THE EPIDEMIOLOGY OF CHRONIC NON-COMMUNICABLE DISEASES (NCDs) AND NCD RISK FACTORS IN ADOLESCENTS & YOUTH LIVING WITH HIV IN CAPE TOWN, SOUTH AFRICA

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Abstract

Introduction: South Africa, like many other low- and middle-income countries (LMIC), is currently undergoing an epidemiological transition with a growing burden of non-communicable diseases (NCDs) co-occurring with an existent burden of infectious diseases like human immunodeficiency virus (HIV). South Africa continues to have the biggest HIV epidemic globally, and adolescents and young people, especially young women, bear a disproportionate burden of HIV in the country. Adolescents and youth living with HIV (AYLHIV) face an elevated NCD risk resulting from chronic immune activation, psychosocial factors and the complications of long-term antiretroviral therapy (ART). However, there is data paucity on the intersection of NCDs and HIV in adolescents in South Africa and Africa. This thesis aims to contribute to the limited evidence base in LMIC settings by investigating NCD multimorbidity and risk factors in AYLHIV within a context of epidemiological transition and urbanisation.

Objectives: This aim is achieved by fulfilling the following research objectives: 1. To investigate the extent to which NCD comorbidity (prevention, screening and management) is incorporated within existing adolescent HIV primary healthcare services in Cape Town, South Africa. 2. To estimate the prevalence of common NCDs and their known cardiometabolic, respiratory and behavioural risk factors in AYLHIV residing in peri-urban Cape Town. 3. To determine individual, household, social and neighbourhood level factors associated with obesity in AYLHIV.

Methods: I conducted a narrative literature review to inform the development of a conceptual framework for investigating the intersection of adolescence developmental theory with NCDs and HIV. The emergent concepts were explored from an over-arching socio-ecological viewpoint, drawing on life course epidemiology and epidemiological transition theories. I conducted a cross-sectional quantitative study in nine primary care facilities across peri-urban Cape Town. The study was conducted in two parts. The first part of the study was comprised of data collected from 491 medical records of AYLHIV accessing HIV care in these facilities. The second part of the study sought to investigate the epidemiology of NCDs and NCD risk factors and to assess multilevel factors associated with abdominal obesity (the primary outcome). I recruited 176 eligible AYLHIV to participate in the study with primary data (on NCDs and NCD risk factors) collected from 92 participants during routine clinic visits between March and December 2019.

Results: The findings from the 491 patient medical records reviewed demonstrated limited attention to NCD comorbidity prevention, screening and treatment within adolescent HIV primary care services. Only 62% of patient folders had documented anthropometric measurements, 59% had documented blood pressure measurements, and less than 11% of patient folders reviewed had any NCD health promotion documented.

Among the 92 participants recruited for primary data collection, 76% were female. More than a quarter (27%) were not in education, employment or training; 70% lived in food-insecure households, and 44% were multidimensionally poor.

At the individual level, a high prevalence of NCDs was found, particularly elevated blood pressure and hypertension (20% and 5% respectively), overweight/obesity (36%), central obesity (37%), and depressive symptoms (43%). With respect to NCD risk factors, 69% reported engaging in sufficient physical activity (79% of males and 66% of females), and 49% reported three or more hours of sedentary behaviour per day. However, unhealthy dietary practices were common, with only 27% eating fresh fruit, 52% eating vegetables and 33% eating whole grains daily. On the other hand, 29% drank sugar-sweetened beverages, and 33% ate sweets and cakes daily, while 42% skipped breakfast regularly. Furthermore, nutritional knowledge was low, especially with respect to healthy food choices and diet-disease relationships. Risky behaviours were also prevalent with 30% current smokers (48% males and 25% females) and 41% alcohol use in the past month (58% males versus 36% females), with binge drinking most commonly reported in the youngest age group < 18 years (55%). Significantly more males reported lifetime use of any illicit substances (53% versus 30% for females), with cannabis the most frequently reported substance used (23% lifetime prevalence).

Beyond individual-level risk factors, household-level factors were also explored. More than half (58%) reported the death of one or both parents, while 47% reported a biological parent as their primary caregiver. Parental level factors were largely positive, with participants reporting high levels of positive parenting and parental supervision. However, 35% lived in informal dwellings, 38% did not have access to piped water inside their dwelling and 62% experienced thermal discomfort in winter. Community experiences revealed a mixed picture, with 61% of participants exposed to high levels of community violence, while participants largely reported high neighbourhood belonging and low levels of stigma.

Multilevel regression was conducted to investigate the factors associated with abdominal obesity at different socio-ecological levels. All models were adjusted for sex and age. Statistically significant individual-level risk factors that were associated with higher odds of abdominal obesity were skipping breakfast (OR= 5.42; 95% confidence interval (CI): 1.32 – 22.25) and absence from school or work (OR= 3.06; 95% CI: 1.11 – 8.40), while daily whole grain consumption (OR= 0.20; 95% CI: 0.05 – 0.71) and weekly moderate-intensity physical activity (OR = 0.24; 95% CI: 0.06 – 0.92) were associated with lower odds of abdominal obesity. At the household- and community levels, experiencing thermal discomfort was associated with increased odds of obesity (OR= 4.42; 95% CI: 1.43 – 13.73), while higher anticipated stigma was associated with reduced odds of obesity (OR= 0.58; 95% CI: 0.33 – 1.00). The features of the built and food environment that were associated with reduced odds of abdominal obesity in AYLHIV were land-use mix diversity (OR= 0.52; 95% CI: 0.27 – 0.97),

access to recreational places (OR= 0.37; 95% CI: 0.18 – 0.74), higher perceived pedestrian and traffic safety (OR= 0.20; 95% CI: 0.05 – 0.80), and having a non-fast-food restaurant within walking distance (OR= 0.30; 95% CI: 0.10 – 0.93).

Conclusion: These results indicate an existent burden of NCDs and NCD risk factors in urban AYLHIV. Beyond the NCD risk attributable to HIV and ART, these multiple risk factors coupled with early initiation of high-risk behaviours like smoking and harmful alcohol use further increase NCD risk. Despite high NCD comorbidity and risk, evidence shows little to no integration of health services and limited responsiveness with regards to NCD health promotion. These findings underscore a missed opportunity in multimorbidity prevention.

Overall, these findings highlight the need for a comprehensive, integrated approach for AYLHIV to both prevent and manage NCD multimorbidity within primary care. This integrated approach should include mental health assessment and screening for weight status, abdominal obesity and blood pressure to identify comorbid NCDs early and intervene to improve NCD outcomes.

Additionally, risk factor screening should be incorporated into HIV care to prevent NCD multimorbidity. Screening should include early identification of the most common NCD risk factors (insufficient physical activity, poor dietary practices, smoking, alcohol use and binge drinking, particularly in male adolescents and younger age groups). These findings also highlight the need for intervention at various levels of the socio-ecological framework through multisectoral interventions in the social and built environments. Finally, this thesis contributes an evidence base to inform the development of integrated and intersectoral models of care to address the colliding epidemics of HIV and NCDs in young people in LMIC settings.

Declarations

I declare that this thesis is my own work or, in the case of multi-authored papers, constitutes work for which I was the lead author. My contribution to multi-authored papers is outlined at the beginning of each results chapter. I further declare that this thesis has not, in whole or in part, been submitted for a degree at any other university.

I confirm that I have been granted permission by the University of Cape Town's Doctoral Degrees Board to include the following publication(s) in my thesis, and where co-authorships are involved; my co-authors have agreed that I may include the publication(s):

Publication 1: Kamkuemah M, Gausi B, Oni T. *Missed opportunities for NCD multimorbidity prevention in adolescents and youth living with HIV in urban South Africa. BMC Public Health*. 2020 Dec; 20:1-1.

Publication 2: Kamkuemah M, Gausi B, Oni T. *High prevalence of NCD multimorbidity in South African Adolescents and Youth Living with HIV: Implications for Integrated Prevention* (*Accepted for publication by South African Medical Journal (SAMJ)*).

.

Signature: Signed by candidate Date: 15 October 2021

Student Name: Monika Kamkuemah Student Number: KMKMON001

Accepted conference abstracts as oral presentations:

1. **International Workshop on HIV & Adolescence, November 2020**
   Organiser: Virology Education,
   Date: 24th November 2020,
   Session 6: The Quest for Well-being: Adolescents and Mental Health,
   Title: *Mental health and substance use in adolescents and youth living with HIV in a context of violence.*
   Accessible at: https://academicmedicaleducation.com/meeting/international-workshop-hiv-adolescence-2020/video/mental-health-and-substance-use

   Presented research showing that community violence, substance use and inadequate parental monitoring and supervision may increase vulnerability to mental health disorders, expressed by high levels of depressive symptoms among AYLHIV residing in townships in Cape Town. Recreational options, including after-school sports activities, can help interrupt pathways that predispose youth to engage in harmful behaviours.

Accepted conference abstracts as poster presentations:

1. **International Workshop on HIV & Adolescence, November 2020**
   Organiser: Virology Education,
   Date: 19th November 2020,
   Session 5: Treatment, Care and Support for Adolescents Living with HIV
   Title: *Epidemiology of Non-communicable Diseases (NCDs) and risk factors in South African adolescents and youth living with HIV in an urban setting.*

   Presented research showing the results of a cross-sectional study conducted in six primary care facilities across urban Cape Town, South Africa. The results showed an existent burden of elevated blood pressure, obesity and multiple risk factors in urban AYLHIV. Beyond the NCD risk attributable to HIV and ART, these multiple risk factors coupled with early initiation of high-risk behaviours like smoking and harmful alcohol use further increase NCD risk. Integrated prevention with NCD and NCD risk factor screening as part of HIV care and early intervention on NCD comorbidities are crucial to prevent multimorbidity in AYLHIV.

2. **8th Annual School Research Day- Virtual Poster Event 2020**
   Organiser: School of Public Health and Family Medicine, Faculty of Health Sciences, UCT.
   Date: 26 November 2020,
   Session: Public Health and Family Medicine Research,
   Title: *Epidemiology of Non-communicable Diseases (NCDs) and NCD Risk factors in South African Adolescents and Youth Living with HIV in an urban setting.*

   Same as Poster 1 above.

3. **17th European AIDS Conference, Basel, Switzerland, November 2019.**
   Organiser: European AIDS Clinical Society,
   Date: November 6-9, 2020
   Title: PE9/36- *Non-communicable disease screening and prevention in adolescents and youth living with HIV in the context of rapid urbanisation in South Africa*.

   Presented research findings from a medical record review on existent NCD burden and risk factors in AYLHIV enrolled for ART in primary healthcare facilities in Cape Town. This research showed that the actual prevalence of NCDs and related risk factors were uncertain due to limited documentation. Thus, prevalence rates could not be determined from medical records and would be an important focus for further investigation. Furthermore, poor documentation of NCD risk factors for most participants demonstrated a missed opportunity for detecting comorbidity and NCD risk in primary care; and early intervention in AYLHIV.

Acknowledgements

This thesis would not have been completed without the invaluable advice, continuous support, and mentorship of my supervisors, Professor Tolu Oni and Dr Keren Middelkoop. I am incredibly grateful for your constant feedback and critical engagement throughout my doctorate. I would also like to thank Professor Susan Cleary, the PhD programme convenor in the School of Public Health and Family Medicine, for her support and guidance during the PhD process. Additionally, I want to express gratitude to Dr Elona Toska and Dr Marija Pantelic from the Mzantsi Wakho Adolescent Health study for their helpful suggestions, which were influential in shaping my methodology.

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Never would I have anticipated writing this thesis in the face of a global pandemic, COVID-19, which has caused unprecedented disruption and loss. While writing, I often thought about the concept of antifragility and how systems must adapt in the face of uncertainty. An antifragile mindset goes far beyond resilience but grows stronger from volatility and stress. I saw this personified in the young people who participated in this study. Your strength is truly inspiring, and I am highly grateful for the patience and openness you showed me as I conducted this research.

To my family, thank you for your unwavering love and support and for helping me reach this milestone. I appreciate your belief in my abilities that kept me going, despite several setbacks.

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List of Acronyms and Abbreviations

AIDS	*Acquired Immunodeficiency Syndrome*
ART	*Antiretroviral therapy*
AYLHIV	*Adolescents and Youth Living with HIV*
BMI	*Body Mass Index*
CDC	*Community Day Centre*
CHC	*Community Health Centre*
CLHIV	*Children living with HIV*
COPD	*Chronic Obstructive Pulmonary Disease*
CVD	*Cardiovascular Disease*
DBP / SBP	*Diastolic or Systolic Blood Pressure*
FEV1	*Forced Expiratory Volume*
HAART	*Highly Active Antiretroviral Therapy*
HAND	*HIV-Associated Neurocognitive disorder*
HDL / LDL	*High-density or Low-density lipoprotein*
HIV	*Human Immunodeficiency Virus*
LMICs	*Low- and middle-income countries (includes low income, lower-middle-income and upper-middle-income countries)*
NCD	*Non-communicable disease*
PA	*Physical activity*
PHIV+	*Perinatally HIV-infected*
PLHIV	*People living with HIV*
PMTCT	*Prevention of mother-to-child transmission of HIV*
PTSD	*Post-traumatic stress disorder*
RBG	*Random Blood Glucose*
SAMPI	*South African Multidimensional Poverty Index*
SES	*Socio-economic status*
SSA	*Sub-Saharan Africa*
T1DM/ T2DM	*Type 1 or Type 2 Diabetes Mellitus*
UNAIDS	*Joint United Nations Programme on HIV/AIDS*
UNICEF	*United Nations International Children's (Emergency) Fund*
WHO	*World Health Organization*
YMPI	*Youth Multidimensional Poverty Index*
YRBS	*Youth Risk Behaviour Survey*

Index of key terms

Adolescent: The United Nations Population Fund (UNFPA) defines an **adolescent** as anyone between the ages of 10 and 19 years, which is similar to the definition used by the World Health Organization (WHO). According to the United Nations Children's Fund (UNICEF), a **young person** is anyone between the ages of 10 – 24 years. Youth is the subset aged 15 – 24 years.

Chronic condition: The WHO defines a **chronic condition** as a human health condition or disease that is persistent or otherwise long-lasting in its effects, lasting three months or more or a disease that develops with time.

Metabolic syndrome: refers to a cluster of conditions — increased blood pressure, high blood sugar, excess body fat around the waist, abnormal cholesterol or triglyceride levels occurring together, increasing the risk of heart disease, stroke and diabetes. According to National Institutes of Health guidelines, you have metabolic syndrome if you have three or more of these traits or are taking medication to control them.

Non-communicable diseases: The WHO defines non-communicable diseases (NCDs) as a broad category of chronic diseases and conditions of long duration and slow progression that cannot be spread from person to person. However, they may be caused by viruses or bacteria that can be transmitted. This definition includes mental health conditions.

Multimorbidity: is defined as the coexistence of two or more diseases/conditions or their risk factors or symptoms in a given individual. However, the Centers for Disease Control and others recognise that the definition is not uniform and needs to include risk factors and symptoms.

Chapter 1 Introduction

1.1 Background

Adolescence, defined by the World Health Organization (WHO) as the stage between 10 - 19 years, is a time of rapid growth and development, both physically and psychologically [1]. Significant determinants of later adult health develop and are established during adolescence [2]. Globally, approximately 1.6 million adolescents (10 - 19 years) were living with HIV in 2018, with the greatest proportion (80%) residing in sub-Saharan Africa (SSA) [3]. Despite the wide scale-up of antiretroviral therapy (ART), which has led to significant declines in AIDS-related morbidity and mortality, treatment outcomes for adolescents are much poorer than for adults and children [4, 5]. Although estimates suggest that mortality in younger adolescents is starting to decline, mortality in older adolescents and youth living with HIV continues to rise [6]. Poor prioritisation of adolescents in HIV programmes and lack of support for retaining adolescents in care has contributed to this shortfall [7].

Alongside HIV and other infectious diseases, non-communicable diseases (NCDs) are emerging and increasing in low-middle-income settings (LMICs), especially amongst the poor residing in urban settings [8]. The last two decades have seen a growing trend in NCD risk factors in LMICs with increasing smoking rates, harmful use of alcohol, unhealthy diets and physical inactivity [9]. Furthermore, there is evidence showing that adults living with HIV on ART have a higher than average risk of NCDs like cardiovascular disease (CVD), pulmonary hypertension, chronic obstructive pulmonary disease (COPD) and chronic kidney diseases [10-12]. The increasing burden of NCDs, in addition to the existent high rates of infectious diseases in LMICs [13], means that adolescents and youth living with HIV (AYLHIV) are potentially at risk of multiple morbidities. However, interactions between HIV, ART, behavioural and environmental risk factors are yet to be sufficiently explored in adolescents with HIV in LMICs on long-term treatment.

1.2 Rationale

SSA has the highest burden of HIV globally, but there is limited information on the intersection of chronic NCDs and infectious diseases, particularly among adolescents. Also, many countries in SSA are currently undergoing epidemiological transition with co-occurring burdens of infectious diseases and NCDs [13]. According to the 2017 Global Burden of Disease study, the top five causes of disability

and premature mortality in adolescents in SSA are HIV/AIDS, interpersonal violence, road injuries, depressive disorders, TB and malaria [14]. SSA has the highest number of adolescents and AYLHIV globally. However, adolescents have been largely overlooked, with a paucity of tailored healthcare programmes and research efforts addressing HIV models of care and retention in care, leading to sub-optimal health outcomes [2]. With the first cohorts of perinatally HIV-infected (PHIV+) adolescents now entering adulthood and the move towards more comprehensive health services, questions remain on NCD risk factors particularly pertinent for AYLHIV and the best way to ensure overall adolescent health and well-being.

