MAKERERE UNIVERSITY

MORTALITY ASSOCIATED WITH HYPERTENSION AMONG PEOPLE LIVING WITH HIV AGED 40 YEARS AND OLDER IN KENYA, UGANDA, AND TANZANIA

BY

DENIS MAYAMBALA (BDRH, KYU)

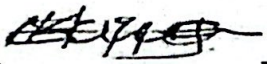
A DISSERTATION SUBMITTED TO THE DIRECTORATE OF GRADUATE TRAINING IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF DEMOGRAPHY AND POPULATION STUDIES OF MAKERERE UNIVERSITY

December 16, 2025

Declaration

I, Denis Mayambala, hereby declare that this dissertation is my own effort and has not been submitted, either in whole or in part, for the award of any degree or diploma at any other institution of higher learning.

This is submitted in partial fulfilment of the requirements for the award of the Master of Demography and Population Studies at Makerere University, Uganda.

Signed:  _____

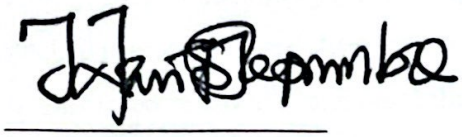
Denis Mayambala

Registration Number: 2023/HD06/22122U
Student Number: 2300722122

Approval

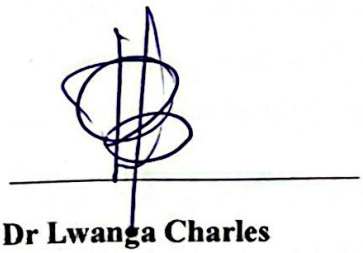
This dissertation has been submitted for examination with the approval of the following supervisors:

Signature and Date:



Dr Wandera Stephen Ojiambo,
Senior Lecturer,
Department of Population Studies,
School of Statistics and Planning
College of Business and Management Sciences,
Makerere University

Signature and Date:



Dr Lwanga Charles

Senior Lecturer,
Department of Population Studies,
School of Statistics and Planning
College of Business and Management Sciences,
Makerere University

Digitisation and Self-Archiving Consent Agreement: Theses

Agreement between Makerere University & Students (Authors of Theses / Dissertations / Reports)

1. The author is a student of Makerere University and author of the thesis / dissertation entitled:
Mortality associated with hypertension among Pltns aged 40 years and older in Kenya, Uganda and Tanzania

2. The author grants to the University:
   a. The right to deposit the electronic version of the Thesis / Dissertation into Makerere University Institutional Repositories (Mak IR) or (Mak UD); and
   b. The right to store the thesis / dissertation in Mak IR / Mak UD and make it permanently available to the general public via the Internet at no cost to the general public after a grace period (if any is specified).
   Choose one of the three options below (c, d, or e):
   c. The Author may opt for immediate open access to the public ..... c .....
   d. Or Restrict access indefinitely: .....
   e. Or Restrict access for the specified number of years: .....
   f. Reason for restriction: .....

3. The author warrants that to the best of the authors knowledge and belief:
   a. The thesis / dissertation is an original work;
   b. The author is the owner of all the intellectual property in the thesis / dissertation;
   or
   c. The Author is entitled to deal with the intellectual property in the thesis / dissertation by publishing it on the Internet
   d. The Author has the right, power and authority to enter into this Agreement and to grant the University the rights contained in this Agreement; and
   e. The University's use of the thesis / dissertation pursuant to this Agreement will not infringe the intellectual property rights of any third party.

4. The Author acknowledges and agrees that the University is not responsible or liable for any breach of the intellectual property rights in the thesis / dissertation, in particular any breach of copyright, as a result of the use of the thesis / dissertation pursuant to this Agreement.

5. The University acknowledges that the rights granted by the Creator in clause 2 of this Agreement, do not cause any transfer or assignment of any proprietary rights in the intellectual property in the article to the University.

Signed by the Author as confirmation that the Author has read and accepted the terms of this Agreement:

Name: Denis Mayambala

College: CoRAMS School: Statistics & Planning

(Tick) Type of Degree: (Undergraduate / PGD / Masters / PhD), Reg. No.: Masters

Tel No.: +256781515518 E-Mail: mukerdenis@yahoo.com

Signature: [signature] Date: 19/12/2025

Supervisor's endorsement: _____

MakIRs Policy

Dedication

This thesis is dedicated to my beloved two sons and daughter: Kaweesa **Deion John Baptist**, Kisitu **Ennis Elijah and Kaweesa Deelilah Osma**.

To **Deion**, whose arrival marked a turning point in my life, your birth ignited in me an urgency to act, to advance, and to secure a future not only for myself but for you. It was this drive that pushed me to pursue this Master's degree with focus and determination, and it was your coming that ushered in the luck and grace through which I received a fellowship to support my studies.

To **Elijjah and Deelilah**, whose peaceful entry into the world and unexpected good health gave me the mental clarity and freedom from worry I needed to carry this work through. Your calm presence brought stability to my life when I needed it most.

To the cherished memory of my father, **Kaweesa Joseph**, whose guidance, though now silent, remains deeply present in every step I take. To my mother, **Namiiro Leticia**, whose sacrifices and resilience have held our family together. I carried your spirit in this journey.

To **people experiencing the dual burden of diseases**, who often remain unseen in health systems. This work is for you. May it contribute, however humbly, to the knowledge and systems that better serve you!

To my **nieces and nephews**, may you grow up knowing that knowledge can reshape destiny, and that each of us is called to leave things better than we found them. *"Okutambula kulaba, okudda kunyumya."*

Acknowledgement

I extend my deepest gratitude to everyone who supported and contributed to the successful completion of this study.

I am profoundly thankful to my academic supervisors, Dr Charles Lwanga and Dr Wandera Stephen Ojiambo, from the Department of Population Studies, College of Business and Management Sciences, Makerere University. Your unswerving guidance, mentorship, and critical feedback helped shape this research and enriched my intellectual journey.

I am equally grateful to Francis Sena Nuvey, Bruno Lokonon, Dan Haydon, Bassirou Bonfoh, and Sayoki G. Mfinanga for their mentorship under the Afrique One–REACH Fellowship Programme. Your interdisciplinary views and encouragement were invaluable throughout my research.

Special thanks to the Afrique One–REACH Coordination Team for awarding me the fellowship that funded my MSc studies and for creating a two-way One Health training environment that is central to my academic growth.

I acknowledge Dr Hannah Kibuuka, Dr Kigozi Godfrey and the MHH-AFRICOS study coordination for their support in facilitating data access, particularly thankful to Emma Duff for her responsiveness and technical assistance during the data request process. I also extend my appreciation to all the Principal Investigators of the AFRICOS study project for their contributions and data stewardship.

To my colleagues and fellow graduate students in the Department of Population Studies, thank you for your friendship, peer feedback, and encouragement throughout this journey.

I am grateful to all those unnamed whose support, prayers, or actions made this work possible.

Table of Contents

List of Tables

List of Figures

Abbreviations and Acronyms

Adj	Adjusted
AFRICOS	African Cohort Study
AIDS	Acquired Immunodeficiency Syndrome
AL	Allostatic load
ART	Antiretroviral therapy
BMI	Body mass index
CD4	Cluster of Differentiation 4
CIs	Confidence intervals
CRP	C-reactive protein
DBP	Diastolic blood pressure
DHS	Demographic and Health Surveys
EWMA	Exponentially weighted moving averages
HIV	Human Immunodeficiency Virus
HTN	Hypertension
IQR	Interquartile range
LLV	Low-level viremia
LOESS	Locally Estimated Scatterplot Smoothing
MCOD	Multiple Cause of Death
MHRP	Military HIV Research Program,
mmHg	Millimeters of mercury
NCDs	non-communicable diseases
ORs	Odds Ratios
PLWH	People living with HIV
WRAIR	Walter Reed Army Institute of Research, Protocol number
SBP	Systolic blood pressure
SES	Socioeconomic status
SSA	sub-Saharan Africa

Abstract

Although mortality among people living with HIV (PLHIV) in sub-Saharan Africa has decreased markedly with the scale-up of antiretroviral therapy (ART), the demographic consequences of this success remain underexamined. Using ten years of longitudinal data from the African Cohort Study (AFRICOS; 2013–2023) in Kenya, Tanzania, and Uganda, we estimated the contribution of hypertension to all-cause mortality among adults aged 40 years and older. We combine descriptive decremental life-table analysis with discrete-time logistic regression, applying both lagged and exponentially weighted moving-average (EWMA) exposure models to capture cumulative risk.

The analytic baseline sample included 1,169 unique participants (Kenya = 698, Tanzania = 256, Uganda = 215), who expanded to 1,360 individuals across all biannual follow-up waves over ten years, contributing a total of 12,462 person-period observations to the final adjusted models. Participants were 51% male, with a mean age of 48 years, and 60% were from Kenya. The cumulative prevalence of hypertension during follow-up was 60%, with 10% mortality among hypertensive participants. The greatest disadvantage occurred in the 50–59 age group, where hypertension-attributable excess mortality accumulated steadily over time, rising to nearly 4% by year nine with modestly higher odds of death. In Model 6 (aOR: 1.13, 95% CI: 0.57–2.23, $p < 0.05$), while participants aged 60 years and above experienced substantially elevated mortality (aOR: 2.32, 95% CI: 0.89–6.01, $p < 0.05$). Subgroup analyses revealed sharper effects in men, underweight individuals, and those with unsuppressed viral load.

Hypertension was an independent predictor of death (aOR = 3.25; 95 % CI 1.26–8.40). High viral load also remained a strong independent risk factor, doubling the odds of death (aOR 2.4; 95 % CI 1.3–4.5). These findings highlight a demographic transformation of the HIV epidemic in East Africa, where mortality among PLHIV increasingly reflects a growing influence of chronic diseases in addition to infection control. Hypertension has become a key driver of excess mortality and a demographic indicator of the region's compressed health transition.

Keywords: HIV, hypertension, mortality, life course, East Africa

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

The scale-up of antiretroviral therapy (ART) has changed the mortality profile of people living with HIV (PLHIV) in sub-Saharan Africa. Before ART, HIV caused very high adult mortality, especially among young and middle-aged adults. With ART, survival has improved greatly. More PLHIV now live into their 40s, 50s, and 60s (Nabukalu et al., 2020; Negin et al., 2012). In Uganda's Rakai cohort, life expectancy before age 50 increased by over a decade in one treatment generation (Nabukalu et al., 2020). Similar trends are seen across East Africa. Women often benefit earlier and more due to higher treatment uptake (Reniers et al., 2014). This study treated Uganda, Kenya, and Tanzania as a connected region. Life course theory frames comorbidities as a cumulative outcome of unique exposures (Elder Jr & Shanahan, 2007).

Among these comorbidities, hypertension (HTN) has emerged as one of the most prevalent and consequential. Globally, over 20% of PLHIV are now aged 50 and above, double the proportion in 2005 (Schnure et al., 2022), and prevalence of hypertension among PLHIV is consistently higher than among HIV-negative peers (Chen et al., 2024; Xu et al., 2017). In East Africa, recent meta-analyses report prevalence rates of 19% in Uganda, 18% in Kenya, and 27% in Tanzania (Tegegne et al., 2023), with some local studies finding rates exceeding 35% (Byonanebye et al., 2023; Sakita et al., 2023). Incidence studies confirm that hypertension often arises earlier in HIV cohorts, with patients on long-term ART developing elevated blood pressure in their 40s, a decade earlier than expected in HIV-negative populations (Byonanebye et al., 2023; Mbuthia et al., 2021).

For demographers, the significance of this trend is not hypertension prevalence per se, but its contribution to all-cause mortality. Mortality schedules are shifting as AIDS deaths decline, hypertension and related conditions account for a growing share (Mollel et al., 2022; Omar et al., 2025). This reflects Omran's epidemiologic transition theory (Omran, 2001). Yet in sub-Saharan Africa, the transition is incomplete and complex, producing a "double burden" where infectious and chronic diseases coexist (Kuate Defo, 2014).

Hypertension's demographic significance is magnified by the life course of PLHIV survival. Older cohorts who initiated ART late carry lasting damage from untreated infection, leaving them more vulnerable despite treatment (Nabukalu et al., 2024). Later cohorts benefit from

earlier initiation but as they age, cumulative ART toxicity, immune activation, and social stress accelerate hypertension onset (Masenga et al., 2019; Prakash et al., 2024). These patterns align with life course theory, which emphasizes accumulated exposures shaping later-life health (Elder et al., 2007). Hypertension is thus not incidental but an expression of cumulative disadvantage and accelerated ageing.

Evidence confirms its mortality effect. In South Africa, uncontrolled hypertension raises all-cause mortality among PLHIV (Chidumwa et al., 2023), while Tanzanian data show rising cardiovascular deaths (Mollel et al., 2022). Comparable findings in North America (Sadinski et al., 2023) highlight its global contribution to survival inequalities. Despite mounting evidence, demographic measurement has lagged. Most East African surveillance still centers on AIDS-specific mortality or aggregate NCD burdens, rarely isolating hypertension's role (Bigna & Noubiap, 2021). These risks overstating life expectancy and dependency ratio gains by ignoring deaths redistributed upward in the age schedule. Demographic tools such as decrement and cause-deleted life tables can capture these shifts (Beltrán-Sánchez et al., 2008), yet have seldom been applied in HIV populations.

The omission is consequential. Premature mortality among hypertensive PLHIV erodes the demographic dividend through reduced workforce participation and heavier caregiving demands (Canning, 2011; Cooper et al., 2003). Country contrasts show structural effects: Uganda's weaker HIV–NCD integration yields higher mortality than Kenya or Tanzania (Kiplagat et al., 2022; Kivuyo et al., 2023; McCombe et al., 2022). Such variation illustrates that demographic transitions unfold unevenly across contexts, conditioned by institutional capacity and cohort exposure histories (Mayer, 2003; Palagyi et al., 2019).

This study quantified excess all-cause mortality from hypertension among PLHIV aged 40+ in East Africa. Using decrement life tables and discrete-time survival models, it shows how hypertension reshapes survival by age, sex, nutrition, and viral load, advancing demographic understanding of comorbidity.

1.2 Problem statement

In East Africa, HIV treatment scale-up has extended life expectancy among people living with HIV (PLHIV) (Nabukalu et al., 2020), shifting the demographic profile away from young-adult mortality toward aging cohorts (Schnure et al., 2022). As these cohorts age, they accumulate exposures and transitions from long-term ART, changing nutritional status, and evolving viral suppression shaping their risk for non-communicable diseases, especially hypertension (Tegegne et al., 2023). Recent meta-analyses show that nearly 20% of PLHIV in East Africa have hypertension, with rates ranging from about 16% in Ethiopia to 27% in Tanzania (Tegegne et al., 2023). In eastern Uganda, hypertension prevalence among PLHIV has been observed at 38%, and many individuals are unaware of their condition (Kanyike et al., 2024).

Despite these trends, demographic models rarely quantify how cumulative exposures across the life course contribute to all-cause mortality among older PLHIV. This gap matters: Life Tables, decomposition analyses, and survival schedules that omit hypertension likely overestimate survival gains from ART and mischaracterize the shifting age pattern of mortality (Chidumwa et al., 2023; Nabukalu et al., 2024). Therefore, we applied a life course thinking to ask: how much of the excess all-cause mortality is associated with hypertension among PLHIV aged 40+ in Kenya, Uganda and Tanzania, especially when considering cohort exposure histories, nutritional vulnerability, and virologic dynamics?

1.3 Objectives of the study

The general objective was to assess the influence of cumulative and time-varying exposure to hypertension, in the context of socio-demographic and clinical trajectories on all-cause mortality among people living with HIV aged 40 and above in Kenya, Uganda, and Tanzania. Specific objectives included:

1. To examine the association between socio-demographic factors, cumulative exposure to hypertension status, and all-cause mortality among people living with HIV (PLHIV).
2. To assess the effect of clinical and behavioral risk factor accumulation and trajectories on all-cause mortality among hypertensive and non-hypertensive PLHIV.
3. To determine whether allostatic load, as a marker of cumulative physiological stress, independently or interactively contributes to all-cause mortality among hypertensive PLHIV.

4. To estimate the excess all-cause mortality associated with cumulative hypertension exposure among PLHIV using life table methods, capturing survival disadvantage over time.
5. To evaluate the effect of cumulative and time-varying hypertension exposure on all-cause mortality among PLHIV using static and moving average models, reflecting life course accumulation and timing of risk.

1.4 Hypotheses

1. Older PLHIV with high cumulative exposure to hypertension status are likely to be associated with all-cause mortality among PLHIV.
2. Accumulation and trajectories of viral loads likely affect all-cause mortality among hypertensive and non-hypertensive PLHIV.
3. PLHIV with cumulative or persistent hypertension exposure will likely have higher all-cause mortality compared to those without hypertension.
4. The association between hypertension and all-cause mortality among PLHIV will likely be stronger when hypertension exposure is modeled cumulatively using exponentially weighted moving averages compared to static single-time-point models.
5. Higher allostatic load scores, as indicators of cumulative physiological stress, will be independently and/or interactively associated with increased all-cause mortality among hypertensive PLHIV, supporting the role of multi-system risk accumulation.

1.5 Significance of the study

The significance of this study lies in its rigorous quantification of the effect of hypertension on all-cause mortality among aging people living with HIV (PLHIV) in East Africa, using advanced demographic and epidemiological methods. By employing decrement life tables and lagged discrete-time logistic regression, the analysis demonstrates that cumulative and persistent hypertension exposure is associated with a substantial and statistically significant increase in mortality risk, particularly when cumulative exposure is modeled.

The study reveals that hypertensive PLHIV experience a progressive accumulation of excess mortality over time, with the risk peaking in early follow-up intervals and remaining elevated across subsequent periods. Importantly, the effect of hypertension on mortality is most pronounced when accounting for time-varying covariates such as BMI and viral load, and the

association is robust across demographic subgroups, including age, gender, and country of residence.

These findings advance demographic practice by illustrating how classical life table methods and dynamic survival models can be adapted to multi-morbid, aging populations in sub-Saharan Africa, where cause-of-death data are often limited. The results bridge a critical gap between epidemiological studies of relative risk and demographic estimates of life expectancy, providing direct evidence of how comorbid hypertension reshapes survival trajectories among PLHIV. Furthermore, the study's identification of high-risk subgroups such as older adults and those with unsuppressed viral load offering actionable insights for public health policy.

