff was the norm across all the facilities thus leading to high workload to the current staff and this also led to long wait times for patients to be seen. Healthcare providers reported that if they were not available on the clinic day, then the patients would have to come back on another day and so the patients would have to do without their medications if they were completely out. Patients with hypertension also noted that they have to wait months to be seen. Others reported that sometimes they would spend their whole day to be seen, while some patients mentioned not booking other activities on the same day as their clinic days. They also noted that they had to arrive very early if they were to be seen early. Patients noted that they were attended to faster in private facilities. Policymakers for the area also noted that there was a shortage of staff in the public community facilities thus the staff are overwhelmed.
"Attending to us well like for example in our clinic at [Facility name], we are over 400 patients and we only go to the clinic on Thursday and we only have one doctor attending to us. I was there in May and I was booked again for the clinic in August. There is a problem with doctors and that's why we have to wait for many months and we would love to be attending clinics at least every month". [IDI (Viwandani), UHTN participant, 200621_002, Female 63].
"Because of the long queues, you can wait for long periods and even decide not to attend the next clinic" - [IDI (Korogocho), UHTN participant, 200710-0606, Female, 62].

R3: "Timings at the private hospitals are ok because they attended to you immediately when you reach the hospital though I had to set aside a whole day when I go for my clinic at Mwae. There is nothing else I could do on that day because I used to go there in the morning then we start with a prayer then we go for blood pressure checkup and then we all assemble to be advised by the doctor" - [FGD (Viwandani), UHTN participant (R3), Female 47].

For me I think staffing [is a barrier], because if I am not around then they [patients] will not go home with drugs, the patient will have to leave their other duties to come here again and they will get tired." - [KII-health care provider, 200701_0043].

The patients also mentioned the attitude of the healthcare providers as a barrier. Some patients felt that they couldn't consult the health providers and some mentioned that the healthcare providers shouted at them.

> "They are supposed to follow up and guide us on how we are supposed to live but we cannot be the once telling the doctor what to do because he will think that you are commanding him and that's why we just keep quiet and change the facility... I would like to tell you to talk to those people [healthcare providers] if at all you work with them because hypertensive patients become worse when they are shouted at." [IDI (Viwandani), UHTN participant, 200715_006, Female 52].

Quality of care at the facilities was reported to be compromised because of the high workload thus the doctors were not able to give proper attention to patient care.
"In our experience, the feedback we get from counties is that there is generally a critical health workers shortage. And that is in their report, but from our own observation we have found out that in the health facilities that provide hypertension care the clinics tend to be very understaffed. And the [facility] tends to lean towards overwhelming the staff that is there. .... Like there is a clinic once in every two weeks so the provider gets a mass of patients to come in on a certain day. And that impacts on the quality of care provided and also impacts on the perception that there is health worker shortage" - [KII - policy/decision maker, 200703_0220].

Lack of equipment, reagents for tests and lab tests in general were cited as barriers to hypertension care in the community because it meant patients needed to go and get the tests in places that required them to pay for the tests. Study participants also reported that sometimes the equipment broke down or they needed maintenance. Delays in replacing and repairing equipment were also cited.
"We also have eeehh... we don't have the capacity and the ability to do routine and follow up investigations like kidney tests and the patient is not able to afford". - [KII health care provider, 200627_2209].
"Yes in terms of investigation. The only thing at our [facility] that we are able to do in terms of hypertension care is only urinalysis. You know there are some investigations like electrolytes, urea, creatinine, and kidney infection tests. We are not able to do them. ....... You find that the investigations are useful in terms of hypertension care but very
expensive so you find that the client cannot afford that". [KII-health care provider, 200626_0102].
"And there is also a lack of or shortage of tools and equipment to provide services for hypertension.....There are no weighing scales, height meters are not available and other equipment for screening for other cardiovascular diseases". [KII - policy/ decision maker, 200703_0220].
"..and course commodity we have the government supply but still especially now for agents and those testing facilities....(Not clear) because some of the monitoring equipment sometimes they break down and may need some maintenance and things" [KII - policy/decision maker, 200701_2332].
5.3.7 Proposed solutions at the health-system level

Various solutions at the health providers' level were proposed by the patients, the health care providers themselves as well as the policy/decision makers. The respondents noted that it was important to ensure the patients and the community in general be knowledgeable on hypertension. However, the health providers noted that heavy workload was a hindrance to achieving this. A healthcare provider mentioned increasing the number of healthcare providers' as a solution to the heavy workload and increasing providers' capacity through trainings and seminars.
"those that provide care should be advising us on what to do. Advice is good" [IDI (Korogocho), UHTN participant, 200712_0542, Male 62].
"There should be more training for the health care workers on the current guidelines and management of hypertension and diabetes. Now if the management can add another health care worker who is equipped with knowledge to handle hypertensive clients then this I think will be good"[KII health care provider, 200627_0158.]
"To increase the capacity of the HPs to offer better care including to those with comorbidities, it was proposed that they could research and get trained regularly...the other one would be to do capacity building through seminars and trainings and CMEs and OJTs, the other one would be... am not saying that it has not been happening.. Mentorship and support supervision..frequent like more frequent than it has been and motivation of staffs" [KII health care provider, 200627_2209].
"They need to do research or improve in their studies because like diabetes and high blood pressure but especially diabetes is a disease that keeps on changing and not only diabetes, diseases keep on changing and different drugs are invented. They should go for refresher courses. If they go there then they will be able to help us. I think that we don't have people who are specialized in the government when it comes to diabetes and pressure. We don't have specialized doctors to deal with such conditions. Doctors are
there but they are very few so I think they should train many doctors on hypertension and pressure. [IDI (Korogocho), UHTN participant, 200712_2239, Male 58].

To counter the heavy workload, setting up special clinics for hypertensive patients was proposed as a possible solution. In addition, the need to set up a follow-up mechanism for patients was proposed. The option to provide continuous support was also mentioned as a possible solution.
"So for workload I think we schedule for their special clinic. Like we just schedule like 3 days of the week where a client knows, even come one knows that from this hour to this hour we are attending to hypertensive clinic...maybe that could help" [KII health care provider, 200531_1126272].

The main solutions mentioned at the health system mainly revolved around availability of medications, tests and equipment for hypertension. Solutions particularly for the public facilities were to ensure that they have continuous medications in stock. A consistent supply of medications for hypertension was suggested by patients and healthcare providers who acknowledged the medication stock out was a major challenge affecting blood pressure control. They also suggested that people with hypertension be treated that same way people with HIV are treated because people with HIV are never without medication.
"Drugs should be provided in plenty so that a person like me doesn't suffer because getting that 10 shillings to buy medicine is not easy, sometimes I have to go borrow". - [IDI (Korogocho), UHTN participant, 200712-001, Female 54].
"We want to get enough support like stocking of drugs at the right time then we will be able to provide services the right way..." - [KII healthcare provider, 200627_0158.]
"..that there is availability of drugs, make investigations available and affordable and if possible make them free". [KII healthcare provider, 200627_2209].
"I said that it would be better if they could help us get drugs easily. They should treat us the same way they treat those patients with other diseases like HIV because it is very hard for HIV people to miss drugs". [IDI (Korogocho), UHTN participant, 200720_001, Male 60].

Majority of the respondents felt that medications for hypertension should be provided for free.
Almost all respondents felt the cost of hypertension medications was prohibitive and the
government needed to intervene and provide these medications for free especially to the elderly.
"Maybe if the government can make sure that the elderly get those drugs or if they can be sent to even some little money for medication or they just be put for something to make sure that they get those whatever". [KII healthcare provider, 200703_0034].

Participants also suggested that taxes needed to be removed from hypertensive medications to make the medications cheaper for patients to buy. They also suggested that a donor can be approached to help with medications while another suggestion was to engage a nongovernmental organization to help with the provision of subsidized medications for hypertension.
"The government should know what to do like maybe not taxing such drugs so that the prices can be cheaper". [IDI (Korogocho), UHTN participant, 200712_2239, Male 58].
"It would be better if we can get a donor to help us on those drugs ..." [IDI (Viwandani), UHTN participant, 200715_006, Female 52].
"I think maybe if we can have a well-wisher or a donor who can supply us with drugs that cannot be supplied by KEMSA and they are prescribed here. I think we can feel very good". [KII healthcare provider, 200709_0207].
"Maybe get donors to donate hypertensive and diabetes drugs for them to help people of low socioeconomic status". [IDI (Korogocho), UHTN participant, 200711_001, Female 58].
"I think on our management part, maybe to liaise with some NGO who can be supporting the drugs for the patients...." [KII healthcare provider, 200627_0158].

Since healthcare provider staffing was a major barrier, most of the respondents suggested that the number of doctors attending to patients with hypertension needed to be increased so that the long wait times are reduced for patients.
"They need to add the number of doctors and by doing that then it will take a shorter period and we will get time for us to hustle for ourselves." [IDI (Korogocho), UHTN participant, 200721_003, Male 50].
"Maybe adding the number of doctors because there is only one doctor there and the other thing is ensuring that we always get drugs." - [IDI (Korogocho), UHTN participant, 200713_0720, Female 55].
"Number one, increase the number of staff, number two, maybe access to facility and infrastructure." - [KII - policy/decision maker, 200701_2332].

Some respondents felt that providers needed to provide hypertension care counselling on issues relating to what they could do to improve their blood pressure control and information on what would be the ideal nutrition for them.

Participants noted the need for better linkage between facilities to improve referrals. They also recommended special clinics in the community to reduce referrals to outside facilities which some patients find difficult to access. Strengthening linkages between the community and the facility was also suggested as was the integration of programs to avoid missing other conditions that the patients have that need attention.

### 5.3.8 Policy-level facilitators and barriers

Few facilitators at the policy level were mentioned. Healthcare providers mentioned that policies/guidelines were available for the management of hypertensive patients.
> "We have policies on how to manage hypertension". [KII - Healthcare provider, 200531_1126272].
> "The guidelines are there. Like when do we diagnose hypertension, when do we start medication and how do we scale up or scale down. So the guidelines especially the clinical ones are in place". [KII - Policy/decision maker, 200702_0216].

Barriers mentioned at the policy level included the lack of guidelines, not having up to date guidelines on hypertension, guidelines not being cascaded to lower level facilities and not having a budget line or specific allocation for hypertension care within the healthcare budget.
"Not really, mostly we have the MOHs like in the bigger hospitals where we can consult, we consult from them but we don't have national guidelines that we are using currently." [KII - Healthcare provider, 200701-0035].
"eehhh,[guidelines] not the latest version. It is an old one. A very old one". [KII healthcare provider, 200625_002].