Moreover, adolescents in LMICs are growing up in the context of epidemiological transition. In light of this transition and the collision of infectious diseases with NCDs, early identification of risk and early intervention is increasingly important. Furthermore, many NCDs share interrelated preventable risk factors, which would be advantageous to identify and eliminate before they become major public health issues and undermine future population health [18]. Adolescence is a critical period during which risk behaviours that lead to adult disease become entrenched. However, it also presents opportunities for sustained health and well-being through education and preventive efforts. Intervening during this critical period can interrupt disease trajectories and have a long-term influence on future health.

Although adolescents are generally healthy and do not frequently access health care, AYLHIV are a well-positioned subgroup for intervention by virtue of the fact that they are living with a chronic condition requiring regular follow-up. A primary concern is how these adolescents will age with HIV in environments that may not be conducive to healthy living due to structural and economic constraints. Previous studies have explored sexual and reproductive health, adherence and mental health issues in AYLHIV, mainly focussing on individual factors. There is a growing body of literature that recognises the importance of sociological factors in shaping health outcomes, especially with regard to NCDs. For example, the growing obesity burden in LMICs is linked to increased urbanisation and globalisation of unhealthy diets and food supply chains [15]. The contribution of this thesis is to bring a unique perspective on NCD multimorbidity and obesity in a young population living with HIV within a dynamic urban setting. This thesis also explores the role of social context and the built and food environments on NCD risk in AYLHIV in a South African city undergoing several transitions.

1.3 Thesis aim

The overall aim was to investigate the prevalence of NCDs and NCD risk factors in AYLHIV accessing HIV treatment across primary care facilities in peri-urban Cape Town. Secondly, I explored multilevel risk factors associated with overweight or obesity status in this subpopulation.

1.4 Thesis outline

The remainder of this thesis follows the structure displayed in **Table 1.1**. Chapter 2 describes the conceptual framework used for the thesis and provides an overview of theoretical and empirical literature relevant to the thesis and used in subsequent chapters. In Chapter 3, the methodology used for the thesis is provided with an overview of the setting, sampling strategy, study procedures, measurement tools and analysis, and ethical considerations.

Chapters 4, 5 and 6 contain empirical results. Chapter 4 provides the results of a cross-sectional study reviewing the medical records of AYLHIV to investigate the extent to which NCD comorbidity prevention, management and risk factor screening are incorporated within existing adolescent HIV primary healthcare services in Cape Town. Chapter 5 presents the results of a cross-sectional study describing the prevalence of NCD comorbidities, multiple NCD risk factors and nutrition knowledge of AYLHIV in Cape Town. Chapter 6 presents the results of a multilevel analysis of the cross-sectional study data exploring the relationship between the urban built and food environments and abdominal obesity in AYLHIV.

Chapter 7 reviews and discusses key findings in light of the research questions and revisits the conceptual framework, proposing a model for integrated adolescent care informed by the findings from the thesis. The thesis contributions are outlined as well as its limitations and suggestions for further research. Chapter 8 concludes by summarising the contributions of this thesis to the knowledge landscape and proposing a dissemination plan.

Table 1.1: Thesis outline

Chapter 1: *Introduction*	Background, rationale, aim and thesis outline
Chapter 2: *Literature Review*	Conceptual framework, theoretical and empirical literature, thesis justification.
Chapter 3: *Methodology*	Overview of study setting, study designs, data sources and data collection, statistical methods and analysis, ethical considerations.
Chapter 4*: Paper 1*	Title: *Missed opportunities for NCD multimorbidity prevention in adolescents and youth living with HIV in urban South Africa.* Introduction, methods, results, discussion, conclusion
Chapter 5: *Paper 2*	Title: *High Prevalence of NCD Multimorbidity in South African Adolescents and Youth Living with HIV: Implications for Integrated Prevention.* Introduction, methods, results, discussion, conclusion
Chapter 6: *Paper 3*	Provisional title: *Neighbourhood Environment and Correlates of Obesity in Adolescents and Youth Living with HIV in Urban Cape Town* Introduction, methods, results, discussion, conclusion
Chapter 7: *Discussion*	Introduction, revisiting research questions and conceptual framework, contributions and limitations, implications for policy and practice, and recommendations, suggestions for further research, conclusion
Chapter 8: *Conclusion*	Summary of thesis contribution
Appendices	Literature search strategy, participant information sheets, assent form, definition of variables and composite variables and proposed HIV/NCD integrated screening and management tool.

Chapter 2 Literature Review

2.1 Introduction

This chapter begins by outlining the theoretical grounding and conceptual framework used throughout this thesis. The theories and conceptual framework are used to guide the narrative literature review that follows. The main purpose of the literature review is to provide an overview of HIV/NCD comorbidity and risk factors in adolescents, highlighting significant areas and gaps in research. The chapter ends with a thesis justification, highlighting contextual implications and the need for research and intervention.

2.2 Conceptual framework

The theoretical grounding for this thesis is based on the socio-ecological model for health, a life course paradigm and epidemiological transition. Three overlapping concepts are explored within these paradigms, as displayed in **Figure 2.1:**

- Adolescents and young people;
- HIV/AIDS as a chronic disease and the effects of ART;
- NCDs and NCD risk factors.

2.2.1 Conceptual framework of adolescent/youth HIV-NCD comorbidity

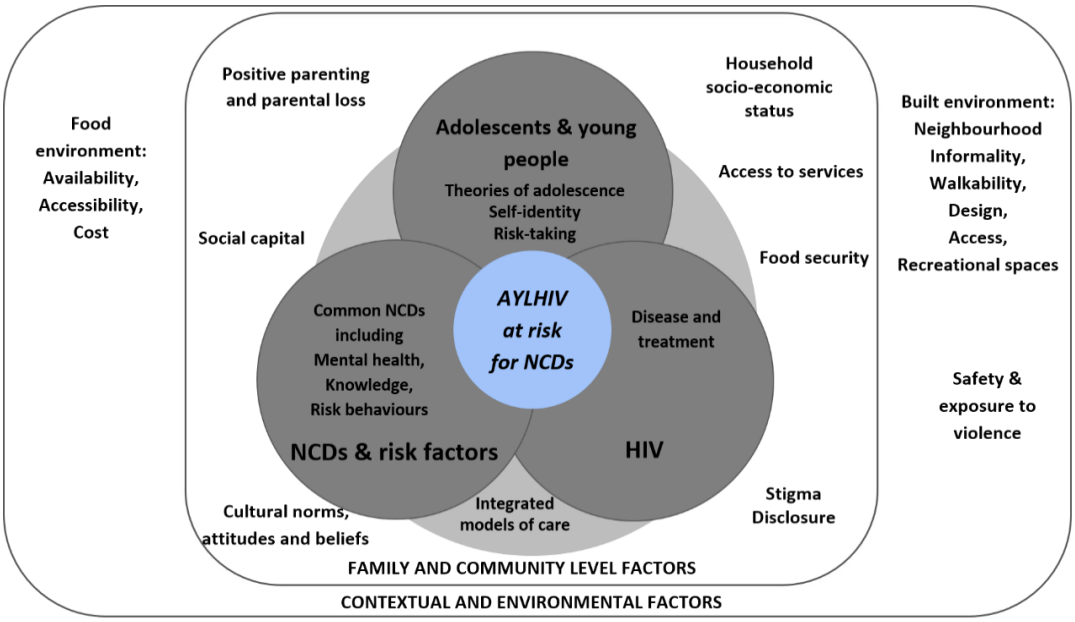

Figure 2.1: Conceptual framework of adolescent/youth HIV-NCD comorbidity

In developing the conceptual framework for the thesis, I combined the socio-ecological model for adolescent health proposed by Blum et al. (**Figure 2.2**) [16] and a life course approach to NCD risk discussed in **Section 2.2.3** to explore how multilevel factors from the individual to broader environmental level affect adolescent health and NCD risk. I then explored these concepts in the context of young people living with a historically highly stigmatised condition within a society and country undergoing epidemiological transition and urbanisation. The following sections illustrate the application of these individual theories in developing the thesis' conceptual framework shown in **Figure 2.1**.

2.2.2 Socio-ecological model

The socio-ecological model of health is one of the most widely used models in public health. In this model, the assumption is that illness occurs because of a host of social, environmental and community-level factors influencing the individual. There is no single root cause of illness but rather a host of factors ranging from the environment to individual-level factors.

Bronfenbrenner's ecological systems theory suggests that adolescent development is greatly influenced by the context in which adolescents develop. This context encompasses the immediate environment of family, peers, school and neighbourhood to the greater cultural and social macro-system and the dynamic interactions between these environments [17, 18]. In addition, there is growing recognition that the health of children and adolescents, maybe more so than other age groups, is primarily determined by factors that lie outside of the health care system [19].

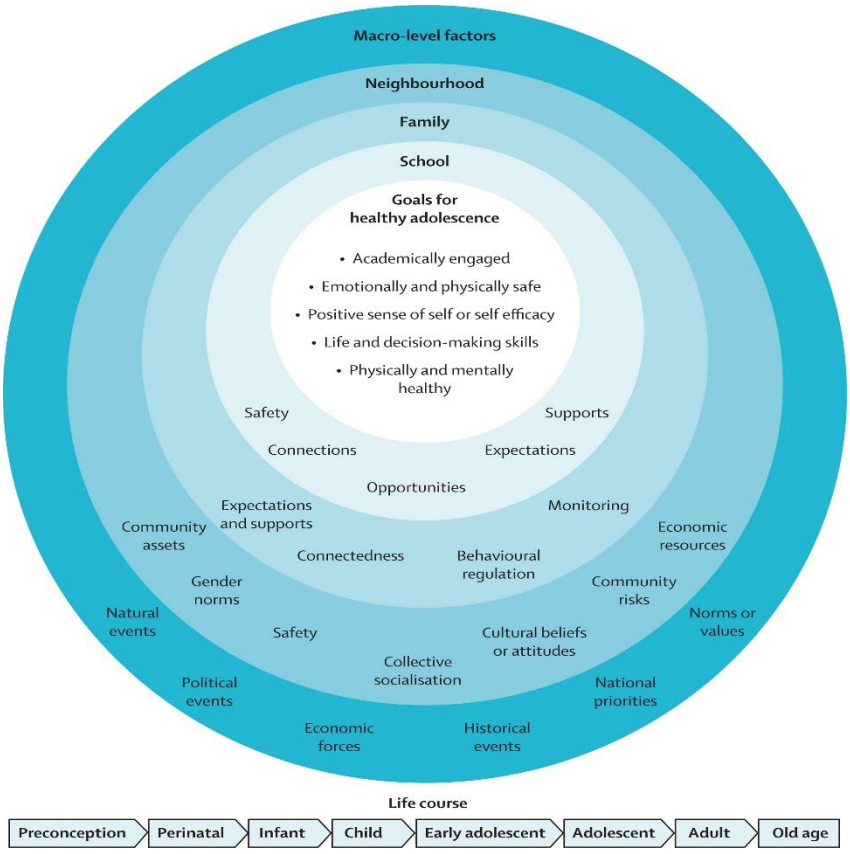

Figure 2.2: Blum's ecological model for adolescent health over the life course

In the diagram above, developed by Blum et al., the authors extrapolate the socio-ecological model for adolescent health across a life course timeline ranging from preconception to adulthood [16]. The model highlights the importance of all levels and how they interact and impact an adolescent's health. This model is particularly relevant in South Africa, where adolescents face various community risks and intergenerational cycles of poverty, violence and malnutrition [20]. The Blum model defines the goals for healthy adolescence as an academically engaged, emotionally and physically safe and healthy young person with a positive sense of self and life skills.

2.2.3 Life course approach

The life course approach considers the long-term effects of physical and social exposures during gestation, childhood, adolescence, young adulthood and later adult life on chronic disease risk [21]. Biological, behavioural, and psychosocial pathways influence chronic disease development across an individual's life and inter-generationally. At its core, a life course perspective underscores the fact that development is lifelong, and no life stage can be understood in isolation from others [22]. Different theories exist for the life course model of health. These include the critical period model,

sometimes referred to as the latency model or biological programming [23], and the accumulation of risk model [24].

In the critical period model, exposures at a specific period in life have lasting effects on biological function. Later life exposures may influence disease risk in an additive way, but foetal exposures, for example, may permanently alter the anatomy and metabolic systems [25, 26]. The Barker hypothesis, also known as "the thrifty phenotype hypothesis", states that poor foetal and infant growth *in utero*, as a result of malnutrition and substance use, predisposes the child to morbidities such as glucose intolerance, insulin resistance, cardiovascular disease, hypertension, obesity and even mental illnesses like schizophrenia in later life [25, 27]. Early life influences like a mother's diet and nutrition affect the later-life health outcomes of her offspring with persistent effects throughout adulthood [28].

In the accumulation of risk model, risk factors at different life stages accumulate over time in a "chain of risk." For example, sustained low socio-economic status (SES) from birth, infancy and childhood may result in a greater propensity for NCDs in adult life [29]. The risk of NCDs accumulates with age, with factors acting at all stages of the life course [30]. There may be developmental periods when the effects of exposures have a more significant impact on future health than factors operating at other times [24]. Adolescence is one of those periods and is regarded as a crucial point of intervention when chains of risk may be broken, and a new life trajectory can be established.

2.2.4 Theory of epidemiological transition

The theory of epidemiological transition was first introduced by Omran in 1971 and describes changes in population patterns in terms of fertility, life expectancy, mortality, and leading causes of death [31]. The theory has its roots in demography but is widely applied in public health [32]. Several critiques of the theory include its overemphasis on mortality rather than disease causation and the distinction made between infectious and chronic diseases, which are now recognised as not being strictly disparate [32]. Omran's theory also assumes that all countries will experience a similar linear progression of transitions, but not all countries experience epidemiological transition in the same way [13].

Countries in SSA and other LMICs are currently undergoing epidemiological transition, characterised by a high co-occurring prevalence of infectious, maternal, perinatal and nutrition-related conditions and increased prevalence of NCDs. South Africa faces a quadruple burden of disease, with concurrent epidemics of infectious diseases (HIV/AIDS and TB); maternal and child mortality; NCDs such as hypertension and CVDs, diabetes, cancer, mental illnesses and chronic lung diseases; as well as injury and trauma [8]. Epidemiological transition in SSA is significantly driven by urbanisation and its associated changes.

2.2.4.1 Urbanisation

Urbanisation is a predominant feature of LMICs, and it is predominantly young people migrating to urban centres [33]. In 1975, Walker predicted that rising urbanisation and improved living standards would lead to a corresponding increase in obesity, hypertension, diabetes and strokes in developing populations [34]. The Population Division of the United Nations (UNDESA) estimates that by 2050, more than half of SSA's population will reside in cities [35]. In the South African context, young people are especially mobile, with national statistics showing that migration increases sharply amongst youth in their late teens and peaks amongst those in their late 20s. These migration rates include all directions of migration: from rural to urban areas and vice versa, as well as moves within urban and within rural areas [36]. Countries in SSA undergoing rapid, unplanned urbanisation have not been able to keep up with the consequent growing infrastructure and sanitation demands, leading to increased slums and informal dwelling, growing poverty and inequality [35].

In addition to facing greater exposure to environmental hazards, such as pollution, inadequate water and sanitation, migrant and other adolescents growing up in socioeconomically disadvantaged settings and living under precarious circumstances (including food insecurity, homelessness and informal housing) are at even higher risk of adopting risk behaviours. They may lack access to health and other services and be more vulnerable to substance abuse, risky sex and resultant consequences like mental health problems, unintentional injuries, unplanned pregnancies, HIV and other sexually transmitted infections [37]. The most recent Census data, collected in 2011 shows that the greatest contributor to net internal migration for the Western Cape is the Eastern Cape Province [38]. Internal migration has implications for retention in care for PLHIV. Patients on ART often switch between healthcare facilities in the two provinces or are sometimes documented as being lost to follow-up due to poor linkage of electronic medical record systems [39].

In following literature review, I will explore the concepts outlined in the conceptual framework in **Figure 2.1,** engaging with literature on NCDs and their determinants in PLHIV and AYLHIV.

2.3 Adolescents and young people

2.3.1 Theories of adolescence

Many, including the WHO, define adolescence as the second decade of life between 10 and 19 years [1]. It is a period when abstract thinking develops, together with improvement in memory, language, processing speed, attention and concentration [40]. Adolescence is a time of transition involving multi-dimensional changes ranging from biological, psychological (including cognitive) and social changes [41]. Adolescence can be grouped into three overlapping developmental stages, as shown in **Table 2.1**.

Table 2.1: Developmental stages of adolescence by age

DEVELOPMENTAL STAGE	WHO DEFINITION
Early Adolescence	Period between the ages of 10 - 15 years characterised by rapid growth.
Middle Adolescence	Period between the ages of 14 - 17 years when growth slows down, and the individual has reached ~95% of adult growth.
Late Adolescence	Occurs from 16 - 19 years when physical maturity is reached, and also cognition and abstract thinking.

Source: World Health Organization. The second decade: improving adolescent health and development [1].

The United Nations (UN) defines youth as people aged 15 - 24 years. For this thesis, a broader definition of adolescence was used that includes youth and is defined as the period from the ages of 10 to 24 years, sometimes collectively referred to as "young people". Nearly half of the world's young people live in SSA, and young people make up about 33% of sub-Saharan Africa's population [42].

Scholars view adolescence as a period of transition or a critical period of development, with varying theories on how best to characterise this life stage, as depicted in **Table 2.2**. Freud viewed adolescence as a "genital" stage where intense sexual drives and impulses break through due to the

physiological changes brought about by puberty. Erikson's theory emphasises the psychological tasks of identity formation or the "ego identity", as discussed in more detail under self-identity [43]. Piaget's theory of cognitive development characterises adolescence as a formal operational stage when the capacity for abstract thinking develops [44]. Adolescents learn to think beyond concrete experiences using more deductive logic and abstract ideas [44].

The commonly used Tanner scale derived from James Tanner's biological development theory outlines the different stages of puberty that occur over time [45]. Puberty is characterised by an accelerated growth spurt, followed by cessation of growth, changes in the amount and distribution of fat and development of the gonads and secondary sex characteristics [45].