Integrating hypertension management into HIV care programs emerges as a clear priority, as doing so could mitigate the growing burden of non-communicable disease mortality and preserve the survival gains achieved through antiretroviral therapy. In sum, this research underscores the necessity of a holistic, chronic disease-oriented approach to HIV care in the region, with direct implications for demographic projections and health system planning.

1.6 Theoretical Framework

This study results drew on the Life Course Theory to interpret how mortality among older PLHIV with hypertension is shaped by the interplay of biological, social, and structural forces across time (Elder, 2018; Mayer, 2003). The theory emphasizes three interrelated principles: (a) life transitions, which mark shifts such as entry into adulthood or onset of chronic illness; (b) cumulative (dis)advantage, where early inequalities compound to produce widening survival gaps; and (c) the timing and sequencing of events, which influence the extent to which exposures translate into later-life outcomes. Together, these principles provide a framework for understanding why some HIV cohorts' age into higher mortality risks from hypertension, while others survive longer with fewer complications.

Of these principles, the concept of cumulative disadvantage is central for interpreting mortality among hypertensive PLHIV. Early disadvantages such as poverty, limited access to care, or stigma accumulate over decades, resulting in amplified health burdens in older adulthood (Dannefer, 2003; Ferraro & Shippee, 2009). Empirical evidence confirms that chronic conditions like hypertension appear earlier and progress more severely in disadvantaged populations, reinforcing health disparities and shortening survival (Kato et al., 2020; Masenga et al., 2019; Prakash et al., 2024). These processes produce stratified mortality schedules, where

survival inequalities are embedded in cohort life tables and expressed in differential life expectancy.

The timing and sequencing of life events further condition these outcomes. Contracting HIV in adolescence, experiencing stigma in young adulthood, and developing hypertension in midlife represent a chain of events that layers stress exposures over the life span (Billari et al., 2006; Friedman et al., 2022; Sarfo et al., 2020). For demographers, the importance lies not only in each exposure, but in how their order and timing redistribute deaths across the age schedule, altering the shape of cohort survival curves.

The concept of allostatic load provides a biological mechanism that links these theoretical principles to measurable outcomes. Defined as the cumulative wear and tear from repeated stress exposures, allostatic load captures how disadvantage becomes biologically embedded over time (McEwen, 2004; Seeman & Gruenewald, 2006). Elevated allostatic load has been associated with higher cardiovascular mortality among PLHIV (Fazeli et al., 2020), reinforcing the interpretation of hypertension as a marker of accelerated aging and cumulative stress. From a demographic perspective, these justify modeling hypertension not as an isolated risk factor but as part of broader survival dynamics, in which layered disadvantages shorten life expectancy and reshape population mortality patterns.

1.7 Conceptual Framework of mortality associated with hypertension among PLHIV

Mortality among hypertensive PLHIV in East Africa results from cumulative processes that unfold across the life course and interact with structural inequalities and health-system dynamics. Our framework adopts a layered perspective that links early exposures, social stratification, comorbidity accumulation, and service contexts to population-level survival outcomes.

At the life course level, early disadvantages such as poverty, malnutrition, stigma, and violence accumulate over time, producing physiological stress responses and setting individuals on trajectories of higher morbidity and mortality risk (Burkey et al., 2014). These disadvantages are stratified by gender, education, income, and geography, shaping differential access to health-promoting resources and care (Crimmins et al., 2019). From a demographic perspective, these stratifications generate systematic survival inequalities that become visible in life tables and cohort survival estimates.

Biomedical processes further intensify these risks. Long-term ART exposure and earlier onset of hypertension in PLHIV accelerate the accumulation of comorbidities, concentrating mortality risks in midlife and older ages (Godongwana & De Wet-Billings, 2021). Rather than viewing hypertension solely as a comorbidity, we conceptualize it as a marker of accelerated aging and cumulative disadvantage which condition that shifts deaths into younger ages and reshapes the age pattern of all-cause mortality.

Health system factors mediate these trajectories. In many East African settings, weak integration of HIV and NCD services, coupled with stigma, cost, and fragmentation, reduces treatment adherence and leaves hypertension frequently undiagnosed or uncontrolled (Kivuyo et al., 2023). These systemic barriers reinforce individual-level vulnerabilities, producing excess mortality that is patterned not randomly but along social and demographic lines.

In demographic terms, the culmination of these layered disadvantages manifests as higher all-cause mortality among hypertensive PLHIV, reduced life expectancy, and widening cohort survival inequalities. This framework therefore emphasizes three principles: (a) the timing and sequencing of exposures across the life course, (b) the compounding effects of comorbidity and social disadvantage, and (c) the role of systemic contexts in shaping how these disadvantages translate into measurable population outcomes.

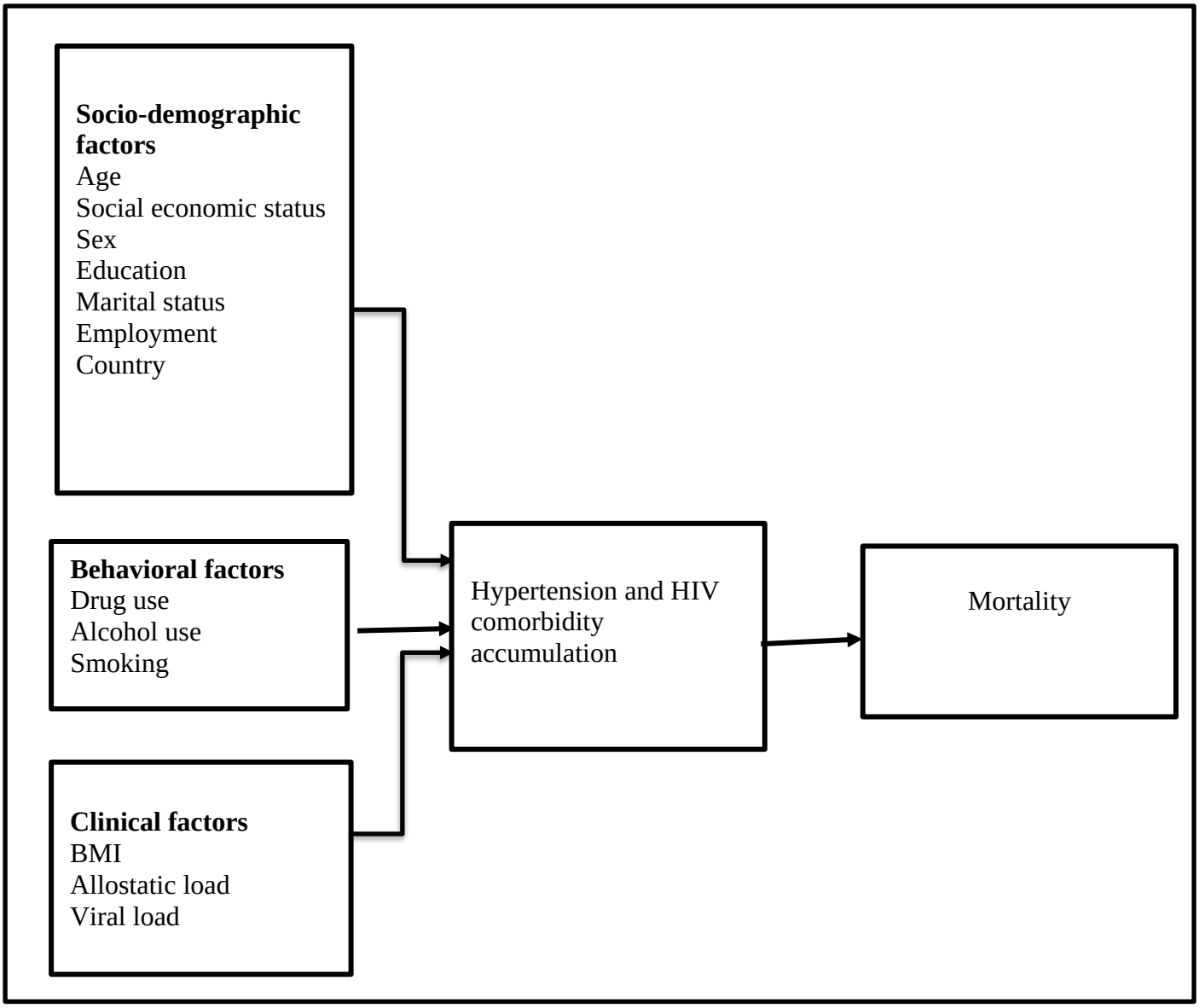


Figure 1.1 Conceptual framework of mortality associated with hypertension among PLHIV (Kibuuka et al., 2021; Mollel et al., 2022; Omar et al., 2025)

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This literature review examined the growing body of knowledge on hypertension-related mortality among aging PLHIV in East Africa situated within demographic framework.

2.2 Mortality patterns in HIV populations

Mortality among people living with HIV (PLHIV) has undergone a profound transformation in East Africa over the past two decades (Mills et al., 2011; Ford et al., 2017). With the expansion of antiretroviral therapy (ART), mortality has shifted from acute AIDS-related deaths in early adulthood to longer survival and increasingly chronic causes of death in later life (Gupta et al., 2019; Mills et al., 2011). This transition is crucial because it reshapes mortality schedules, alters life expectancy, and creates new survival differentials across age groups and cohorts (Ford et al., 2017; Mills et al., 2011). This subsection reviews highlight how mortality levels, age-patterns, and cohort dynamics have changed, and why these shifts foreground the importance of quantifying the contribution of hypertension to all-cause mortality.

The expansion of ART in sub-Saharan Africa has reduced adult mortality and increased life expectancy, especially among women, as shown in population-based studies (Reniers et al., 2014). In Uganda's Rakai cohort, partial life expectancy before age 50 rose by over a decade within one treatment generation(Nabukalu et al., 2020). As HIV-positive cohorts age, mortality patterns shift upward, and chronic comorbidities like hypertension increasingly shape survival, marking a demographic turning point (Reniers et al., 2014; Nabukalu et al., 2020).

Biological and clinical evidence provides the context for why non-communicable causes specifically hypertension emerges earlier and with greater severity in HIV populations, shaping downstream mortality. This is largely because HIV infection and long-term ART exposure place additional strain on cardiovascular and metabolic systems (Kato et al., 2020; Masenga et al., 2019; Prakash et al., 2024; Sarfo et al., 2020). These mechanisms are not ends in themselves but explanations for altered survival trajectories: they clarify why hypertension prevalence rises faster and earlier in HIV cohorts than in general populations (Ajayi et al., 2024).

Accelerated chronic disease risks, such as hypertension, may cause mortality to appear at younger ages in life tables, redistributing deaths and reducing cohort life expectancy (Geng et

al., 2015). Despite ART's benefits, mortality hazards remain highest during early treatment, especially for those starting ART with advanced disease or low CD4 counts (Geng et al., 2015). Ethiopian studies confirm mortality clusters in the first six months of ART, then decline (Kebede et al., 2020). These patterns mean stationary life tables cannot capture HIV mortality's complexity. Instead, demographic estimates must reflect time-varying hazards: early attrition reduces average survival, even as long-term mortality falls (Geng et al., 2015; Kebede et al., 2020). Quantifying hypertension's contribution to all-cause mortality requires advanced demographic methods beyond simple survival curve descriptions.

Translating individual-level risks into population contributions requires demographic tools that explicitly allocate mortality to specific causes. Cause-deleted life tables and decomposition techniques, pioneered in demographic analysis, estimate how the removal of a given condition would alter life expectancy (Beltran-Sanchez et al., 2008). Their value lies in estimating the share of all-cause mortality attributable to hypertension: not merely whether hypertension raises risk, but how many years of life are lost at different ages when its contribution is isolated (Franco et al., 2005; Mak et al., 2025). To apply these methods meaningfully, however, demographic analysis must account for the fact that HIV populations are not homogeneous. Differences in cohort timing, treatment history, and exposure shape who survives into older ages and thus who is at risk of hypertension-related mortality (Byonanebye et al., 2023; van Zoest et al., 2016).

The extension of survival under ART has produced a marked demographic shift in the age structure of HIV populations. Increasingly, individuals now live into their fifties and sixties, expanding the older age groups within which mortality risks accumulate (Negin et al., 2012; Schnure et al., 2022). Yet this transition is uneven across cohorts. Adults who initiated treatment in earlier eras often carried prolonged untreated infection and extensive exposure to opportunistic illnesses, leaving them with higher mortality even after ART became available. In contrast, later cohorts, who entered care earlier and with higher CD4 counts, show improved survival trajectories (Nabukalu et al., 2020). These patterns highlight the importance of cohort timing and exposure history meaning mortality differentials cannot be interpreted purely by age, but context in which cohorts matured.

Within these shifting cohorts, mortality remains strongly stratified by demographic and clinical characteristics. Across East African, Western, and Southern African studies, older age, male sex, and low baseline CD4 counts consistently emerge as predictors of higher mortality hazards

(Kibuuka et al., 2021; Mollel et al., 2022; Omar et al., 2025). These findings reveal layered inequalities where survival is shaped simultaneously by life course position, gendered patterns of health-seeking, and clinical vulnerability at treatment initiation (Kibuuka et al., 2021). This stratification underscores why hypertension cannot be analyzed in isolation. Its contribution to all-cause mortality must be evaluated against the backdrop of these broader differentials, since comorbid risks compound rather than substitute existing survival disadvantages.

The structure of deaths in HIV populations has shifted decisively toward non-communicable causes with AIDS-related mortality declined under ART. Longitudinal evidence from rural Tanzania shows a rising proportions of cardiovascular and other chronic conditions in cause-of-death attribution over the past decade (Mollel et al., 2022), while mortality surveillance in South Africa highlights hypertension and vascular disease as increasingly prominent contributors (Omar et al., 2025). These changes signal more than clinical diversification: they mark a demographic transition in which the distribution of deaths within HIV cohorts is being redrawn. The implication is that; all-cause mortality can no longer be understood without disaggregating the contribution of conditions like hypertension, whose growing share directly reshapes life expectancy and survival projections.

At the same time, mortality patterns under ART remain heterogeneous across contexts. Comparative analyses of East African treatment sites reveal that mortality hazards differ substantially, reflecting variations in service delivery, retention, and patient composition (Geng et al., 2015). Broader population-based surveillance in Malawi, Kenya, and Uganda shows persistent gender gaps, with men experiencing higher mortality risks than women, largely due to later ART initiation and weaker care engagement (Reniers et al., 2014). Such findings demonstrate that survival outcomes are not solely driven by biological aging or comorbidity profiles, but also by structural and programmatic contexts. This heterogeneity complicates the task of estimating comorbidity contributions, since the share of all-cause mortality attributable to hypertension will vary not only by age and cohort but also by the institutional and social environments in which PLHIV are embedded.

2.3 Socio-demographic differentials

Socio-demographic characteristics are not merely control variables but axes that shape the age-pattern, timing, and magnitude of deaths. Understanding their joint effects is therefore essential for estimating the share of hypertension in population-level mortality.

Age structures the relationship between hypertension and mortality more than any other factor. As PLHIV survive into older adulthood, hypertension prevalence rises steeply, and onset often occurs earlier than in HIV-negative peers. Evidence from East African cohorts shows that older patients on ART are disproportionately hypertensive (Byonanebye et al., 2023; Mbuthia et al., 2021), while longitudinal analyses confirm that these age groups also experience higher all-cause mortality (Bwogi et al., 2025; Nabukalu et al., 2020; Nabukalu et al., 2024). Historical cohort studies further indicate that those who initiated ART in the early years of rollout, often at advanced disease stages, carry greater vulnerability in later life (Negin et al., 2012).

Sex and gender also stratify exposure to hypertension and shape survival outcomes. Across HIV cohorts, men consistently face higher mortality risks than women, a pattern linked to delayed care-seeking and lower retention in treatment programs (Connelly et al., 2022). Yet, women report greater morbidity and higher rates of hypertension, particularly during midlife and menopause transitions (Connelly et al., 2022; Masenga et al., 2022). Despite these differences, women often achieve better long-term survival, reflecting earlier ART initiation and stronger health-seeking behaviors (McGraw et al., 2021).

Socioeconomic status fundamentally conditions both the risk of hypertension and its contribution to mortality among PLHIV. Lower education, unstable income, and reduced access to NCD services are consistently linked to higher prevalence of hypertension and worse survival outcomes (Burkey et al., 2014; Yang et al., 2020) . These associations reflect how disadvantage operates cumulatively over the life course, compounding biological vulnerability with structural barriers to care. This means that mortality schedules cannot be modeled without accounting for SES as a stratifying dimension. Cumulative disadvantage theory (Dannefer, 2003) suggests that inequalities intensify with age, so the burden of hypertension-related mortality is likely concentrated among poorer and less-educated PLHIV. Because SES also structures health-related behaviors, it provides the bridge to understanding how lifestyle factors interact with hypertension to shape mortality.

2.4 Clinical and behavioral influence

Health behaviors amplify or mitigate the mortality risks associated with hypertension in HIV populations. Tobacco use, harmful alcohol consumption, poor diet, and physical inactivity all elevate hypertension incidence and worsen blood pressure control, with direct implications for survival (Alebel et al., 2021; Denu et al., 2024). These behaviors are not randomly distributed

but patterned by age, sex, and socioeconomic position, reinforcing social gradients in health outcomes. Behaviors are best modeled as time-varying covariates, since their influence on mortality unfolds dynamically across the life course (Elder et al., 2007).

Clinical vulnerability remains a decisive modifier of the hypertension–mortality relationship. Individuals with low baseline CD4 counts, unsuppressed viral loads, or prolonged exposure to older ART regimens exhibit elevated cardiometabolic risk and earlier onset of hypertension (Geng et al., 2015; Hatleberg et al., 2018; Masenga et al., 2019; Masuku et al., 2019). These clinical trajectories magnify mortality hazards and can confound estimates of hypertension's independent effect if not properly accounted for (Hatleberg et al., 2018; Nduka et al., 2016).

The later evidence indicates that the burden of hypertension-related mortality is highest among those with advanced HIV disease or complex treatment histories, underscoring the need for stratified demographic analyses. Comparative analyses illustrate that: some cohorts find that older men of lower socioeconomic status who have lived longest with HIV face markedly higher hypertension-related mortality, while younger women with stronger engagement in care show lower mortality despite comparable hypertension prevalence (Van Deurzen & Vanhoutte, 2019).