It further emerged that to have access to certain hypertension medications and products, health facilities needed to be in a higher level and this may have contributed to the medication stock outs experienced in the lower level facilities.
"So there is...Eeehh I'll call it unapparent lack of harmony in the policies of the ministry. And the general programming within the ministry has a detrimental effect on care for hypertension. Where you find that up until late last year, the access to health products for hypertension was limited to certain levels of health facilities - basically from level four and above. Secondary care and above. Where at the same time the guidelines for care for hypertension were promoted or cascading to the lowest levels like level 2 and 3. So there is discordance between what the guidelines say and what these facilities can access in regards to products to provide hypertension care". [KII policy/decision maker, 200703_0220].

Allocation of resources was cited also as a barrier to blood pressure management. It was noted that there is no specific allocation or budget line for hypertension care, which falls under noncommunicable diseases. It was further noted that much of the emphasis in regards to resource allocation was more geared towards communicable diseases yet there was a growing burden of non-communicable diseases.
"We don't differentiate into specifics. What we have is a comprehensive package for the sector that is the health sector. Under which it is very difficult to quantify specifically for hypertension. Because if it is for example a file for procurement of commodities, they all go together including the other essential commodities and nonpharmaceuticals. So it is quite difficult to tease out specifically for hypertension it's further a comprehensive package". [KII policy/decision maker, 200629_2302].
"So you find that at the national level there are no dedicated budgets for programming for hypertension despite being condition that has high prevalence in the country", [KII policy/decision maker, 200703_0220].
"We don't have a specific allocation for example for NCDs that is non-communicable diseases of which hypertension falls under. I think we all, how do I put it. All health care budgets are combined. Again you see we are battling a lot of communicable diseases. So the non communicable ones are eeehh. We don't give them the emphasis that they deserve because we are overwhelmed already. Our emphasis is more on communicable ones like you have seen of late, the non-communicable diseases like hypertension and diabetes are going up". [KII policy/decision maker, 200702_0216].

Healthcare providers felt there was an absence of healthcare providers in the policymaking arena. They felt that health care representatives needed be present in decision making.
"The only thing I can say about that is that when they are making their decisions, most of us are usually not involved, not like we need to be involved but come of our leaders like let's say the clinic officers council, the nurses council they need to be involved so that the information reaches us if there are changes in the management". [KII healthcare provider, 200627_0158].

It was suggested that data on hypertension needed to be strengthened. Data was needed to know the number of people dying from hypertension as it is known for Malaria. Data was mentioned to be important because it informs policies needed. Increased research on hypertension was suggested to inform interventions and policies.
"And then also provide data like a database. I think also our database is not very good.....It is easy for me to say there is this number of people dying from malaria each year but it's not easy for me to to get the number of people dying from hypertension for example every year". [KII policy/decision maker, 200702_0216].

### 5.3.9 Proposed policy-level solutions

At the policy level, several strategies were suggested by the study participants that would help with blood pressure control. Respondents emphasized repeatedly that the government needed to provide hypertension medications and tests at no cost. Respondents felt that patients with hypertension needed to be accorded the same benefits as patients with HIV and TB and be given medications and testing at no cost.
"It would be better if the government ordered that high blood pressure medication be given for free but the government is not thinking about us. They are not giving us drugs for free. The government should think about cancer patients, those that are hypertensive and also the Diabetic ones". [IDI (Korogocho), UHTN participant, 200713_0305, Female 62].
"The medicines for TB are free, the medicines for HIV are free, and why don't they [government] make the medicine for hypertension free as well?" [KII healthcare provider, 200626_001].

Study respondents suggested that medications for hypertension should not be taxed in order to make them more affordable for patients, leading to better adherence. Additionally strategies suggested that donors who can support the provision of hypertension drugs should be approached. Some hypertensive patients felt they needed monetary support from the government so that they could buy their medications and foods in line with hypertension care. Another strategy suggested to help with reducing the medication burden was the implementation of universal health coverage.
"The government should know what to do like maybe not taxing such drugs so that the prices can be cheaper". [IDI (Korogocho), UHTN participant, 200712_2239, Male 58].
"It would be better if we can get a donor to help us on those drugs like for my case it is very hard because the drugs that my husband is using for cancer are also expensive. Sometimes I have to stay without drugs when I don't have money and my blood pressure goes up when I stay without drugs to the extent that I fall down and end up being admitted in wards". [IDI (Viwandani), UHTN participant, 200715_006, Female 52].
"They [government] should send me money so that I can go to the hospital and buy the things that I am advised to use. I am told to buy many things yet I don't have money". [IDI (Viwandani), UHTN participant, 200714_2253, Female 50].
"If the government would implement universal health whereby people who don't have money are catered for". [KII - Healthcare provider, 200625_002].

In regards to guidelines, there were suggestions that it should be available at all facilities and the guidelines needed to be the most updated versions. It was further suggested that there should be policies for non-communicable diseases as they are for communicable diseases.
"They should make sure that every facility has a guideline". [KII - Healthcare provider, 200701_0043].
"They should come up with policies that don't just focus on communicable diseases but also non-communicable diseases." [KII - policy/decision maker, 200702_0216].

Healthcare providers suggested that there be more awareness and advocacy activities around NCDs in general hopefully to garner the same attention that HIV has. Policy and decision makers noted more effort needs to be put on non-communicable diseases as has been put on communicable diseases.
"To create more awareness, give health education on management of care of patients with NCDs...Updates yeah. Especially from my experience the education on NCDs is never rampant like the HIV, you know HIV everybody knows about it but when it comes to NCDs it seems that nobody cares as in it's not highlighted as much. (In Swahili) There's not as much education on it like those other things that are highlighted ...now that corona has come it is being highlighted, or malaria but these ones for NCD there is no one who is concerned with them". [KII - healthcare provider, 200703_0034].

### 5.4 Discussion

This study used the SEM framework (Centers for Disease Control Prevention, 2015b) to assess the facilitators, barriers and solutions to blood pressure control among participants with
uncontrolled hypertension and comorbidities in two Nairobi slums. This study provides key insights collated from patients', healthcare providers' and policy/decision makers' perspective on the facilitators and barriers encountered by people with uncontrolled hypertension in the slums and solutions to identified barriers. The application of the SEM framework to analyse the data collected demonstrates that there is a need to intervene at multiple levels of the SEM framework.

Our findings reveal that access to medication is the major barrier to blood pressure control among patients with uncontrolled hypertension and comorbidities in Korogocho and Viwandani. High prices and the poor socio-economic capabilities of the urban slum residents in this study have limited access to treatment thus affecting compliance to hypertension medications. This high cost of medicines has been confirmed in slums across Africa and other low-and-middle income countries (Cameron et al., 2009, Ahmed et al., 2020). While access to medicines is a barrier to blood pressure control in some low-middle-income countries, it seems other countries have started embracing universal health coverage thus providing healthcare and medications for free. For instance a study conducted in Eritrea looking at barriers and facilitators of hypertension management reported that patients appreciated their governments support in providing free medication for hypertension thus improving adherence to medication (Gebrezgi et al., 2017). A study in Malaysia also found that patients with hypertension had no problem with accessing medications because they were provided free of charge at public facilities (Tan et al., 2017).

At the individual level, adherence to medication regimens by patients is also affected by the cost associated with buying medicines as well as the regular unavailability of drugs in the facilities that are expected to provide them for free. Adherence is also worsened by the cost of the medicines thus patients are buying inadequate doses and missing or skipping doses due to inability to buy the medicines. This was evident in a study conducted among low income
earners in five regions in Kenya (Julie Zollmann and Nirmala Ravishankar, 2016). The study found that $38 \%$ of households forwent healthcare needs due to lack of money and at times bought less than their required treatment regimen. Compliance to medications is important in hypertension management. However, in this study compliance is affected due to inaccessibility of medications in the community. Unavailability of medication and the cost of medications were barriers mentioned by the majority of study participants and this adversely affected blood pressure control and adherence to treatment. One of the sustainable development goals' (SDG) target, "access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all" (World Health Organization, 2010) is not being met in these two community settings.

Other barriers at the patient level were poverty, lack of formal employment, lack of information and knowledge, misconceptions, not having medical cover, being older in age and depending on others for hypertension care. These barriers are similar to barriers to hypertension management that have been reported in similar type settings in sub-Saharan Africa (Gebrezgi et al., 2017, Naanyu et al., 2016). Knowledge about hypertension plays an important role in blood pressure control. In the current study patients' knowledge was limited and they did not seem to understand the rationale for the lifelong treatment of hypertension. Previous research has shown lack of knowledge coupled with misperceptions about the disease can affect adherence to treatment (Rajpura and Nayak, 2014, Meinema et al., 2015). A study by Meinema et al. (2015) conducted among African Surinamese and Ghanaians with uncontrolled hypertension in the Netherlands showed that using a culturally adapted hypertension education program gave the patients a better understanding of hypertension and improved their understanding about the chronic nature of hypertension thus improving medication adherence. In the current study, all the patients were older adults with other comorbidities in addition to having uncontrolled hypertension. Comorbidities can have an effect on blood pressure control
and this may explain the inadequacy of blood pressure control in this population. Studies in high income countries have shown that people with comorbidities have higher risks for uncontrolled hypertension (Degli Esposti et al., 2004, Liu and Song, 2013). A review of the literature estimated that more than $50 \%$ of the older adults have multimorbidity and the prevalence of multimorbidity increases with age (Marengoni et al., 2011). A recent study conducted in the current patient population also found that close to a third (28.7\%) of the study participants had multimorbidity (defined as two or more chronic conditions) and the commonest identified chronic conditions were hypertension and obesity in this population (Mohamed et al., 2021). There is also literature from similar settings showing that hypertension co-exists with other comorbidities (Hendriks et al., 2012, Jenson et al., 2011, Joshi et al., 2014, Mathenge et al., 2010). Excess weight is a known risk factor for high blood pressure. An earlier study also in the same study population suggested lifestyle changes in this community has led to a rise in overweight and or obesity (Ziraba et al., 2009). The prevalence of overweight/obesity coupled with hypertension may explain the inadequacy of the blood pressure. A recent study in China has found a positive association between BMI and blood pressure (Linderman et al., 2018).. Therefore, in addition to clinical management of patient comorbidities, this population will require lifestyle changes to address modifiable risk factors to enable them to get their blood pressures under control.

Staffing for healthcare providers was noted to be low in this study. Previous research has shown that increased health care personnel staffing has a positive effect on health outcomes (Anand and Bärnighausen, 2007, Speybroeck et al., 2006). However, most low and middle income countries including Kenya lack the needed number of healthcare personnel to provide essential services. Likely reasons for this shortfall include migration of health personnel in search of greener pastures and the reduced capacity of countries or institutional bodies graduating people with the needed qualification for healthcare. It has been estimated that countries with fewer
than 23 physicians, nurses and midwives per 10,000 population generally fail to achieve adequate coverage rates for selected primary health-care interventions (World Health Organization, 2006b). The pervasive lack of skilled care is likely the reason for reduced communication among physicians with patients as has been reported in the current study. Good communication between patients and their physicians have many benefits. Benefits include improved compliance to prescribed treatments (Harmon et al., 2006). A recent article by Zulman and colleagues (2020) looking at practices to foster patient physician connection in clinical encounters pointed out how impersonal patient and physician encounters have become.