Table 2.2: Theories of adolescence

DEVELOPMENTAL AREA	PRIMARY THEORISTS	FOCUS AREA
BIOLOGICAL	Stanley Hall, Arnold Gesell, James Tanner	Physical and sexual development determined by genes and biology.
PSYCHOLOGICAL	Sigmund Freud, Anna Freud	Adolescence viewed as a period of sexual excitement and anxiety.
PSYCHOSOCIAL	Erik Erikson	Identity formation; the struggle between achieving identity versus identity confusion.
COGNITIVE	Jean Piaget	Formal operational thought; moving beyond concrete, actual experiences and beginning to think in logical and abstract terms.
ECOLOGICAL	Urie Bronfenbrenner	The context in which adolescents develop; adolescents are influenced by family, peers, religion, schools, the media, community, and world events.
SOCIAL COGNITIVE LEARNING	Albert Bandura	The relationship between social and environmental factors and their influence on behaviour. Children learn through modelling.
CULTURAL	Margaret Mead, Carol Gilligan	The culture in which the child grows up.

Adapted from: http://www.actforyouth.net/resources/rf/rf_stages_0504.cfm

2.3.2 Self-identity

Identity refers to an existential position or an inner organisation of needs, abilities and self-perceptions [46]. Erikson, one of the strongest proponents of identity theory in adolescence,

conceptualised the theory of psychosocial development in which he described development as occurring in stages across the life course from infancy to old age [47]. He describes adolescents as having to establish identity independently from parents and peers by accomplishing specific psychosocial tasks at different developmental stages [47]. These tasks involve identifying and selecting values and roles for their adult life, which may require questioning or rejecting previously held beliefs and norms, leading to a crisis or identity confusion [48]. Marcia describes how identity formation, particularly in late adolescence, coincides with physical development, cognitive skills, and social expectations, enabling a young person to synthesise their previous childhood identifications and construct a viable pathway towards adulthood [46].

2.3.3 Risk-taking

Adolescents are not children, but they are also not yet adults. Adolescence is a period of increasing socialisation as adolescents start to explore their identity and sexuality, attempting to establish a viable identity distinct from parents and peers [48]. It is a developmental period of rapid physical, psychological, socio-cultural and cognitive changes characterised by efforts to surmount challenges and establish a sense of identity and autonomy [37]. Adolescents are critically dependent on peer approval, affiliation and immediate benefits, impacting risk perception and their ability to exercise self-regulation [49].

In addition to the quest for self-identity, which may lead to behaviours that appear rebellious and unpredictable [48], concurrent brain development leads to more impulsivity and risk-taking during puberty [50]. Steinberg has proposed a dual model of adolescent risk-taking, which explains why adolescents are more prone to risk-taking behaviours [51]. His hypothesis states that risky adolescent behaviour is the product of the interaction between changes in two separate neurobiological systems: a ‘‘socio-emotional’’ system, which is localised in the limbic and paralimbic areas of the brain; and a ‘‘cognitive control’’ system, which is mainly composed of the lateral prefrontal and parietal cortices. This interaction creates heightened vulnerability to risk-taking, particularly in middle adolescence, due to excessive dopamine and reward-seeking before the development of cognitive control [51, 52]. Studies on sensation-seeking have also shown increased dopamine activity in the brain's pleasure centre in young adolescents in response to risky behaviours compared to

children and adults, showing that engaging in risky behaviours stimulates the reward system in the adolescent brain [51].

These structural changes in the brain lead to increased risk-taking, including experimenting with alcohol and drugs, increased vulnerability to road traffic accidents and other injuries, antisocial behaviour and delinquency [53], and difficulty maintaining appropriate self-care activities such as condom use and proper use of medications [54]. This risk-taking behaviour is reflected in mortality statistics, which show that road injuries, self-harm/ suicide, interpersonal violence, and maternal conditions were the leading causes of morbidity and mortality for young people aged 15 - 19 years between 1990- 2013 [55]. Many potentially harmful health behaviours begin in adolescence, and many causes of adult illness and premature death in adulthood commonly develop during adolescence and possibly even earlier [29, 56]. Smoking, which frequently begins during adolescence, will lead to an estimated 150 million tobacco-related deaths during adulthood [41].

In addition to heightened risk-taking behaviours, most threats to adolescent health are consequences of social morbidities. Therefore, it is essential to be mindful of the environment in which young people grow up to gain a broader understanding of adolescent health [37]. Although the concept of social morbidities is not well-defined, it refers to a broad spectrum of health risks resulting from social, environmental and behavioural factors [57]. Substance use and abuse, unhealthy diets, sedentary behaviour, violence, suicide, and sexually transmitted diseases fall under the umbrella of social morbidities to which young people are increasingly exposed.

2.4 **HIV**

2.4.1 Global statistics and trends in SSA and South Africa

HIV is considered one of the world's most serious public health challenges since its discovery in the early eighties. At the end of 2019, approximately 38 million people globally were living with HIV/AIDS, of which 1.8 million were children under 15 years of age [58]. Global AIDS-related deaths have been reduced by 60% since 2004 [58]. In 2019, around 690 000 people died from AIDS-related illnesses worldwide, compared to 1.7 million people in 2004 [58].

Sub-Saharan Africa (SSA) bears the brunt of the HIV/AIDS epidemic, with an estimated 68% of people living with HIV residing in SSA. Young women and girls in SSA bear a disproportionate burden of new infections. Five in six new infections among adolescents aged 15–19 years are among girls, and young women aged 15–24 years are twice as likely to be living with HIV than young men [58].

South Africa has the biggest HIV epidemic globally, with 7.5 million people estimated to be living with HIV in 2019, equating to a prevalence rate of 13.1% and 19.0% for adults aged 15–49 years [59]. South Africa also has the world's largest-scale ART programme, with 5.2 million, or 70% of PLHIV, receiving ART [59]. Following the rollout and scale-up of ART in South Africa, AIDS-related mortality has significantly declined by more than 50% since 2006 [60].

2.4.2 HIV models of care

Globally, improved care and treatment options have increased the life expectancy of PLHIV, with decreases in AIDS-related morbidity and mortality. Care for HIV happens on a continuum - from testing to care, treatment, and viral suppression, referred to as the HIV "treatment cascade" [61]. Global targets for HIV speak to this cascade as the key to reducing HIV transmission, morbidity and mortality. The 90-90-90 targets, developed by UNAIDS in 2014 in line with the treatment cascade, proposed that 90% of all HIV-positive people should be diagnosed, 90% of all people with diagnosed HIV infection should receive sustained ART, and 90% of all people receiving ART should achieve viral suppression by 2020 [62]. South Africa has made significant progress in reaching the 90-90-90 targets, with 92% of PLHIV knowing their status, 70% of all PLHIV on ART and 64% of all PLHIV achieving suppressed viral loads in 2019 [59].

In Cape Town, ART is delivered through government clinics and is free for all patients. Various differentiated models for ART delivery were designed to support ART expansion and retention in care [63, 64]. Patients with well-controlled disease are managed in ART Adherence "clubs", which are either facility- or community-based and provide more streamlined access to repeat prescriptions, health promotion, education and socialisation for stable patients [64]. Other differentiated service delivery models implemented as part of National Adherence Guidelines for HIV, TB and NCDs [65] to support chronic disease management include fast-tracked health facility pick-up points and external pick-up points for medication refills. These service delivery models provide two-monthly medication refills and semi-annual or annual clinical assessments at the health facility [66]. For patients with

more than one chronic condition, medication refill visits and clinical assessment visits are integrated to reduce the time burden on patients [66].

2.5 Non-communicable diseases

2.5.1 Global statistics and trends in sub-Saharan Africa and South Africa

Globally, NCDs are the leading cause of disability and premature mortality accounting for 71% of deaths worldwide and 80.6% of years lived with disability (YLD) in 2016 [67, 68]. While the concept of NCDs is not universally agreed upon, the WHO defines NCDs as a broad category of chronic diseases and conditions, which tend to be of long duration due to a combination of genetic, physiological, environmental and behavioural factors [9]. The four main types of NCDs are cardiovascular diseases (such as heart attacks and stroke), cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma) and diabetes mellitus (DM) [9]. NCDs share common, interrelated risk factors: tobacco use, harmful use of alcohol, physical inactivity and unhealthy diets [69]. In 2018, the UN/WHO expanded the global NCD agenda beyond four diseases and four risk factors to the 5x5 NCD agenda which includes mental health conditions and air pollution as a fifth NCD risk factor [70].

The global prevalence of daily smoking was 25.0% in men, and 5.4% in women and 11.5% of global deaths were attributable to cigarette smoking in 2015 [71, 72]; while alcohol was the leading cause of premature death and disability in people aged 15–49 years in 2016 [73, 74]. Globally a quarter of adults are not sufficiently physically active, and physical inactivity accounted for 1 in 10 deaths worldwide [75] and 34.6 million disability-adjusted life years (DALYs) in 2016 [76], making physical inactivity the fourth leading risk factor for mortality globally [72]. Unhealthy diets contribute to a range of NCDs, specifically diabetes, cancers, and cardiovascular diseases. Dietary risk factors – low intake of fruits, vegetables and whole grains; high intake of sodium and added sugar from processed foods and sugar-sweetened beverages (SSBs) – are significant contributors to mortality and DALYs globally [77]. In 2017, one in five global deaths were associated with unhealthy diets [77].

NCDs affect LMICs disproportionately, with more than three-quarters of NCD deaths occurring in LMICs [9]. In 2017, the burden of NCDs in sub-Saharan Africa was higher than the global average,

with countries in central and southern sub-Saharan Africa (Congo (Brazzaville), Central African Republic, South Africa, Lesotho, Swaziland) having the highest rates of NCDs and DALYs due to NCDs within sub-Saharan Africa [14]. It was almost equivalent to the total burden associated with communicable, maternal, neonatal, and nutritional diseases (CMNN) [14]. Four NCDs accounted for 80% of NCD mortality and two-thirds of the disability from NCDs in LMICs: cardiovascular diseases, cancers, respiratory diseases and diabetes [78]. These rates are reported to be rising with increasing levels of urbanisation, inequality, and associated factors [14].

NCD risk factors are also increasing in SSA, where NCDs are emerging in the context of rapid urbanisation, contributing to unhealthy diets and sedentary behaviour, especially amongst the poor residing in urban settings [79]. Most adults in SSA are exposed to at least one risk factor for NCDs, including tobacco, harmful alcohol use, unhealthy diet, physical inactivity, obesity, or high blood pressure [80]. Over 80% of tobacco users live in LMICs [81]. Epidemiological analyses from 1980–2014 show that age-standardised average body mass index (BMI) and diabetes prevalence have increased steadily across Africa, at least as steeply as the global average [82].

South Africa, an upper-middle-income country, faces a quadruple disease burden with high levels of HIV/AIDS and tuberculosis (TB); CMNN diseases and deficiencies; NCDs, and injuries and trauma [83]. In 2016, 51% of deaths in South Africa were due to NCDs, and the risk of premature mortality from NCDs was 26% [84]. The prevalence of NCD risk factors has increased over the last two decades. For example, the prevalence of overweight and obesity among adult South African women increased from 56% to 68% between 1998 and 2016 [85]. South Africa has the highest rates of overweight and obesity in SSA [86]. One in three South African adults has hypertension; 16.2% smoke daily [87], and 18.3% engage in heavy episodic drinking [88]. South African adults aged 15 years and older who consume alcohol account for the fifth-highest consumption rate of absolute alcohol in the world [88].

2.6 **HIV and adolescents**

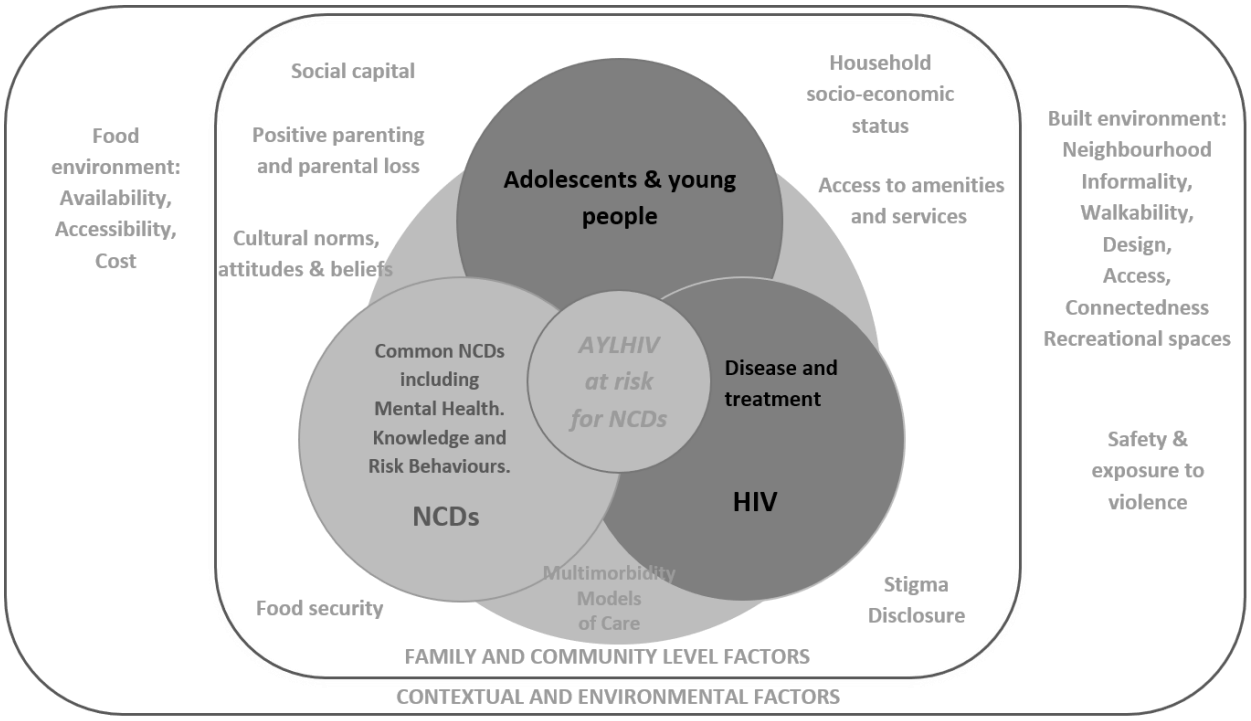

Figure 2.3: HIV and adolescents

2.6.1 Global statistics and trends in SSA and South Africa

AYLHIV belong to two distinct groups; those who acquired HIV perinatally (PHIV+) and have grown up with HIV, and those who acquired HIV during their teenage years, known as horizontal transmission. Youth in SSA are at the epicentre of the HIV/AIDS epidemic. In 2018, about 1.6 million adolescents between the ages of 10 and 19 were living with HIV globally, with the highest number (1.44 million, 80%) residing in SSA [3]. Despite significant progress in preventing HIV in young children, through the prevention of mother-to-child transmission (PMTCT), infection rates in adolescents remain high. Nearly 700 adolescents aged between 10 and 19 become infected with HIV every day [89].

Increasing survival of PHIV+ children and ongoing high incidence of horizontal HIV infection has led to an increase in the population of AYLHIV [6]. As the generation of children infected with HIV perinatally grow into adolescence, AIDS-related deaths in adolescents continue to increase while decreasing among all other age groups, particularly in the African Region [55]. Although the HIV mortality risk might be the same as other age groups, the absolute number of HIV-related adolescent deaths is presumed to be increasing partially due to the “bulge” of PHIV+ children ageing into the

adolescent age group [6]. The United Nations International Children's Emergency Fund (UNICEF) estimates that at current rates, 76 adolescents will die of AIDS every day by 2030 if additional investments are not made in HIV prevention, testing and treatment programmes [89].

South Africa has the highest reported burden of adolescent HIV globally. Of the 1.6 million adolescents (10 - 19 years) reported to be living with HIV worldwide in 2018, 310,000 (19%) were South African [3]. In South Africa, AYLHIV bear a disproportionate burden of the HIV epidemic and have the highest incidence of HIV [85, 90]. HIV prevalence amongst young women is nearly four times greater than in young men [91]. Social dynamics like inter-generational sex, early sexual debut and unprotected sex, driven by poverty, gender inequality and sexual or gender-based violence are commonly referenced as some of the reasons for the difference in HIV prevalence [92, 93].

2.6.2 HIV models of care in adolescents

Only 53% of children living with HIV (CLHIV) under 15 years received ART compared to 84% of pregnant women and 74% of adults aged 15 and older living with HIV in 2019 [58, 94]. In South Africa, adolescents and young adults have lower retention rates in care and lower viral suppression rates than older adults [95]. In 2013, it was estimated that only 14% of AYLHIV aged 15–24 were on ART, and 10% completed the HIV continuum of care, managing to reach viral suppression [95]. Many older adolescents are lost to care before starting the transition to adult care [61].

Models of adolescent ART care in Cape Town vary across facilities and different levels of care from primary, secondary, to tertiary health facilities. Some sub-districts have developed adolescent ARV clubs, whilst others see adolescents within mainstream paediatric/adult ARV care [96, 97] Facilities with adolescent clubs have developed individualised standard operating procedures for services offered and clinic structure. Some facilities have periodic youth clinic days whilst others rely on an appointment system.