Precisely because risks accumulate and overlap, the way mortality is measured becomes central to demographic analysis. Most clinical and epidemiological studies stop at reporting hazard ratios for individual risk factors, which, while valuable, do not tell us how much of population survival is eroded by hypertension (Alebel et al., 2021; Denu et al., 2024). Demographic methods fill this gap by translating individual risks into population-level consequences. Cause-deleted life tables, decomposition techniques, and population-attributable fractions make it possible to ask counterfactual questions on how life expectancy would change if hypertension were eliminated and to quantify the proportion of deaths that hypertension contributes in specific subgroups (Beltrán-Sánchez et al., 2008). Applying these methods with stratification by age, sex, socioeconomic status, and clinical profile turns disparate individual-level findings into interpretable measures of survival at the population level (Beltrán-Sánchez et al., 2008).

The contribution of hypertension to mortality depends not only on biological and social vulnerabilities but also on the strength of health systems to detect and control it. Evidence from East Africa shows that weak integration of HIV and NCD services, alongside poor retention in chronic care, leaves hypertension underdiagnosed and undertreated among PLHIV (Kivuyo et

al., 2023; Moyo-Chilufya et al., 2023). This means that two populations with the same age and hypertension prevalence may exhibit very different mortality outcomes depending on service coverage (Kivuyo et al., 2023; Moyo-Chilufya et al., 2023). Demographic projections that abstract away from these system realities risk overestimating future survival or underestimating the true burden of hypertension-related deaths. Situating quantitative estimates within health-system constraints ensures that demographic analysis remains not only rigorous but also relevant for policy and planning.

2.5 Hypertension as a contributor to all-cause mortality among PLHIV

Understanding how hypertension contributes to all-cause mortality among people living with HIV (PLHIV) is a demographic challenge that extends beyond measuring prevalence. The key issue is how hypertension alters survival schedules, modifies mortality differentials, and influences life expectancy. This subsection synthesizes evidence to demonstrate how hypertension intersects with HIV-related mortality, and why quantifying its share of all-cause mortality is essential for survival projections in East Africa.

Evidence consistently shows that hypertension has become a widespread condition among PLHIV, both in East Africa and globally. Pooled estimates from East African studies place prevalence around one-fifth in Uganda and Kenya and more than a quarter in Tanzania, confirming that hypertension is now common in treated cohorts (Tegegne et al., 2023). Research across sub-Saharan Africa further indicate that prevalence is not only higher among PLHIV than among HIV-negative peers, but also emphasized among those on long-term ART, suggesting that treatment histories shape the risk profile (Chang et al., 2022; Chen et al., 2024; Sarfo et al., 2020). Global meta-analyses report similar levels, with nearly one in four PLHIV affected worldwide (Xu et al., 2017), underscoring that this is not an isolated regional pattern but a broader demographic transformation of HIV populations.

Beyond the cross-sectional prevalence figures, longitudinal analyses reveal that hypertension emerges earlier and progresses faster in HIV populations. Ugandan cohort data show that incidence accumulates rapidly in midlife, meaning many PLHIV face hypertensive risk well before reaching older ages (Byonanebye et al., 2023). Comparable findings from Nigeria and Kenya demonstrate not only earlier onset but also more rapid progression and clustering with other metabolic conditions relative to HIV-negative populations (Denu et al., 2024; Mbuthia et al., 2021). This evidence suggests an accelerated exposure trajectory in HIV cohorts:

hypertension does not merely appear more frequently; it also compresses into earlier life stages (Denu et al., 2024; Mbuthia et al., 2021). This acceleration shifts the age-pattern of mortality risk upward in HIV populations and increases the likelihood that hypertension contributes significantly to all-cause mortality at ages where survival gains from ART should otherwise be strongest.

A growing body of evidence demonstrates that hypertension significantly contributes to mortality among PLHIV, not simply as an individual comorbidity but as a factor reshaping population survival patterns. Across African cohorts, elevated blood pressure has been shown to increase mortality risk independently of HIV status, confirming that hypertension compounds existing vulnerabilities in HIV populations (Houle et al., 2022). The analyses from South Africa further reveal that uncontrolled hypertension and diabetes cluster among PLHIV and drive excess mortality compared to those without these conditions (Chidumwa et al., 2023). These findings are reinforced by similar pattern from high-income settings: in North America, hypertensive women living with HIV experienced markedly higher one-year mortality than normotensive peers (Sadinski et al., 2023).

The effect of hypertension is also visible in the changing cause-of-death structure of HIV cohorts. Longitudinal evidence from Tanzania documented a decade-long rise in deaths attributable to cardiovascular and hypertension-related causes within ART programs (Mollel et al., 2022). South African data show similar trends with vascular causes emerging as leading contributors to mortality in HIV clinics (Omar et al., 2025). These shifts illustrate the epidemiological transition within HIV populations: as ART reduces AIDS-related deaths, non-communicable conditions increasingly define survival trajectories.

The critical issue is not simply whether hypertension is common among PLHIV, but the extent to which it alters population-level mortality. Estimating this contribution requires moving beyond relative risks reported in clinical studies to measures that capture aggregate effects (Batavia et al., 2018; Houle et al., 2022; Hickey et al., 2021). Tools such as population-attributable fractions quantify the proportion of deaths that would be avoided in the absence of hypertension, while cause-deleted life tables and decomposition methods (Beltrán-Sánchez et al., 2008) could translate disease-specific risks into losses of life expectancy. Applied to HIV populations, these methods allow us to compare the years of life lost to hypertension against those lost to other comorbidities, thus positioning hypertension within the broader mortality schedule of aging HIV cohorts.

Cohort dynamics intensify the demographic weight of hypertension. Survivors from earlier treatment eras, who often initiated ART late, carry cumulative physiological damage that makes them especially vulnerable to hypertension-related deaths. Longitudinal analyses confirm that older PLHIV face persistently higher mortality risks despite ART (Nabukalu et al., 2024), while evidence from population-level studies shows that survival into the fifties and sixties is now common, creating a larger at-risk population (Negin et al., 2012; Schnure et al., 2022). These findings suggests that hypertension's contribution is magnified not only because prevalence increases with age.

HIV-specific pathways i.e., chronic inflammation, ART-related metabolic changes, and accelerated vascular aging (Masenga et al., 2019) which expose the entire cohorts to hypertension earlier and with greater severity than in the general population. The result is widening survival inequalities both within and across HIV populations, a demographic trend that demands explicit quantification through stratified life tables and decomposition analyses.

2.6 Theoretical perspectives

Theoretical perspectives provide important scaffolding for interpreting how hypertension contributes to mortality among PLHIV in demographic terms. Life course theory reminds us that health outcomes at older ages reflect the accumulation of exposures across time (Dannefer, 2003; Ferraro & Shippee, 2009). Within this framework, hypertension is not simply a comorbidity but a marker of accelerated and premature aging, arising from the cumulative physiological stress of HIV infection, ART exposure, and social disadvantage (Dannefer, 2003; Ferraro & Shippee, 2009).

The concept of allostatic load i.e., the "wear and tear" on the body from repeated stress exposures deepens this interpretation by linking chronic inflammation, metabolic changes, and structural inequities to earlier and more severe onset of hypertension in PLHIV (McEwen, 2004). Little or no empirical evidence supports the connection of elevated allostatic load scores to predict higher mortality risks among older PLHIV, translating biological processes into demographic outcomes of shortened survival.

These theoretical insights make the policy stakes clear. If hypertension embodies cumulative disadvantage across the life course, then failure to measure its contribution to mortality leads to systematic underestimation of health inequalities in survival projections. Yet health systems in East Africa remain oriented toward AIDS-specific indicators, with limited integration of

NCD care into HIV programs (Kivuyo et al., 2023; Moyo-Chilufya et al., 2023). As a result, hypertension often goes undetected and untreated, even as it becomes a leading driver of mortality in older HIV populations (Kivuyo et al., 2023; Moyo-Chilufya et al., 2023). Therefore, producing robust estimates of the share of deaths attributable to hypertension is more than a methodological exercise: it is essential for aligning survival projections, life expectancy calculations, and resource allocation with the realities of population aging under dual disease burdens.

2.7 Summary of the literature review

This literature review examines how hypertension shapes mortality among aging PLHIV in East Africa within a demographic and life-course framework. ART has shifted mortality to older ages, creating cohorts increasingly affected by chronic conditions. Hypertension now emerges earlier and progresses faster in HIV populations, contributing significantly to changing cause-of-death patterns. Its effect varies by age, sex, socioeconomic status, clinical history, and health-system capacity, reflecting cumulative disadvantage and allostatic load. Demographic tools such as cause-deleted life tables and decomposition techniques are essential for quantifying hypertension's share of all-cause mortality.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter presents the study design, data sources, and analytical methods utilized in the study.

3.2 Data source and study design

This study employed a retrospective cohort design using secondary longitudinal data from the African Cohort Study (AFRICOS), a multi-country prospective cohort study. This is coordinated by the U.S. Military HIV Research Program, executed in collaboration with national research institutions in Kenya, Uganda, Tanzania, and Nigeria.

The recruitment into AFRICOS follows standardized inclusion criteria with eligible participants including HIV-positive and HIV-negative adults and adolescents receiving care at participating clinics, who are aged 15 years and older, willing to provide informed consent, and capable of attending biannual follow-up visits. The enrollment is continuous, with replacement of participants lost to follow-up.

By design, AFRICOS uses clinic-based consecutive sampling, recruiting individuals who attend care at selected military and civilian HIV treatment sites. The cohort was established in 2013 and, as of 2023, had enrolled 4,176 participants, including both HIV-positive and HIV-negative individuals. At each visit, participants undertake standardized clinical assessments and provide socio-demographic, behavioral, and laboratory data. Mortality, treatment history, and comorbid conditions are routinely recorded and validated through clinic systems.

For this study, we limited the AFRICOS dataset to HIV-positive individuals aged 40 years and above at enrollment from sites in Kenya, Uganda, and Tanzania from January 2013 to June 2023 (AFRICOS, 2023). We adopt age 40 as the lower threshold for “aging” PLHIV in East Africa, diverging from the ≥50 benchmark common in high-income settings to reflect the regional demographic realities: multimorbidity, particularly hypertension, emerging earlier (Chang et al., 2022) and truncated life expectancy renders mid-life mortality highly consequential.

This yielded an analytic baseline sample of 1,169 (Kenya=698, Tanzania=256 and Uganda=215) unique participants. Across all biannual follow-up waves, these individuals who expanded to a total of 1,360 participants at the end of the tenth-year visit yielding 12,462

person-period observations involved in the final adjusted models. Individuals were included if they had at least one follow-up visit and available blood pressure.

From this analytic cohort, we constructed exposure groups based on hypertension status, assessed at baseline and longitudinally. We did not apply age standardization because the age distributions of PLHIV across Kenya, Tanzania, and Uganda were broadly similar. In both the 40–49 and 50–59-year groups, proportions were nearly identical across countries, while the ≥60 category showed only modest variation (Kenya 17%, Tanzania 19%, Uganda 12%). Our analysis proceeded with crude mortality probabilities thus preserving the interpretability of estimates while minimizing the risk of confounding by age.

3.3. Variables and measures

The primary outcome variable was all-cause mortality – mortality from any cause. This was defined as the likelihood of death among people living with HIV. For each individual, the dependent variable was coded as 1 in the year of death (from any cause) and 0 for all prior years during which they remained alive. Individuals who were alive at the end of follow-up were right-censored. Mortality was modeled as a person-period outcome using a discrete-time approach. The outcome is permissible for modeling time-varying differences between hypertensive and non-hypertensive individuals, supporting estimation of all-cause excess mortality we could attribute to hypertension.

In this study, the primary exposure of interest was hypertension, categorized based on clinical single blood pressure measurements as recorded in routine visits. The classification of **hypertension (HTN)** was defined strictly according to the 2023 ESH Hypertension Guideline (Prasantha L Vemu, 2024) without consideration on information on diagnosis or antihypertensive treatment. Hypertensive state was defined as systolic blood pressure of 140 mmHg or higher given diastolic blood pressure of 90 mmHg or higher (Ojangba et al., 2023), coded as 1 if hypertensive and 0 otherwise. Systolic blood pressure (SBP) refers to the maximum pressure in the arteries when the heart contracts and pumps blood through the body, while diastolic blood pressure (DBP) reflects the pressure in the arteries when the heart rests between beats. These two measurements are expressed in millimeters of mercury (mmHg) and are commonly written as a ratio, such as 140/90 mmHg (Whelton et al., 2018).

The independent variables used in this study were grouped into **socio-demographic, behavioral and clinical factors, and physiological domains. Socio-demographic variables**

included: Age (in years), also grouped into 40–49, 50–59, and 60+ for stratified analysis. Employment status was categorized as employed/unemployed based on reported income-generating activity. Education level was classified as none, primary, secondary, or post-secondary. Marital status included single, married/cohabiting, divorced/separated, and widowed. Socioeconomic status (SES) followed the Demographic and Health Surveys (DHS)-style composite tradition, we adapted to available AFRICOS variables derived as a composite score based on using from household income, number of meals per day, and number of adult and child dependents. Each variable was standardized and assigned weights based on theoretical relevance and prior literature. SES was then categorized into tertiles: low, middle, and high. Internal consistency of the index was assessed using Cronbach's alpha.

Behavioral variables included alcohol use., smoking and drug use. Alcohol use (self-reported past year) coded as 1 = yes, 0 = no. Cigarette smoking and drug use (any substance) were binary (yes/no).

Clinical variables included BMI, allostatic load, and viral load. For BMI was calculated as weight (kg) divided by height (m) using measured height and weight. Categories were defined as: underweight (<18.5), normal weight (18.5–24.9), overweight (25.0–29.9), and obese (≥30) (WHO, 2000). Allostatic load (AL) measure was consistent with established operationalizations in the literature (Seeman & Gruenewald, 2006), adapted to available biomarkers in AFRICOS computed operationalized as a composite of six biomarkers: systolic and diastolic blood pressure, CD4 count, C-reactive protein (CRP), total cholesterol, and BMI. Each biomarker was dichotomized into high-risk vs. normal range using clinical cutoffs (SBP ≥140 mmHg or DBP ≥90 mmHg; CD4 <200 cells/mm³; CRP >3 mg/L; cholesterol >200 mg/dL; BMI >30). Domain-specific scores (cardiovascular, immune, inflammatory, and metabolic) adopted from (Fazeli et al., 2020) were weighted and summed into a total AL score, which was standardized and dichotomized into low vs. high (median split). Reliability was tested using Cronbach's alpha, and construct validity examined through correlation with key clinical indicators.

Duration of HIV infection was calculated in years from the self-reported diagnosis date because variables on confirmatory test was absent in the dataset to the last follow-up visit. Date of first enrollment in HIV care, ART initiation date, ART regimen, and current ART status were extracted from clinical records. ART status was coded as 1 = currently on ART, 0 = not on

ART. Viral load was categorized using standard WHO clinical thresholds as: 1 = suppressed (<50 copies/mL), 2 = low-level viremia (50–999 copies/mL), and 3 = high (≥1000 copies/mL).

All covariates that vary over time (viral load, BMI, blood pressure) were defined at baseline and treated as fixed characteristics. Thus, stratified decrement life tables reflect differences in mortality by baseline status, without accounting for subsequent changes during follow-up.

3.4 Data analysis

Descriptive statistics were used to summarize the characteristics of PLHIV aged 40 years and above across the three countries. Categorical variables (sex, country, BMI, viral load) were summarized as frequency distributions; continuous variables (age, duration on ART) were summarized using medians and interquartile ranges.

Chi-square and Kruskal-Wallis tests were used to assess associations between hypertension and mortality status across key demographic and clinical factors. The log-rank tests were used to examine survival differences by hypertension status and subgroup. We tabulated the number and proportion of participants who had ever developed hypertension and who died during the ten years of follow-up, stratified by sex, age group, BMI, viral load, and country selected based on bivariate analysis. Pearson chi-square tests were used to assess differences across categories, and median follow-up time with interquartile range (IQR) was calculated for each subgroup.

The selection of confounders was informed by prior literature on HIV, hypertension, and mortality, and by demographic relevance within the East African context. Five variables were considered as potential confounders: country of residence, age category, gender, BMI category, and viral load category. Each variable was assessed for its influence on the odds ratio for hypertension by applying a change-in-estimate criterion, where a ≥10% shift in the effect size compared to the unadjusted model indicated confounding. All five were subsequently included in the fully adjusted model to account for demographic, clinical, and contextual variation.

We constructed two separate single-decrement Life Tables (hypertensive PLHIV and non-hypertensive PLHIV) using interval-specific mortality probabilities (**Appendix 2 and 3**). This was to aid estimation of the additional mortality burden attributable to hypertension among people living with HIV (PLHIV). Each Life Table was computed using standard methods to derive the probability of dying in each interval (q_x), and cumulative mortality up to each time point. Interval-specific death probabilities (q_x) for each exposure interval, q_x was derived as the

ratio of deaths in that interval (D_x) to the number at risk, expressed in person-years. These probabilities formed the basis for constructing the decrement life tables used in the analysis.

To quantify the excess all-cause mortality associated with hypertension, we computed the difference in interval-specific mortality probabilities between the two subgroups at each follow-up interval. This yielded a derived table that reflects the excess probability of death attributable to hypertension per interval, rather than for a single cohort. Mathematically, excess all-cause mortality at interval x, denoted Δq_x, was calculated as:

$$\Delta q_x = {q_x}^{HTN} - {q_x}^{non-HTN}$$

where:

- ${q_x}^{HTN}$ is the probability of dying during interval x among hypertensive PLHIV, and
- ${q_x}^{non-HTN}$ is the probability of dying during interval x among non-hypertensive PLHIV.

The resulting excess all-cause mortality was estimated and presented using a LOESS-smoothed graph (frac=0.6) to minimize line crisscrossing, alongside a numerical table. These outputs quantify the additional all-cause mortality attributable to hypertension among PLHIV across follow-up time. This approach offered a clear method to assess differential attributable to a single health condition within cohort-based survival analysis.

These values were visualized using a line graph of Δq_x over time, highlighting intervals where hypertension contributed most substantially to increased mortality. This approach emphasizes within-cohort mortality differentials. At the multivariable level, to model time-to-death, the dataset was transformed into person-period format, with each individual contributing multiple records (one per follow-up interval) until death or censoring.

We then fitted a discrete time model with logistic regression using a binary outcome for death at each interval. AFRICOS data is visit based and interval structured thus does not exactly capture failure times. Discrete-time models were appropriate because they accommodate interval-censored event data and allow the use of person-period observations. Hypertension exposure and other covariates were lagged by one time period to reduce simultaneity bias. Visit dummy variables were included to account for time effects.