A health service provision assessment conducted in the above two slums about a decade ago revealed that the majority of public health facilities did not have the required staff, equipment, drugs or the mandate to handle chronic diseases (Kyobutungi et al., 2010). These barriers continue to persist in 2020 and as a result, the majority of healthcare visits continue to occur in private facilities which are also typical in the slum areas. Drug and equipment stock out in public facilities force the poor urban populations to visit private pharmacies for care thus increasing their out of pocket expenditure (Julie Zollmann and Nirmala Ravishankar, 2016). A study conducted in a rural part of Western Kenya also found that lack of drugs at the facilities patients visited was among the health system barriers to blood pressure control (Naanyu et al., 2016). Another study by Buigut et al (2015) in the study area showed that seeking care in a public health facility was associated with increased odds of experiencing catastrophic health expenditure and for this reason many informal slum residents would forgo health service utilization. Out of pocket payments for health services and lack of health insurance coverage was identified in this study as a barrier to accessing health care coverage. A study conducted in the above two slums in 2012 revealed nearly $90 \%$ of the slum residents did not have access to any type of health insurance (Kimani et al., 2012). A more recent study in 2018 in the Viwandani slum revealed only $43 \%$ of the sampled population had health insurance (Otieno et
al., 2019). While this is an improvement from the study conducted in 2012 by Kimani and colleagues, the coverage is still very low.

Decision making requires reliable information. Hypertension and NCDs in general have not received the same type of support as communicable diseases as evidenced by global initiatives such as the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM) and the United States President's Emergency Plan for AIDS Relief (PEPFAR) which have significant resources and good reporting systems. In this study, participants reported lack of and limited mortality data on hypertension was a concern to policy makers. This type of information is readily available for other conditions such as Malaria, Tuberculosis and HIV due to the funding attached to these programs. Funding of research and good information systems are therefore important in hypertension care in order to provide early warning, basis for planning, analysis of health data among other functions (World Health Organization, 2010).

Hypertension has been identified to be a major contributor (Institute for Health Metrics and Evaluation and the International Centre for Humanitarian Affairs, 2016) to the observed rising deaths due to NCDs in Kenya. These deaths have risen from 35\% to $45 \%$ in a span of seven years (2003 to 2010) (Phillips-Howard et al., 2014). Results from the current study showed that there were no clear guidelines for hypertension care in some of the facilities which is likely to contribute to some of the above deaths. It also emerged that even though the guidelines are disseminated to all levels of the health facilities, access to medication is limited to facilities in the higher levels thus also contributing to the gaps in access in medication observed in the two slum communities.

This study showed that majority of patients lacked health insurance and this has been previously described in the 2013 Kenya budget and utilisation survey. The survey reported that approximately $83 \%$ of the Kenyan population lack financial protection from health care costs and about 1.5 million Kenyans are pushed into poverty each year as a result of paying for health
care (Ministry of Health, 2014). The 2015/16 Kenya Integrated Household Budget Survey revealed $19 \%$ of the Kenyan population had some form of health insurance which is a slight improvement from the 2013 estimate (Kenya National Bureau of Statistic (KNBS), 2018). Even though the provision of public health care in Kenya is subsidized, it is inadequate due to the dense population in urban areas. Furthermore, the public health care system suffers from inadequate infrastructure and workforce, long queues, and shortage of drugs (Muriithi, 2013). In 2018, the Government of Kenya committed to achieving Universal Health Coverage (UHC) by the year 2022. This is a bold initiative and a major step in the right direction for many Kenyans who lack financial protection. The National Hospital Insurance Fund (NHIF) is the main insurance scheme in Kenya and it is expected to improve the provision of healthcare services in Kenya. The scheme covers both the formal and the informal sector. Coverage is high in the formal sector due to the mandatory nature of contributions from employers while the coverage from the informal sector is very low due to the voluntary nature of contributions. The majority of the study respondents in this study have strongly articulated the need to have free healthcare and the full implementation of the UHC in Kenya can make this a reality. Otherwise, the provision of care will be inequitable and more biased towards those who can afford the premium contributions.

### 5.4.1 Strengths and limitations

To our knowledge, this is one of the first studies to ask healthcare providers, policymakers and patients with uncontrolled hypertension and comorbidities in an urban slum setting to explore their experiences and views about facilitators, barriers and solutions to hypertension management at the different levels of the SEM framework. This study captured an integrated and diverse range of perspectives on facilitators and barriers to blood pressure control in slum communities by purposively engaging with patients with uncontrolled hypertension, health care providers and policy/decision makers. Examining uncontrolled hypertension through the socio-ecological model has increased our understanding of how to tackle blood pressure control
while highlighting potential strategies at the different levels of the SEM. However, some limitations should be noted. The results from this study are from two Nairobi slum communities and even though it may be applicable to other slums; it may not be generalizable beyond slum communities. While a strength of this study is that views from different study participants were sought for each of the SEM levels including the family/community members who did not participate in the study, it is thus possible that this particular groups perspectives may not have been accurately captured by the current study respondents. Another limitation to consider is the timing of data collection which corresponded with the current pandemic spread of SARS-CoV-2 which posed disruptions in the delivery of health care services. Thus it may be that some of the patients' challenges discussed could have been a result of the measures put in place to curb further spread of the virus. Similarly, the switch to phone interviews for most of the interviews rather than the traditional face-to-face interviews due to the pandemic may have reduced or limited the level of detail needed to capture the non-verbal cues that are important in guiding further discussions. Nonetheless, findings from this study can help inform efforts to develop multi-level interventions to improve hypertension control among similar urban slum residents in similar settings.

### 5.4.2 Recommendations

At the patient level, barriers affecting patients' access to hypertension medication need to be removed and or alleviated through the provision of free medications or subsidized medicines. Also, more frequent educational sessions should be conducted with patients so that they are well informed about their conditions and what they need to do to control their blood pressure. At the community level, hypertension care awareness is critical in ensuring a good understanding among the community and family members on hypertension care. Approaches at this level should also consider more involvement of community health workers/volunteers. At the health system level, approaches should focus on improvements at various levels within the health system structures such as; human resources, health management, health systems and
governance. Lastly, at the policy level there is need for policies and directives that ensure equitable care is received by all including those in the slum communities or those seeking care at lower level health facilities.

### 5.5 Chapter summary

This chapter presents the findings from a qualitative study of multiple levels of factors associated with uncontrolled hypertension. The findings demonstrate that uncontrolled hypertension is a major public health issue in slums of Nairobi and it is associated with barriers at different levels of the socio-ecological framework. The findings from the present study can be used to design interventions to address the interplay of factors operating at multiple levels of the SEM, from the patient level all the way to the policy level. Importantly there is a need for policies that facilitate increased access to subsidized or free medication.

This chapter has outlined the qualitative work completed for this thesis. It explored views from participants with uncontrolled hypertension and other key stakeholders in blood pressure control. The results from this research has provided a better understanding of the multitude of barriers at different levels of the socio-ecological framework. This chapter adds value to the other chapters by highlighting the family and community, health system and policy level issues in controlling blood pressure. The next chapter is the discussion in which I summarise the findings of this thesis.

## 6. Discussion, implications and future directions

### 6.1 Overview

The overall aims of this study were to understand the burden of uncontrolled hypertension among adults with comorbidities in SSA, and to examine the factors associated with uncontrolled hypertension among these patients. This chapter summarises the key findings from the study, which used a mixed method approach comprising a systematic review and meta-analysis of aggregate data from several countries, meta-analysis of nationally representative individual level participant data from the WHO STEPS survey conducted in 20 countries is SSA, and primary quantitative and qualitative data collected from two slums in Nairobi. The findings are summarised in line with the research questions. The overall strengths and limitations of the study are then discussed along with the clinical and public health implications of the research and recommendations for future research.

### 6.2 Key findings

Key findings from this thesis are as follow:
What is the prevalence of uncontrolled hypertension among people with comorbid conditions in sub-Saharan Africa?

A systematic review and meta-analysis examining the prevalence of uncontrolled hypertension overall and the prevalence of uncontrolled hypertension among people with comorbid conditions in SSA showed a high prevalence ( $75.9 \%$ ) of uncontrolled hypertension among individuals with comorbidities. The prevalence of uncontrolled hypertension varied among people with different comorbidities and was highest among people with chronic kidney disease ( $75.9 \%$ ) and diabetes ( $74.5 \%$ ). The results highlight the importance of addressing patient comorbidities' in blood pressure control as a core aspect of the care and support offered to patients with hypertension.

What is the prevalence of uncontrolled hypertension overall and the prevalence of uncontrolled hypertension among individuals with diabetes, dyslipidemia, obesity and general obesity in sub-Saharan Africa?

Analysis of pooled individual level WHO STEPS data from 20 countries in SSA with nationally representative samples showed that $61.4 \%$ of people on treatment for hypertension have uncontrolled hypertension. This prevalence is similar to the global estimate of $62.9 \%$ (Mills et al., 2016). There were significant regional differences with the highest median uncontrolled hypertension prevalence estimated for the Western region [72.3\% (IQR: 64.0, 73.1)] while the lowest median uncontrolled hypertension was estimated for the Eastern region [59.0\% (IQR: 47.7, 62.2)]. Further, the prevalence of uncontrolled hypertension was higher among people with comorbidities confirming results from the systematic review and metaanalysis. Among individuals with diabetes, dyslipidemia, general obesity and abdominal obesity; uncontrolled hypertension was $66.1 \%, 66.4 \%, 68.4 \%$ and $69.1 \%$ respectively.

What is the relationship between uncontrolled hypertension with being obese, having abdominal obesity, diabetes, and dyslipidemia?

A meta-analysis of the individual level WHO STEPS data showed that there is an association between uncontrolled hypertension and comorbidities. Although the prevalence of uncontrolled hypertension was higher among those with diabetes compared to those without diabetes, the differences were not statistically significant. In contrast, significantly higher odds of uncontrolled hypertension were noted in people with dyslipidemia compared to those without dyslipidemia. Similar findings have been reported in other studies although these studies did not focus on those on treatment for hypertension rather it was among all hypertensive patients (Halperin et al., 2006, Hunt et al., 1991). The relationship between uncontrolled hypertension and dyslipidemia found in this research study is concerning
considering that both uncontrolled hypertension and dyslipidemia contribute to cardiovascular disease and mortality (Stone et al., 2014, Roth et al., 2017).

Both general obesity and abdominal obesity were significantly associated with a higher risk of uncontrolled hypertension compared to those without general obesity and abdominal obesity respectively. Similar results were found in a recent study conducted in 13 African countries (Akpa et al., 2020), which found that obese individuals were more likely to have hypertension compared to individuals who do not have obesity. Again, this study did not focus on individuals on treatment for hypertension. Nonetheless, obesity is a known independent risk factor for cardio-metabolic diseases and it is associated with higher risk of cardiovascular disease mortality (Sun et al., 2019). Trials have demonstrated that weight reductions can result in blood pressure reduction leading to reductions in mortality from cardiovascular diseases.