2.7 NCDs and adolescents

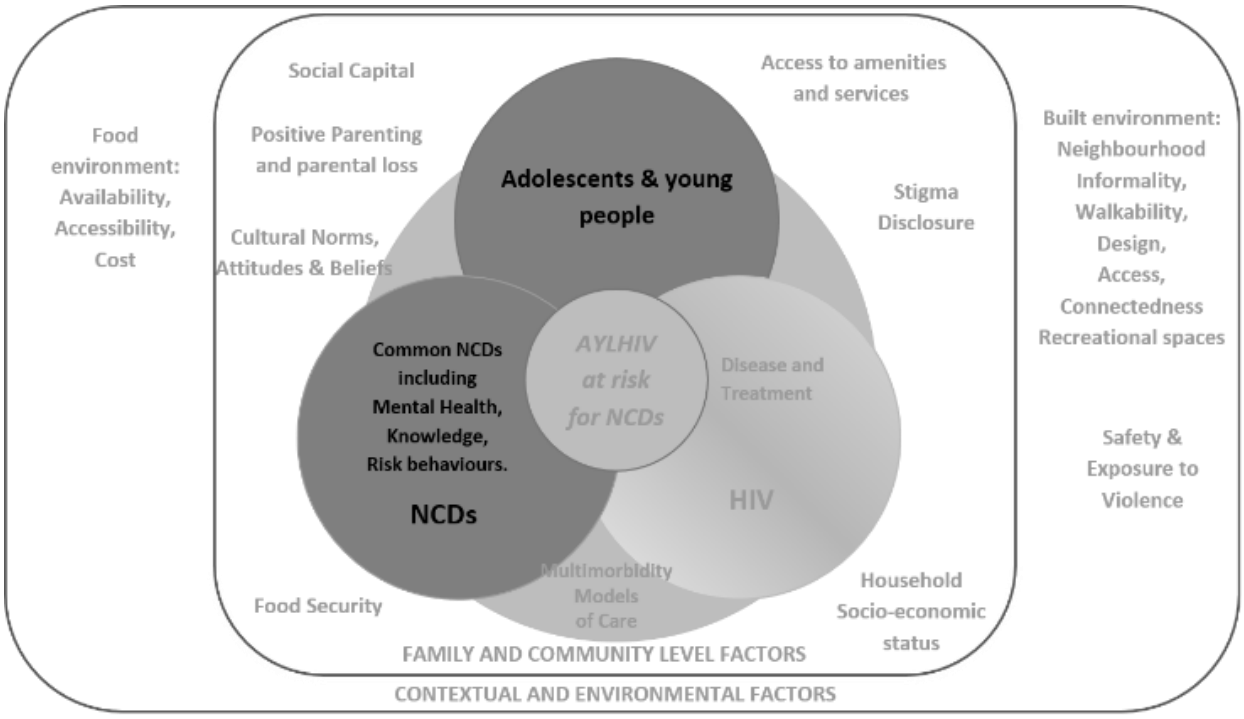

Figure 2.4: Adolescents and NCDs

2.7.1 Common NCDs in adolescents

In addition to increasing prevalence, NCDs affect younger populations and are associated with worse health and economic outcomes in LMICs than high-income countries [98]. The most frequently reported NCDs in adolescents and young people are mental health disorders, metabolic conditions, overweight and obesity, and asthma [99]. These are discussed in more detail below.

2.7.1.1 Mental health disorders

Every year, about 20% of adolescents will experience a mental health problem, most commonly depression or anxiety [100]. Depression and anxiety disorders are among the leading causes of illness and disability among adolescents globally [101]. Together with substance use disorders, they are the most significant contributors to disability in young people [68]. Estimated prevalence rates of mental disorders in the Western Cape province of South Africa for children and adolescents range from 11% for generalised anxiety disorder and 8% for post-traumatic stress disorder (PTSD) and major depressive disorder [102].

Mental health disorders frequently co-occur with other risk behaviours like harmful use of alcohol, tobacco use, unhealthy diet and physical inactivity, behaviours which have been shown to cluster in people with mental disorders [103]. Mental health disorders are also a key risk factor for suicide and self-harm [104]. Suicide is the third leading cause of death in older adolescents aged 15-19 years [105].

In South Africa, HIV infection, stigma and discrimination, substance use, and exposure to violence increase young people's vulnerability to mental disorders [106]. There is a stark unmet need for mental health care, especially in young people living in low-income conditions [106]. Mental health disorders may persist into adulthood, impacting physical and mental health and limiting opportunities and quality of life in adulthood [107].

2.7.1.2 Overweight and obesity in adolescents

Rates of adult and childhood overweight and obesity are increasing globally [108, 109], to the point where obesity is considered a global pandemic [110]. Similar to adults, South Africa has the highest prevalence rates of childhood overweight and obesity (19% of boys and 26% of girls under 20 years), rivalling many high-income countries [86]. A gender differential is evident in overweight and obesity rates, with females facing higher rates of overweight and obesity than males [111].

At the individual level, energy imbalance caused by increased caloric intake and lack of physical activity is the main driver of obesity [110]. Broader social and environmental influences also play a significant role, as discussed under Contextual and environmental factors. Documented risk factors for childhood obesity are early life exposures such as maternal and child malnutrition [112], parental obesity [113], family SES, particularly maternal employment [114, 115], school food and physical activity environments [116, 117] and community and neighbourhood environment factors such as density of fast-food restaurants, neighbourhood safety and residential proximity to parks and playgrounds [118, 119].

Adolescents with obesity are at increased risk of developing other comorbidities, including hypertension, high cholesterol, asthma, orthopaedic problems, cardiovascular risk factors and type 2 diabetes mellitus (T2DM) [120, 121]. Childhood and particularly adolescent obesity also tend to persist into adulthood, with health consequences beyond those immediately observed. Several

longitudinal studies document that children with obesity remain obese as adults [122, 123]. Furthermore, childhood obesity is associated with cardiovascular risk factors and increased adult cardiovascular morbidity and premature mortality [121, 122]. Other adverse consequences of childhood obesity include a higher likelihood of experiencing psychological problems like low self-esteem and behavioural problems [121].

2.7.1.3 Asthma in adolescents

Asthma is the most common chronic disease in children [124]. The prevalence of childhood asthma has been increasing in LMICs over the past two decades [125]. In a cross-sectional survey conducted in 2017 that recruited a randomised sample of 13–14-year-old Cape Town adolescents, and that used the standardised Global Asthma Network written, video and environmental questionnaires, asthma prevalence was found to be highest in Cape Town at 21.3% [126], higher than estimates from other LMICs [124, 126]. The prevalence of severe asthma increased from 7.8% in 2002 to 11.8% in 2017 and was associated with environmental factors like smoking, pet exposure, exposure to outdoor pollution and informal housing [126]. Asthma symptoms are more severe in children living in LMICs than in high-income settings [127]. Increasing asthma prevalence and symptom severity in LMICs have been attributed to resource constraints, rapid urbanisation, sub-standard living conditions and increased exposure to air pollution [127].

2.7.2 Knowledge and risk behaviours

Adolescence is often a time of experimentation with drugs and alcohol and initiation of sexual activity as adolescents explore their identity and sexuality [50]. In addition, many risk behaviours associated with chronic NCDs later in life, including tobacco, alcohol, substance use, unsafe sexual practices, obesity, and lack of physical activity, typically emerge during adolescence [128, 129]. Globally, 11% of adolescents use tobacco products [130], 81% have insufficient levels of physical activity [76], and 13.6% engage in heavy episodic drinking [88].

Many adult illnesses have been identified to have roots in childhood and adolescence, and it is estimated that about 70% of premature adult deaths are caused by behaviours started in adolescence [1]. For example, smoking, which frequently begins during adolescence, will lead to an estimated 150 million tobacco-related deaths during adulthood [41]. Childhood and adolescent obesity, which tend to persist into adulthood [123, 131], are associated with increased cardiovascular risk factors,

including hypertension, dyslipidaemia and hyperinsulinemia [132], which may culminate in adult cardiovascular morbidity and premature mortality [121, 122]. Half of all lifetime cases of mental health disorders emerge by 14 years, and three quarters are established by 24 years [133]. Thus, adolescence is a critical period of both opportunity and risk accompanied by rapid physical and psychological development that sets the foundation for adult health and the next generation's health [134, 135].

In South Africa, a third of adolescents and youth (aged 11 - 20 years) reported drinking alcohol in the Youth Risk and Behaviour Survey (YRBS), with a quarter engaging in heavy episodic drinking, 18% were current smokers, and 13% reported smoking cannabis in their lifetime [136]. Significantly more males than females reported alcohol use, heavy episodic drinking, smoking, and substance use [136]. Moreover, over 40% of young people had insufficient physical activity levels, with significantly more inactive females than males [136].

Health knowledge is another significant factor. For example, nutrition knowledge is strongly correlated with dietary intake and is conducive to healthier dietary habits [137]. A study conducted in school-going South African adolescents found that 77.5% scored less than 50% on diet and nutrition knowledge related questions [138]. Young people are often targeted by fast-food marketing and are susceptible to tobacco and alcohol advertising [139]. They may live in unfavourable environments that inhibit healthy behaviour like physical activity and healthy, balanced diets. However, many young people have access to information in the media and internet, unlike generations before, which they can use to shape their behaviour and ultimately determine their health status [140].

2.8 NCDs and HIV in adolescents

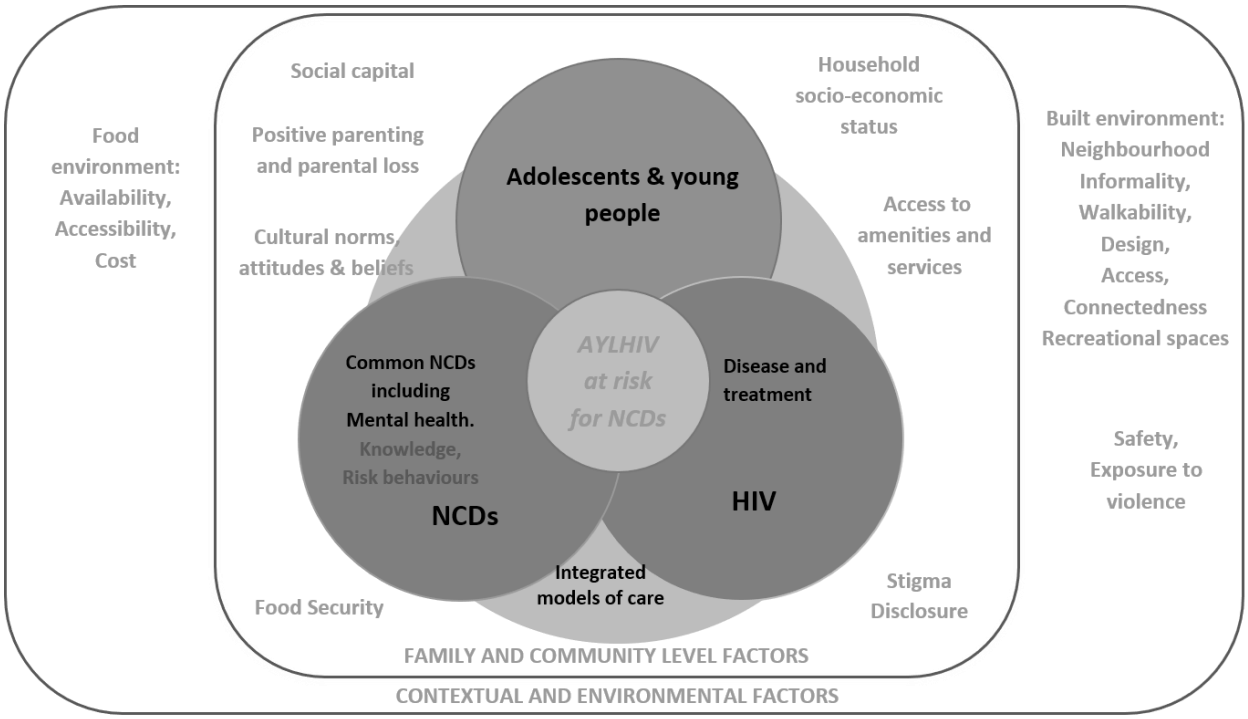

Figure 2.5: NCDs and HIV in adolescents

2.8.1 Dual and interacting epidemics

Sub-Saharan Africa is facing parallel and interacting epidemics of HIV and increasing NCD prevalence in the backdrop of complex health and social transitions [141]. Data shows that cardiometabolic diseases, injuries and cancer are fast becoming a significant health problem in SSA, competing with infectious diseases for health resources [142]. To illustrate, in Uganda and Tanzania, a high prevalence of NCD risk factors (overweight/ obesity, current smoking, problem drinking, low fruit and vegetable intake and no regular vigorous physical activity) and untreated hypertension [16% (95% CI: 12- 22) in district towns in Tanzania, and 19% (95% CI: 14 -26) in district towns in Uganda] was found in a population with a high HIV prevalence [143]. Overall, 5% (95% CI: 2.2 - 11.3) of rural Tanzanian men were overweight or had obesity and up to 46% (95% CI: 35.0 - 38.2) of women in district towns in Uganda were overweight or had obesity. A fifth of participants (20% to 34% in Tanzania and 39% to 61% in Uganda) reported eating fruit or vegetables on fewer than five days per week and up to 35% (95% CI: 27.8–42.9%) of men in district towns in Tanzania and 95.6% (95% CI: 89.4–98.2%) of women in district towns in Uganda had no regular vigorous physical activity weekly. Current smoking was reported by 12% – 23% of men and 1% – 3% of women. Problem drinking (defined by Alcohol Use Disorder Identification Test (AUDIT) criteria) affected 6% – 15% of men and 1% – 6% of women [143].

South Africa faces a quadruple burden of communicable, maternal and perinatal conditions, non-communicable diseases and injury-related disorders [8]. A pattern of increasing comorbidity was found in patients accessing chronic disease care in a peri-urban clinic in South Africa, with hypertension being the most common comorbidity in HIV patients after TB (77% of HIV patients had comorbid hypertension and 24% had TB) [144]. The prevalence of multimorbidity increased with age. However, a high prevalence of multimorbidity was found among younger patients on ART (26% and 30% in the 18-35 year and 36–45-year age groups respectively) [144]. Similar findings were found in a rural setting with a high prevalence of HIV and hypertension in a rural South African population [141].

PLHIV face an elevated risk for NCDs resulting from both infection with HIV and the complications of long-term ART. Inflammation resulting from HIV replication causes vascular abnormalities, potentially leading to heart disease, strokes, altered glucose metabolism, malignancy, and neurologic disease [145, 146]. Systematic reviews have shown that HIV has an adverse effect on high-density lipoprotein (HDL) cholesterol and triglycerides, suggesting that PLHIV may be at increased risk of cardiovascular disease and that there may be an acceleration of the already increasing prevalence of cardiometabolic conditions [10, 141]. Initial analyses exhibiting increased risk of comorbidities (metabolic syndrome, dyslipidaemia, cardiovascular disease (CVD), osteoporosis, fractures, and renal disease) were conducted in adult populations. Similar patterns have now been identified in paediatric and adolescent cohorts [147-149]. The Paediatric HIV/AIDS Cohort Study (PHACS) of adolescent patients in the US showed increased cholesterol and triglyceride levels in participants, particularly those with increased HIV viral load [150].

In a meta-analysis, Patel et al. found a pooled prevalence of 21.2% for hypertension (95% CI 16.3–27.1); 22.2% for hypercholesterolemia (95% CI 14.7–32.1); 23.2% for elevated low-density lipoprotein (LDL) (95% CI 15.2–33.6); 27.2% for hypertriglyceridemia (95% CI 20.7–34.8); 52.3% for low HDL (95% CI 35.6–62.8); 7.8% for obesity (95% CI 4.3–13.9), and a diabetes prevalence ranging from 1.3–18% in PLHIV in LMICS [151]. These results are consistent with those from PLHIV in North American and European settings, where differences have been noted in cardiometabolic traits between HIV-infected and uninfected individuals, which may be further modified by the use of ART [152].

In addition to biological risks, AYLHIV face several psychosocial challenges associated with living with a highly stigmatised communicable disease [153]. HIV in Africa occurs in the context of orphanhood,

poverty and inconsistent guardianship, resulting in elevated risk of emotional and behavioural problems and psychiatric disorders [154-156]. AYLHIV experience emotional and behavioural problems at higher rates than the general population, including PTSD, depression, severe anxiety and neurocognitive deficits, which affect their school performance, career prospects, relationships and autonomy [153].

2.8.2 Antiretroviral therapy and NCDs

For patients on life-long ART, HIV becomes a manageable chronic condition. However, they are increasingly susceptible to other comorbidities like cardiovascular diseases, metabolic disorders, diabetes, lipodystrophy, depression, and cancer [151]. Long-term use of ART is associated with mitochondrial toxicity-related complications [157], and specific ART regimens are associated with an increased risk of myocardial infarction in adults [158, 159]. Several metabolic complications resulting from long-term use of ART have been documented, including dyslipidaemia [158], hyperlactatemia, lactic acidosis, pancreatitis, lipodystrophy and other changes in body fat distribution [160, 161], glucose intolerance and insulin resistance [162, 163]. ART has also been found to be associated with increased triglycerides and cholesterol [164]. Subsequently, the causes of morbidity and mortality in PLHIV in the ART era are shifting from AIDS-related opportunistic infections to age-related NCD comorbidities such as dyslipidaemia, hypertension, and DM [157].

Similar findings are evident in adolescents [149]. AYLHIV on ART are at increased risk of cardiometabolic complications like elevated blood pressure [165] and higher lipids and triglycerides, which are associated with cardiovascular diseases in adulthood [149, 166]. In addition, abnormal fat distribution resulting from long-term ART is associated with negative self-perception and issues with adherence as adolescents experience puberty [54, 149, 167]. However, while dyslipidaemia has been associated with the use of ART [149], newer ART drugs with lower toxicity and side effects have been found to decrease not only disease progression but also the risk of comorbidities like CVD through long-term viral suppression [149]. ART treatment guidelines have subsequently been updated, moving away from use of stavudine to include simplified first-line, fixed-dose combinations with less toxic side-effects such as TEE (tenofovir + emtricitabine + efavirenz) and TLD (tenofovir + lamivudine + dolutegravir) [168]. For purposes of this thesis, we do not distinguish between ART-associated and HIV-associated NCDs as all adolescents under consideration have grown up in the ART era.