Exponentially weighted moving averages (EWMA) modeled Hypertension as a cumulative exposure to reflect recency and duration. Six models were fitted using a static lagged hypertension indicator, and EWMA-based exposure measures with smoothing parameters α = 0.3 and α = 0.7. For each exposure type, we estimated an unadjusted model and adjusted model, controlling for key covariates (age category, sex, BMI category, viral load category, and country). The purpose was to test whether cumulative hypertension exposure better captured mortality patterns.

The EWMA apply a decay factor (α) to weight past exposures with a lower α = 0.3 retaining more influence from older exposures and higher α = 0.7 giving more weight to recent exposures which approach is grounded in life course theory, which recognizes the layered, time-dependent nature of chronic disease progression. In modelling, hypertension status and covariates were lagged by one time interval (t–1) to temporally separate predictors from the outcome. This allowed for time-specific mortality estimation and identification of critical follow-up intervals with elevated hypertension effect.

The **Akaike Information Criterion and Bayesian Information Criterion** were used to assess internal consistency and estimation stability. The final form of the models estimated the probability of death at time *t* as a function of hypertension exposure at time *t−1*, covariates at time *t−1*, and fixed visit-level effects:

$$\log\left(\frac{(P(Death_{it}=1)}{1-P(Death_{it}=1)}\right) = \beta_0 + +\beta_1 EMA_{HTN_{i(t-1)}} + \beta_2 X_{i(t-1)} + \gamma t$$

Where:

- $EMA_{HTN_{i(t-1)}}$ is the lagged value of hypertension status for individual *i* at time *t-1*.
- $X_{i(t-1)}$ is a vector of lagged confounders for individual *i* at time *t-1*, including country, age category, gender, BMI category, viral load category.
- β_0 is the intercept.
- β2 is a vector of coefficients for the confounders.
- γtrepresents time-fixed effects (visit-specific indicators), controlling for any unobserved heterogeneity that varies across time points.

Odds ratios (ORs) and 95% confidence intervals (CIs) was reported for the coefficients. Model diagnostics included checks for multicollinearity (using VIF), and fit statistics (Linktest and

Hosmer-Lemeshow test) to assess model adequacy. No severe collinearity was observed among key covariates.

A composite socioeconomic status (SES) index was constructed using z-scores for education, employment, income, and food security, and an allostatic load (AL) index was derived from six biomarkers reflecting cardiovascular, metabolic, and immune function. Both indices were entered as continuous predictors.

3.5 Ethical Considerations

This study adhered to ethical standards set in RV329 / WRAIR 18971 ensuring the protection of participants and the integrity during the research. This ensured that any research modifications aligned with participant safety and data use policies, maintaining ethical standards for studies using existing cohort data. A letter permitting the use of data was granted to the researcher attached in the **Appendix 2**.

3.6 Strengths and Limitations

A key strength of this study lies in its use of longitudinal AFRICOS data, which moves beyond the cross-sectional "snapshots" typical of HIV-hypertension studies in sub-Saharan Africa (Kazibwe et al., 2022; Kivuyo et al., 2023). By following individuals over time, we were able to align more closely with life course frameworks (Elder et al., 2007; Ferraro & Shippee, 2009) and capture how cumulative exposure to hypertension reshapes mortality trajectories.

Methodologically, our application of decrement life tables extended traditional demographic tools by disaggregating survival differences between hypertensive and non-hypertensive PLHIV across subgroups defined by BMI, viral load, and country. The addition of interval-specific excess mortality enhanced their interpretive value for population-level burden estimation. The use of lagged discrete-time logistic regression provided a pragmatic way to incorporate time-varying exposures, accommodating the sequencing of hypertension and mortality events. Combined with exponentially weighted moving averages (EWMA), this allowed us to approximate cumulative exposure and align with life course principles of accumulation.

At the same time, several limitations must be acknowledged. The AFRICOS mortality data did not include secondary or tertiary causes of death, preventing the application of Multiple Cause

of Death (MCOD) frameworks. This constrains our ability to fully disentangle hypertension-attributable mortality from competing comorbidities, a limitation for demographic analyses of cause-deleted survival (Beltrán-Sánchez et al., 2008).

Similarly, survival time was measured from cohort enrollment rather than from HIV diagnosis or ART initiation, restricting our ability to model full disease histories and their effect on mortality schedules. The models used for the study still treat exposure changes in a stepwise fashion and rely on fixed decay rates (Heagerty & Comstock, 2013), which may obscure nonlinearities in chronic disease progression. Our operationalization of allostatic load relied on cross-sectional biomarkers, limiting our capacity to fully model dynamic stress accumulation. This reduces our ability to capture how social disadvantage, immune dysfunction, and comorbidity interact across the life course to structure mortality risks (Van Deurzen & Vanhoutte, 2019; Yang et al., 2023).

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings, structured around the key research objectives and hypotheses described in Sections 1.3 and 1.4. Results are presented through univariate, bivariate, and multivariable analyses, including descriptive statistics, survival analysis, and regression models, to examine the effect of hypertension and related covariates on mortality among people living with HIV aged 40 and above in Kenya, Uganda and Tanzania.

4.2 Associations between social-demographic factors, hypertension, and mortality

Table 4.1 shows the association between hypertension and mortality with key demographic factors. At baseline (visit 1), hypertension prevalence was 19%, differing significantly by country ($p<0.001$). Tanzania had the highest prevalence (32%), followed by Kenya (17%), while Uganda had the lowest prevalence (10%). By visit 17, the prevalence of hypertension was 21%, differed significantly across countries ($p<0.001$) with prevalence highest in Tanzania (40%), followed by Kenya (19%), and lowest in Uganda (14%). Age was significantly associated with hypertension ($p < 0.001$), with 32% among those aged 60+, compared to 14% in the 40–49 age group.

Gender did not show statistically significant association with hypertension ($p = 0.53$), though females (19%) slightly had higher proportion of hypertension compared to males (18%). Other socio-demographic factors, such as education, employment, socioeconomic class, and alcohol use, did not exhibit strong associations with hypertension status.

Cumulative mortality was slightly higher among participants with baseline hypertension (8%) compared to those without baseline hypertension (6%). However, this difference was not statistically significant ($p=0.24$). Mortality was significantly associated with age ($p = 0.04$) at baseline, with the highest mortality observed among participants aged 60+ (13%). Gender differences in mortality were also notable ($p = 0.04$), with males exhibiting a higher mortality rate (8%) than females (5%). Employment and socioeconomic class did not significantly predict mortality.

Table 4.1 continued shows that alcohol consumption and cigarette smoking showed some notable mortality trends with ($p = 0.99$) among smokers ($p = 0.05$) and also could not predict hypertension. BMI categories (defined according to WHO criteria: underweight <18.5 kg/m,

normal 18.5–24.9 kg/m², overweight 25.0–29.9 kg/m², and obese ≥30.0 kg/m²), was strongly associated with hypertension ($p < 0.00$), with a clear gradient observed among obese participants (38%) compared to only 13% of those who were underweight. Additionally, viral load significantly was associated with hypertension ($p = 0.02$), with the highest prevalence seen among those with suppressed viral loads (21%).

Body Mass Index was strongly associated with mortality ($p = 0.00$), with the highest mortality recorded among underweight participants (13%), however, mortality among obese individuals was significantly lower (2%). Viral loads had a statistically significant difference ($p = 0.00$) with participants with high viral loads having the highest mortality rate (10%) compared to those with suppressed viral loads (4%).

Table 4.1 Socio-demographic characteristics at baseline (visit 1) by exposure status and mortality distribution

Variable		Exposure		Outcome	
	Frequency (n)	Hypertensive n(row%)	P-value	Dead n(row%)	P-value
Country of residence					
Kenya	698	118(16.9)		44(6.3)	
Tanzania	256	82(32)		11(4.3)	
Uganda	215	21(9.8)	<0.00	20(9.3)	0.09
Age categories (years)					
40-49	720	98(13.6)		41(5.7)	
50-59	349	90(25.8)		22(6.3)	
60+	96	31(32.3)	<0.00	12(12.5)	0.04
Sex					
Male	595	107(17.9)		47(7.9)	
Female	566	110(19.4)	0.53	28(4.9)	0.04
Educational level					
No education	72	12(16.7)		5(6.9)	
Primary	683	118(17.3)		38(5.6)	
Secondary	330	73(22.1)		28(8.5)	
Post-secondary	84	18(21.4)	0.26	4(4.8)	0.31
Marital status					
Single	69	12(17.4)		2(2.9)	
Married traditional or civil incl. Living together with partner	682	117(17.2)		47(6.9)	
Divorced/separated	143	22(15.4)		12(8.4)	
Widowed	275	70(25.5)	0.02	14(5.1)	0.33
Employment status					
No	742	154(20.8)		50(6.7)	
Yes	427	67(15.7)	0.03	25(5.9)	0.55
Socio-economic status					
Low	416	74(17.8)		26(6.2)	
Middle	422	72(17.1)		30(7.1)	
High	331	75(22.7)	0.12	19(5.7)	0.74
Total	**1169**				

Table 4.1 Continued

Variable		Exposure		Outcome	
	Frequencies (n)	**Hypertensive n (row%)**	**P-value**	**Dead n (row%)**	**P-value**
Alcohol consumption history					
No	964	179 (18.6)		62 (6.4)	
Yes	202	41 (20.3)	0.59	13 (6.4)	0.99
Cigarette smoking					
No	1114	213 (19.1)		75 (6.7)	
Yes	52	7 (13.5)	0.31	0 (0.0)	0.05
Drug use					
No	1139	213 (18.7)		71 (6.2)	
Yes	27	7 (25.9)	0.34	4 (14.8)	0.07
BMI categories					
Underweight	142	18(12.7)		19(13.4)	
Normal	717	101(14.1)		44(6.1)	
Overweight	210	65(30.9)		10(4.8)	
Obese	100	37(37.8.)	<0.00	2(2.0)	0.00
Viral load categories					
Suppressed	694	146(21.0)		30(4.3)	
Low-level viremia	132	27(20.5)		10(7.6)	
High viral load	343	48(13.9)	0.02	35(10.2)	0.00
Allostatic load					
Low	786	51 (6.5)		38 (4.8)	
High	383	170 (44.4)		37 (9.7)	0.00
Total	**1169**				

4.3 Participants follow-up characteristics by exposure status and mortality

Table 4.2 shows the end of follow-up characteristics of the respondents. Overall, 702 participants (60%) were hypertensive at any point/cumulative prevalence during follow-up. There were 75 deaths among all participants (6%). Among hypertensive participants, 71 deaths occurred (10%), while 4 deaths occurred among non-hypertensive participants (1%). Among 599 males, 359 (60%) were hypertensive and 47 (8%) died during follow-up, with a median follow-up of 7 years (IQR 3.70). Among 570 females, 343 (60%) were hypertensive and 28 (5%) died, with a median follow-up of 7.2 years (IQR 3.2).

Among participants aged 40-49, 50-59 and 60+, the proportions ever hypertensive were 57%, 64%, and 68%, respectively. Deaths occurred in 6%, 6%, and 12% of respondents in these age groups. Median follow-up ranged from 7.0 to 7.4 years. Among respondents in BMI categories

underweight, normal, overweight, and obese, the proportion ever hypertensive was 44%, 54%, 72%, and 82%, respectively. Deaths occurred in 18%, 6%, 3%, and 3% of respondents across these categories. Median follow-up ranged from 7.1 to 7.5 years.

Among respondents with viral load categories suppressed, low-level viremia and high viral load, the proportion ever hypertensive was 62%, 63%, and 50%, respectively. Deaths occurred in 4%, 8%, and 16% of respondents across these categories. Median follow-up ranged from 6.5 to 7.5 years. Among respondents from countries Kenya, Tanzania and Uganda, the proportion ever hypertensive was 63%, 74%, and 33%, respectively. Deaths occurred in 6%, 4%, and 9% of respondents from these countries. Median follow-up ranged from 5.5 to 7.6 years.

Table 4.2 End of follow-up characteristics of the respondents

Variable	Frequencies (n)	Ever hypertensive n (%)	P-value	Ever dead n (%)	P-value	Median follow-up (years, IQR)
Hypertension	702 (60.1%)					
Mortality (all respondents)	75 (6.4%)					
Mortality among hypertensive	702 (10.1%)					
Mortality among non-hypertensive	467 (0.86%)					
Sex						
Male	599	359 (59.9)	0.93	47 (7.9)	0.04	7.2 (3.7)
Female	570	343 (60.2)		28 (4.9)		7.2 (3.2)
Age group						
40-49	663	376 (56.7)	0.03	37 (5.6)	0.05	7.2 (3.3)
50-59	347	221 (63.7)		22 (6.3)		7.4 (3.3)
60+	99	67 (67.7)		12 (12.1)		6.9(3.8)
BMI categories						
Underweight	148	65 (43.9)	<0.00	26 (17.6)	<0.00	7.2 (3.9)
Normal	631	340 (53.9)		38 (6.0)		7.1 (3.6)
Overweight	228	165 (72.4)		7 (3.1)		7.5 (3.5)
Obese	162	132 (81.5)		4 (2.5)		7.3 (3.0)
Viral load						
Suppressed	900	557 (61.9)	0.01	39 (4.3)	<0.00	7.5 (2.7)
Low-level viremia	87	55 (63.2)		7 (8.1)		6.6 (4.0)
High viral load	182	90 (49.5)		29 (15.9)		6.5 (7.7)
Country						
Kenya	698	441 (63.2)	0.00	44 (6.3)	0.09	7.5 (2.2)
Tanzania	256	190 (74.2)		11 (4.3)		5.5 (4.5)
Uganda	215	71 (33.0)		20 (9.3)		7.6 (5.0)
Total	**1169**					

4.4 Assessment of confounding effect of different variables on the effect of hypertension and death

Table 4.3 shows the confounding effect of different variables on the effect of hypertension and mortality. When adjusting for viral load, the association strengthens (OR: 1.62, 95% CI: 0.94–2.78, p=0.08). The most pronounced effect is observed after adjusting for BMI, where the association reaches statistical significance (OR: 1.72, 95% CI: 1.00–2.98, p=0.05). However, there was a non-significant increase in mortality among hypertensive individuals (OR: 1.44, 95% CI: 0.84–2.45, p=0.18). However, after adjusting for age, the association slightly attenuated (OR: 1.34, 95% CI: 0.78–2.31, p=0.28). The adjustment for gender does not also substantially alter the estimate (OR: 1.48, 95% CI: 0.87–2.53, p=0.15).

Table 4.3 Confounding effect of different variables on the effect of hypertension and mortality

Variables	Odds Ratios (95%CI)	P-value
Crude OR	1.44 (0.84-2.45)	0.18
Adjusting for age	1.34 (0.78-2.31)	0.28
Adjusting for sex	1.48 (0.87-2.53)	0.15
Adjusting for Viral load	1.62 (0.94-2.78)	0.08
Adjusting for BMI	1.72 (1.00-2.98)	0.05

4.5 Hypertension contribution to all-cause excess mortality

Table 4.4 presents all-cause excess mortality associated with hypertension obtained from difference between hypertensive and non-hypertensive decremental life table, stratified by confounders. Among the total cohort, hypertensive individuals exhibited consistently elevated likelihood of mortality relative to their non-hypertensive counterparts across all follow-up intervals (**Figure 4.2**).

The excess mortality started modestly at 0.004 during the first survival interval and increased steadily over time, peaking at 0.044 by interval 9. Although minor fluctuations were observed across intermediate intervals such as a slight dip at interval 4 (0.006) compared to interval 3 (0.009), the overall trend was one of progressive accumulation of survival disadvantage associated with hypertension. After reaching the maximum excess mortality at interval 9, the mortality modestly declined to 0.032 in intervals 10 and 11.

In Kenya, hypertensive individuals exhibited slightly lower mortality than non-hypertensives during the early intervals, reflected by negative excess mortality values (e.g., -0.004 at interval 1 and -0.008 at interval 2). However, this trend reversed after interval 7, with hypertensive respondents showing positive excess mortality by interval 8 (0.019) and a further increase to 0.030 by intervals 9 and 10.

In contrast, Tanzania showed consistently elevated excess mortality attributable to hypertension across all intervals. Beginning with a positive excess mortality of 0.028 at interval 1, the mortality rose sharply to 0.067 at interval 2 and remained relatively stable thereafter, fluctuating slightly around 0.053 across later intervals. The pattern was more variable in Uganda after a near-neutral excess mortality at interval 1 (0.001), negative excess mortality was observed at interval 2 (-0.005), followed by a sharp spike in positive excess mortality at

interval 3 (0.102) and interval 4 (0.084). Toward the later intervals (10–11), Uganda displayed small negative values again (-0.011).

Among respondents aged 40–49 years, excess mortality was initially negligible or slightly negative (e.g., -0.002 at interval 1). However, by interval 9, the excess mortality had risen to 0.045. In contrast, individuals aged 50–59 years consistently demonstrated positive excess mortality across nearly all time points. Although initially small (0.011 at interval 1), the excess mortality increased steadily, peaking at 0.054 from interval 8 onwards.

Notably, among respondents aged 60 years and older, excess mortality fluctuated substantially. After an early positive excess (0.018 at interval 1), the values turned negative by intervals 3 and 4 (-0.032 and -0.066, respectively). The **Figure 4.2** indicate that individuals aged 60 and above exhibited the steepest decline in survival probabilities over time, followed by those aged 50–59. Surprisingly, the 40–49 age group showed relatively lower survival probabilities throughout the follow-up period despite their younger age.

Among males, hypertensive individuals consistently exhibited higher mortality than non-hypertensives throughout the follow-up. Starting with a modest excess mortality of 0.018 at interval 1, the excess mortality steadily increased, peaking at 0.0779 by interval 8. Although the magnitude decreased slightly thereafter (0.062 at interval 9 and 0.039 at interval 10).

In contrast, females' hypertensive PLHIV showed a less consistent pattern. Early in follow-up, excess mortality among hypertensive females was either negative or near zero (e.g., -0.009 at interval 1, 0.002 at interval 2, -0.004 at interval 4 and 5). Positive excess mortality appeared only later, with values of 0.028 from interval 9 onward, although these gains remained modest relative to males. **Figure 4.2** shows that females experienced a more pronounced decline in survival probabilities over time compared to males. Males maintained consistently higher survival probabilities across the 10-year follow-up period.