What is the prevalence of multimorbidity and what are the factors associated with multimorbidity in slum communities?

Using quantitative data collected from two slums in the Nairobi Urban Health Demographic Surveillance Survey (NUHDSS), we found a high prevalence of multimorbidity. The most common co-occurring conditions were hypertension, obesity, drug use, HIV and tuberculosis. The presence of chronic conditions in the slum population is high. A large proportion (65\%) of the study population had single chronic conditions while $28.7 \%$ had multimorbidity. Gender was associated with both single morbidity and multimorbidity. Further, multimorbidity was more likely to occur in individuals who were unemployed, and current smokers compared to their counterparts. This study results highlight the burden of multimorbidity and pinpoints to the common conditions and determinants of multimorbidity. This results point out to the need to have targeted interventions to tackle multimorbidity in these settings. Addressing
multimorbidity can result in reduced cost to the healthcare system, reduced risk of mortality, disability, and improved quality of life.

What are the patient, family/community, health system and policy level facilitators and barriers to blood pressure control in the slum communities?

Using qualitative data collected in two Nairobi slums we found that uncontrolled hypertension among individuals with comorbidities is an important health concern in the slums of Nairobi. Facilitators, barriers and solution to care were revealed and these cut across the different levels of the socio-ecological framework (Centers for Disease Control Prevention, 2015b). At the individual level, poverty was a major barrier to accessing medicines. At the family and community level, unsupportive care from family members was commonly cited as a barrier. Numerous health system issues were revealed. These issues ranged from poor and inconsistent medical supply management systems to poor healthcare personnel staffing. Lastly, at the policy level, the availability of up-to-date guidelines and specific resource allocations to hypertension care were major barriers. Given the interplay of factors operating at multiple levels, there is a need for programmes to have multi-level approaches to blood pressure control in the slums of Nairobi.

### 6.3 Study strengths and limitations

This study has strengths and limitations. A major strength of this thesis was the use of a mixed method approach thus expanding and strengthening the thesis's conclusions. Given the limited data on the association between uncontrolled hypertension and comorbidities, this study adds to existing knowledge. In particular, to the best of my knowledge, this is the first study to use nationally representative data from sub-Saharan Africa to examine the role of comorbidities in people with uncontrolled hypertension while focussing on those on treatment for hypertension. The use of nationally-representative surveys from multiple sub-Saharan African countries is
also a strength as it improved the power and generalizability of the findings. The use of qualitative data further enriches our understanding of the facilitators and barriers to blood pressure control among people with comorbidities that exist at different levels of the socioecological model. Lastly, given all the COVID-19 challenges, I addressed all the thesis objectives.

A major limitation of the study is the small number of cases of people with uncontrolled hypertension and on treatment. Although the use of individual participant data were used to increase statistical power, the sample size was very small. This is because a large proportion of SSA residents are unaware of their hypertension status thus not on treatment and even among those who are aware of their condition, very few are on treatment for a number of reasons.

The use of cross-sectional data precludes temporal causality inference i.e. that comorbidities cause uncontrolled hypertension. Prospective longitudinal studies are needed to confirm this. In the aggregate level studies, we had to estimate uncontrolled hypertension from the data provided in the articles. For the individual participant data (IPD) meta-analysis, the use of the self-reported covariates may have introduced some bias; some may have over reported socially desirable behavioural factors and under-reported socially undesirable behavioural factors thus affecting the results. The IPD analysis was used to increase statistical power however the sample sizes for some of the countries in the analysis were too small thus limiting the generalizability of the findings.

Finally, the qualitative data was conducted in 2020 when the COVID-19 measures were in place. Thus some of the barriers mentioned by the respondents may have been as a result of the measures in place. Also, further probes that are usually observed through cues from face-toface interviews may not have been identified thus limiting the richness of the data.

### 6.4 Thesis contribution

This research has contributed to an area that has not been well studied and requires more attention. Previous large studies on hypertension in SSA have mainly focussed on providing prevalence estimates for awareness, treatment and control of hypertension. This research has enhanced existing knowledge by further examining the role of comorbidities among individuals with uncontrolled hypertension in SSA. This research has also identified the presence of multimorbidity in low resourced settings (slums).

Existing knowledge suggests that there is substantial burden of uncontrolled hypertension in SSA. However, detailed information on uncontrolled hypertension among people with comorbidities in SSA is scarce. Almost all research on hypertension in SSA focuses on prevalence, awareness, treatment and control with very little exploration of the factors that influence blood pressure control among those already on treatment for hypertension.

To the best of my knowledge, this is the largest study using individual level data from nationally representative cross-sectional samples from SSA to examine the role of comorbidities in blood pressure control among those already on treatment for hypertension. This research has enhanced existing knowledge in several ways. First, the data on the burden of uncontrolled hypertension among people with comorbidities can be used to prioritize effective care for people with comorbidities. Second, estimates on the prevalence of uncontrolled hypertension among individuals with specific comorbidities (diabetes, dyslipidemia, general obesity and abdominal obesity) in SSA highlight the need to target these individuals for specific interventions. Third, as one of the first studies on uncontrolled hypertension and comorbidities in SSA, results serve as a benchmark against which progress in hypertension care can be compared.

### 6.5 Clinical and public health implications and future directions

Hypertension prevalence has been declining in high income countries while significant increases have been experienced in LMICs (Mills et al., 2016). Despite the known and effective
treatment for hypertension, the prevalence of uncontrolled hypertension is still high and it is unlikely that the WHO global target of lowering blood pressure by $25 \%$ in 2025 in SSA will be attained (World Health Organization, 2013b). High uncontrolled blood pressure rates have economic and public health implications for SSA due to the fragile health systems. Morbidities such as diabetes and stroke, associated with uncontrolled hypertension are costly to treat and pose a huge burden to health care systems in SSA given that the healthcare facilities in this region are already overburdened by high infectious diseases (WHO Africa, 2011).

Although more studies are needed, the current research has implications for the development of strategies for uncontrolled hypertension particularly in people with comorbidities. Study findings highlight the high prevalence of uncontrolled hypertension among people with comorbidities stressing the importance of examining uncontrolled hypertension alongside comorbidities. Also highlighted in the qualitative study are barriers to hypertension care and strategies to improve access and uptake of treatment are essential.

Access to antihypertensive care and medications is limited in urban slums. In addition to promoting blood pressure screenings, efforts to improve access to affordable blood pressure medicines are needed to improve blood pressure control in SSA. Implementation of innovative integrated programs to tackle blood pressure control among patients with comorbidities are needed to address barriers at the patient, family, community, health system and policy levels. As more research on hypertension is conducted, it is important that comorbidity data is also collected and used when analysing uncontrolled hypertension. Programmes monitoring hypertension care should integrate the screening for comorbidities in the treatment guidelines to ensure effective blood pressure control. This could lead to more effective blood pressure management.

There is growing attention and research on the contribution of comorbidities. This research showed that people with comorbidities were more likely to have uncontrolled hypertension compared those without comorbidities. However, these findings will need further investigations with consideration of hypertension control differences in their design. The current national surveys are not designed to address differences in uncontrolled hypertension due to the small sample sizes within these surveys thus necessitating analyses that requires pooling of multiple surveys. This research offers unique insight into the effect of comorbidities on uncontrolled hypertension in SSA. Of note, no national level studies in SSA appears to provide information on uncontrolled hypertension and comorbidities. Future national level studies need to provide this information for better programming in blood pressure control programmes. Analysis of comorbidities in uncontrolled hypertension has identified variations among countries. At the SSA level, older individuals were more likely to have uncontrolled hypertension. Also the western region of Africa were more likely to have uncontrolled hypertension compared to the other regions. This evidence provides a basis for future investigations looking at the impact of comorbidities on uncontrolled hypertension.

### 6.6 COVID-19 implications for hypertension care

In December 2019, the novel corona virus was first reported in Wuhan, China. By March 2020, the WHO declared the COVID-19 infection a pandemic. By May $3^{\text {rd }} 2020$, more than 152 million cases had been confirmed and more than 3.2 million deaths reported globally (Worldometer, 2021, Wikipedia, 2021). These estimates are likely lower than the actual real estimates as many of the cases go unreported (Li et al., 2020).

Hypertension has been cited to be the most prevalent comorbidity found in people with COVID-19 infection (Hosseinzadeh et al., 2021, Emami et al., 2020, Zhou et al., 2020, Wu et al., 2020, Richardson et al., 2020). Current literature also suggests people with uncontrolled hypertension are at an increased risk of developing severe illness with COVID-19 infection (Hosseinzadeh et al., 2021). Though the exact mechanism of action between hypertension and

COVID-19 is not well understood, the virus is thought to gain entry to human cells by binding to the angiotensin converting enzyme 2 (ACE2) receptor (Wan et al., 2020, Clark et al., 2021). Some patients with hypertension who take the angiotensin converting enzyme inhibitors (ACEI) which increase ACE2 levels thus facilitating COVID-19 infection. However, there have been no studies showing direct links to suggest that these medicines are harmful in people with COVID-19 infection.

Hypertension in the SSA region is not well managed given the high prevalence coupled with low awareness, treatment and control of hypertension (Ataklte et al., 2015). Within the region hypertension care does not get the attention it deserves due to a myriad of challenges within the healthcare systems in the region. These challenges range from shortage of healthcare workers (WHO AFRO Health Workforce Observatory Database, 2017) to limited access to medications. These challenges worsened with the COVID-19 pandemic because most efforts were diverted to deal with the pandemic adversely impacting hypertension care services in general. For instance, in Kenya, there were reports of clinics that provide care to patients with hypertension and diabetes being closed and others in which the hours of operations were limited due to curfews. These challenges may have further slowed the earlier gains made in the management of hypertension care. It is therefore important that guidelines for hypertension management are in place during the COVID-19 pandemic to allow access to continued followup and screening options for those at risk.

### 6.7 Conclusion

This study provides important original contributions on the epidemiology of uncontrolled hypertension among people with comorbidities while on treatment for hypertension in SSA. The risk of cardiovascular disease in people with uncontrolled hypertension with comorbidities cannot be fully eliminated as long as blood pressure is not controlled. Taken together, the results from this study can inform the development of integrated programmes of care for people with comorbidities while on treatment for hypertension.