2.8.3 Cardiovascular disease and HIV

CVD is a collective term for diseases involving the heart and blood vessels. More people die annually from CVDs globally than from any other cause [101]. CVD is a major public health problem globally and accounted for 31% of all global deaths in 2015; more than three-quarters occurred in LMICs [169].

As mentioned above, both persistent inflammation and immune activation from chronic HIV infection and side effects associated with the use of ART result in adults living with HIV having an increased risk of CVD compared to the general population [152]. More specifically, HIV infection and ART may affect the heart and vasculature, leading to CVD development [170]. After cancer, CVD is the most frequent cause of death amongst ageing PLHIV in high-income settings [171]. CVD risk factors frequently reported in PLHIV include hypertension, dyslipidaemia [172], raised cholesterol and more prolonged duration on ART [173]. Similarly, in SSA, established CVD risk factors like smoking, alcohol consumption and physical inactivity may predispose PLHIV on ART towards developing CVD further modified by ART-associated dyslipidaemia [174]. Similar findings have been documented in children and adolescents living with HIV, with higher levels of carotid intima-media thickness and other cardiac biomarkers compared to healthy uninfected controls [175] and elevated risk of ART-associated dyslipidaemia [167].

2.8.3.1 Hypertension and HIV

There are inconsistent findings on the interaction of HIV with hypertension. Some studies suggest an increased risk of hypertension with ART [176]. Some reported no association with HIV or ART [174, 177, 178], and others, including a meta-analysis, showed lower diastolic and systolic blood pressure in HIV-infected individuals compared to uninfected controls irrespective of ART [10, 179].

In a cohort of children, adolescents and young adults living with HIV aged 2-17 and 18-25 years respectively in the United States, a surprising 20% prevalence of high blood pressure was found compared to 3.2–4.5% in the general population of similar age [165]. Although several risk factors were found to be associated with elevated BP, the study investigators found no single definitive rationale to explain a causal relationship between HIV infection and elevated blood pressure risk in this population.

2.8.4 Metabolic disease and HIV

2.8.4.1 Diabetes and HIV

Observational studies have suggested that HIV may be a risk factor for T2DM [180, 181]. However, the direction of effect is unclear, especially with the use of PI-based antiretroviral regimens, which have been linked to insulin resistance and impaired glucose metabolism [182]. Adult population-based surveys in Uganda and Tanzania found a high burden of hypertension and risk factors for diabetes in a high HIV burden setting. The investigators project that the burden of other NCDs, such as diabetes and heart failure, is likely to increase in these settings [143]. Similarly, in a South African cohort of patients attending primary care services, 75% of hypertensive clients had comorbid diabetes [144]. Amongst adult patients attending HIV primary care services in Cape Town, around 12% had HIV and T2DM comorbidity [144].

Type 1 diabetes mellitus (T1DM) is the most common type of diabetes in children and adolescents, accounting for more than 85% of all diabetes cases in children below 20 years of age worldwide [183]. The most commonly cited hypothesis for the cause of T1DM is that genetic risk, together with an environmentally triggered reaction leads to autoimmune destruction of pancreatic beta cells [184]. However, T2DM, characterised by a combination of resistance to insulin action and inadequate compensatory insulin secretory response, is increasingly being diagnosed in youth [183, 185]. Moreover, ART may adversely affect glucose metabolism through mitochondrial toxicity resulting in dysglycaemia [186]. Insulin resistance is caused by the direct or indirect effects of both protease-inhibitors (PIs) and nucleoside reverse transcriptase inhibitors (NRTIs) on mitochondrial function and by chronic inflammatory changes induced by HIV [187]. However, introducing newer ARVs with less metabolic impact could lower Diabetes-ART interaction in the future [157].

In AYLHIV, impaired glycaemic control and insulin resistance have also been reported [167]. Possible intergenerational transmission of diabetes through intra-uterine exposure of a developing foetus to hyperglycaemia is particularly concerning [188]. Intra-uterine exposures are associated with diabetes and obesity in later life, which raises concerns around a perpetuated cycle of diabetes in high HIV burden LMICs [188, 189]. Interventions are needed, which are tailored towards treatment-experienced adolescent girls of reproductive age.

2.8.4.2 Overweight and obesity and HIV

Obesity might aggravate metabolic abnormalities associated with HIV or its treatment and contribute to morbidity as patients with HIV live longer. For example, in a cohort of adults with HIV in the US, obesity was more prevalent than wasting as HIV patients survived longer on treatment, particularly amongst African-American women [190].

Advanced stages of HIV are associated with lower BMI in children and adolescents living with HIV [160], but no differences in BMI by HIV or ART status was found in a meta-analysis [10]. Thus, it remains unclear what effect HIV and ART have on BMI in AYLHIV. On the other hand, fat redistribution has emerged as a significant issue in PLHIV with specific ART regimens linked to abnormal body fat distribution, including lipodystrophy, lipoatrophy and truncal obesity [160, 161, 191].

Lipodystrophy syndrome is highly prevalent amongst both adults and adolescents, particularly those on PI-based ART regimens [167]. PI-induced lipodystrophy can manifest as fat loss and abnormal fat build-up in the body of the patient on ART. Visible signs of lipodystrophy have severe implications for AYLHIV, who may feel stigmatised due to their appearance and may struggle with body image issues, leading to depression and non-adherence to medication [54, 167].

2.8.5 Chronic respiratory diseases and HIV

Studies have shown that PLHIV are more likely to have respiratory problems and lung diseases compared to their uninfected counterparts [192, 193]. For example, in the US Veteran's cohort, despite ART and controlling for various factors associated with Chronic Obstructive Pulmonary Disease (COPD), adults living with HIV were 50–60% more likely to have COPD than HIV-negative controls [194].

Studies have also shown that the most common chronic disease presentation in AYLHIV in SSA is chronic lung disease (CLD) [195]. Lung diseases are common in children living with HIV (CLHIV), ranging from lymphocytic interstitial pneumonia, immune reconstitution inflammatory syndrome (IRIS), bronchiectasis, malignancies, and interstitial pneumonitis [196]. With the maturation of the HIV epidemic in SSA, adolescents with previously undiagnosed HIV frequently present to health services with severe immunosuppression and a heavy burden of chronic complications [195].

Respiratory diseases, in particular, including TB, are the most common cause of hospital admissions in CLHIV [197, 198].

The first published study examining the prevalence of asthma in CLHIV in 2007 reported an asthma prevalence of 34% in HIV patients aged 1 to 24 years at the Texas Children's Hospital, while 42% were on short-acting inhaled bronchodilators, and 19% were on daily preventative medications for asthma [199]. This asthma prevalence was almost threefold higher than in the general population of children and youth in the United States at the time. The higher prevalence of asthma diagnoses and asthma medication use amongst children and young adults living with HIV on improved ART regimens was linked to immune preservation of CD4 cells or reconstitution [199].

2.8.6 Neuropsychiatry and HIV

Several studies have documented neurocognitive and other mental health challenges experienced by adults living with HIV. HIV has been linked to increased risk of psychiatric disorders [200], neurocognitive problems [201], substance use disorders [202], post-traumatic stress disorder (PTSD) and psychological distress [203]. A systematic review and meta-analysis found a 17% prevalence of major depression in PLHIV in SSA, 26% prevalence of depressive symptoms, and 33% prevalence of psychological distress. These prevalence rates are up to twofold higher than in non-HIV populations in Africa [204]. In Cape Town, 19% of HIV patients attending routine follow-up care had mental disorders, including depression, PTSD and alcohol dependence [205].

Similar psychological challenges have been documented in adolescents living with HIV. Petersen et al. documented several triggering psychosocial challenges adolescents face, including dealing with illness and loss of biological parents, coming to terms with their HIV status, identity and disclosure difficulties [206]. The literature differentiates between the mental health outcomes of perinatally infected versus horizontally infected adolescents, with the latter displaying more mental health problems [207]. Other psychological stressors at a family and societal level include responsibility for the welfare of younger siblings or other ill family members, external and internalised stigma and discrimination, the fear of being viewed as abnormal, and confronting mortality and the prospect of an uncertain future [208].

2.8.6.1 Neurocognitive disorders

HIV-associated Neurocognitive disorders (HAND) have frequently been reported in patients in the ART era [201]. HAND is associated with increased risky behaviours and negatively impacts adherence to ART. Although HAND is common in South African adults [209], very little published data exists for adolescent cohorts. However, gradual encephalopathy, characterised by a continuous decline in brain function, is well recognised in infants and young children living with HIV [208].

There is conflicting evidence on whether receiving ART earlier in infancy or later in adolescence is associated with better neurocognitive outcomes [210, 211]. In the PREDICT trial, the authors concluded that cognitive and developmental deficits in CLHIV occur earlier than at one year of life and do not improve with ART initiation [211]. Thus, there might only be a small window of opportunity in early infancy to intervene and prevent neurocognitive deficits through ART initiation. These findings also suggest the occurrence of chronic persistent neurocognitive impairment even in the presence of successful ART when ART is initiated in older children and adolescents [211].

2.8.6.2 Neurodevelopmental disorders

Neurodevelopmental disorders (defined in the DSM-5 as attention-deficit/hyperactivity disorder (ADHD), autism, learning and intellectual disabilities, conduct disorders, cerebral palsy, and communication and motor disorders) typically start in childhood, before puberty. These disorders are characterised by early-onset neurocognitive impairments and affect males more commonly [212, 213]. The most common measure of neurodevelopmental outcomes is general cognition. Few studies have looked at the effect of ART initiation on cognitive development in school-aged children and adolescents living with HIV in LMICs [166, 214]. Children living with HIV have been found to perform significantly poorer in executive function tasks, particularly processing speed and memory, with reports of them lagging on age-appropriate grades compared to their peers [214].

One study from South Africa showed that up to 90% of preschool-aged children who initiated ART in the late stages of disease progression had significant developmental delays [95]. In the PREDICT trial, 300 Thai and Cambodian children living with HIV (aged 1–12 years) were randomised to either early or deferred ART. Despite the early ART arm achieving higher CD4 levels and viral suppression at three years after study entry, both groups of children performed worse on cognitive and

neurodevelopmental tests compared to age- and gender-matched HIV-uninfected control groups (HIV-exposed and unexposed) [211].

2.8.6.3 Depression and anxiety

According to the WHO, depression is the leading cause of disability worldwide as measured by Years Lived with Disability (YLDs) and the fourth leading contributor to the global burden of disease [215]. Psychiatric assessments have found high rates of anxiety disorders and major depression in CLHIV and AYLHIV, both in high-income and lower-income regions [166]. Depression directly affects medication adherence and HIV management: a meta-analysis showed that depression was significantly associated with non-adherence to HIV treatment [216].

The prevalence of depressive symptoms in AYLHIV in SSA ranges from 17.8%- 25% [217]. However, similar rates of psychiatric conditions have been reported in HIV-exposed but uninfected youth entering adolescence [218]. Due to the use of inadequate comparison groups, concerns remain about whether these impairments are, in fact, due to HIV infection or other social confounding factors. For example, depression and PTSD have been noted to be significantly higher amongst AIDS-orphaned children compared to other orphaned children, which is likely mediated by stigma [219, 220].

2.8.6.4 Suicidal ideation

Global burden of disease estimates show that suicide is one of the leading causes of death in young people. On average, 9.5% of unnatural deaths in young people in South Africa are due to suicide [221]. Suicide rates among South African adolescents tend to increase as exposure to adverse childhood events like parental death by AIDS or homicide, abuse, and exposure to community violence accumulates [222]. Suicide rates are higher in boys than girls, and this differential continues into adulthood [223].

Elevated rates of suicidal attempts and suicidal ideation have been found among PLHIV [224], but little is known about suicidal behaviours among AYLHIV in Africa [225]. One study conducted in the Eastern Cape province of South Africa found that 8% of AYLHIV had had suicidal thoughts in the preceding month, and about half of these adolescents had attempted suicide [226]. In this study, suicidal ideation was directly linked to HIV-related stigma and mediated by depression [226].

2.8.7 Integrated models of HIV / NCD care in adolescents

The low number of health workers per 1000 population in South Africa (5.88 skilled health professionals per 1000 population) leads to limited provider-patient interaction [227]. This shortage limits clinical care provided to physiological outcomes instead of more holistic and comprehensive care, including health promotion and prevention (physical activity, diet, and mental health [228]). Besides workforce shortages, few HIV-NCD integrated programs with contextually appropriate screening and management protocols exist for resource-limited settings [151].

In South Arica, HIV patients in the public sector are primarily seen and treated in HIV clinics. They are routinely monitored via physical examination, point-of-care and laboratory assessments as part of routine clinical management for HIV. Routine care includes general health screening, patient history and biomedical assessments, which can also be used for other chronic disease screening. There has been a gradual move away from vertical services within HIV care towards more integrated care, including NCD screening and management in LMICs, which face a dual burden of HIV and NCDs. An integrated approach that harnesses the successful programmatic approach of the HIV treatment program is recommended to scale up services for NCDs [229].

The South African National Health Department introduced the Integrated Chronic Disease Management (ICDM) model into primary health care facilities in 2011 to bridge fragmented chronic disease care within the public health care system and improve chronic disease health outcomes [230, 231]. However, to date, these efforts have focused on adults, despite recognition of an increasing burden of NCDs among PLHIV occurring at increasingly earlier ages [144, 232, 233] and the importance of the adolescent and early youth period for the development of risk factors that increase NCD risk in later life [1, 50]. Although health screening and laboratory tests are done routinely to identify ART-associated side effects and contraindications, systematic NCD screening is not formally integrated within adolescent primary care HIV services.

2.9 NCD risk behaviour and HIV in adolescents

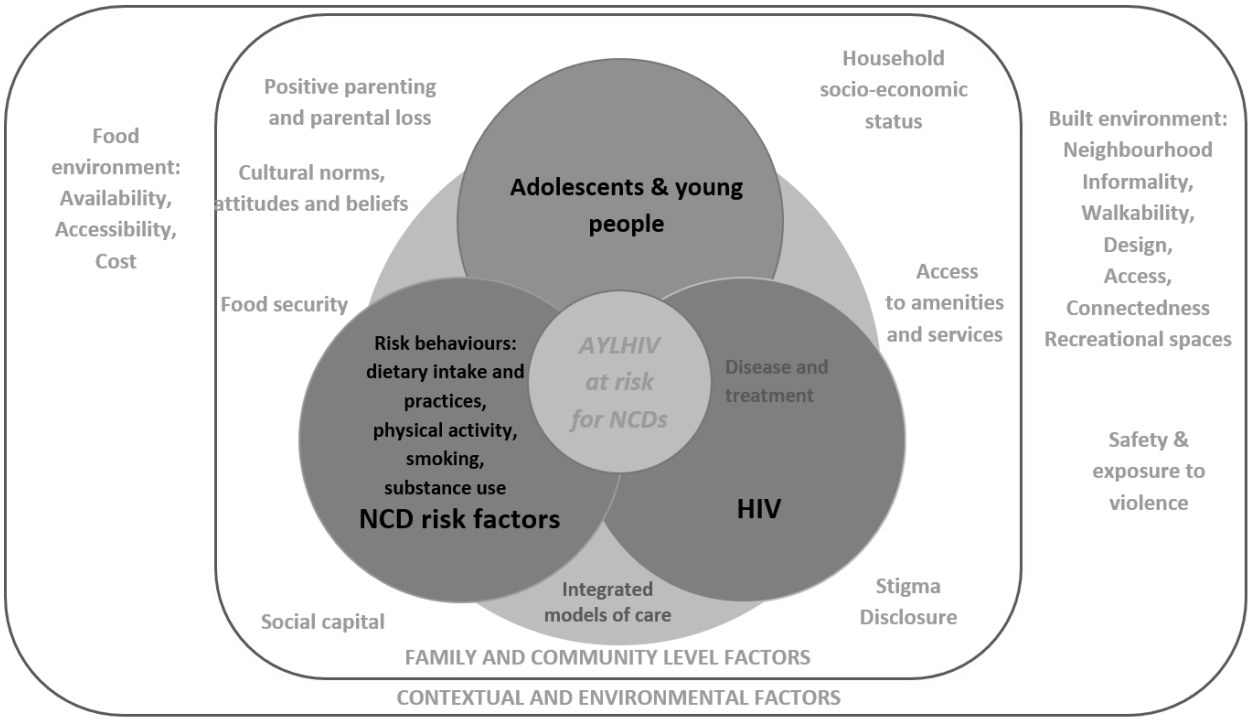

Figure 2.6: NCD risk behaviour and HIV in adolescents

2.9.1 Diet and HIV

Dietary intake of PLHIV has important implications regarding the future development of cardiovascular disease, metabolic syndrome, and other health risks associated with overweight and obesity [234]. Studies that have assessed the dietary habits of PLHIV show diets rich in saturated fats and low in fibres and calcium, which contribute to metabolic risk factors additional to traditional risk factors like insufficient physical activity [234, 235]. A high prevalence of stunting and overweight was found in children and adolescents in El-Salvador, whose diets predominantly consisted of cereals, beans, eggs and processed foods and low consumption of fruits, vegetables and dairy products [236].

Numerous studies report stunting and undernutrition [237, 238], but very limited data exist on the dietary behaviour of AYLHIV in SSA. The few studies conducted report inadequate protein and fibre intake, iron and vitamin A deficiencies [239], meal skipping, and limited dietary diversity [240]. HIV in SSA occurs in a context of undernutrition and food insecurity, which exacerbate adverse health outcomes [241]. Food security is discussed as a sociological factor in **Section 2.10.2**.

2.9.2 Physical activity and HIV

Research has shown that HIV leads to a decline in muscle function and reduced physical activity levels, especially in ageing PLHIV [242, 243]. Globally, almost half of PLHIV are insufficiently physically active [244]. A study conducted in Botswana found that youth living with HIV had significantly lower daily physical activity levels than uninfected controls [245]. Similarly, a study in Brazil in 10–15-year-old PHIV+ adolescents and age-sex matched controls also found that AYLHIV had lower physical activity scores compared to their uninfected peers [246].