The hypertensive PLHIV classified as underweight consistently experienced the highest excess mortality attributable to hypertension. Starting with an excess mortality of 0.121 at interval 1, it sharply rose to 0.287 by interval 5. Although slight declines followed, the values remained markedly elevated (above 0.27) until missing data emerged beyond interval 7. In contrast, individuals with normal BMI exhibited small or even negative excess mortality in early intervals (e.g., -0.005 at interval 1, -0.006 at interval 2). Only in later intervals (e.g., 0.031 at interval 8) did a slight excess mortality appear, although the magnitude remained low overall.

The hypertensive PLHIV classified as overweight group showed modestly positive but stable excess mortality attributable to hypertension throughout follow-up. After early small increases (e.g., 0.0017 at interval 1), the values rose slightly toward later periods (0.069 at intervals 9 to 11). Among the obese subgroup, excess mortality attributable to hypertension was initially negative (-0.016 at interval 1) but turned consistently positive by interval 2 (0.015), persisting at low but steady levels thereafter.

Caution in interpreting late-stage patterns for this group due to the limited number of events (as seen in missing values after interval 9). **Figure 4.2** shows that underweight individuals had the steepest decline over time. In contrast, those classified as overweight or obese maintained the highest survival probabilities throughout the follow-up period.

Hypertensive respondents with suppressed viral load consistently exhibited modest but positive excess mortality throughout follow-up. Starting at 0.011 in interval 1 and gradually increasing to 0.067 by interval 9. In stark contrast, individuals with low-level viremia (i.e., detectable but not fully suppressed virus) showed progressively negative excess mortality over time. For example, by interval 4, the excess mortality was -0.091, and further declined to -0.122 by interval 8. However, missing values after interval 8 limit full interpretation for later periods. Among hypertensive individuals with high viral load, the excess mortality attributable to hypertension was consistently positive and substantial, peaking early (0.063 at interval 2) and remaining stable around 0.070 thereafter.

Hypertensive individuals with low allostatic load exhibited positive and increasing excess mortality across most follow-up intervals, peaking around intervals 6–8 before declining. In contrast, those with high allostatic load showed negative or near-zero excess mortality during early follow-up, but this trend reversed in later intervals reaching a positive excess mortality of 0.116 by the final interval.

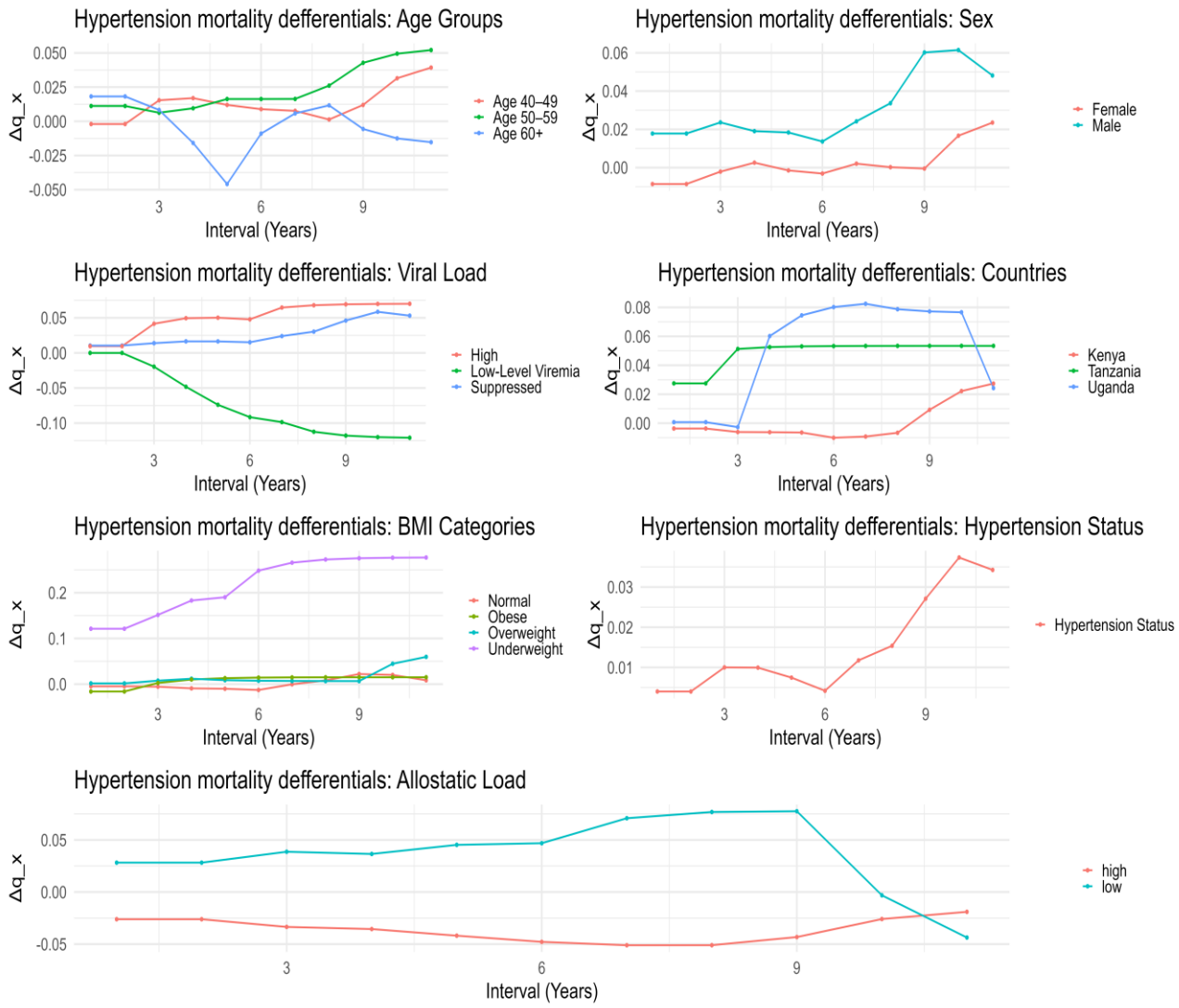


Figure 4.2 Excess mortality across demographic and clinical subgroups

Table 4.4 Cumulative excess mortality by demographic and clinical subgroup, AFRICOS 2013–2023

Variable	1	2	3	4	5	6	7	8	9	10	11
Hypertension Status	0.004	0.014	0.009	0.006	0.002	0.017	0.018	0.035	0.044	0.032	0.032
Age Groups											
Age 40–49	-0.002	0.027	0.018	0.009	0.007	0.007	-0.003	0.019	0.045	0.045	0.045
Age 50–59	0.011	0.003	0.012	0.021	0.016	0.016	0.033	0.054	0.054	0.054	0.054
Age 60+	0.018	0.002	-0.032	-0.066	0.016	0.016	0.016	-0.017	-0.017	NA	NA
Sex											
Male	0.018	0.028	0.016	0.018	0.011	0.031	0.040	0.078	0.062	0.039	NA
Female	-0.007	0.002	0.006	-0.004	-0.004	0.006	-0.001	-0.001	0.028	0.028	0.028
BMI											
Underweight	0.121	0.172	0.204	0.195	0.287	0.2774	0.2774	NA	NA	NA	NA
Normal	-0.005	-0.006	-0.012	-0.011	-.015	0.008	0.014	0.031	0.019	0.001	0.001
Overweight	0.002	0.012	0.015	0.007	0.007	0.007	0.007	0.007	0.069	0.069	0.069
Obese	-0.016	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	NA	NA
Viral Load											
Suppressed	0.0105	0.016	0.018	0.016	0.014	0.029	0.035	0.057	0.067	0.049	0.049
Low-Level Viremia	0.0000	-0.031	-0.067	-0.091	-0.103	-0.103	-0.122	-0.122	NA	NA	NA
High	0.0096	0.063	0.055	0.051	0.046	0.074	0.070	0.070	0.070	0.070	0.070
Country											
Kenya	-0.0037	-0.008	-0.006	-0.007	-0.013	-0.009	-.005	0.019	0.031	0.031	NA
Tanzania	0.0275	0.067	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	NA
Uganda	0.0007	-0.005	0.102	0.084	0.084	0.084	0.076	0.076	0.076	-0.011	-0.011
Allostatic load											
low	0.028	0.046	0.035	0.051	0.048	0.087	0.081	0.078	-0.057	-0.071	-0.071
high	-0.026	-0.038	-0.037	-0.046	-0.052	-0.053	-0.051	-0.038	-0.014	-0.014	0.116

Note: *Excess mortality is calculated as the difference between hypertensive and non-hypertensive mortality within each subgroup at each time point. Positive values indicate higher mortality among hypertensives, while negative values suggest higher mortality among non-hypertensives or small-sample fluctuations. NA = Data not available for evaluation beyond. 1-11 intervals describe the time in years*

4.6 Cumulative mortality from hypertension exposures by visits

Table 4.5 shows Time (visits) unadjusted and adjusted odds ratios for all-cause mortality by hypertension exposure, modeled using standard lag and EWMA approaches, across biannual follow-up visits. Mortality varied significantly over the follow-up time, with hypertension included as a main effect. In the standard lagged discrete-time logistic regression model, hypertension was associated with 1.53 times higher odds of mortality (OR = 1.53, 95% CI: 0.845–2.77), though this association was not statistically significant. However, when hypertension exposure was modeled using an Exponentially Moving Average (EWMA) approach with a smoothing factor of 0.3, the odds ratio increased to 2.15 (OR = 2.15, 95% CI: (0.86, 5.34), while the EWMA model with a smoothing factor of 0.7 produced a slightly lower odds ratio of 1.76 (OR = 1.758, 95% CI: 0.84–3.69). The inclusion of demographic and clinical covariates in adjusted Models 4–6, the estimated effect of hypertension on mortality became more pronounced.

The adjusted standard lagged model (**Model 4**) indicated that hypertensive individuals had more than twice the odds of mortality compared to non-hypertensives (OR = 2.04, 95% CI: 1.10–3.79), reaching statistical significance at the 0.05 level. Notably, the EWMA-based models, which incorporate cumulative exposure to hypertension, yielded even stronger associations. In the adjusted EWMA model with a smoothing factor of 0.3 **(Model 5),** hypertension was associated with 3.25 times higher odds of mortality (OR = 3.25, 95% CI: 1.26–8.39, $p < 0.05$), while the model with $\alpha = 0.7$ **(Model 6)** estimated 2.51 times increase in mortality (OR = 2.51, 95% CI: 1.16–5.44, $p < 0.05$).

The highest mortality was observed during the early phases of follow-up. Across all models, the odds of mortality were sharply elevated at visit 2, where unadjusted models estimated odds ratios ranging from 17.47 to 17.55 ($p < 0.01$), and adjusted models showed slightly higher estimates between 17.85 and 18.44 ($p < 0.01$). This elevated likelihood of mortality persisted into visit 3 (ORs: 15.88–18.18), visit 4 (ORs: 13.42–16.59), and visit 5 (ORs: 13.46–16.43), all statistically significant. Although the odds of mortality declined progressively in subsequent visits, they remained statistically elevated through visit 12 across all model specifications. For example, at visit 8, the adjusted models showed mortality odds between 9.64 and 9.87 ($p < 0.05$), while by visit 12, the odds reduced to 5.79–5.88 ($p < 0.05$). From visit 13 onwards, the estimates were lower and often not statistically significant, with odds ratios gradually tapering toward approximately 2.3 by visit 17.

Table 4.5 All-cause mortality by hypertension exposure, modeled using standard lag and EWMA approaches, across biannual follow-up visits

Variable	Model 1 (Standard Lag)	Model 2 EMA α=0.3	Model 3 EMA α=0.7	Model 4 (Standard Lag)	Model 5 EMA α=0.3	Model 6 EMA α=0.7
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**aOR (95% CI)**	**aOR (95% CI)**	**aOR (95% CI)**
Hypertensive	1.53*(0.85-2.77)	2.15*(0.864- 5.3)	1.76*(0 .84 -3.69)	2.04**(1.10-3.79)	3.25**(1.26- 8.39)	2.51**(1.16- 5.44)
visit= 1	1(1-1)	1(1-1)	1(1-1)	1(1-1)	1(1-1)	1(1-1)
visit= 2	17.47**(2.49-122.6)	17.55**(2.51-122.5)	17.48**(2.49-122.4)	18.44**(2.84-119.9)	17.85**(2.76-115.5)	18.07**(2.79-117.0)
visit= 3	15.88**(2.27-111.2)	16.21**(2.31-113.8)	16.00**(2.28-112.3)	18.18**(2.91-113.6)	18.15**(2.89-114.0)	18.09**(2.89-113.20)
visit= 4	13.42**(1.93-93.20)	13.77**(1.97-96.22)	13.50**(1.94-93.98)	16.36**(2.62-102.1)	16.59**(2.64-104.4)	16.26**(2.60-101.60)
visit= 5	13.46**(1.93-93.69)	13.76**(1.97-96.37)	13.52**(1.94-94.23)	16.43**(2.69-100.3)	16.43**(2.67-101.1)	16.21**(2.65-99.04)
visit= 6	11.46*(1.65-79.45)	11.70*(1.68-81.54)	11.50*(1.66-79.80)	13.81**(2.26-84.49)	13.89**(2.26-85.28)	13.70**(2.24-83.70)
visit= 7	9.827*(1.43-67.48)	10.12*(1.46-70.20)	9.899*(1.44-68.16)	12.41**(2.04-75.30)	12.71**(2.08-77.67)	12.41**(2.04-75.34)

Table 4.5 Continued

Variable	Model 1 (Standard Lag)	Model 2 EMA α=0.3	Model 3 EMA α=0.7	Model 4 (Standard Lag)	Model 5 EMA α=0.3	Model 6 EMA α=0.7
	OR (95% CI)	OR (95% CI)	OR (95% CI)	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Visit= 8	7.52*(1.12-50.62)	7.76*(1.14-52.92)	7.56*(1.12-51.09)	9.66*(1.61-58.08)	9.87*(1.61-59.85)	9.63*(1.60-57.92)
Visit= 9	6.66*(1.00-44.36)	6.87*(1.02-46.22)	6.68*(1.02-44.53)	8.06*(1.34-48.40)	8.24*(1.36-49.92)	8.02*(1.34-48.19)
Visit= 10	6.4834(0.98-43.01)	6.66(0.99-44.68)	6.49(0.98-43.11)	7.71*(1.30-45.72)	7.93*(1.33-47.27)	7.67*(1.29-45.35)
Visit= 11	5.72(0.87-37.61)	5.84(0.88-38.70)	5.72(0.87-37.63)	7.41*(1.24-44.22)	7.49*(1.25-44.81)	7.35*(1.24-43.74)
Visit= 12	4.39(0.69-28.16)	4.46(0.69-28.75)	4.39(0.69-28.15)	5.83*(1.02-33.39)	5.89*(1.03-33.78)	5.79*(1.01-33.05)
Visit= 13	4.58(0.72-29.07)	4.64(0.73-29.59)	4.57(0.72-29.02)	5.62(0.97-32.72)	5.66(0.97-33.04)	5.56(0.96-32.33)
Visit= 14	3.54(0.580-21.64)	3.66(0.593-22.56)	3.56(0.582-21.80)	4.44(0.772-25.56)	4.56(0.785-26.52)	4.44(0.768-25.61)
Visit= 15	2.11(0.39-11.48)	2.14(0.39-11.75)	2.10(0.39-11.42)	2.46(0.48-12.69)	2.50(0.48-13.03)	2.43(0.47-12.52)
Visit= 16	1.89(0.39-9.34)	1.91(0.39-9.42)	1.89(0.38-9.23)	2.38(0.54-10.54)	2.39(0.54-10.63)	2.35(0.53-10.34)
Visit= 17	2.33(0.47-11.56)	2.31(0.47-11.43)	2.31(0.47-11.42)	1.78(0.17-18.84)	1.75(0.16-18.62)	1.75(0.17-18.48)

***Notes**: aOR= adjusted Odds Rations; EMA*= Exponentially weighted moving averages*;* **α**= smoothing parameter; *Adj = adjusted; OR = unadjusted Odds Ratios*

4.7 Cumulative mortality from hypertension exposure by covariates

Table 4.6 show that the influence of hypertension on all-cause mortality varies across key subgroups specifically by country, age, gender, and viral load status. We included interaction columns help identify effect modification or to show whether the association between hypertension and mortality differs depending on these demographic or clinical factors. Across all three models, the interaction between hypertension and these factors had significantly lower odds of mortality compared to the reference group and did not reach statistical significance.

In Models 4 through 6, interaction terms were introduced to assess subgroup differences in mortality among hypertensive PLHIV aged 40 and above. The odds ratios for the Tanzania–Kenya interaction were 0.21 (95% CI: 0.08–0.55) in **Model 4**, 0.19 (95% CI: 0.07–0.52) in **Model 5**, and 0.20 (95% CI: 0.08–0.54) in **Model 6**, all statistically significant at the $p < 0.01$ level. For Uganda compared to Kenya, the interaction term was not statistically significant in **Models 4** and **5** but reached statistical significance in **Model 6** with an odds ratio of 1.238 (95% CI: 0.53–2.89, $p < 0.05$).

Individuals aged 50–59 had slightly higher odds of mortality compared to those aged 40–49 in **Model 6** (OR: 1.13, 95% CI: 0.57–2.23, $p < 0.05$). Similarly, for individuals aged 60 and above, the interaction became statistically significant in **Model 6** (OR: 2.32, 95% CI: 0.89–6.01, $p < 0.05$). Gender-based interactions indicated that male respondents had lower odds of mortality compared to females in all models, but the effect was highest in **Model 6** (OR: 0.63, 95% CI: 0.31–1.26, $p < 0.05$).

For viral load status, individuals with low viremia had significantly higher odds of mortality than those with suppressed viral load in all models: **Model 4** (OR: 2.41, 95% CI: 1.16–4.99), Model 5 (OR: 2.4, 95% CI: 1.1–5.09), and **Model 6** (OR: 2.42, 95% CI: 1.16–5.04), all significant at $p < 0.05$. Those with high viral load also had significantly higher odds of mortality compared to the suppressed group, with odds ratios of 2.355 (95% CI: 1.280–4.334) in **Model 4**, 2.44 (95% CI: 1.32–4.51) in **Model 5**, and 2.39 (95% CI: 1.29–4.41) in Model 6, all significant at $p < 0.01$. The high allostatic load category showed higher odds of mortality in **Model 4** (OR: 1.59, 95% CI: 0.85–2.99, $p < 0.05$), though in **Models 5** and **6**, the direction of association varied slightly. In

Model 5, the odds ratio was 0.743 (95% CI: 0.317–1.74), and in **Model 6**, it was 0.79 (95% CI: 0.29–2.19).