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## 8. Appendices

### 8.1 Appendix 1: Search strategy

## Medline - search

1. exp Hypertension/ or hypertension.mp.
2. exp Hypertension/ or uncontrolled hypertension.mp.
3. exp Hypertension/ or uncontrolled blood pressure.mp.
4. high blood pressure.mp. or exp Hypertension/
5. 1 or 2 or 3 or 4
6. type 2 diabetes mellitus.mp. or exp Diabetes Mellitus, Type 2/
7. type 2 diabetes.mp. or exp Diabetes Mellitus, Type 2/
8. exp Diabetes Mellitus, Type 2/ or type II diabetes.mp.
9. dyslipidemia.mp. or exp Dyslipidemias/
10. exp Dyslipidemias/ or dyslipidimia.mp.
11. exp Dyslipidemias/ or dyslipidaemia.mp.
12. Hypercholesterolemia.mp. or exp Hypercholesterolemia/
13. Hypercholesterolaemia.mp. or exp Hypercholesterolemia/
14. Hypercholesterolimia.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
15. hypertriglyceridemia.mp. or exp Hypertriglyceridemia/
16. exp Hypertriglyceridemia/ or hypertriglyceridaemia.mp.
17. hypertriglyceridimia.mp.
18. hyperlipidemia.mp. or exp Hyperlipidemias/
19. exp Hyperlipidemias/ or hyperlipidaemia.mp.
20. hyperlipidimia.mp.
21. obesity.mp. or exp Obesity/
22. chronic kidney disease.mp. or exp Renal Insufficiency, Chronic/
23. stroke.mp. or exp Stroke/
24. transient ischemic attack.mp. or exp Ischemic Attack, Transient/
25. Stroke/ or exp Ischemic Attack, Transient/ or transient ischaemic attack.mp.
26. coronary heart disease.mp. or exp Coronary Disease/
27. Heart failure.mp. or exp Heart Failure/
28. peripheral vascular disease.mp. or exp Peripheral Vascular Diseases/
29. atrial fibrillation.mp. or exp Atrial Fibrillation/
30. depression.mp. or exp Depression/
31. HIV/ or HIV.mp.
32. human immunodeficiency virus.mp. or exp HIV/
33.6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32
33. (Angola or Benin or Botswana or "Burkina Faso" or "Upper Volta" or Burundi or Urundi or Cameroon or Cameroons or "Cape Verde" or "Central African Republic" or Chad or Comoros or "Comoro Islands" or Comores or Mayotte or Congo or Zaire or "Cote d'Ivoire" or "Ivory Coast" or ("Democratic Republic of the Congo" or Djibouti or "French Somaliland" or Eritrea or Ethiopia or Gabon or "Gabonese Republic" or Gambia or Ghana or "Gold Coast" or Guinea or Kenya or Lesotho or Basutoland or Liberia) or (Madagascar or "Malagasy Republic" or Malawi or Nyasaland or Mali or Mauritania or Mauritius or Mozambique or Namibia or Niger or Nigeria) or (Rwanda or "Sao Tome" or Seychelles or Senegal or "Sierra Leone" or Somalia or "South Africa" or Sudan or Swaziland or Tanzania or Togo or "Togolese Republic" or Uganda or Zambia or Zimbabwe or Rhodesia)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
34. sub-Saharan africa.mp. or exp "Africa South of the Sahara"/
35. subsaharan africa.mp. or exp "Africa South of the Sahara"/
37.34 or 35 or 36
38.5 and 33 and 37
36. limit 38 to (humans and $\mathrm{yr}=$ ="2000-2019")

## Embase - search

1. hypertension.mp. or exp hypertension/
2. exp hypertension/ or uncontrolled hypertension.mp. or exp antihypertensive agent/
3. exp antihypertensive agent/ or exp hypertension/ or uncontrolled blood pressure.mp.
4. high blood pressure.mp. or exp hypertension/
5. 1 or 2 or 3 or 4
6. type 2 diabetes mellitus.mp. or exp non insulin dependent diabetes mellitus/
7. type 2 diabetes.mp. or exp non insulin dependent diabetes mellitus/
8. type II diabetes.mp. or exp non insulin dependent diabetes mellitus/
9. dyslipidemia.mp. or exp dyslipidemia/
10. dyslipidimia.mp.
11. dyslipidaemia.mp. or exp dyslipidemia/
12. exp hypercholesterolemia/ or Hypercholesterolemia.mp.
13. Hypercholesterolaemia.mp. or exp hypercholesterolemia/
14. Hypercholesterolimia.mp.
15. hypertriglyceridemia.mp. or exp hypertriglyceridemia/
16. hypertriglyceridaemia.mp. or exp hypertriglyceridemia/
17. hypertriglyceridimia.mp. or exp hypertriglyceridemia/
18. hyperlipidemia.mp. [ $\mathrm{mp}=$ title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 19. hyperlipidaemia.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
19. hyperlipidimia.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 21. obesity.mp. or exp obesity/
20. chronic kidney disease.mp. or exp chronic kidney failure/
21. stroke.mp. or exp cerebrovascular accident/
22. transient ischemic attack.mp. or exp transient ischemic attack/
23. transient ischaemic attack.mp. or exp transient ischemic attack/
24. coronary heart disease.mp. or exp ischemic heart disease/
25. Heart failure.mp. or exp heart failure/
26. peripheral vascular disease.mp. or exp peripheral vascular disease/
27. atrial fibrillation.mp. or exp atrial fibrillation/
28. exp depression/ or depression.mp.
29. HIV.mp. or exp Human immunodeficiency virus/
32.6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31
30. (Angola or Benin or Botswana or "Burkina Faso" or "Upper Volta" or Burundi or Urundi or Cameroon or Cameroons or "Cape Verde" or "Central African Republic" or Chad or Comoros or "Comoro Islands" or Comores or Mayotte or Congo or Zaire or "Cote d'Ivoire" or "Ivory Coast" or ("Democratic Republic of the Congo" or Djibouti or "French Somaliland" or Eritrea or Ethiopia or Gabon or "Gabonese Republic" or Gambia or Ghana or "Gold Coast" or Guinea or Kenya or Lesotho or Basutoland or Liberia) or (Madagascar or "Malagasy Republic" or Malawi or Nyasaland or Mali or Mauritania or Mauritius or Mozambique or Namibia or Niger or Nigeria) or (Rwanda or "Sao Tome" or Seychelles or Senegal or "Sierra Leone" or Somalia or "South Africa" or Sudan or Swaziland or Tanzania or Togo or "Togolese

Republic" or Uganda or Zambia or Zimbabwe or Rhodesia)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
34. sub-Saharan africa.mp. or exp "Africa south of the Sahara"/
35. subsaharan africa.mp. or exp "Africa south of the Sahara"/
36. 33 or 34 or 35
37.5 and 32 and 36
38. limit 37 to (human and $\mathrm{yr}=$ "2000-2019")

## Web of Science - search

| \# 38 | 2,114 | \#37 AND \#33 AND \#5 <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ |  |
| :---: | :---: | :---: | :---: | :---: |
| \# 37 | 421,085 | \#36 OR \#35 OR \#34 <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\square$ |  |
| \# 36 | 301 | TS=(subsaharan Africa) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\square$ |  |
| \# 35 | 33,673 | $\begin{aligned} & \text { TS=(sub-Saharan Africa) } \\ & \text { Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI } \\ & \text { Timespan=2000-2019 } \end{aligned}$ | Edit $\square$ |  |
| \# 34 | 407,520 | TS=(Angola OR Benin OR Botswana OR "Burkina Faso" OR "Upper Volta" OR Burundi OR Urundi OR Cameroon OR Cameroons OR "Cape Verde" OR "Central African Republic" OR Chad OR Comoros OR "Comoro Islands" OR Comores OR Mayotte OR Congo OR Zaire OR "Cote d'Ivoire" OR "Ivory Coast" OR "Democratic Republic of the Congo" OR Djibouti OR "French Somaliland" OR Eritrea OR Ethiopia OR Gabon OR "Gabonese Republic" OR Gambia OR Ghana OR "Gold Coast" OR Guinea OR Kenya OR Lesotho OR Basutoland OR Liberia OR Madagascar OR "Malagasy Republic" OR Malawi OR Nyasaland OR Mali OR Mauritania OR Mauritius OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR "Sao Tome" OR Seychelles OR Senegal OR "Sierra Leone" OR Somalia OR "South Africa" OR Sudan OR Swaziland OR Tanzania OR Togo OR "Togolese Republic" OR Uganda OR Zambia OR Zimbabwe OR Rhodesia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ |  |
| \# 33 | ,764,519 | \#32 OR \#31 OR \#30 OR \#29 OR \#28 OR \#27 OR \#26 OR \#25 OR \#24 OR \#23 OR \#22 OR \#21 OR \#20 OR \#19 OR \#18 OR \#17 OR \#16 OR \#15 OR \#14 OR \#13 OR \#12 OR \#11 OR \#10 OR \#9 OR \#8 OR \#7 OR \#6 <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | $\text { Edit } \Gamma$ |  |


| \# 32 | 85,771 | TS=(Human immunodeficiency virus) Indexes=SCl-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| :---: | :---: | :---: | :---: | :---: |
| \# 31 | 272,497 | TS=(HIV) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\square$ | Г |
| \# 30 | 369,094 | TS=(depression) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 29 | 80,988 | TS=(atrial fibrillation) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 28 | 20,886 | TS=(peripheral vascular disease) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 27 | 226,090 | TS=(heart failure) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 26 | 144,037 | TS=(coronary heart disease) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCl Timespan=2000-2019 | Edit $\Gamma$ | 「 |
| \# 25 | 1,959 | TS=(transient ischaemic attack) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 24 | 11,095 | TS=(transient ischemic attack) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 23 | 278,508 | ```TS=(stroke) Indexes=SCl-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019``` | Edit $\Gamma$ | $\Gamma$ |
| \# 22 | 75,433 | TS=(chronic kidney disease) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 21 | 280,562 | TS=(obesity) <br> Indexes=SCl-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 20 | 5 | TS=(hyperlipidimia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |


| \# 19 | 2,534 | TS=(hyperlipidaemia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | Г |
| :---: | :---: | :---: | :---: | :---: |
| \# 18 | 21,065 | TS=(hyperlipidemia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCl Timespan=2000-2019 | Edit $\Gamma$ | Г |
| \# 17 | 2 | TS=(hypertriglyceridimia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 16 | 1,000 | TS=(hypertriglyceridaemia) Indexes=SCl-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | Г |
| \# 15 | 8,591 | TS=(hypertriglyceridemia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | 「 |
| \# 14 | 0 | TS=(hypercholesterolimia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | 「 |
| \# 13 | 3,188 | TS=(hypercholesterolaemia) Indexes=SCl-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 12 | 27,232 | TS=(hypercholesterolemia) Indexes=SCl-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | Г |
| \# 11 | 4,539 | TS=(dyslipidaemia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 10 | 6 | TS=(dyslipidimia) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI <br> Timespan=2000-2019 | Edit $\Gamma$ | $\Gamma$ |
| \# 9 | 25,588 | TS=(dyslipidemia) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\Gamma$ | Г |
| \# 8 | 16,630 | TS=(type II diabetes) Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCl Timespan=2000-2019 | Edit $\Gamma$ | Г |
| \# 7 | 173,805 | TS=(type 2 diabetes) | Edit $\Gamma$ | $\Gamma$ |

Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI
Timespan=2000-2019

| \# 6 | 94,317 | $\begin{aligned} & \text { TS=(Type } 2 \text { diabetes mellitus) } \\ & \text { Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI } \\ & \text { Timespan=2000-2019 } \end{aligned}$ | Edit $\square$ |  |
| :---: | :---: | :---: | :---: | :---: |
| \# 5 | 375,418 | \#4 OR \#3 OR \#2 OR \#1 Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\square$ | Г |
| \# 4 | 113,713 | $\begin{aligned} & \text { TS=(high blood pressure) } \\ & \text { Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI } \\ & \text { Timespan=2000-2019 } \end{aligned}$ | Edit $\square$ | $\Gamma$ |
| \# 3 | 3,503 | TS=(uncontrolled blood pressure) <br> Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 | Edit $\square$ | $\Gamma$ |
| \# 2 | 4,063 | $\begin{aligned} & \text { TS=(uncontrolled hypertension) } \\ & \text { Indexes=SCI-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI } \\ & \text { Timespan=2000-2019 } \end{aligned}$ | Edit $\square$ | 「 |
| \# 1 | 307,652 | TOPIC: (hypertension) <br> Indexes=SCl-EXPANDED, SSCI, A\&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2000-2019 |  |  |

### 8.2 Appendix 2: Assessment of Risk of Bias (RoB) assessment domains

|  | External validity | Yes/No | Internal validity |
| :--- | :--- | :--- | :--- |$\quad$ Yes/No

10 Summary item on the overall risk of study bias
Adapted from Hoy D, Brooks P, Woolf A, Blyth F, March L, Bain C, et al. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. Journal of clinical epidemiology. 2012;65(9):934-9.
8.3 Appendix 3: Supplement tables

Table s1: Prevalence (\%) of hypertension by comorbidities and regions

| Countries | Non-diabetic | Diabetic | No central obesity | Centrally obese | Not obese | Obese | No dyslipidemia | Dyslipidemia | Overall |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| West | 30.6 (28.6, 32.7) | 54.5 (50.7, 70) | 24.7 (24.2, 30.7) | 38.5 (38.4, 39.5) | 27.1 (27, 30.7) | 45 (44.7, 48.5) | 28.1 (24.7, 33.7) | 45.1 (40.4, 49.9) | (23.6, 29) |
| Benin | 28.6 (24.5, 33.2) | 54. | 24 | 40.2 | 27 | 53 | $24.8(21.4,28.6)$ | 2) | 29 (24.9, 33.4) |
| Gambi | 30.6 (24.3, 37.7) | $70(49.5,84.8)$ | 24.3 (21.8, 27.1) | 38.5 (34.4, 42.9) | $27.1(24.5,29.8)$ | 40.3 (32.6, 48.4) | $28.1(25.5,30.9)$ |  |  |
| Liberia | $32.7(30,35.5)$ | 72 (60.6, 81.1) | $30.7(27.3,34.2)$ | $8.4(34.7,42$ 3) | 30.8127 | $4.7(39.7,49.8)$ | 33.8 (31.3, 36.4) |  |  |
| Tog | 22.9 | $40.3(28.1,53.8)$ | 20.3 (18.1, 22.6) | 32.8 (2 | 21 | 48.6 (40.8, 56.4) | 22.8 (20.8, 24.9) |  | 6) |
| SL` | $50.9(39,62.8)$ | $50.8(26.4,74.8)$ | 34.8 (29.8, 40.2) | 39 | $35.9(32,39.9)$ | 45 | $36.8(33.3,40.5)$ |  |  |
| Central | 28.6 (28.6, 28.6) | 40.2 (40.2, 40.2) | 22.2 (22.2, 22.2) | $41(41,41)$ | 27.3 (27.3, 27.3) | $50.4(50.4,50.4)$ | $\mathbf{2 6 . 7}(\mathbf{2 6 . 7}, 26.7)$ | ) | 7) |
| CAR | 28.6 (21.6, 36.7) | 40.3 (29.2, 52.5) | 22.2 (16.8, 28.8) | $41(36.7,45.5)$ | $27.4(22,33.6)$ | 50.4 (42.2 | $26.8(22.2,31.9)$ | 47.9 (38.6, 57.4) | $29.7(24.6,35.4)$ |
| Eastern | 24.7 (17.2, 31.1) | $56.2(46,68)$ | 20 (15.8, 23.7) | 35.5 (26.5, 41.5) | 23.2 (16.7, 26) | 48.5 (36.2, 52.7) | 24.1 (16.8, 28.2) | $35.2(25.2,43.2)$ | 25.3 (17.1, 28.2) |
| Comoros | $31.1(28.5,33.8)$ | 56.3 | 22. | $35.5(33,38.1)$ | 24 | 48.6 | $26.5(24.8,28.3)$ | $51.6(44.7,58.4)$ | $28(26.2,29.8)$ |
| Eritrea | 15 | 48.6 (39.5 | 13 (11.8, 14.4) | $25.2(22.6,27.9)$ | 15 | $35.2(26,45.8)$ | 12.5 (11.3, 13.8) | $20.9(18.8,23)$ | 16.3 (15.1, 17.7) |
| Ethiopia | 17.2 | 20.6 | $14.9(13.6,16.3)$ | 32. | 16.8 | 48.5 (38.7 | 15.1(13.8, 16.5) | $25.3(22.7,28.1)$ | $17.1(15.8,18.5)$ |
| Keny | 24. | 68 | 20 | 38 | 23. | 49 | $24.1(21.1,27.3)$ | $26.7(24.2,29.5)$ | $25.4(23.1,27.9)$ |
| Rwanda | 17 | 31. | $15.8(14.5,17.1)$ | 22 | 16 | 35 | 19.8 (17.9, 21.9) | 2) | $17.1(15.9,18.4)$ |
| Sudan | 31. | 63 | 24. | 48 | $30.4(28.7,32.1)$ | 58.6 (53.3, 63.7) | 30.5 (27.2, 33.9) | 35.2 (33.3, 37.1) | $34.2(32.4,35.9)$ |
| Tanzania | 27 | 49. | 21 (18.5, 23.6) | 41.5 (38.3, 44.7) | 26 (23.5, 28.6) | $51.2(45.9,56.4)$ | $26.4(23.4,29.7)$ | $37.7(33.6,41.9)$ | $28.3(26,30.7)$ |
| Uganda | 26.4 (24.2, 2 | $68.7(51.3,82.1)$ | 23.8 (21.4, 26.3) | $37(33,41.2)$ | $25.7(23.7,27.9)$ | $52.7(42.7,62.4)$ | $28.3(25.4,31.3)$ | $26.2(23.6,29)$ | 27 (24.9, 29.2) |
| Zanzibar | $34.9(30.4,39.6)$ | 75.7 (57.5, | 31.3 (26.8, 36.1) | 43.6 (37.6, 49.8) | $33.1(28.3,38.3)$ | 53.7 (45.9, | 33.6 (28.7, 38.7) | 43.8 (38.1, 49.7) | 36.3 (32, 40.9) |
| Southern | $31.7(27.2,33)$ | $79(68,79.5)$ | 26.5 (18.8, 28.1) | 45.4 (42.2, 47.2) | 29.6 (22.2, 30.7) | 52.7 (51.4, 59.7) | 33 (25.6, 35) | 32.7 (31.2, 36) | 33.7 (28.1, 34.2) |
| Lesotho | 33 (29.9, 36.1) | $79(63.4,89.1)$ | 26.5 (22.6, 30.7) | 47.3 (43.1, 51.6) | 29.6 (26.7, 32.8) | $52.7(46.6,58.8)$ | 35 (30.5, 39.7) | 32.7 (28.3, 37.4) | 33.8 (31, 36.8) |
| Botswana | $31.7(29.3,34.2)$ | $79.5(69.6,86.8)$ | $28.1(25.3,31)$ | $45.4(41.9,48.9)$ | 30.7 (28.2, 33.2) | 59.7 (53.9, 65.2) | 33 (29.9, 36.2) | 36 (32.5, 39.7) | $34.2(31.9,36.6)$ |
| Malawi | 18.1 (15.3, 21.2) | $46(25.7,67.6)$ | 16.4 (13.4, 19.9) | 26.5 (22.5, 30.9) | $17.4(14.6,20.6)$ | 36.3 (28.9, 44.4) | $16.9(14.2,20.1)$ | $36.2(29.1,44)$ | $18.4(15.7,21.5)$ |
| Eswatini | $27.2(25.1,29.5)$ | $68.1(55.1,78.8)$ | 18.9 (16.5, 21.5) | 42.3 (39.3, 45.4) | $22.2(20.1,24.4)$ | $51.4(47,55.9)$ | 25.6 (22.9, 28.4) | $31.2(28.5,34.1)$ | $28.1(26.2,30.1)$ |
| Zambia | $21.5(19.6,23.5)$ | $62.9(48.8,75.1)$ | $19(17.1,21)$ | 33.2 (29.9, 36.6) | $20.7(19,22.5)$ | $47.5(41,54)$ | $21.5(19.8,23.3)$ | $43.2(36.8,49.8)$ | 23 (21.2, 24.8) |
| ESA | 26.7 (18.1, 31.7) | $63(48.5,68.6)$ | 20.5 (16.3, 24.6) | $37.7(32.7,43.5)$ | $23.6(17.3,29.6)$ | $50.4(47.5,52.7)$ | 26 (19.7, 30.5) | 33.9 (26.2, 37.7) | 27.5 (18.3, 33.7) |
| WCA | 29.6 (28.6, 32.7) | 52.7 (40.2, 70) | 24.5 (22.2, 30.7) | 39 (38.4, 40.2) | $27.2(27,30.7)$ | $46.7(44.7,50.4)$ | $27.4(24.7,33.7)$ | 47.9 (40.4, 49.9) | $29(23.6,29.7)$ |
| SSA | 28 (22.2, 31.7) | 59.5 (47.2, 69.3) | 22.2 (18.9, 25.6) | $38.5(33,41.9)$ | 25.8 (21.2, 30) | $49(44.8,52.7)$ | 26.4 (22.1, 31.7) | 36 (26.7, 43.2) | $28(23,29.7)$ |