2.9.3 Smoking and HIV

One of the main risk factors for respiratory diseases and other NCDs is smoking, which is more prevalent in PLHIV than in the general population [247-249]. Smoking increases the vulnerability of PLHIV for adverse lung health and multiplies their risk of developing cardiovascular diseases compared to HIV-negative smokers [250-252]. Studies have reported smoking rates as high as 50-70% in adults living with HIV and early onset of smoking in adolescents living with HIV [248, 253]. South African studies report current smoking rates ranging from 15-25% amongst adult patients attending HIV clinics in urban settings [254, 255]. Only a few studies, most from high-income settings, address smoking prevalence among AYLHIV [256-258]. These studies report higher smoking rates among AYLHIV compared to the general population, particularly among those who were horizontally infected [253].

2.9.4 Substance use and HIV

Alcohol use is highly prevalent amongst PLHIV. Almost half of the adult patients attending HIV clinics in Cape Town engaged in hazardous or harmful alcohol use, and 15% had problematic drug use [259]. Several studies conducted on young people in SSA have reported increased alcohol and drug use in AYLHIV, especially among males in late adolescence [260-262]. Rates of problem alcohol drinking and lifetime drug use in South African AYLHIV range from 4 and 5% in females [263] to as high as 31% and 54% in male AYLHIV [264]. However, these rates do not necessarily differ from HIV-uninfected young people in the same setting [264]. Data on substance use in AYLHIV in the SSA context are limited and outdated, requiring further investigation to elucidate whether HIV infection is associated with increased alcohol and substance use in settings where heavy drinking is endemic [88].

That being said, puberty comes with increased risk-taking and experimentation with alcohol and other substances. Nevertheless, what may be normative behaviour for adolescents, may have more significant consequences for AYLHIV, compromising their future health and potentially increasing immune dysfunction [257, 265]. For example, alcohol and substance use negatively impact adherence to ART and viral suppression [266, 267]. Substance use also influences sexual decision-making, increasing the likelihood of participating in sexual risk behaviours that increase the risk of STIs and secondary HIV transmission [268, 269].

2.10 Family and community-level factors influencing adolescent health

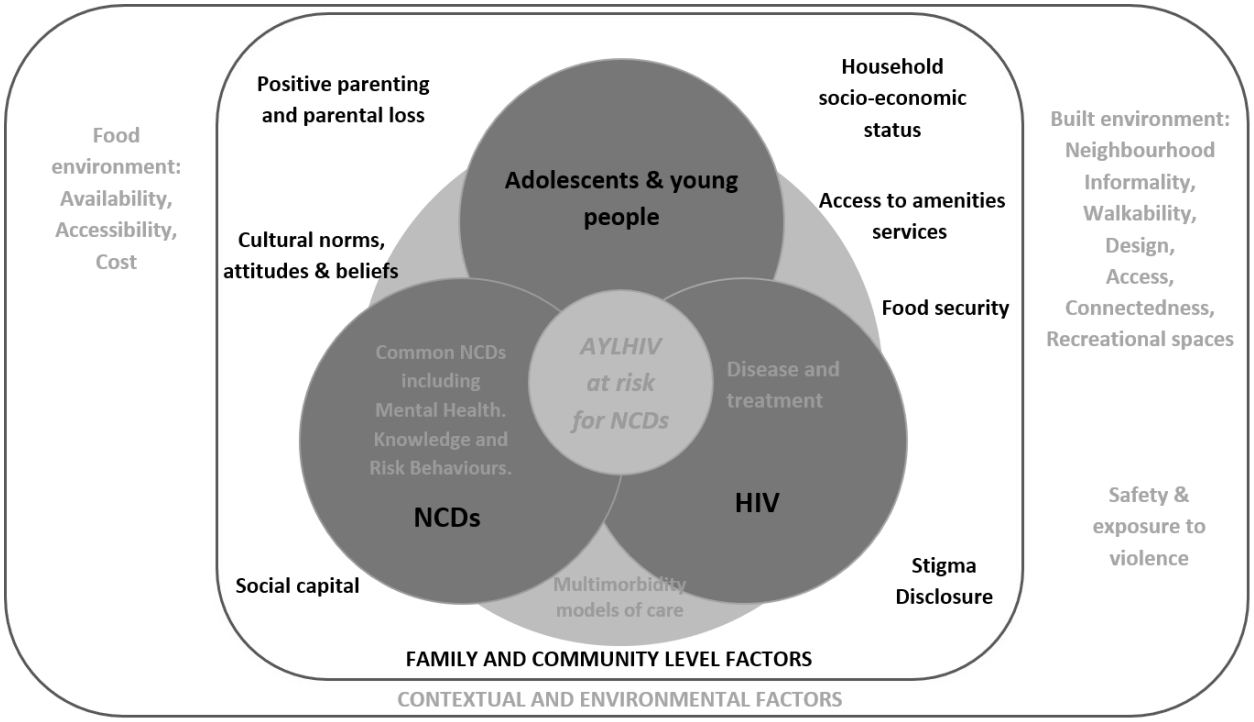

Figure 2.7: Family and community-level factors influencing adolescent health

2.10.1 Household socio-economic status and access to services

Household SES is often cited as a determinant of health. It has been posited that the influence of SES on health occurs on a gradient and begins early in life with lasting influences well into adulthood [270]. Asthma and obesity, two of the most prevalent health conditions in childhood and adolescence, follow the SES gradient. Low household SES is associated with greater prevalence and severity of asthma and is associated with a greater likelihood of overweight or obesity in childhood and adolescence [270]. However, the obesity-SES relationship is not strictly linear. It has been hypothesised that higher disposable income and maternal employment may result in reliance on and

increased family consumption of high-calorie, convenience meals with low nutritional value, leading to an increased incidence of obesity [114].

In addition to SES, other correlated factors such as housing informality and household air pollution are linked to psychological and physical well-being. Multidimensional poverty measures have been proposed, which include health, education, and standard of living indicators as opposed to income measures and poverty lines [271]. These measures incorporate access to critical services such as water and sanitation, electricity, education, and housing which are not captured in income poverty measures [271]. People residing in sub-standard living conditions suffer disproportionately from ill health throughout their life course due to poor-quality housing, lack of infrastructure and minimal access to refuse collection, sanitation, health care and other essential services [272, 273]. Previous studies in South Africa have demonstrated that HIV/AIDS-affected and infected youth face multiple deprivations of poverty [156, 207], including poor educational outcomes [274], informal housing, lack of necessities like toiletries and school fees [275] and food insecurity [276]. Thus, navigating living with HIV against a background of poverty and deprivation introduces an additional layer of vulnerability for ill health.

2.10.2 Food security

As previously noted, HIV in SSA occurs in the context of food insecurity and malnutrition [241]. Food security is defined as access by all household members at all times to enough food for an active, healthy life [277]. Food insecurity exists whenever the availability of nutritionally adequate, safe foods or the ability to acquire personally acceptable foods in socially acceptable ways is limited or uncertain [277]. With sustained urbanisation, low-income households in urban South Africa are increasingly experiencing food insecurity, with 70% of poor urban households reporting conditions of ‘significant’ and ‘severe food insecurity’ [278].

Food insecurity is a commonly cited challenge for AYLHIV in SSA. It impacts their adherence to ART and retention in HIV care [279], which has implications for viral suppression and chronic disease pathways [233, 280, 281]. Food insecurity also impacts mental health and may increase susceptibility to alcohol and substance use [282, 283]. Furthermore, household food insecurity has been linked to adolescent overweight and obesity rates [284]. Previous studies in SSA report stunting and malnutrition in children and adolescents as a result of food insecurity [237, 240]. Paradoxically,

undernutrition and obesity have been found to co-occur even in the same household in South Africa, highlighting the complexities of dietary behaviour in the context of food insecurity [285].

2.10.3 Positive parenting and parental loss

Positive parenting is conceptualised in terms of an involved, nurturing, and accepting parent-child relationship [286]. Research has highlighted the critical role of parenting in mediating the relationship between HIV and health outcomes for the child and the caregiver [287]. A study in South Africa found that families affected by HIV/AIDS were associated with less positive parenting compared to nonaffected families [288]. Caregiver disengagement due to illness or instability was reported to contribute to the lack of positive parenting.

AYLHIV are typically orphans, and many reside in non-nuclear family settings [289]. Generally, scientific evidence has shown that children who have lost a parent are prone to poor mental health [290]. Perinatally infected adolescents often face multiple losses of loved ones throughout their life course, which predisposes them to psychopathology [291]. A South African study in a group of children who had lost their parents to AIDS found increased and significant PTSD, depression, conduct problems and delinquency in AIDS orphans compared to controls, a relationship that appeared to be fully mediated by AIDS-related stigma [292].

Doka described the phenomenon of “disenfranchised grief”: children fear openly acknowledging the death of a parent or peer to AIDS [293, 294]. Different grief reactions were documented in cancer, HIV/AIDS, and suicide-related bereavement [295], leading to heightened feelings of bereavement with intensified feelings of anger, guilt, and depression. Adolescents may also experience delayed responses to grief as they struggle to come to terms with loss and bereavement, leading to aggression and incidents of acting out [292]. Moreover, a large community-based study of AYLHIV in South Africa demonstrated that horizontally infected adolescents were more likely to experience depression if they were maternal orphans compared to PHIV+ adolescents, demonstrating the long-reaching consequences of the “disruption of mothering” [207].

2.10.4 Cultural norms, attitudes and beliefs

Young people in urbanised LMIC settings are increasingly exposed to globalisation and have increased access to worldwide information through the internet and social media [33]. These factors influence their individual beliefs, attitudes, and behaviours beyond their immediate community and cultural norms. Schools, traditional and social media, are also important vehicles for delivering messages that influence social norms, especially for young people who are early adopters of technology [296, 297].

One example of this is perceptions of body weight and body image. Despite the health risks associated with overweight/obesity, being overweight is viewed as a sign of affluence in many South African cultures. In contrast, weight loss is often associated with negative connotations such as HIV/AIDS [285]. In the South African National Health and Nutrition Examination Survey (SANHANES), most South Africans surveyed acknowledged when they were overweight, but the majority were happy with their 'fat' body image [87]. These perceptions influence adolescents, especially girls who report body dissatisfaction and conflicting body image perceptions and attitudes [298]. Adolescents' self-perception may also increasingly be influenced by Western media, portraying a slim image of the preferred female shape [299].

2.10.5 Social capital

Social capital is viewed as both an individual and a collective property existing across various levels of social groupings from the family, school or occupation to community and societal levels [300]. Various constructs and measures exist for social capital, but there is a lack of consensus on exactly how it affects individual health [301]. For purposes of this thesis, social capital is defined as *resources accessed through social connections,* for example, the exchange of favours, maintenance of group norms, the presence of trust, and the exercise of sanctions– available to members of social groups [302].

Nevertheless, social capital can affect health through different pathways. For example, social capital can benefit health by facilitating access to resources, health promotion and positive mental health. However, social capital can also be damaging to health via what is described as "social contagion" or promoting health-damaging behaviours or norms [303, 304]. To illustrate, peer influence in a school setting can promote harmful behaviours like heavy episodic drinking and illicit drugs through social contagion [305].

Some indicators of social capital include generalised trust, norms of reciprocity, social networks and belonging [306]. These indicators can all be measured at various sociological levels, from individual to structural, depending on the mechanism being studied. For example, family and neighbourhood social capital are commonly cited as influential on uptake of risk behaviours such as adolescent smoking and drinking and deviancy while promoting the likelihood of healthy norms such as physical activity [307].

2.10.6 Stigma and disclosure

2.10.6.1 Stigma

Stigma is defined as labelling of the other, attachment of negative stereotypes, and subjugation of one group perceived as different by another more powerful group [308]. Stigma is a critical form of negative social capital that plays out in the social exclusion of those living with HIV [309]. HIV-related stigma may be either perceived or anticipated discrimination or internalised stigma [310]. Enacted stigma refers to negative public attitudes or discrimination towards people living with HIV [310]. Internalised stigma is more prevalent than enacted stigma [309] and refers to when a person living with HIV endorses negative attitudes associated with HIV and accepts them as applicable to him or herself, resulting in feelings of shame, guilt and worthlessness [311].

In adults, this manifests in refusal to undergo HIV testing, not disclosing status to others, delays in seeking treatment, non-adherence to medication and mental health problems [203]. In addition, stigma inhibits access to supportive networks and treatment through disclosure; and behaviour change by restricting safer sexual practices [312]. HIV-related stigma is highly prevalent in South African communities and was a significant predictor of depressive symptoms in a sample of adults living with HIV [203, 312]. Stigma also increases psychological distress, undermining HIV-related health outcomes and ART adherence [313].

Adolescents living with HIV are exceptionally vulnerable to stigma, reporting feelings of isolation, fear and shame due to their status [314]. Those born to parents living with HIV experience stigma connected to HIV disclosure and exposure within the family, while those infected horizontally may face judgement related to cultural perceptions of adolescent sexuality and promiscuity [314]. Visible

effects of HIV infection, like stunting, lipodystrophy and pubertal delay, especially in perinatally infected adolescents, may also lead to stigmatisation and discrimination [208].

2.10.6.2 Disclosure

Adolescent HIV disclosure is a complicated process, which should ideally be performed in incremental stages. Greene and Faulkner have described disclosure as a fluid process ranging from non-disclosure, partial disclosure, disclosure through third parties, future plans to disclose and full disclosure [315]. Earlier disclosure is beneficial as it facilitates better psychological adjustment and treatment adherence [316]. Current national guidelines encourage starting partial disclosure from the age of six and ensuring full disclosure before the age of twelve years. However, this depends on the cognitive and emotional maturity of the child.

Adolescents cannot become autonomous and independent without knowing and sharing their HIV status [317]. Caregivers may delay disclosing the status of an AYLHIV, who in turn faces pressure and stress around disclosing their status to others or remaining silent [314]. Disclosure can be protective against mental health problems by empowering young people with agency [318] and aspirations for the future [319]. Adolescents who have been told their status and understand it are less anxious than those who have not, have fewer behavioural problems, improved social and school performance and better adherence to ART [319].

2.11 Contextual and environmental factors influencing adolescent health

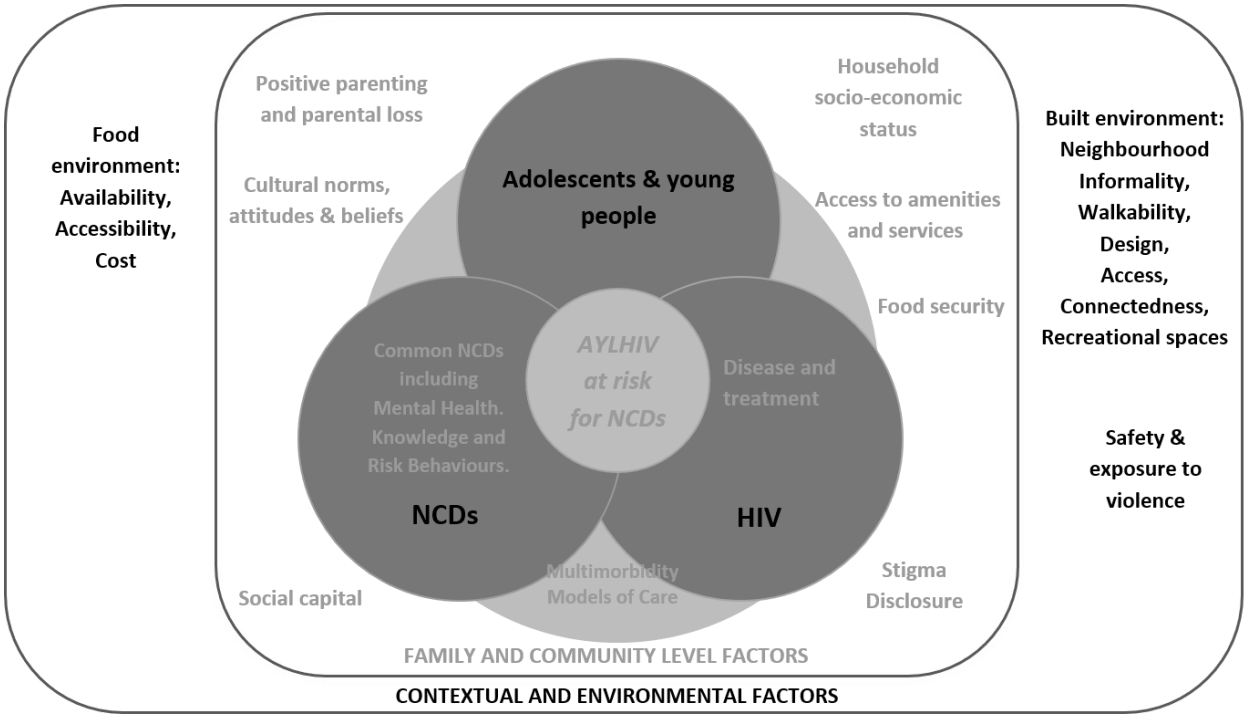

Figure 2.8: Contextual and environmental factors influencing adolescent health

Many of the risk factors for NCDs are environmental and shaped by socio-political and structural determinants of health. Framing NCDs within a broader socio-ecological framework moves away from an individualistic perspective of risk factors and behaviour and integrates the broader sociological and environmental determinants of health. At a macro level, increasing obesity rates may be a symptom of urbanisation and increased globalisation with resultant unhealthy diets and sedentary behaviour as countries experience nutrition and epidemiological transition [320].