Table 4.6 Cumulative hypertension exposure among PLHIV aged 40 and above, controlled for key demographic and clinical covariates

Variable	Model 4 (Standard Lag)	Model 5 EMA α=0.3	Model 6 EMA α=0.7
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Country			
Kenya			
Tanzania	0.21* (0.08- 0.55)	0.19* (0.07- 0.52)	0.202* (0.08- 0.54)
Uganda	1.21* (0.52- 2.82)	1.27* (0.54- 2.96)	1.24* (0.53- 2.89)
Age group			
Age 40-49			
Age 50–59	1.16* (0.59- 2.274)	1.09* (0.5- 2.16)	1.13* (0.57- 2.23)
Age 60+	2.40* (0.94- 6.16)	2.23* (0.85- 5.83)	2.32* (0.89- 6.01)
Gender			
Female			
Male	0.53* (0.24 1.17)	0.63* (0.31- 1.25)	0.63* (0.31- 1.26)
BMI			
Underweight			
Normal BMI	0.63* (0.31- 1.31)	0.63* (0.30- 1.29)	0.63* (0.31- 1.31)
Overweight	0.31* (0.11- 0.90)	0.29* (0.10- 0.85)	0.30* (0.10- 0.88)
Obese	0.15* (0.04- 0.59)	0.14* (0.04- 0.53)	0.14* (0.04- 0.56)
Viral load			
Suppressed			
Low viremia	2.41** (1.16- 4.99)	2.43** (1.16- 5.09)	2.42** (1.16- 5.04)
High viral load	2.36** (1.28-4.33)	2.44** (1.32-4.51)	2.39** (1.29-4.41)
Allostatic load			
Low			
High	1.59* (0.85-2.99)		
Observations	12,462	12,462	12,462

All models include time-fixed effects for the follow-up wave—results presented as ORs (95% Confidence Intervals).

4.8 Discussion

The objective of this study was to examine how hypertension shaped all-cause mortality trajectories among people living with HIV (PLHIV) aged 40 years and above in Kenya, Uganda, and Tanzania. Hypertension was common and increased slightly over time, with consistently higher prevalence in Tanzania and lower prevalence in Uganda. Although crude comparisons showed only modest differences in mortality between hypertensive and non-hypertensive individuals, hypertension was strongly associated with age, BMI, and viral load. These same factors also predicted mortality.

Hypertension was highly prevalent during follow-up and was associated with substantially higher cumulative mortality. This confirms the pooled estimates showing a prevalence of 19% in Uganda, 18% in Kenya, and 27% in Tanzania (Tegegne et al., 2023), with higher rates among those on long-term ART (Chen et al., 2024). Nearly one in four PLHIV globally is estimated to be hypertensive (Xu et al., 2017). While such studies highlight the scale of exposure, they leave open the question of mortality contribution. Our findings move beyond prevalence to directly assess survival differentials, quantifying the demographic cost of hypertension in terms of earlier deaths and compressed life expectancy. This aligns with recent evidence showing persistently high mortality among older PLHIV in East African cohorts despite ART coverage (Geng et al., 2015; Nabukalu et al., 2024).

During follow-up, hypertensive respondents experienced a markedly greater mortality burden, and models that accounted for cumulative exposure demonstrated that hypertension was independently associated with higher all-cause mortality. Comparable evidence has been documented in sub-Saharan Africa, where uncontrolled hypertension significantly increased all-cause mortality among PLHIV (Chidumwa et al., 2023). Similar results were found in South African surveillance, where elevated blood pressure predicted premature death independent of HIV status (Houle et al., 2022). These patterns are observed globally; in a North American cohort, hypertensive women with HIV had higher one-year mortality compared to normotensive peers (Sadinski et al., 2023). These results confirm that hypertension is a determinant of mortality in HIV populations, not merely an associated morbidity.

The excess-mortality Life-Table profiles and the pronounced early-follow-up mortality peaks in the regression models point to substantially steeper mortality gradients among hypertensive PLHIV. This might indicate accelerated survival loss relative to normotensive individuals with ART expansion shifting HIV survival schedules upward, moving mortality out of young adulthood and into middle and older ages (Nabukalu et al., 2020; Reniers et al., 2014). Cohorts are now living long enough to accumulate risks of chronic disease, producing a redistribution of deaths away from opportunistic infections and toward non-communicable conditions. Within this shift, hypertension plays a leading role, advancing mortality into the forties and fifties, which is a decade earlier than typically observed in HIV-negative populations (Godongwana & De Wet-Billings, 2021; Okello et al., 2015).

Our results demonstrate that hypertension substantially elevates early and cumulative mortality, with the most pronounced effects among older adults, those with underweight BMI, and respondents with high viral load. These findings highlight how, HIV populations in East Africa undergoing an epidemiological transition toward chronic disease mortality (McKeown, 2009; Omran, 2001). Health systems remaining largely organized around infectious outcomes with weak integration of NCD screening (Kivuyo et al., 2023; Mayo-Clinic, 2023) risking eroding the survival gains secured by ART and leaves demographic projections of life expectancy overly optimistic if hypertension's contribution is not incorporated.

Early-interval mortality spikes and cumulative-exposure models all pointed to earlier deaths and compressed survival among hypertensive PLHIV. Mortality schedules are being reconfigured: HIV is no longer defined by early deaths in young adulthood but by midlife and older-age mortality shaped by chronic comorbidities. Hypertension accelerates this shift by precipitating earlier deaths within cohorts already disadvantaged by decades of infection and treatment histories (Nabukalu et al., 2024; Negin et al., 2012). As a result, cohort survival is increasingly determined not just by ART access, but by the management of chronic conditions layered onto HIV. Without embedding comorbidity contributions into demographic models through decrement Life Tables, population-attributable fractions, and stratified survival estimates (Beltrán-Sánchez et al., 2008) the future survival of HIV populations cannot be fully understood.

The Exponentially Weighted Moving Average results, which accounted for both the duration and recency of hypertension exposure, hypertensive PLHIV exhibited substantially higher mortality exceeding that observed in standard lagged models. This implies survival among PLHIV might be well understood as a trajectory shaped by repeated exposures rather than discrete events (Dannefer, 2003; Elder et al., 2007; Ferraro & Shippee, 2009). In HIV populations, prolonged ART use, chronic immune activation, and persistent socio-economic strain interact to accelerate physiological wear, producing mortality schedules distinct from those of HIV-negative cohorts (Kato et al., 2020; Masenga et al., 2019; Prakash et al., 2024). Hypertension, therefore, operates not only as a comorbidity but as a temporal process that accumulates silently before manifesting in mortality. This interpretation echoes earlier findings that suggested elevated long-term mortality risks among hypertensive PLHIV (Hatleberg et al., 2018; Nduka et al., 2016), but extends them by demonstrating how cumulative exposure alters cohort survival patterns.

The EWMA results where hypertensive PLHIV exhibited substantially higher mortality exceeding that observed in standard lagged models suggest that cumulative and recent hypertension exerts additive physiological stress over time. Similar mechanisms have been described in global cohort collaborations, which document accelerated cardiovascular ageing among PLHIV on long-term ART (Althoff et al., 2024; Friis-Møller & Worm, 2007). These dynamics illustrate what (Singer & Clair, 2003) termed a "Syndemic": the convergence of biological vulnerability and structural disadvantage, producing mortality risks greater than the sum of their parts. For demographers, the key contribution is showing that hypertension must be modelled as a time-varying exposure shaping survival curves, not simply as a baseline status.

The mortality patterns among PLHIV aged 60 and above underscore the complexity of ageing processes in these populations. Contrary to linear expectations, the results shows that older normotensive PLHIV display higher mortality than their hypertensive peers. This phenomenon likely reflects competing risks and selective survival processes. Those with hypertension who survive into their sixties may constitute a resilient cohort of individuals buffered by favorable genetics, adaptive health behaviors, or better access to healthcare across the life course. Such "survivor effects" have long been recognized in demographic research on frailty and heterogeneity (Fine & Gray, 1999; Markides & Machalek, 1984), and have been observed in African HIV cohorts where older survivors often defy expected mortality gradients (Houle et al., 2022; Nabukalu et al.,

2024). This mirrors evidence from cardiovascular epidemiology, which notes that hypertension-related excess mortality often peaks in midlife before attenuating in older cohorts due to selective survival (Kadota et al., 2007).

The diminished effect of hypertension observed among the oldest PLHIV is therefore best understood as a redistribution rather than a true reduction of risk, consistent with competing risk theory. Evidence from general aging populations shows that in advanced age, frailty and competing comorbidities can supplant hypertension as dominant mortality drivers (Sairenchi et al., 2005). More recent findings suggest paradoxical associations in which elevated systolic blood pressure is linked to improved survival among frail elderly, obscuring linear models of risk (Kremer et al., 2022). Demographic theory reinforces these insights: heterogeneity in frailty means that survivors into advanced ages often represent more resilient subgroups. These dynamics highlight the importance of demographic analyses that incorporate non-linear, age-dependent mortality processes shaped by vulnerability and competing risks (Fine & Gray, 1999). In such contexts, deaths from unmeasured or undiagnosed conditions such as cancer, diabetes, or frailty may preempt hypertension-related deaths, particularly in resource-limited health systems (Houle et al., 2022; Nabukalu et al., 2024).

Age showed a general positive gradient with mortality; the variation in risk across early follow-up intervals and the modifying effects of BMI, sex, and cumulative hypertension indicate that age alone is insufficient to capture the true mortality risk in this cohort. This finding challenges the adequacy of chronological age as the sole marker of mortality risk. Instead, it underscores the salience of biological ageing, shaped by early HIV infection, prolonged ART exposure, and the cumulative burden of social and physiological disadvantage (Ferraro & Shippee, 2009; Van Deurzen & Vanhoutte, 2019). Mortality among older HIV cohorts in Tanzania and South Africa increasingly reflects cardiovascular and metabolic conditions (Mollel et al., 2022; Omar et al., 2025), confirming that survival heterogeneity arises not only from age itself but from accumulated disadvantage across the life course.

Among PLHIV aged 40–49, excess mortality attributable to hypertension was initially low but increased steadily over follow-up. This indicates that hypertension imposes a measurable survival disadvantage even in younger adults, signaling early truncation of the life course relative to

normotensive peers. Premature deaths in this age band reduce workforce participation and intensify intergenerational care demands, thereby exacerbating existing socioeconomic vulnerabilities (Canning, 2011; Cooper et al., 2003). In regions where PLHIV are aging into midlife with poorly managed comorbidities, survival losses extend beyond individual life expectancy, reshaping age structures and increasing dependency burdens on families and states.

Excess-mortality estimates showed consistently greater survival disadvantage among hypertensive males throughout follow-up, while hypertensive females experienced smaller and more delayed excess mortality. Male PLHIV in sub-Saharan Africa continue to show higher mortality hazards than women, partly due to weaker engagement with care and higher rates of treatment discontinuation (Cornell et al., 2012; McGraw et al., 2021). These behaviors are deeply embedded in cultural norms that discourage preventive health-seeking and valorize patience, producing late diagnoses, poor adherence, and unmanaged comorbidities. Such entrenched social dynamics contribute to the observed male disadvantage in survival. These highlight the persistence of gendered survival inequalities even in an era of ART scale-up, and point to the need for sensitive interventions not only biology but also to life course and social determinants (Crimmins et al., 2019).

Excess-mortality analyses showed that hypertensive PLHIV with low allostatic load experienced steadily increasing mortality across follow-up, while those with high allostatic load initially showed near-zero or negative excess mortality that became substantially positive in later intervals. These findings indicate that cumulative physiological stress, as measured by allostatic load, modifies the timing and magnitude of hypertension-related mortality. Therefore, signals cohort-level vulnerability rather than a discrete, one-off illness (Elder et al., 2007; Fazeli et al., 2020; McEwen & Stellar, 1993). The result is that elevated blood pressure in these cohorts is likely to reflect cumulative disadvantage and to manifest as earlier and more severe mortality than seen in HIV-negative populations (Masenga et al., 2019). Allostatic load provides a mechanism linking poverty, stigma, and fragmented care to earlier onset of hypertension and mortality (McEwen, 2004; Venkatapuram & Marmot, 2014).

In our analysis, underweight hypertensive PLHIV experienced the highest cumulative mortality, consistent with literature showing that undernutrition amplifies vulnerability to infection and

reduces physiological reserve (Alebel et al., 2021). By contrast, overweight and obese PLHIV sometimes showed relatively better survival; this pattern is consistent with the "obesity paradox" or the protective role of metabolic reserves in frail or immunocompromised populations (Hainer & Aldhoon-Hainerová, 2013; Lainscak et al., 2012). From a demographic viewpoint, these patterns imply that BMI classifies different risk trajectories within cohorts (early truncation vs. resilient survival), and so survival models and life-table estimates must be stratified by nutritional status to avoid biased, aggregate conclusions (Nazarenko et al., 2025).

Our evidence shows that persistent LLV is associated with mortality. Research has document higher risk of virologic failure and inflammation among PLHIV with LLV, particularly when combined with comorbidities such as hypertension (Lanz et al., 2024; Zhang et al., 2022). Early mortality among the most immunologically compromised PLHIV produces a survival bias: those who remain in LLV groups appear stable but continue to face elevated cardiovascular and hypertension-related risks (Fleming et al., 2019; Lanz et al., 2024; Pham et al., 2022). This creates the illusion of stability while redistributing deaths toward middle adulthood, truncating life expectancy at ages where the demographic dividend is typically realized (Canning, 2011). Rather than a benign clinical state, LLV signals the intersection of incomplete viral suppression, cumulative stress, and comorbidity accumulation that accelerates population-level mortality schedules (Hatleberg et al., 2018).

The Ugandan lower prevalence but relatively higher mortality suggests that hypertensive PLHIV in Uganda may experience delayed diagnosis, suboptimal management, or interacting risk factors, shaped by health system histories. Vertical HIV programming, designed for speed and scale during ART rollout, extended life but has left hypertension largely undiagnosed. Consequently, hypertensive PLHIV in Uganda face disproportionately high midlife mortality compared to counterparts in Kenya and Tanzania, where decentralized and task-shifted care models embedded hypertension screening into HIV programs (Kiplagat et al., 2022; Kivuyo et al., 2023; McCombe et al., 2022). These contrasts reflect institutional path dependency: early design choices created enduring differences in service integration, now visible as survival inequalities across national cohorts (Mayer, 2003; Palagyi et al., 2019).

CHAPTER FIVE: SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

This chapter presents the final synthesis of the study by drawing together the key findings, proposing actionable recommendations, and offering a concise conclusion.

5.2 Summary

Hypertension was highly prevalent during follow-up (60%) and was associated with substantially higher cumulative mortality (10%) compared with non-hypertensive PLHIV (1%). Multivariable models indicated that the association between hypertension and all-cause mortality varied by country, age, sex, and viral load status. Compared with Kenya, hypertensive PLHIV in Tanzania experienced significantly lower odds of mortality across all models (OR range: 0.19–0.21; $p < 0.01$), while excess mortality in Uganda was observed only in the fully adjusted model (OR: 1.24; $p < 0.05$). Mortality risk increased with age, with higher odds among individuals aged 50–59 years (OR: 1.13; $p < 0.05$) and those aged ≥60 years (OR: 2.32; $p < 0.05$) relative to the 40–49-year reference group, indicating premature truncation of survival in mid-life.

Men exhibited lower mortality than women (OR: 0.63; $p < 0.05$). Viral load status strongly modified mortality risk: compared with virologically suppressed individuals, those with low-level viremia had more than twice the odds of death (OR range: 2.40–2.42; $p < 0.05$), while those with high viral load had similarly elevated mortality (OR range: 2.35–2.44; $p < 0.01$). Elevated allostatic load was associated with higher mortality in partially adjusted models, though estimates attenuated after full adjustment. Overall, these findings demonstrate that hypertension-related mortality among PLHIV is structured by demographic, virologic, and institutional contexts, with important implications for population-level survival and life-expectancy projections.

5.3 Conclusion

Hypertension is a significant and growing comorbidity among people living with HIV (PLHIV) in East Africa, with prevalence rates ranging from 14% to over 37% depending on country and population subgroup. The risk of hypertension and associated mortality is strongly influenced by older age, higher body mass index, and male sex, while viral load status also plays a critical role. PLHIV with low-level or unsuppressed viral loads face substantially higher mortality

risks. Notably, the integration of hypertension management into HIV care platforms, as seen in Kenya and Tanzania, is associated with improved survival outcomes. Uganda experiences higher excess mortality due to less integration or steaking with the vertical structure.

Despite the widespread use of antiretroviral therapy, these findings collectively signal that mortality among PLHIV is no longer defined solely by opportunistic infections. Instead, survival trajectories are shaped by a combination of ART timing, cohort exposure, socio-demographic differentials, and emerging chronic conditions. The challenge is not only to describe mortality decline but also to measure how new causes of death, especially hypertension, alter survival schedules and life expectancy. Few studies have systematically quantified the share of all-cause mortality attributable to hypertension, leaving a critical gap in demographic knowledge.

5.4 Recommendations

The findings highlight three broad areas where demographic research and practice should advance. First, we recommend prioritizing integrated hypertension screening and management within HIV care, especially in Tanzania where prevalence and risk are highest. Special attention should be given to older adults (particularly those aged 60+), who face significantly elevated mortality risks. Second, Enhanced monitoring and intervention are also warranted for PLHIV with low-level or high viral loads, as these groups demonstrated substantially higher odds of mortality. Country-specific strategies are essential, as mortality risk varied significantly between Tanzania, Kenya, and Uganda. Finally, targeted interventions for men, who exhibited higher mortality, and for underweight individuals, are advised to address demographic disparities and improve survival outcomes among PLHIV.

5.5 Areas for further research

Future research should explore the underlying mechanisms driving the significant country-level differences in hypertension prevalence and mortality among PLHIV, particularly focusing on health system factors, access to care, and cultural determinants in Tanzania, Kenya, and Uganda. Longitudinal studies are needed to clarify the causal pathways linking hypertension, viral load status, and mortality, especially in older adults and those with varying BMI.