[^4]Table s2: Prevalence (\%) of treatment by comorbidities and regions

| Countries | Non-diabetic | Diabetic | No central obesity | Centrally obese | Not obese | Obese | No dyslipidemia | Dyslipidemia | Overall |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| West | 17.7 (10.3, 34) | 40 (39.7, 70.6) | 7.3 (7.19, 13.8) | 17.2 (15.6, 19.6) | 10 (8.3, 12.1) | $23.2(18,24.7)$ | 10.6 (9.5, 15.3) | 17.6 (11.3, 23.7) | 10.1 (9.69, 10.5) |
| Benin | $8.9(6.8,11.5)$ | 39.8 (23.3, 59) | $7.2(4.9,10.5)$ | 13.2 (10.1, 17.2) | $8.2(6.1,10.9)$ | 17.9 (12.2, 25.5) | $9(6.9,11.6)$ | $11.4(6.8,18.5)$ | 9.7 (7.5, 12.3) |
| Gambia | $34(22.9,47.2)$ | $70.7(48.1,86.3)$ | $13.8(10.1,18.5)$ | 19.6 (14.6, 25.7) | 12.2 (9.4, 15.8) | 31.3 (22.6, 41.5) | $15.4(12.4,18.9)$ |  |  |
| Liberia | 17.8 (14.2, 21.9) | $40(24.6,57.7)$ | 15.9 (11.6, 21.3) | $22.9(17,30.1)$ | $16.7(13.1,21.2)$ | 23.3 (15.7, 33.2) | $19.2(15.8,23.1)$ |  |  |
| Togo | 10.3 (7.4, 14.2) | $33.3(17.5,54.2)$ | $7.3(5,10.6)$ | 15.7 (11, 21.9) | $8.3(5.7,11.9)$ | $24.8(15.8,36.6)$ | $9.5(7,12.7)$ | $23.8(13,39.5)$ | 10.5 (7.8, 14.1) |
| SL` & \(43.2(27,60.9)\) & \(86.3(63.5,95.8)\) & 6.7 (4.7, 9.4) & 17.2 (12.6, 22.9) & \(10(7.6,13.2)\) & \(18(11.5,27)\) & 10.7 (8.2, 13.7) & & \\ \hline Central & 18.5 (18.5, 18.5) & \(33(33,33)\) & 13.5 (13.5, 13.5) & 23.2 (23.2, 23.2) & \(17.6(17.6,17.6)\) & 26.3 (26.3, 26.3) & \(17.2(17.2,17.2)\) & 25.1 (25.1, 25.1) & \(19(19,19)\) \\ \hline CAR & 18.5 (15.8, 21.5) & \(33(22.8,45)\) & 13.5 (10.4, 17.3) & 23.3 (18.7, 28.6) & \(17.6(13.7,22.4)\) & 26.4 (19.5, 34.8) & \(17.2(13.7,21.4)\) & \(25.1(17.8,34.1)\) & \(19(15.6,22.8)\) \\ \hline Eastern & 12.6 (6.9, 16.2) & 39.2 (24.1, 47.2) & 9.1 (5.69, 12.8) & 14.5 (13.3, 27.8) & 13.6 (7.3, 17.2) & 17.6 (15.5, 31.7) & 14.1 (6.9, 17.2) & 15.3 (8.69, 25.7) & \(14.3(8,18.5)\) \\ \hline Comoros & 18.2 (14.6, 22.5) & 39.2 (28.2, 51.4) & 11.6 (8.5, 15.7) & 23.7 (20, 27.7) & \(16.4(13.7,19.6)\) & 23.8 (18.5, 30.1) & \(17.2(14.6,20.2)\) & 25.7 (17.1, 36.7) & 18.2 (15.5, 21.1) \\ \hline Eritrea & 16.3 (12.9, 20.4) & \(52.2(37.5,66.6)\) & \(11.7(9,15.1)\) & \(27.9(21.7,35)\) & \(17.5(14.3,21.3)\) & 36.5 (19.7, 57.4) & \(17.2(12.6,23)\) & 19.7 (15.9, 24.1) & 18.7 (15.3, 22.6) \\ \hline Ethiopia & \(6.4(4.6,8.8)\) & \(21.7(11.3,37.6)\) & \(6.2(4.3,8.9)\) & \(8.1(5.7,11.3)\) & \(6.4(4.7,8.7)\) & \(14.1(8.5,22.4)\) & \(5.2(3.8,7.3)\) & \(10.2(6.2,16.4)\) & \(6.7(5,8.9)\) \\ \hline Kenya & \(7.6(5.6,10.3)\) & 24.1 (13.3, 39.5) & 5.7 (3.5, 9.1) & \(13.8(10.4,18)\) & \(7.9(6,10.3)\) & 16.1 (10.6, 23.6) & 10.5 (7.4, 14.7) & \(8.4(6.2,11.2)\) & 9.3 (7.3, 11.9) \\ \hline Rwanda & \(4.8(3.5,6.6)\) & \(15(4.7,38.5)\) & \(4.4(3,6.6)\) & \(6.5(4.2,9.7)\) & \(4.3(3,6.1)\) & \(16.1(9,27.1)\) & \(3.4(2.1,5.4)\) & 5.8 (4.1, 8.2) & \(4.9(3.6,6.7)\) \\ \hline Sudan & 12.7 (10.9, 14.6) & \(43.4(36.4,50.6)\) & \(9.1(6.9,12)\) & \(21.9(19.4,24.6)\) & 13.6 (11.6, 15.9) & \(27(22.9,31.6)\) & \(14.8(10.8,20)\) & \(15.4(13.4,17.7)\) & 15.3 (13.4, 17.4) \\ \hline Tanzania & \(8.8(6.3,12.2)\) & 33.3 (19.6, 50.7) & \(5.9(4.1,8.5)\) & 13.4 (9.4, 18.8) & \(8.4(6.6,10.7)\) & 17.6 (11.2, 26.5) & \(8(6.5,9.9)\) & 16 (9.7, 25.2) & \(9.8(7.5,12.6)\) \\ \hline Uganda & \(6.9(5.3,8.8)\) & 40.6 (23.1, 60.8) & \(5.1(3.6,7)\) & 13.7 (10.1, 18.3) & 7.3 (5.7, 9.3) & 15.5 (8.9, 25.7) & \(6.9(4.6,10)\) & \(8.7(6.5,11.6)\) & \(8(6.3,10)\) \\ \hline Zanzibar & 13.3 (9.2, 18.7) & \(25.9(9.6,53.5)\) & \(14.4(8.9,22.5)\) & \(14.5(10.5,19.7)\) & 14.5 (9.9, 20.7) & \(13(8.8,18.8)\) & 14.9 (10.4, 21) & \(13.4(9,19.4)\) & \(14.4(10.4,19.6)\) \\ \hline Southern & 19.2 (16.5, 22.7) & 61.4 (59.4, 72.4) & 8.8 (8.1, 14.8) & 33.4 (29, 37.7) & 16.1 (14.8, 20.2) & 35.4 (27.2, 43.2) & 18.7 (18, 20.2) & 26.7 (19.7, 33.4) & 23.5 (18.7, 24.7) \\ \hline Botswana & 22.8 (19.8, 26.1) & 59.4 (45.5, 71.9) & 14.9 (11.5, 19.1) & \(37.8(33.8,42)\) & 20.3 (17.4, 23.7) & 43.2 (36.1, 50.6) & \(18.7(15.7,22.3)\) & \(33.4(28.3,38.8)\) & \(24.8(22,27.9)\) \\ \hline Lesotho & 16.5 (13.5, 19.9) & \(61.4(39.1,79.8)\) & \(8.1(5.1,12.6)\) & 29 (24.7, 33.7) & \(14.8(11.3,19.3)\) & 27.3 (21.9, 33.4) & \(18(13.4,23.8)\) & 19.7 (15.2, 25.1) & 18.8 (15.8, 22.3) \\ \hline Malawi & \(17.1(12.6,22.9)\) & \(71.9(46.2,88.4)\) & 14.3 (9.4, 21.2) & 29.1 (22, 37.4) & 17.3 (12.8, 23) & \(31.7(21.4,44.2)\) & \(14.2(9.9,19.8)\) & \(43(31.8,55)\) & \(18.5(14,24)\) \\ \hline Eswatini & 19.2 (15.6, 23.5) & \(72.4(61.1,81.4)\) & \(8.8(5.9,13)\) & 33.4 (29.2, 37.9) & \(16.1(12.5,20.6)\) & \(35.4(29.7,41.6)\) & \(20.3(16.7,24.5)\) & \(26.7(22.1,31.8)\) & 23.5 (20.2, 27.2) \\ \hline Zambia & 15.7 (12.7, 19.2) & 47.3 (30.9, 64.3) & 12.9 (9.7, 16.8) & 30.4 (25.1, 36.2) & 17.3 (14.1, 21) & 32.8 (24.2, 42.8) & \(18.4(15.1,22.3)\) & 29.9 (22.4, 38.7) & 19.9 (16.8, 23.4) \\ \hline ESA & 14.5 (7.59, 17.1) & \(42(25.8,59.4)\) & 8.94 (5.9, 12.8) & 22.7 (13.6, 29.1) & 14.6 (7.9, 17.2) & 25.3 (16.1, 32.7) & \(14.8(8,18)\) & 17.8 (10.1, 26.7) & \(16.7(9.3,18.7)\) \\ \hline WCA & 18.1 (10.3, 34) & 39.9 (33.2, 70.6) & 10.3 (7.19, 13.8) & 18.3 (15.6, 22.8) & \(11.1(8.3,16.7)\) & \(24(18,26.3)\) & \(13(9.5,17.2)\) & 23.7 (11.3, 25.1) & \(10.5(9.69,19)\) \\ \hline SSA & 16 (8.85, 18.3) & 40.2 (33.1, 60.4) & 8.94 (6.44, 13.6) & 20.7 (13.7, 28.4) & \(14(8.25,17)\) & 24.2 (16.8, 31.5) & 14.8 (9.25, 17.6) & 19.7 (11.3, 25.7) & 15.3 (9.69, 18.7) \\ \hline \multicolumn{7}{\|l|}{CAR* - Central African Republic; SL` - Sierra leone; ESA - Eastern and Southern Africa; SSA - sub-Saharan Africa} |  |  |  |  |  |  |  |  |  |

### 8.4 Appendix 4: Qualitative study guides

I. In-depth interviews and focus group discussions with participants with uncontrolled hypertension and comorbid conditions (diabetes, overweigh/obese, hypercholesterolemia)

This community has been identified to have a high burden of uncontrolled hypertension which is a leading risk factor to premature death and disability. I am trying to gather information about the hypertension care in your community. To avoid hypertension related complications, it is recommended that people with high blood pressure change their lifestyle (in regards to diet, physical activity, alcohol consumption, and smoking) and taking blood pressure medications.

Jamii hii imetambuliwa kuwa mzigo mkubwa wa hali ya shinikizo la damu ambayo haijadhibitiwa ambayo inasababisha vifo vya mapema na ulemavu. Najaribu kukusanya habari kuhusu matibabu ya shinikizo la damu katika hii jamii yenyu.. ili kudhibiti matatizo yanayotokana na shinikizo la damu, watu wenye msukumu wa damu ulio juu wanahimizwa kubadilisha mienendo yao ya kimaisha(kuhusiana na lishe,shughuli za mwili unywaji wa pombe na uvutaji wa sigara) na kutumia madawa ya msukumo wa damu.

1. Tell me about your experience with having high blood pressure?

Nieleze kuhusu uzoefu wako wa kuwa na ugonjwa wa shinikizo la damu?
a. How long have they had high blood pressure?