Behaviours such as physical activity or lack thereof are primarily shaped by the built environment, particularly factors such as availability of basic infrastructure for exercising, neighbourhood walkability [119], the prevalence of violence and risk to personal safety [321]. Likewise, consumption of fruit and vegetables or diets high in saturated fats and refined sugar are shaped by supply chains and the availability of healthy foods in the broader food environment as described below [15]. Kickbusch et al define the commercial determinants of health (CDoH) as “strategies and approaches used by the private sector to promote products and choices that are detrimental to health.” [322]. Factors related to the food system that promote obesogenic dietary behaviours have broadly been labelled as the “commercial determinants of obesity. The most frequently reported CDoH targeting

children and adolescents is marketing and preference shaping [323]. Obesity prevention efforts should be targeted at wider commercial determinants such as restricting the marketing of unhealthy foods and drinks to children, taxation of sugar-sweetened beverages, front-of pack labelling and limiting portion and package sizes [324].

2.11.1 Food environment

No standard definition exists for the food environment; however, Swinburn and others have defined it as the "collective physical, economic, policy and socio-cultural surroundings, opportunities and conditions that influence people's food and beverage choices and nutritional status" [325]. The food environment can be characterised into four socio-ecological domains: the individual-, social-, physical- and macro-level food environments [326]. Various factors influence food consumption at each level.

The individual level includes cognitive and socio-demographic factors that influence food consumption, such as motivation, self-efficacy, age and income [326]. The social food environment includes networks and interactions with family, friends, and peers instrumental in shaping dietary choices and behaviour through role modelling and social norms [326]. The social level is particularly influential in shaping adolescent's dietary behaviour as they are more likely to mirror the behaviour of family and peers [327]. The physical food environment refers to how people produce, acquire, and consume foods and settings where this occurs, such as the home, local neighbourhood, retail food stores, food outlets, schools, or workplaces [326]. Finally, the macro-level environment includes distal factors which make up the food system like food supply chains from production to distribution, food prices, food trade, marketing and advertising, and related policies [327].

Different levels of the food environment can be measured in terms of multiple dimensions, including availability, accessibility, affordability, stability, desirability, and convenience [328]. A variety of methods and tools can be used depending on which dimension is being measured. For example, geographic analysis can measure the distribution and types of food stores and food outlets available in a specified area. Sales analysis can determine the availability and patterns of purchase for various foods using data from cashier receipts [329]. Nutrient analysis can evaluate the nutrient content of foods available as part of school lunches or sold by food vendors [329].

2.11.1.1 Food environment and urban food insecurity

The availability, accessibility and affordability of foods in the immediate physical environment or local neighbourhood influence dietary behaviour. In urban areas, cash income and access to retail stores are essential for household food security [330]. Data from South Africa suggests that formal food retail stores are mostly located in wealthier areas impacting urban food security in low-income areas [331]. Households in low-income areas are more dependent on the informal food sector and less formal means of securing food, threatening their food security [331].

People living in neighbourhoods with fewer supermarkets and more fast food and convenience stores have a greater likelihood of being overweight [332, 333]. Food prices may also deter from purchasing healthier foods if unhealthy foods cost less than healthy foods, especially in low SES neighbourhoods [334]. While food insecurity was traditionally linked to undernutrition, increasing evidence from LMICs has shown links between food insecurity and obesity [335]. Low dietary quality and affordability of high-energy, processed foods are the main mechanisms through which food insecurity leads to obesity in LMICs [335].

2.11.2 Built environment

The built environment includes all buildings, spaces and products created or modified by human activity, including homes, schools, workplaces, recreational areas, business areas, roads, and electric transmission lines [336]. Research on the built environment and health mainly focuses on how housing, transportation and neighbourhood characteristics affect health [336]. Firstly, sub-standard housing environments affect physical and mental health. Inadequate housing or disrepair may result in exposure to pests, air pollution and other contaminants [337], leading to asthma, substance abuse, stress, depression and anxiety [336]. Residential crowding and loud exterior noise may also lead to psychological distress [338].

Secondly, increased motorisation and traffic lead to higher levels of air pollution which contributes to lung and cardiovascular diseases [339] and may compound respiratory problems in children and adolescents with pre-existing asthma [340]. Low SES neighbourhoods generally contain more sources of pollution and greater traffic density, resulting in higher levels of pollutants and resulting health effects [270]. Research has increasingly shown that the burden of illness due to built environment shortcomings tends to fall on marginalised and low-income communities [341, 342]. For example, in

the US, racial minorities in lower SES communities had limited access to quality housing and lived in neighbourhoods that were not conducive to outdoor activities or provided healthy food options [343].

Finally, several studies have linked physical neighbourhood characteristics to adolescent risk for overweight and obesity [344], mental health conditions [338], asthma [345] and future risk for cardiovascular disease and lung cancer in adulthood [336]. However, the majority of these studies are from high-income settings, and there is limited evidence from LMICs. Most research on the built environment and child and adolescent health focuses on physical activity behaviours such as active play and active transport (walking and cycling to and from school) [346] and obesity [347]. Neighbourhood built environments affect the uptake of physical activity, sedentary behaviour and obesity via various mechanisms, as discussed below.

2.11.2.1 Built environment and obesity

Neighbourhood environment features that support physical activity in adolescents include less traffic exposure, more safety features, pedestrian infrastructure for walking and cycling, and schools and playgrounds within walking distance from home [348, 349]. Adolescents living in more walkable neighbourhoods with well-connected streets, sidewalks, safe crossing points and low traffic volumes [350] are more likely to be physically active than those living in less walkable environments [346, 351]. This relationship is mediated by parental and individual perceptions of safety, which may potentially restrict access to the neighbourhood environment [346].

Other built environment factors, including urban design and aesthetics [352], access to physical activity facilities, parks, and green spaces, also affect perceived walkability and shape physical activity options, affecting overweight and obesity outcomes. However, research on the direct effects of green spaces on health is inconclusive due to poor study designs [353]. Furthermore, increased urbanisation may lead to increased motorisation, congestion [350], increased crime rates and limited recreational spaces, which inhibit the ability to walk and cycle and participate in other methods of physical activity [354, 355].

2.11.3 Safety and violence

Adolescents in South Africa are increasingly exposed to violence in the home, school, and community settings, predisposing them to mental health problems and HIV acquisition [356]. Local studies reveal high rates of physical, emotional, and sexual abuse among youth. Seven out of ten adolescents in South Africa have experienced some form of lifetime victimisation [357]. More than half of adolescents have experienced physical abuse, more than one-third have been emotionally abused, and 9% have been sexually abused in their lifetime [357]. In a cohort of young South African women aged 15–26 years followed over two years, intimate partner violence increased the risk of incident HIV infection [93]. This relationship may also be bidirectional as HIV disclosure may trigger violence from romantic partners [358]. Some women, especially pregnant women, are at increased risk of intimate partner violence following disclosure of their HIV-positive status [359, 360].

Cape Town is considered one of the most violent cities in the world [361], with interpersonal and community violence rife in peri-urban township areas, which have some of the highest homicide rates in the world [362]. Violence can lead to premature death or non-fatal injuries [363] and psychological distress [364]. Lifetime exposure to community violence has been linked to several adverse health outcomes in adolescents and young people, including decreased lung functioning and asthma [365, 366], obesity [367] and mental health problems [106, 368].

2.12 Thesis justification

2.12.1 Rising multimorbidity in low- and middle-income settings

Along with other LMICs, South Africa is currently undergoing an epidemiological transition with changes in disease patterns accompanied by changes in population composition and age distribution [31]. Subsequently, there has been an increase in NCD prevalence in addition to the existing high burden of infectious diseases such as HIV and TB [144, 191]. Recent national cause of death statistics reveal that diabetes moved from the fifth leading underlying cause of death in 2013 to be the second underlying cause of death after tuberculosis in 2015, accounting for 5,4% of deaths, surpassing HIV, which accounted for 4,8% of deaths [369]. The surge in T2DM is directly linked to poor eating habits and increased prevalence of overweight and obesity [370].

Studies conducted in long-surviving cohorts in high-income countries have demonstrated that HIV-positive adults on ART with suppressed viral loads are at risk of developing "serious non-AIDS events", including cardiovascular disease, cancer, kidney disease, liver disease, osteopenia/osteoporosis and neurocognitive disease [232]. After adjusting for traditional risk factors in the US Veterans' study, adults living with HIV had a 1.5 fold increased risk of having a heart attack compared to demographically and behaviourally similar uninfected veterans [371]. Multimorbidity is defined both in terms of the coexistence of two or more conditions and their risk factors or symptoms such as hypertension, osteoporosis, hypercholesterolemia, overweight and obesity [372]. Multimorbidity increasingly manifests in HIV-infected individuals, particularly in light of premature ageing caused by HIV infection, increased life expectancy due to ART, and the metabolic complications linked to certain ARVs [373]. Younger persons in the US Veteran's cohort and other studies had a higher risk for heart-related conditions attributed to HIV infection, which is concerning for LMICs with a younger age distribution of PLHIV [232, 374].

SSA has the highest burden of HIV globally, but there is a shortage of information on the intersection of chronic NCDs and infectious diseases. Coupled with the rising burden of hypertension, diabetes, obesity and smoking in LMICs, PLHIV are at an increased risk of comorbidity [232]. Hence, it is increasingly important to clarify the difference in cardiometabolic traits between HIV-infected and uninfected individuals in order to adequately monitor and manage cardiometabolic risk in PLHIV in SSA [10]. In addition, early identification of disease and NCD risk factors at critical periods in the life course can prevent the development of chronic diseases in adulthood and even across future generations.

A crucial consideration in the SSA setting is the large cohort of PHIV+ adolescents reaching adulthood with foetal exposure to HIV and prolonged exposure to ART. HIV exposure predisposes both HIV-infected and HIV-uninfected infants to preterm birth and being small-for-gestational age with lower birth weights than HIV-unexposed infants [375, 376]. Health outcomes in HIV-exposed infants and long-term effects as they age are poorly understood and warrant further study in high HIV burden settings like South Africa [377]. Applying the Barker hypothesis to this scenario potentially signals future accumulated risk for developing NCDs in HIV-infected adolescents who may have experienced adverse birth outcomes like low birth weight [378] and might experience malnutrition in childhood further exacerbated by HIV infection [379]. In addition, uptake of risk behaviours like smoking in adolescence may further increase NCD vulnerability.

The specificity of NCD multimorbidity within the South African context and population of adolescents and young people growing up and living with a chronic condition makes this thesis particularly pertinent at the current time of epidemiological transition.

2.12.2 Implications of epidemiological transition for adolescent and future adult health

Considering this transition and the collision of infectious diseases with NCDs, early identification of risk and early intervention is crucial for adolescents in LMICs as they age. Many NCDs share interrelated preventable risk factors, which it would be advantageous to identify and eliminate before they become major problems and undermine future population health in LMICs [55]. The very young age distribution in LMICs and the increasing burden of NCDs calls for investment in primary prevention and resources to expand access to screening and prevention for those most vulnerable to NCDs. Adolescence is a life stage that harbours many risks and dangers but also presents opportunities for sustained health and well-being [380]. A significant aspect of adolescence lies in its power to translate childhood experiences into competencies and statuses that facilitate the transition to adulthood [22]. Introducing and normalising healthier behaviours and preventive efforts during the critical period of adolescence can significantly change an individual's health trajectory into adulthood [135].

AYLHIV, particularly those infected perinatally, have grown up with a chronic condition. Those who are treatment-experienced have grown up interacting with the health care system. Therefore, these adolescents are ideally placed to be educated on and manage their chronic condition(s) as they transition into adulthood. In particular, targeting adolescent girls of reproductive age will potentially reduce future disease incidence in their offspring by interrupting maternal exposures and gestational disease pathways [189]. However, there is a possibility that those who are treatment-experienced may also be neurocognitively impaired to varying degrees, which may significantly impact their ability to manage their condition. Thus, their transition to adult care may require additional support.

2.12.3 Need and opportunity for early NCD intervention in AYLHIV

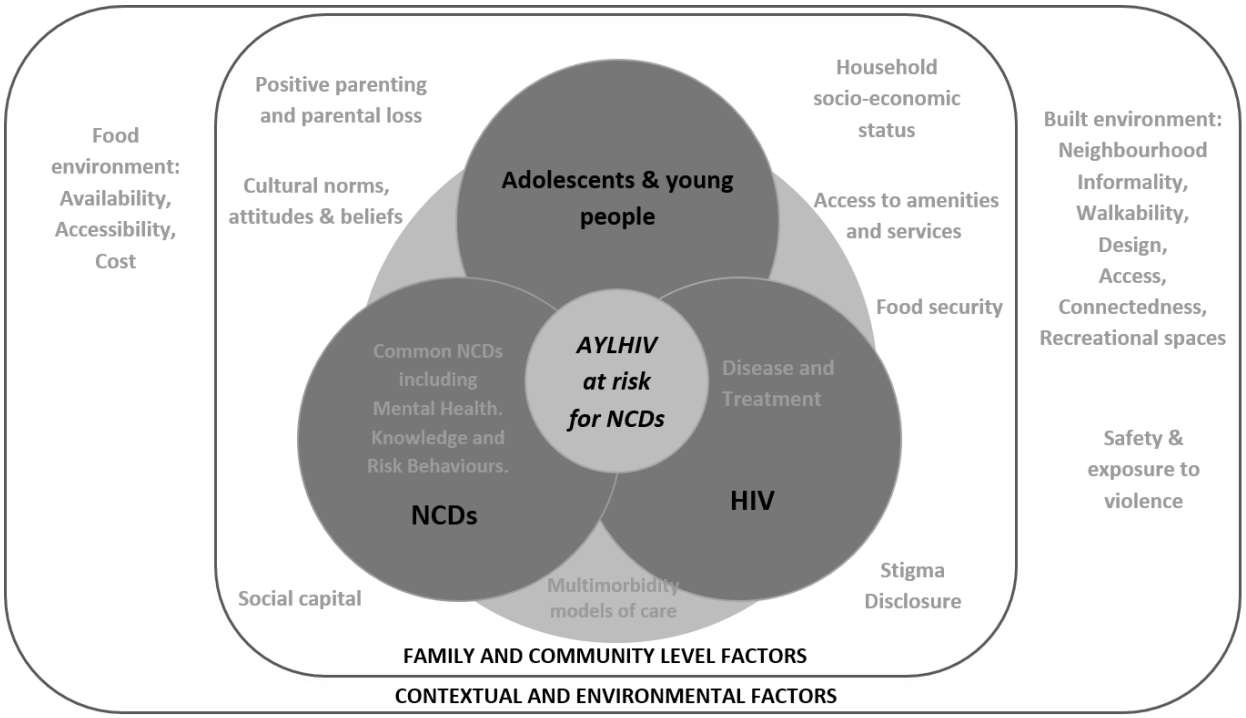

Figure 2.9: Adolescents and youth living with HIV at risk for NCDs

Adolescents and young adults living with HIV are documented to have NCD risk factors associated with chronic HIV infection and the effects of ART, as illustrated in this review. They are at increased risk of multimorbidity due to the effects of accelerated ageing brought about by HIV and prolonged exposure to ART [381]. These include CVD risk factors and metabolic complications: elevated blood pressure, dyslipidaemias [165], lipodystrophy, insulin resistance, lactic acidosis, bone mass loss [167], respiratory problems [195, 382] and neuropsychiatric problems [214], as discussed in the preceding sections. However, there is limited data for adolescents in SSA as they progress into young adulthood and adulthood.

A large and growing body of literature has investigated comorbidities in adult cohorts living with HIV who have been documented to be at higher risk of NCDs compared to the general population [252, 383-386]. AYLHIV will potentially age into adults with multimorbidity (HIV and NCD) if there is no attempt at early intervention. Therefore, it is increasingly important to screen for NCDs and their risk factors during adolescence and possibly even earlier in the life course to interrupt disease pathways and prevent future disease. However, in the context of resource limitations, particularly in LMICs, cost benefit analyses will be needed to inform the prioritisation of interventions such as early screening and management.

2.13 Conclusion

It is clear from this review that there is limited data on the epidemiology of chronic NCDs in AYLHIV in SSA. Although there have been some research studies on multimorbidity in adult PLHIV in LMICs, studies on NCDs and risk factors in AYLHIV in SSA are sparse and provide limited reliability due to being cross-sectional, small in sample size and lacking in controls [208]. Data scarcity has resulted in extrapolating from adult studies and studies from higher-income settings despite limited generalisability and insufficient evidence to support guidelines and best practices. The WHO's recent updated HIV guidelines make a conditional recommendation for integrating NCD care into HIV services [387]. A conditional recommendation is made when evidence around the benefits and risks of intervention are less certain. This thesis provides the opportunity to investigate the prevalence of NCDs and NCD risk factors in AYLHIV in a peri-urban setting undergoing nutritional and epidemiological transition providing evidence for a high HIV burden setting.

In conclusion, this thesis aims to contribute to the limited knowledge base on NCD comorbidity and NCD risk factors in AYLHIV in sub-Saharan Africa demonstrated in this literature review. In particular, this thesis aims to provide insight into the extent to which NCD comorbidity prevention and screening are integrated within existing adolescent HIV primary healthcare services in Cape Town. We further incorporated environmental, multilevel determinants of NCDs to propose an integrated model of NCD prevention beyond the health system and individual risk factors.

Chapter 3 Methodology

3.1 Introduction

To generate the empirical evidence for this thesis, I conducted a review of the medical records of AYLHIV and a cross-sectional study, recruiting a subset of patients identified through the review of the medical records. This methodology chapter outlines the study's aims and objectives and details the methods used to achieve each objective and the ethical issues considered in recruiting and working with participants under 18 years.

3.2 Aims and objectives

The overall aim was to investigate the prevalence of NCDs and NCD risk factors in AYLHIV accessing treatment across primary care facilities in peri-urban Cape Town and explore risk factors associated with overweight or obesity status in this population with a focus on urban built and food environments.

Specific objectives were:

Objective 1: To investigate the extent to which NCD comorbidity (prevention, screening and management) is incorporated within existing adolescent HIV primary healthcare services in Cape Town, South Africa.

Objective 2: To estimate the prevalence of common NCDs and their known cardiometabolic, respiratory and behavioural risk factors in AYLHIV residing in peri-urban Cape Town.