Further investigation into the effectiveness of integrated hypertension and HIV care models, including interventions tailored to high-risk subgroups such as men, older individuals, and those with unsuppressed viral loads, is warranted. Additionally, research should assess the effect of early detection and sustained hypertension control on long-term survival. And evaluate the role of other potential confounders, such as medication adherence, comorbidities, and socioeconomic factors, that were not significantly associated in this study but may influence outcomes in different contexts.

REFERENCES

AFRICOS, A. C. s. (2023). Dataset for the desertation extracted from Africa Cohort study main dataset. In.

Ajayi, O. A., Okonkwo, P., Ojo, T. O., Ajayi, O. K., Ogunsola, O., Osayi, E., Onwuatuelo, I., & Samuels, J. O. (2024). Time to incident hypertension and independent predictors among people living with HIV in Nigeria. *Therapeutic Advances in Infectious Disease*, *11*, 20499361241289800. https://doi.org/10.1177/20499361241289800

Alebel, A., Demant, D., Petrucka, P., & Sibbritt, D. (2021). Effects of undernutrition on mortality and morbidity among adults living with HIV in sub-Saharan Africa: a systematic review and meta-analysis. *BMC Infect Dis*, *21*(1), 1. https://doi.org/10.1186/s12879-020-05706-z

Althoff, K. N., Stewart, C., Humes, E., Gerace, L., Boyd, C., Gebo, K., Justice, A. C., Hyle, E. P., Coburn, S. B., Lang, R., Silverberg, M. J., Horberg, M. A., Lima, V. D., Gill, M. J., Karris, M., Rebeiro, P. F., Thorne, J., Rich, A. J., Crane, H., . . . Kasaie, P. (2024). The forecasted prevalence of comorbidities and multimorbidity in people with HIV in the United States through the year 2030: A modeling study. *PLOS Medicine*, *21*(1), e1004325. https://doi.org/10.1371/journal.pmed.1004325

Beltran-Sanchez, H., Canudas-Romo, V., & Preston, S. (2008). An integrated approach to cause-of-death analysis: cause-deleted life tables and decompositions of life expectancy. *Demographic Research*, *19*(35), 1323-1350. https://doi.org/10.4054/DemRes.2008.19.35

Beltrán-Sánchez, H., Preston, S. H., & Canudas-Romo, V. (2008). An integrated approach to cause-of-death analysis: cause-deleted life tables and decompositions of life expectancy. *Demogr Res*, *19*, 1323. https://doi.org/10.4054/DemRes.2008.19.35

Bigna, J. J., & Noubiap, J. J. (2021). Global burden of hypertension in people living with HIV. *BMC medicine*, *19*(1), 112.

Billari, F. C., Fürnkranz, J., & Prskawetz, A. (2006). Timing, sequencing, and quantum of life course events: A machine learning approach. *European Journal of Population/Revue Européenne de Démographie*, *22*, 37-65.

Burkey, M. D., Weiser, S. D., Fehmie, D., Alamo-Talisuna, S., Sunday, P., Nannyunja, J., Reynolds, S. J., & Chang, L. W. (2014). Socioeconomic determinants of mortality in HIV: evidence from a clinical cohort in Uganda. *J Acquir Immune Defic Syndr*, *66*(1), 41-47. https://doi.org/10.1097/qai.0000000000000094

Bwogi, K., Lwanira, C. N., Kasamba, I., Baluku, J. B., Nakiwala, J. K., Ndagire, R., Nassolo, C., Wabomba, G., Bwanika, C., Nakawesi, J., Namayanja, G., Kabanda, J., Kalamya, J. N., Ssempiira, J., Ssenyimba, C., Mulebeke, R., Fitzmaurice, A. G., & Mukasa, B. (2025). Factors associated with mortality among people with advanced HIV disease in rural uganda: a retrospective study. *BMC Infectious Diseases*, *25*(1), 976. https://doi.org/10.1186/s12879-025-11397-1

Byonanebye, D. M., Polizzotto, M. N., Parkes-Ratanshi, R., Musaazi, J., Petoumenos, K., & Castelnuovo, B. (2023). Prevalence and incidence of hypertension in a heavily treatment-experienced cohort of people living with HIV in Uganda. *PLoS One*, *18*(2), e0282001.

Canning, D. (2011). The causes and consequences of demographic transition. *Popul Stud (Camb)*, *65*(3), 353-361. https://doi.org/10.1080/00324728.2011.611372

Chang, D., Esber, A., Dear, N., Iroezindu, M., Bahemana, E., Kibuuka, H., Owuoth, J., Maswai, J., Crowell, T., & Polyak, C. (2022). Non-communicable diseases in older people living with HIV in four African countries: a cohort study. *The Lancet HIV*, *9*, S5.

Chen, A., Chan, Y.-K., Mocumbi, A. O., Ojji, D. B., Waite, L., Beilby, J., Codde, J., Dobe, I., Nkeh-Chungag, B. N., Damasceno, A., & Stewart, S. (2024). Hypertension among people living with human immunodeficiency virus in sub-Saharan Africa: a systematic review and meta-analysis. *Scientific Reports*, *14*(1), 16858. https://doi.org/10.1038/s41598-024-67703-5

Chidumwa, G., Mazibuko, L., Olivier, S., Rahman, K., Gareta, D., Aung, T. N., Busang, J., Herbst, K., Wong, E., & Baisley, K. (2023). HIV, hypertension and diabetes care and all-cause mortality in rural South Africa in the HIV antiretroviral therapy era: a longitudinal cohort study. *BMJ Public Health*, *1*(1).

Connelly, P. J., Currie, G., & Delles, C. (2022). Sex Differences in the Prevalence, Outcomes and Management of Hypertension. *Current hypertension reports*, *24*(6), 185-192. https://doi.org/10.1007/s11906-022-01183-8

Cooper, R., Bloom, D., Canning, D., & Sevilla, J. (2003). The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change. *Foreign Affairs*, *82*, 148. https://doi.org/10.2307/20033592

Cornell, M., Schomaker, M., Garone, D. B., Giddy, J., Hoffmann, C. J., Lessells, R., Maskew, M., Prozesky, H., Wood, R., & Johnson, L. F. (2012). Gender differences in survival among adult patients starting antiretroviral therapy in South Africa: a multicentre cohort study.

Crimmins, E. M., Shim, H., Zhang, Y. S., & Kim, J. K. (2019). Differences between men and women in mortality and the health dimensions of the morbidity process. *Clinical chemistry*, *65*(1), 135-145.

Dannefer, D. (2003). Cumulative advantage/disadvantage and the life course: Cross-fertilizing age and social science theory. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *58*(6), S327-S337.

Denu, M. K., Revoori, R., Buadu, M. A. E., Oladele, O., & Berko, K. P. (2024). Hypertension among persons living with HIV/AIDS and its association with HIV-related health factors. *AIDS Research and Therapy*, *21*(1), 5.

Elder, Glen H Shanahan, & J, M. (2007). The life course and human development. *Handbook of child psychology*, *1*.

Elder, G. H. (2018). *Children of the great depression*. Routledge.

Fazeli, P. L., Waldrop-Valverde, D., Yigit, I., Turan, B., Edberg, J., Kempf, M., & Vance, D. (2020). An Exploratory Study of Correlates of Allostatic Load in Older People Living With HIV. *J Acquir Immune Defic Syndr*, *83*(5), 441-449. https://doi.org/10.1097/qai.0000000000002293

Ferraro, K. F., & Shippee, T. P. (2009). Aging and cumulative inequality: How does inequality get under the skin? *The Gerontologist*, *49*(3), 333-343.

Fine, J. P., & Gray, R. J. (1999). A proportional hazards model for the subdistribution of a competing risk. *Journal of the American statistical association*, *94*(446), 496-509.

Fleming, J., Mathews, W. C., Rutstein, R. M., Aberg, J., Somboonwit, C., Cheever, L. W., Berry, S. A., Gebo, K. A., & Moore, R. D. (2019). Low-level viremia and virologic failure in persons with HIV infection treated with antiretroviral therapy. *Aids*, *33*(13), 2005-2012. https://doi.org/10.1097/qad.0000000000002306

Friedman, M. R., Liu, Q., Meanley, S., Haberlen, S. A., Brown, A. L., Turan, B., Turan, J. M., Brennan-Ing, M., Stosor, V., & Mimiaga, M. J. (2022). Biopsychosocial health outcomes and experienced Intersectional stigma in a mixed HIV Serostatus longitudinal cohort of

aging sexual minority men, United States, 2008–2019. *American journal of public health*, *112*(S4), S452-S462.

Friis-Møller, N., & Worm, S. W. (2007). Can the Risk of Cardiovascular Disease in HIV-Infected Patients Be Estimated from Conventional Risk Prediction Tools? *Clinical Infectious Diseases*, *45*(8), 1082-1084. https://doi.org/10.1086/521936

Geng, E. H., Odeny, T. A., Lyamuya, R. E., Nakiwogga-Muwanga, A., Diero, L., Bwana, M., Muyindike, W., Braitstein, P., Somi, G. R., Kambugu, A., Bukusi, E. A., Wenger, M., Wools-Kaloustian, K. K., Glidden, D. V., Yiannoutsos, C. T., & Martin, J. N. (2015). Estimation of mortality among HIV-infected people on antiretroviral treatment in East Africa: a sampling based approach in an observational, multisite, cohort study. *Lancet HIV*, *2*(3), e107-116. https://doi.org/10.1016/s2352-3018(15)00002-8

Godongwana, M., & De Wet-Billings, N. (2021). Time to hypertension development among people living with HIV in South Africa: A longitudinal analysis of the National Income Dynamics Survey (NIDS). *Heliyon*, *7*(8).

Hainer, V., & Aldhoon-Hainerová, I. (2013). Obesity paradox does exist. *Diabetes Care*, *36 Suppl 2*(Suppl 2), S276-281. https://doi.org/10.2337/dcS13-2023

Hatleberg, C. I., Ryom, L., d'Arminio Monforte, A., Fontas, E., Reiss, P., Kirk, O., El-Sadr, W., Phillips, A., de Wit, S., Dabis, F., Weber, R., Law, M., Lundgren, J. D., & Sabin, C. (2018). Association between exposure to antiretroviral drugs and the incidence of hypertension in HIV-positive persons: the Data Collection on Adverse Events of Anti-HIV Drugs (D:A:D) study. *HIV Med*, *19*(9), 605-618. https://doi.org/10.1111/hiv.12639

Heagerty, P. J., & Comstock, B. A. (2013). Exploration of lagged associations using longitudinal data. *Biometrics*, *69*(1), 197-205. https://doi.org/10.1111/j.1541-0420.2012.01812.x

Houle, B., Kabudula, C. W., Tilstra, A. M., Mojola, S. A., Schatz, E., Clark, S. J., Angotti, N., Gómez-Olivé, F. X., & Menken, J. (2022). Twin epidemics: the effects of HIV and systolic blood pressure on mortality risk in rural South Africa, 2010-2019. *BMC Public Health*, *22*(1), 387. https://doi.org/10.1186/s12889-022-12791-z

Kadota, A., Hozawa, A., Okamura, T., Kadowak, T., Nakmaura, K., Murakami, Y., Hayakawa, T., Kita, Y., Okayama, A., Nakamura, Y., Kashiwagi, A., & Ueshima, H. (2007). Relationship between metabolic risk factor clustering and cardiovascular mortality stratified by high blood glucose and obesity: NIPPON DATA90, 1990-2000. *Diabetes Care*, *30*(6), 1533-1538. https://doi.org/10.2337/dc06-2074

Kanyike, A. M., Nakawuki, A. W., Akech, G. M., Kihumuro, R. B., Kintu, T. M., Nalunkuma, R., Nakandi, R. M., Mugabi, J., Twijukye, N., Bwayo, D., & Katuramu, R. (2024). Prevalence, Awareness, and Factors Associated with Hypertension Among People Living with HIV in Eastern Uganda. A Multicentre Cross-Sectional Study. *HIV AIDS (Auckl)*, *16*, 325-335. https://doi.org/10.2147/hiv.S477809

Kato, I., Tumaini, B., & Pallangyo, K. (2020). Prevalence of non-communicable diseases among individuals with HIV infection by antiretroviral therapy status in Dar es Salaam, Tanzania. *PLoS One*, *15*(7), e0235542.

Kebede, A., Tessema, F., Bekele, G., Kura, Z., & Merga, H. (2020). Epidemiology of survival pattern and its predictors among HIV positive patients on highly active antiretroviral therapy in Southern Ethiopia public health facilities: a retrospective cohort study. *AIDS Research and Therapy*, *17*(1), 49. https://doi.org/10.1186/s12981-020-00307-x

Kibuuka, H., Musingye, E., Mwesigwa, B., Semwogerere, M., Iroezindu, M., Bahemana, E., Maswai, J., Owuoth, J., Esber, A., Dear, N., Crowell, T. A., Polyak, C. S., Ake, J. A., &

Group, A. S. (2021). Predictors of All-Cause Mortality Among People With Human Immunodeficiency Virus (HIV) in a Prospective Cohort Study in East Africa and Nigeria *Clinical Infectious Diseases*, *75*(4), 657-664. https://doi.org/10.1093/cid/ciab995

Kiplagat, J., Tran, D. N., Barber, T., Njuguna, B., Vedanthan, R., Triant, V. A., & Pastakia, S. D. (2022). How health systems can adapt to a population ageing with HIV and comorbid disease. *The Lancet HIV*, *9*(4), e281-e292.

Kivuyo, S., Birungi, J., Okebe, J., Wang, D., Ramaiya, K., Ainan, S., Tumuhairwe, F., Ouma, S., Namakoola, I., & Garrib, A. (2023). Integrated management of HIV, diabetes, and hypertension in sub-Saharan Africa (INTE-AFRICA): a pragmatic cluster-randomised, controlled trial. *The Lancet*, *402*(10409), 1241-1250.

Kremer, K.-M., Braisch, U., Rothenbacher, D., Denkinger, M., Dallmeier, D., & Group, A. S. (2022). Systolic blood pressure and mortality in community-dwelling older adults: frailty as an effect modifier. *Hypertension*, *79*(1), 24-32.

Kuate Defo, B. (2014). Demographic, epidemiological, and health transitions: are they relevant to population health patterns in Africa? *Glob Health Action*, *7*, 22443. https://doi.org/10.3402/gha.v7.22443

Lainscak, M., von Haehling, S., Doehner, W., & Anker, S. D. (2012). The obesity paradox in chronic disease: facts and numbers. *J Cachexia Sarcopenia Muscle*, *3*(1), 1-4. https://doi.org/10.1007/s13539-012-0059-5

Lanz, C., Meier, J., Stöckle, M., Furrer, H., Calmy, A., Cavassini, M., Bernasconi, E., Schmid, P., Braun, D. L., Kouyos, R. D., Loosli, T., Kusejko, K., Günthard, H. F., & Study, t. S. H. C. (2024). Human Immunodeficiency Virus 1 Low-Level Viremia Predicts Viral Failure in Participants on Antiretroviral Therapy in the Swiss HIV Cohort Study. *Clinical Infectious Diseases*. https://doi.org/10.1093/cid/ciae569

Markides, K. S., & Machalek, R. (1984). Selective survival, aging and society. *Arch Gerontol Geriatr*, *3*(3), 207-222. https://doi.org/10.1016/0167-4943(84)90022-0

Masenga, S. K., Hamooya, B. M., Nzala, S., Kwenda, G., Heimburger, D. C., Mutale, W., Munsaka, S. M., Koethe, J. R., & Kirabo, A. (2019). Patho-immune mechanisms of hypertension in HIV: a systematic and thematic review. *Current hypertension reports*, *21*, 1-19.

Masenga, S. K., Povia, J. P., Mutengo, K. H., Hamooya, B. M., Nzala, S., Heimburger, D. C., Munsaka, S. M., Elijovich, F., Patel, K. P., & Kirabo, A. (2022). Sex differences in hypertension among people living with HIV after initiation of antiretroviral therapy. *Frontiers in Cardiovascular Medicine*, *9*, 1006789.

Masuku, S. K. S., Tsoka-Gwegweni, J., & Sartorius, B. (2019). HIV and antiretroviral therapy-induced metabolic syndrome in people living with HIV and its implications for care: A critical review. *Journal of Diabetology*, *10*(2), 41-47.

Mayer, K. U. (2003). The sociology of the life course and lifespan psychology: Diverging or converging pathways? In *Understanding human development: Dialogues with lifespan psychology* (pp. 463-481). Springer.

Mayo-Clinic. (2023). High blood pressure dangers: Hypertension's effects on your body. Retrieved 9/15/2024, from https://www.mayoclinic.org/diseases-conditions/high-blood-pressure/in-depth/high-blood-pressure/art-20045868

Mbuthia, G. W., Magutah, K., & McGarvey, S. T. (2021). The prevalence and associated factors of hypertension among HIV patients. *International journal of hypertension*, *2021*(1), 5544916.

McCombe, G., Lim, J., Hout, M. C. V., Lazarus, J. V., Bachmann, M., Jaffar, S., Garrib, A., Ramaiya, K., Sewankambo, N. K., Mfinanga, S., & Cullen, W. (2022). Integrating Care for Diabetes and Hypertension with HIV Care in Sub-Saharan Africa: A Scoping Review. *Int J Integr Care*, *22*(1), 6. https://doi.org/10.5334/ijic.5839

McEwen, B. S. (2004). Stress and Adaptation: Allostasis and Allostatic Load. *Allostasis, homeostasis, and the costs of physiological adaptation*, 65.

McEwen, B. S., & Stellar, E. (1993). Stress and the individual: Mechanisms leading to disease. *Archives of internal medicine*, *153*(18), 2093-2101.

McGraw, J., White, K. M., & Russell-Bennett, R. (2021). Masculinity and men's health service use across four social generations: Findings from Australia's Ten to Men study. *SSM-population health*, *15*, 100838.