Umekuwa na shinikizo la damu kwa muda gani?
b. How often do they check their blood pressure? Where do they check it? Do you keep a record of your blood pressure measurements (ask them to tell you about their last blood pressure (BP) record even if they don't keep a record)?
Huwa unaangalia msukumo wako wa damu baada ya muda gani? Huwa unaangalia wapi? Huwa unarekodi vipimo vya msukumo wa damu yako? (Ulizia akuambie matokeo ya kipimo chake cha mwisho)
c. What other conditions do you have apart from high blood pressure?

## Uko na magonjwa mengine kando ya shinikizo la damu?

d. What have you been told is your target blood pressure by your healthcare provider?
Umeambiwa na daktari wako kuwa vipimo vyako vinafaa kuwa kiwango gani?
e. Tell me a little bit more about the medications you are for your high blood pressure?
Tafadhali niambie kuhusu madawa unatumia kudhibiti halii hii ya shinikizo la damu?
i. How many medications are you taking, Unatumia aina ngapi ya madawa
ii. How has the number of medications you are taking changed since you were first diagnosed with high blood pressure?
Idadi ya madawa unayotumia imebadilika vipi tangu ulipopatikana kuwa na shinikizo la damu
iii. How has the strength of the medication you are taking changed since you were first diagnosed with high blood pressure?
Nguvu za madawa unayotumia imebadilikaje tangu ulipopatikana kuwa na shinikizo la damu?
2. How has having high blood pressure affected you?

Kuwa na shinikizo la damu kumekuadhiri vipi?
3. Apart from the medications, how do you manage your high blood pressure condition? Huwa unashughulikia vipi hali yako ya shinikizo la damu, kando na kutumia madawa?
a. Probe if not mentioned

Dadisi iwapo hajataja
i. Diet, physical activity, medication including traditional medications etc.

Lishe, shughuli za mwili, madawa pamoja na ya kienyeji n.k
ii. What else do you do to keep your blood pressure under control? Ni nini kingine wewe hufanya ili kudhibiti hali yako ya msukumo wa damu?
b. Who do you see?

Wewe huona nani?
i. What can you say about how your healthcare provider is managing your high blood pressure?
Unaweza sema nini kuhusu jinsi mhudumu wako wa afya anavyoshughulikia hali yako ya shinikizo la damu?

1. What are your views concerning your healthcare providers decisions?
Mtazamo wako ni upi kuhusu muhudumu wako wa afya?
2. Have you sought care elsewhere? If so, what were you told? Umetafuta matibabu mahali pengine? Kama ndio, uliambiwaje?
3. In the community, where would you access hypertension care services in your area?

Je katika jamii hii, unaweza pata wapi huduma zinazohusiana na shinikizo la damu?
a. What type of services are offered?

Ni huduma za aina gani ambazo hupeanwa?
b. Do you receive hypertension care services in the community?

Wewe hupokea huduma za kushughulikia shinikizo la damu katika jamii?
c. Probe for where, why and why not

Dadisi kujua ni wapi, mbona anapokea na mbona hapokei?
d. Probe for types of services received (free medication, blood pressure measurements, advice from health care workers, etc.) and how often these services are received (weekly, monthly, every 3 months etc.).
Dadisi kuhusaina za huduma alizopokea (matibabu ya bure, kupimwa msukumo wa damu, ushauri kutoka kwa wahudumu wa afya n.k)
umepokea huduma hizo mara ngapi? (Kila juma;kila mwezi, baada ya kila wiki tatu n.k
5. Do you have any difficulties or barriers in managing/controlling your blood pressure? Je uko na shida/ vizuizi vyovyote katika kushughulikia/Kudhibiti msukumo wa damu yako?
a. Probe for all the difficulties or barriers they face in maintaining blood pressure control.
Dadisi shida au vizuizi vyote wanavyokumbana navyo wanapojaribu kudhibiti msukumo wa damu yao.
i. Individual level factors/ Sababu za kibinafsi

1. Cost/Bei- Ask about healthcare insurance (NHIF or private insurance) and whether it covers hypertension care or whether they pay for themselves.
2. Age/umri
3. Comorbidity/ Kuweepo kwa magonjwa mengine
4. Compliance/adherence to medication regimen/ Kufuata maelekezo ya utumizi wa madawa
5. Behavioural factors e.g alcohol use, smoking, sedentary lifestyle etc/ sababu za kitabia k.m Utumizi wa pombe, uvutaji wa sigara, hali ya maisha ya kuketi tu n.k
ii. Community and family level factors/ Sababu za kijamii na kifamilia
6. Family structure/ Muundo wa familia
7. Environment e.g more unhealthy foods/ Mazingira km vyakula vingi visivyo na afya
iii. Providers perspective/ Sababu za muhudumu wako
8. Quality of care provided/Ubora wa matibabu.n.k.
9. Workload of provider/ Wingi wa kazi kwa wahudumu
10. Timing that care is provided in the community/ Wakati/Masaa ambayo matibabu yanapeanwa katika jamii
11. Adequacy of information shared? Utoshelevu wa habari zinazopeanwa
iv. Health system level factors/ Sababu zinazotokana na mfumo wa afya
12. Drug stock outs/ Kuishiwa kwa madawa
13. Poor infrastructure in the facility/ Miundo msingi mbovu katika vituo
14. Timing that care is provided in the community/ Wakati/Masaa ambayo
15. Adequate space for consultation of patients with hypertension Nafasi ya kutosha ya mashauriano ya wagonjwa wenye msukumo wa damu
v. Policy level factors/ Sababu zinazotokana na ubunifu wa sera
16. Guidelines
17. What do you think are the possible solutions to the difficulties or barriers you have mentioned?
Je unafikiri ni nini ambacho chaweza suluhisha vizuizi ulivyotaja?
Note: Make sure to remind the respondent of all the challenges/barriers they have mentioned and ask what the possible solutions to those challenges are.

Nakili: Hakikisha kumkumbusha unayemhoji kuhusu changamoto zote alizotaja na uulizie ni nini chaweza fanywa ili kusuluhisha changamoto hizo.
a. Probe for what the patient could do differently?

Dadisi kuhusu kile ambacho mgonjwa anaweza fanya tofauti?
b. Probe for what the healthcare provider can do differently?

Dadisi kuhusu kile ambacho mhudumu wa afya anawezafanya tofauti.
c. Probe for what the healthcare facility can do differently?

Dadisi kuhusu kile ambacho kituo cha afya kinawexa fanya tofauti.
7. How has the current COVID-19 situation affected how you get hypertension care in this community?
Hali ya COVID-19 kwa sasa imeadhiri vipi upokeaji wako wa huduma za ugonjwa wa shinikizo la damu katika jamii hii?
8. Is there anything else you want to talk about in regards to hypertension?

Kuna kingine ambacho ungependa tuzungumzie kuhusiana na hali ya ugonjwa ya shinikizo la damu?

## **End of Interview**

## II. Key informant interviews with healthcare providers in the community

This community has been identified to have a high burden of uncontrolled hypertension which is a leading risk factor to premature death and disability. I am trying to gather information about the provision of hypertension care in this community particularly for patients on treatment and who have their blood pressure not under control. I am seeking your views on uncontrolled hypertension among those on treatment in this community and factors driving these high rates.

1. Please tell me about hypertension care in this community.
2. Please tell me about the hypertensive clinic in this facility.
a. How do you diagnose high blood pressure?
b. Are there national guidelines for hypertension that you use? Ask to see a copy of the guidelines?
c. Do you see patients with hypertension and other conditions?
i. Probe for what the conditions are
ii. How do you manage these patients?
iii. Are there guidelines specific to patients with other conditions?
3. What factors are associated with good and poor blood pressure control?
a. Probe if not mentioned: What factors are associated with good control
b. Probe if not mentioned: What factors are associated with poor control?
4. What challenges do you encounter in the provision of the hypertension care services you provide to your patients with uncontrolled hypertension?
a. What are the challenges you are facing with your patients in regards to blood pressure control?
i. Are there any challenges related to the facility hours?
ii. Are there challenges related to medication such as stock out?
iii. How about the capacity or workload of employees providing this care?
iv. Challenges you face when prescribing medications to patients with hypertension:

- Changing prescriptions;
- Increasing the number of medications
- Increasing the strength
b. What are the factors that contribute to uncontrolled hypertension in the patients you see?
i. Individual level/ patient perspectives
ii. Community and family level perspectives
iii. Provider's perspective
iv. Health system level perspectives
v. Policy level perspectives

5. What in your view would be possible solutions to the challenges you have mentioned?
a. Note: Make sure to remind the respondent of all the challenges they have mentioned and ask what the possible solutions to those challenges are.
6. How has the current COVID-19 situation affected your provision of care to hypertensive patients in this community?
a. Hours of operation?
b. Availability of antihypertensive medication?
c. Patients not coming for clinic appointments?
d. Change in priorities?
e. Outreaches?
f. Is there anything else that has been affected that we have not covered?
7. Is there anything else you want to talk about in regards to hypertension?
**End of Interview**

## III. Key informant interviews with policy makers/decision makers for the area

There are several challenges in access and uptake of hypertension which include; physical, structural, policy and financial challenges. I am seeking your views on uncontrolled hypertension particularly among those who are on treatment.

1. In your view, what are the challenges in the access and uptake of hypertension care in the community you serve?
a. If not mentioned, probe for: physical (number of public facilities in the area), structural, policy (clear guidelines for hypertension care) and financial (allocations for hypertension care) challenges.
i. Are there any challenges in terms of expertise in healthcare providers, equipment for blood pressure monitoring, etc.?
ii. What are the staffing challenges?
iii. Are there any challenges related to the facility hours?
iv. Are there challenges related to medication such as stock out?
v. How about the capacity or workload on the employees providing this care?
2. What in your opinion can be done in these communities to alleviate the access and uptake challenges for uncontrolled hypertension care?
i. Individual level/patient perspectives
ii. Community and family level perspectives
iii. Provider's perspective
iv. Health system level perspectives
v. Policy level perspectives
3. How has the current COVID-19 situation affected your provision of care to hypertensive patients in the community you serve?
4. Is there anything else you want to talk about concerning hypertension care, which we have not discussed?

[^0]:    Source: Adapted from the Centers for Disease Control and Prevention (CDC), The Social Ecological Model: A Framework for Prevention, http://www.cdc.gov/violenceprevention/overview/social-ecologicalmodel.html (retrieved January 23, 2019).

[^1]:    SSA=sub-Saharan Africa
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[^2]:    SSA=sub-Saharan Africa

[^3]:    *CAR -Central African Republic, ~PA -Physical Activity, ESA - Eastern and Southern Africa, WCA - Western and Central Africa, SSA - sub-Saharan Africa

[^4]:    CAR* - Central African Republic; SL` - Sierra leone; ESA - Eastern and Southern Africa; SSA - sub-Saharan Africa