McKeown, R. E. (2009). The Epidemiologic Transition: Changing Patterns of Mortality and Population Dynamics. *Am J Lifestyle Med*, *3*(1 Suppl), 19s-26s. https://doi.org/10.1177/1559827609335350

Mollel, G. J., Moshi, L., Hazem, H., Eichenberger, A., Kitau, O., Mapesi, H., Glass, T. R., Paris, D. H., Weisser, M., & Vanobberghen, F. (2022). Causes of death and associated factors over a decade of follow-up in a cohort of people living with HIV in rural Tanzania. *BMC Infect Dis*, *22*(1), 37. https://doi.org/10.1186/s12879-021-06962-3

Moyo-Chilufya, M., Maluleke, K., Kgarosi, K., Muyoyeta, M., Hongoro, C., & Musekiwa, A. (2023). The burden of non-communicable diseases among people living with HIV in Sub-Saharan Africa: a systematic review and meta-analysis. *eClinicalMedicine*, *65*, 102255. https://doi.org/https://doi.org/10.1016/j.eclinm.2023.102255

Nabukalu, D., Reniers, G., Risher, K. A., Blom, S., Slaymaker, E., Kabudula, C., Zaba, B., Nalugoda, F., Kigozi, G., Makumbi, F., Serwadda, D., Reynolds, S. J., Marston, M., Eaton, J. W., Gray, R., Wawer, M., Sewankambo, N., & Lutalo, T. (2020). Population-level adult mortality following the expansion of antiretroviral therapy in Rakai, Uganda. *Popul Stud (Camb)*, *74*(1), 93-102. https://doi.org/10.1080/00324728.2019.1595099

Nabukalu, D., Yiannoutsos, C. T., Semeere, A., Musick, B. S., Murungi, T., Namulindwa, J. V., Waswa, F., Nakigozi, G., Sewankambo, N. K., Reynolds, S. J., Lutalo, T., Makumbi, F., Kigozi, G., Nalugoda, F., & Wools-Kaloustian, K. (2024). Mortality Among HIV-Infected Adults on Antiretroviral Therapy in Southern Uganda. *J Acquir Immune Defic Syndr*, *95*(3), 268-274. https://doi.org/10.1097/qai.0000000000003330

Nazarenko, N., Chen, Y. Y., Borkowski, P., Biavati, L., Parker, M., Vargas-Pena, C., Chowdhury, I., Bock, J., Garg, V., Bhakta, S., Maliha, M., Raptis, D., Shah, M. K., Faillace, R., & Palaiodimos, L. (2025). Weight and mortality in people living with HIV and heart failure: Obesity paradox in the era of glucagon-like peptide 1 (GLP-1) receptor agonists and sodium-glucose cotransporter-2 (SGLT-2) inhibitors. *HIV Med*. https://doi.org/10.1111/hiv.13760

Nduka, C. U., Stranges, S., Sarki, A. M., Kimani, P. K., & Uthman, O. A. (2016). Evidence of increased blood pressure and hypertension risk among people living with HIV on antiretroviral therapy: a systematic review with meta-analysis. *J Hum Hypertens*, *30*(6), 355-362. https://doi.org/10.1038/jhh.2015.97

Negin, J., Bärnighausen, T., Lundgren, J. D., & Mills, E. J. (2012). Aging with HIV in Africa: the challenges of living longer. *Aids*, *26 Suppl 1*(0 1), S1-5. https://doi.org/10.1097/QAD.0b013e3283560f54

Ojangba, T., Boamah, S., Miao, Y., Guo, X., Fen, Y., Agboyibor, C., Yuan, J., & Dong, W. (2023). Comprehensive effects of lifestyle reform, adherence, and related factors on hypertension control: A review. *The Journal of Clinical Hypertension*, *25*(6), 509-520.

Okello, S., Kanyesigye, M., Muyindike, W. R., Annex, B. H., Hunt, P. W., Haneuse, S., & Siedner, M. J. (2015). Incidence and predictors of hypertension in adults with HIV-initiating antiretroviral therapy in south-western Uganda. *J Hypertens*, *33*(10), 2039-2045. https://doi.org/10.1097/hjh.0000000000000657

Omar, T., Sabet, N., Calver, A., Chita, G., Hermans, L. E., Venter, W. D. F., Basson, A., Nijhuis, M., Wensing, A., Martinson, N., Papathanasopoulos, M., & Variava, E. (2025). Causes of death in adults living with HIV in South Africa: A single-centre postmortem study. *South Afr J HIV Med*, *26*(1), 1673. https://doi.org/10.4102/sajhivmed.v26i1.1673

Omran, A.-R. (2001). The epidemiologic transition: a theory of the epidemiology of population change/Abdel R. Omran.

Palagyi, A., Marais, B. J., Abimbola, S., Topp, S. M., McBryde, E. S., & Negin, J. (2019). Health system preparedness for emerging infectious diseases: A synthesis of the literature. *Glob Public Health*, *14*(12), 1847-1868. https://doi.org/10.1080/17441692.2019.1614645

Pham, M. D., Nguyen, H. V., Anderson, D., Crowe, S., & Luchters, S. (2022). Viral load monitoring for people living with HIV in the era of test and treat: progress made and challenges ahead - a systematic review. *BMC Public Health*, *22*(1), 1203. https://doi.org/10.1186/s12889-022-13504-2

Prakash, P., Swami Vetha, B. S., Chakraborty, R., Wenegieme, T.-Y., Masenga, S. K., Muthian, G., Balasubramaniam, M., Wanjalla, C. N., Hinton, A. O., Kirabo, A., Williams, C. R., Aileru, A., & Dash, C. (2024). HIV-Associated Hypertension: Risks, Mechanisms, and Knowledge Gaps. *Circulation research*, *134*(11), e150-e175. https://doi.org/10.1161/CIRCRESAHA.124.323979

Prasantha L Vemu, M. E. Y., MD, FACC; Joseph Ebinger, MD, FACC. (2024). *2023 ESH Hypertension Guideline Update: Bringing Us Closer Together Across the Pond* https://www.acc.org/Latest-in-Cardiology/Articles/2024/02/05/11/43/2023-ESH-Hypertension-Guideline-Update

Reniers, G., Slaymaker, E., Nakiyingi-Miiro, J., Nyamukapa, C., Crampin, A. C., Herbst, K., Urassa, M., Otieno, F., Gregson, S., Sewe, M., Michael, D., Lutalo, T., Hosegood, V., Kasamba, I., Price, A., Nabukalu, D., McLean, E., & Zaba, B. (2014). Mortality trends in the era of antiretroviral therapy: evidence from the Network for Analysing Longitudinal Population based HIV/AIDS data on Africa (ALPHA). *Aids*, *28 Suppl 4*(4), S533-542. https://doi.org/10.1097/qad.0000000000000496

Sadinski, L. M., Westreich, D., Edmonds, A., Breger, T. L., Cole, S. R., Ramirez, C., Brown, T. T., Ofotokun, I., Konkle-Parker, D., Kassaye, S., Jones, D. L., D'Souza, G., Cohen, M. H., Tien, P. C., Taylor, T. N., Anastos, K., & Adimora, A. A. (2023). Hypertension and one-year risk of all-cause mortality among women with treated HIV in the United States. *Aids*, *37*(4), 679-688. https://doi.org/10.1097/qad.0000000000003461

Sairenchi, T., Iso, H., Irie, F., Fukasawa, N., Yamagishi, K., Kanashiki, M., Saito, Y., Ota, H., & Nose, T. (2005). Age-specific relationship between blood pressure and the risk of total and cardiovascular mortality in Japanese men and women. *Hypertens Res*, *28*(11), 901-909. https://doi.org/10.1291/hypres.28.901

Sakita, F. M., O'Leary, P., Prattipati, S., Kessy, M. S., Kilonzo, K. G., Mmbaga, B. T., Rugakingira, A. A., Manavalan, P., Thielman, N. M., & Samuel, D. (2023). Six-month

incidence of hypertension and diabetes among adults with HIV in Tanzania: A prospective cohort study. *PLOS Global Public Health*, *3*(8), e0001929.

Sarfo, F. S., Singh, A., Tagge, R., Mensah, G., & Ovbiagele, B. (2020). Duration of antiretroviral therapy among people living with HIV and incidence of hypertension in Ghana. *The Journal of Clinical Hypertension*, *22*(12), 2361-2371.

Schnure, M. C., Kasaie, P., Dowdy, D. W., Genberg, B. L., Kendall, E. A., & Fojo, A. T. (2022). Forecasting the effect of HIV-targeted interventions on the age distribution of people living with HIV: a case study from Kenya. *Aids*, 10.1097.

Seeman, T. E., & Gruenewald, T. L. (2006). Allostasis and Allostatic Load Over the Life Course.

Singer, M., & Clair, S. (2003). Syndemics and public health: Reconceptualizing disease in bio-social context. *Medical anthropology quarterly*, *17*(4), 423-441.

Tegegne, K. D., Adela, G. A., Kassie, G. A., Mengstie, M. A., Seid, M. A., Zemene, M. A., Feleke, S. F., Dejenie, T. A., Abebe, E. C., Anley, D. T., Dessie, A. M., Gesese, M. M., Yimer, N., & Gebeyehu, N. A. (2023). Prevalence and factors associated with hypertension among peoples living with HIV in East Africa, a systematic review and meta-analysis. *BMC Infect Dis*, *23*(1), 724. https://doi.org/10.1186/s12879-023-08679-x

Van Deurzen, I., & Vanhoutte, B. (2019). A longitudinal study of allostatic load in later life: the role of sex, birth cohorts, and risk accumulation. *Research on aging*, *41*(5), 419-442.

Venkatapuram, S., & Marmot, M. (2014). Social determinants of health and health inequalities. In *The Routledge Companion to Bioethics* (pp. 16-32). Routledge.

Whelton, P. K., Carey, R. M., Aronow, W. S., Casey, D. E., Collins, K. J., Dennison Himmelfarb, C., DePalma, S. M., Gidding, S., Jamerson, K. A., & Jones, D. W. (2018). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Journal of the American College of Cardiology*, *71*(19), e127-e248.

Xu, Y., Chen, X., & Wang, K. (2017). Global prevalence of hypertension among people living with HIV: a systematic review and meta-analysis. *Journal of the American Society of Hypertension*, *11*(8), 530-540. https://doi.org/https://doi.org/10.1016/j.jash.2017.06.004

Yang, D., Wheeler, M., Karanth, S. D., Aduse-Poku, L., Leeuwenburgh, C., Anton, S., Guo, Y., Bian, J., Liang, M., & Yoon, H. S. (2023). Allostatic load and risk of all-cause, cancer-specific, and cardiovascular mortality in older cancer survivors: An analysis of the National Health and Nutrition Examination Survey 1999–2010. *Aging and cancer*, *4*(2), 74-84.

Yang, Y. C., Schorpp, K., Boen, C., Johnson, M., & Harris, K. M. (2020). Socioeconomic Status and Biological Risks for Health and Illness Across the Life Course. *J Gerontol B Psychol Sci Soc Sci*, *75*(3), 613-624. https://doi.org/10.1093/geronb/gby108

Zhang, X., Yang, J., Ruan, H., Zheng, Y., Zhao, L., Li, L., Zhang, M., Duan, L., & He, S. (2022). Association of cumulative blood pressure with cardiovascular mortality in Chinese older people: A longitudinal prospective study. *Experimental Gerontology*, *168*, 111952.

APPENDICES

Appendix 1: AFRICOS data use approval and request

MAKERERE UNIVERSITY
Plot 51, Pool Road
P.O. Box 7062
Kampala, UGANDA
Website: www.bams.mak.ac.ug

Phone: +256 414 541558/9
Fax: +256 414 530756
E-mail: dps.bams@mak.ac.ug

COLLEGE OF BUSINESS AND MANAGEMENT SCIENCES (COBAMS)
School of Statistics and Planning (SSP)
Department of Population Studies (DPS)

17th April, 2024
The Executive Director,
Makerere University Walter Reed Project (MUWRP),
Plot 42, Nakasero Road
P.O. Box 16524, Kampala, Uganda

DEPARTMENT OF POPULATION STUDIES - SSP
18 APR 2024
COBAMS
MAKERERE UNIVERSITY
P. O. BOX 7062, KAMPALA

Dear Dr. Kibuuka Hannah,

RE: INTRODUCING MR. DENIS MAYAMBALA

This is to introduce Mr. Denis Mayambala who is currently pursuing a Master of Demography and Population Studies offered at Department of Population studies, School of Statistics & Planning, College of Business and Management Sciences- CoBAMs at Makerere University. He is a registered student of the department under with registration number 2023/HD06/22122U.

Denis is currently working on a research project titled "Examining the Effects of Diabetes and Hypertension on Longevity in HIV+ Patients aged 40+ in East and West Africa (LAEW)," which is funded by the DELTAS AFRICA II. This research project is a crucial part of Denis's academic and professional development as an early career researcher in the field of population studies and demography.

The purpose of this communication is to request MUWRP's support in providing Denis with access to the data required for his research. The access to the Africa Cohort study (AFRICOS) longitudinal data will not only contribute to Denis's career development but will also add valuable insights to the field of population studies and public health. We believe that his collaboration with MUWRP under the mentorship of Dr Hannah will be mutually beneficial, providing Denis with valuable practical experience while also supporting the important work of AFRICOS.

We look forward to a fruitful collaboration with MUWRP.

Yours Sincerely,

Dr. Allen Kabagenyi
Chair, Department of Population Studies, School of Statistics and Planning
Makerere University
Tel: 256 -772 480022 • Fax: 256 – 41 – 4530756 • E-mail: allen.kabagenyi@mak.ac.ug

Leveraging 100 years of Excellence in Building a Transformed Society

WRAIR
Walter Reed Army Institute of Research
MILITARY HIV RESEARCH PROGRAM

28 August 2025

Re: <u>Approval for Use of AFRICOS Data in Master's Dissertation</u>

To Whom It May Concern,

This letter serves to confirm that **Mr. Denis Mayambala**, a graduate student at Makerere University, has been granted permission to use data from the African Cohort Study (AFRICOS) in fulfillment of the requirements for his Master's dissertation entitled: *"The contribution of hypertension to all-cause mortality among PLHIV aged 40 years and older in East Africa"*.

The AFRICOS study, conducted under the leadership of the U.S. Military HIV Research Program (MHRP) and partner institutions, has provided the data required for this dissertation. Access has been approved following internal review through Dr. Hannah Kibuuka's mentorship, and thus Denis has met the conditions of confidentiality and responsible data use as stipulated by AFRICOS governance policies.

The analyses and findings from this dissertation will be limited to the approved research objectives. For any other objectives extended beyond the agreed-upon scope, there shall be additional approval from the AFRICOS team therein. All research analyses and findings included in any abstract, manuscript or presentation developed will be provided to the AFRICOS investigators for review and approval before submissions or presentation of findings. AFRICOS investigators and collaborating institutions retain ownership of the data, and all dissemination of findings (including publications, presentations, or policy briefs), and Denis will permit to acknowledging AFRICOS as the source.

We hereby confirm our approval and support of Denis's use of AFRICOS data for the above-stated academic purpose.

Sincerely,

Neha Shah
Digitally signed by Neha Shah
DN: cn=Neha Shah, o, ou, email=NShah@hivresearch.org, c=US
Date: 2025.09.03 10:48:54 -07'00'

Neha Shah MD
CAPT, USPHS
Associate Director of Clinical and Laboratory Services
Co-Chair AFRICOS Cohort Study
International HIV Prevention and Treatment
US Military HIV Research Program
Walter Reed Army Institute of Research
Phone: 240-271-2838

The U.S. Military HIV Research Program at the Walter Reed Army Institute of Research is supported by a cooperative agreement between the United States Army Medical Research and Materiel Command and the Henry M. Jackson Foundation for the Advancement of Military Medicine, Inc.

Appendix 2: Decremental life tables by different participant characteristics among hypertensives

Variable	1	2	3	4	5	6	7	8	9	10	11
Hypertension Status											
Hypertensive	0.024	0.044	0.049	0.055	0.055	0.074	0.081	0.100	0.118	0.118	0.118
Age Categories											
40-49	0.021	0.056	0.0566	0.056	0.056	0.056	0.056	0.0776	0.115	0.115	0.115
50-59	0.023	0.036	0.049	0.062	0.062	0.077	0.093	0.114	0.114	0.114	0.114
60+	0.034	0.034	0.034	0.034	0.133	0.133	0.133	0.133	0.133		
sex											
Male	0.039	0.059	0.059	0.071	0.071	0.097	0.112	0.1544	0.154	0.154	-
Female	0.009	0.029	0.041	0.041	0.041	0.053	0.053	0.053	0.082	0.082	0.082
BMI categories											
underweight	0.171	0.231	0.289	0.289	0.391	0.391	0.391				
Normal	0.010	0.021	0.021	0.033	0.033	0.060	0.076	0.0969	0.096	0.096	0.096
Overweight	0.016	0.033	0.052	0.052	0.052	0.052	0.052	0.0522	0.115	0.115	0.115
Obese	0	0.031	0.031	0.031	0.031	0.031	0.031	0.0312	0.031		
Viral load categories											
Suppressed	0.014	0.022	0.029	0.038	0.038	0.056	0.065	0.0909	0.113	0.113	0.113
low-level viremia	0	0	0	0	0	0	0	0			
High viral load	0.067	0.139	0.139	0.139	0.139	0.179	0.179	0.1785	0.179	0.179	

Appendix 3: Decremental life tables by different participant characteristics among non-hypertensives

Variable	1	2	3	4	5	6	7	8	9	10	11
Hypertension Status											
Non-hypertensive	0.019	0.029	0.039	0.049	0.053	0.057	0.063	0.065	0.073	0.085	0.085
Age Categories											
40-49	0.023	0.029	0.038	0.047	0.049	0.049	0.059	0.059	0.071	0.071	0.071
50-59	0.0119	0.033	0.037	0.041	0.046	0.060	0.060	0.060	0.060	0.060	0.060
60+	0.016	0.032	0.066	0.099	0.117	0.117	0.117	0.150	0.150	0.363	
Sex											
Male	0.021	0.032	0.044	0.053	0.061	0.066	0.072	0.077	0.092	0.115	0.115
Female	0.018	0.028	0.035	0.045	0.045	0.048	0.054	0.054	0.054	0.054	0.054
BMI categories											
underweight	0.050	0.059	0.086	0.094	0.104	0.114	0.114	0.114	0.114	0.114	
Normal	0.015	0.028	0.033	0.044	0.048	0.052	0.062	0.066	0.078	0.096	0.096
Overweight	0.014	0.022	0.038	0.046	0.046	0.046	0.046	0.046	0.046	0.046	
Obese	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	
Viral load categories											
Suppressed	0.004	0.007	0.012	0.022	0.024	0.026	0.031	0.034	0.047	0.064	0.064
low-level viremia	0	0.033	0.067	0.091	0.103	0.103	0.122	0.122	0.122	0.122	
High viral load	0.057	0.077	0.085	0.089	0.093	0.103	0.108	0.108	0.108	0.108	0.108