Objective 3: To determine individual, household, social and neighbourhood level factors associated with overweight and obesity status.

3.3 Study context

3.3.1 Setting

I conducted this cross-sectional study in peri-urban Cape Town, the second biggest metropolitan city in South Africa, with an estimated population of 4.2 million people, of which 16.3% are aged 15 - 24 years, making up a total adolescent population of 684,600 [362, 388]. The City of Cape Town experiences high levels of circular migration from the surrounding Eastern and the Northern Cape provinces, leading to a proliferation of unplanned informal settlements, lacking access to basic amenities and subject to fires and forced removals [389-391].

Recruitment and data collection took place at public primary health care facilities across Cape Town. These primary care facilities serve a catchment population living in peri-urban, high-density, low-income townships, collectively known as the Cape Flats [392]. The area consists of a mix of formal and informal dwellings, with 21% of the population residing in informal dwellings [392], high rates of poverty [393], and high levels of violent and drug-related crime [394, 395]. NCDs and HIV are ranked among the top causes of premature deaths in the City of Cape Town [45], with the top five causes of death in the Western Cape in 2016 ranked as diabetes mellitus, HIV, ischaemic heart diseases, cerebrovascular diseases and tuberculosis [47]. Antenatal HIV prevalence in Cape Town was estimated at 21.6% in 2015 [48] and as high as 34.3% in Khayelitsha in 2012 [50].

3.3.2 Health system and HIV healthcare delivery

The City of Cape Town Metro Health District has eight legislated sub-districts (see **Figure 3.1**). Primary health care services are delivered through four sub-structures (comprising two sub-districts in each sub-structure): Khayelitsha/Eastern, Mitchell's Plain/Klipfontein, Western/Southern and Northern/ Tygerberg sub-structures [396]. ART care is delivered through government clinics and is free for all patients, with patients with well-controlled disease managed in ART "clubs", which are either facility- or community-based, and provide health screening, more streamlined access to repeat prescriptions, health promotion, education and socialisation for patients.

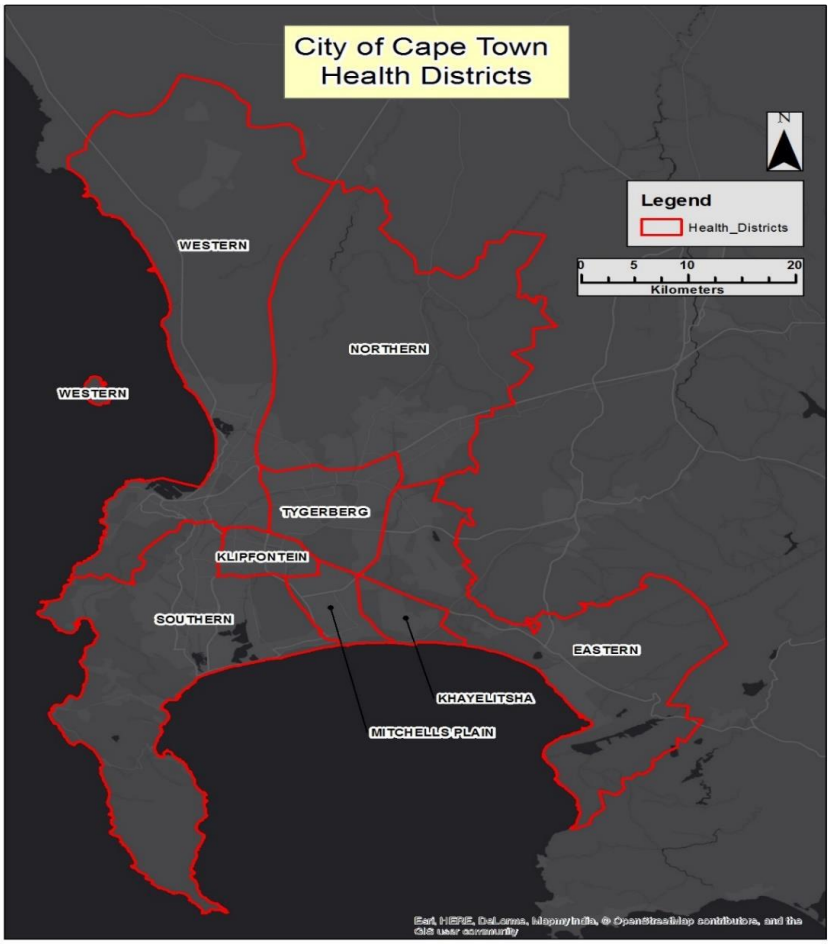

Figure 3.1 Map of the Cape Town Metro region and health sub-districts [396].

The following facilities located within the Cape Town Metro region were identified and approved as potential sites for recruitment.

Table 3.1: Facilities approved for recruitment by sub-district

Area	Sub-district	Facility	Access Approved by
Eastern and Khayelitsha	*Eastern*	Dr Ivan Toms CDC	City of Cape Town
		Ikhwezi CDC	City of Cape Town
	Khayelitsha	Kuyasa CDC	City of Cape Town
		Nolungile CDC	Provincial Government
		Nolungile Youth Clinic	City of Cape Town
		Michael Mapongwana CDC	Provincial Government
Klipfontein and Mitchells Plain	*Klipfontein*	Crossroads CDC	Provincial Government
	Mitchells Plain	Gugulethu CHC	
Southern and Western	*Southern*	Masiphumelele Clinic	City of Cape Town
	Western	Hout Bay Main Road Clinic	City of Cape Town
		Langa Clinic	City of Cape Town
		Albow Gardens Clinic	City of Cape Town
Northern and Tygerberg	*Northern*	Bloekombos Clinic	City of Cape Town
	Tygerberg	Delft South Clinic	City of Cape Town

CDC = Community Day Centre, CHC = Community Health Centre.

3.4 Study population

The study population consisted of AYLHIV aged 10 - 24 years, enrolled for ART at public-sector health facilities as displayed in the table below (**Table 3.2)**. By definition, adolescence ends at 19 years. However, young people up to 24 years were included as they were still receiving care at adolescent clinics and in order to diversify the sample to represent older youth who acquired HIV during their teenage years. The number potentially eligible for the study included all adolescents enrolled for care at facilities across Cape Town. While there are no data on the exact number of AYLHIV receiving ART in primary care facilities across the city as this indicator does not form part of routine reporting, there were 5723 children under 15 years receiving ART in the public health system in Cape Town in November 2016 (*personal communication with Director of HIV Treatment Programme: Provincial Government of the Western Cape*).

Table 3.2: Study population and recruitment numbers per objective

		OBJECTIVE 1	**OBJECTIVE 2**	**OBJECTIVE 3**
Sub-structure	Total number of adolescents on ART	Folder review sample Age 10 – 24 years	Recruitment sample Age >14 years	
Eastern & Khayelitsha	1533	153	66	
Mitchells Plain & Klipfontein	942	261	40	
Southern & Western	1001	100	44	
Northern & Tygerberg	1155	116	50	
TOTAL	4632	**463**	**200**	

Note: The total number of adolescents on ART shown in column 2 reflects the number of adolescents and youth aged 10-24 years on ART according to ART registers at the respective facilities estimated during the folder review process as part of objective 1.

3.4.1 Eligibility and inclusion criteria

Eligible participants were AYLHIV aged between 10 and 24 years, irrespective of the mode of infection, who were aware of their HIV status (full disclosure) and were accessing ART in primary care facilities across Cape Town regardless of duration on ART. For Objectives 2 and 3, the age of eligibility was 15 years, as adolescents aged ≥ 15 years can consent to clinical procedures and HIV testing without parental consent [397]. Participants also had to have adequate capacity to understand the study procedures and requirements, which was ascertained using teach-back questions [398] during the enrolment process (*see Appendix 2: Information sheets, consent and assent forms*).

3.5 Study design

The study was a cross-sectional study utilising primary data collection and a review of medical records of adolescents and youth enrolled for ART.

3.6 Sampling strategy and sample size estimation

3.6.1 Objective 1

The target population was AYLHIV between the ages of 10- and 24-years accessing ART care in public sector clinics. At each facility selected, a de-identified population master list of all AYLHIV aged 10–24 years receiving ART was generated with the assistance of data clerks. In order to gain a representative sample across sub-districts in Cape Town, the master list at each respective facility was used as a sampling frame. The aim was to sample 10% of adolescents on ART from each sub-structure (n = 463 overall, as shown in **Table 3.2**). A systematic random sampling approach was used to select participant folders, with the first folder selected from the population list at random, and every *nth* folder sampled thereafter, where the sampling interval n was determined by the number of adolescents in the clinic population divided by the number of adolescents needed for the sample. If the *nth* folder was not found, the following folder in the list was selected, and the systematic sampling continued until 10% of folders of adolescents in each sub-structure were reviewed.

3.6.2 Objectives 2 and 3

For Objectives 2 and 3, the sample size was determined using prevalence estimates for youth aged 15–24 years. **Table 3.3** indicates the reported prevalence of various conditions and risk factors for the 15 - 24-year age group as reported in the 2012 South African National Health and Nutrition Examination Survey (SANHANES-1) [87] and the Youth Risk and Behaviour Survey [136]. Overweight/obesity was the primary outcome of interest. The confidence level was set at 95%, with a 5% degree of precision, and an obesity prevalence of 5.5%, yielding a minimum required sample size of 84, adjusted for non-response as illustrated in **Table 3.3.** For example, for obesity with an estimated prevalence of 5.5%, we expect the true population proportion to lie between 0.5 and 10.5%.

Table 3.3: Required sample size estimations

Condition	Anticipated Prevalence (%)	Precision (d) %	Required Sample Size (n)	Final n adjusted for 5% non-response rate
Cardiovascular disease risk[1]	8.3	5	117	**123**
Abnormal triglycerides[1]	6.1	5	88	**93**
Diabetes Mellitus[1*]	0.6	5	500	**525**
High blood pressure[1]	6.7	5	96	**101**
Overweight[1]	20.2	5	248	**261**
Obesity[1]	5.5	5	80	**84**
COPD (Asthma)[2]	14.4	5	189	**199**
Binge or risky drinking[3]	28.5	5	313	**330**
Current tobacco use[3]	40	5	369	**388**

[1] From reported survey rates of SANHANES-2012 Clinical Examinations 15-24-year age group,
[2] The International Study of Asthma and Allergies in Childhood (ISAAC-Phase III) for Cape Town adolescents,
[3] South African National Youth Risk Behaviour Survey (YRBS)-2011.
**For diabetes, the sample size calculation was based on the Poisson distribution used to detect rare events (< 1% prevalence) with expected event rate, λ= 0.006 and critical tolerance limit, r=1.*

Study procedures were conducted at each clinic using a convenience sampling approach from March 2019 until January 2020. Approaching any adolescents in care at the respective facilities, a total of 92 participants were enrolled from the total adolescents in care, proportional to the number potentially eligible at each site, as illustrated in **Figure 3.2.**

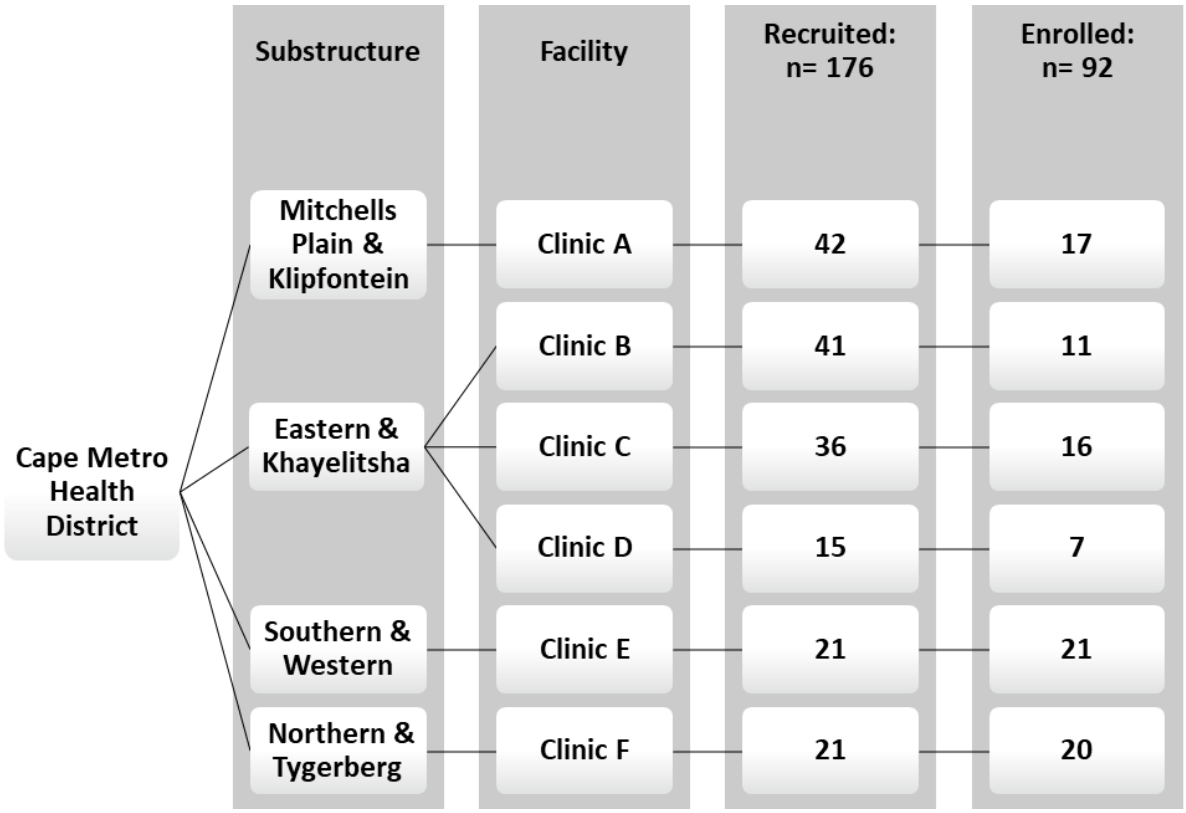

Figure 3.2: Recruitment and enrolment at respective facilities

Note: Although 200 was the planned recruitment number, this was curtailed due to Covid-19, and eventually, only 176 participants were recruited, of which 92 were successfully interviewed.

3.7 Study procedures

3.7.1 Objective 1

I conducted a descriptive, retrospective study from November 2018 to March 2019, reviewing medical records of adolescents and youth enrolled in HIV care across Cape Town.

3.7.1.1 Data collection

The following information was extracted from patient folders:

1. **Demographic information:** birth date, sex, age.
2. **HIV-treatment related information**: ART start date, age at ART initiation, duration on ART, initial and current ART regimen, most recently recorded CD4 level and viral load, dates of recent CD4 and viral load, treatment failure and contraindications, previous illness and opportunistic infections, ART-related conditions.

3. **NCD comorbidities, treatment and risk factors:** smoking, alcohol, substance abuse, overweight/obesity, diabetes, asthma, blood pressure, mental health screen/psychological distress, family history.
4. **Health promotion interventions:** HIV- and NCD-related, sexual and reproductive health-related interventions.
5. **Model of HIV care received**: based on the record of recent visits to the clinic.

This data pertains to health care visits in the preceding 12 months. In patients with another chronic disease/ NCD diagnosis recorded, all episodes ever recorded in the folder were extracted irrespective of date. Family history was any family history ever recorded.

3.7.1.2 Data management

An electronic form was developed for data capturing using Open Data Kit (*ODK-Collect*). ODK-Collect is an open-source Android application used for survey data collection that functions well without network connectivity [399]. An automatically generated participant identifier (PID) was assigned to each folder reviewed, and no identifying information was captured electronically to ensure anonymity. The electronic form was downloaded to Android tablet devices that were used to record the data extracted from patient folders. The electronic form had offline functionality and was automatically synced to a customised ODK Aggregate database once internet connectivity was re-established. The database was hosted on an encrypted server hosted on Google Cloud and backed up on university servers. Access was password-protected. All data were kept confidential and only accessible to the study team and the principal investigator. Data quality control and monitoring of missing data were done weekly.

Paper-based records were used to capture folder numbers and patient names, which served as a participant log linking the electronic PID to the patient's folder. These records were stored in a secure location only accessible to the study team.

3.7.1.3 Analysis

Descriptive statistics (median, interquartile range (IQR) and frequencies and percentages) were used to describe continuous and categorical variables, respectively. All statistical analyses for Objectives 1, 2 and 3 were done using Stata (version 14) (*Stata Corporation, College Station, Texas, USA*).

3.7.2 Objectives 2 and 3

Stakeholder engagement was conducted prior to data collection, liaising with facility managers and adolescent healthcare providers to devise customised recruitment plans for each facility according to their models of HIV care. The candidate and research coordinator conducted data collection, beginning February 2019 until January 2020. The same study was conducted for Objectives 2 and 3, generating one dataset. For Objective 3, additional data were collected on the home-, social-, built and food environments detailed in **Section 3.7.2.5.**

3.7.2.1 Informed consent process

Informed consent and assent forms were developed in English and translated into two local languages: isiXhosa and Afrikaans. Eligible participants were invited to participate in the study at the start of the clinic day. At the first encounter, participants were given information sheets and a detailed overview of the study procedures and invited to participate during routine clinical visits. Those aged less than 18 years received the informed consent and assent forms to gain parental or caregiver approval. A return date was scheduled on which the interview would take place (usually the date of their next clinic appointment) (see **Figure 3.3**). Teach-back questions on the nature of the study were incorporated into the assent form to ascertain adequate understanding. The teach-back method is commonly used in clinical settings to improve understanding in populations with limited health literacy by asking potential participants to “teach-back” key concepts before asking them to sign the consent document [400].

Those of legal age (18–24 years) were immediately enrolled after signing the consent forms, and a convenient, future time was scheduled for their interview if they were unable to participate on the same day. Participants were allocated a generic study ID to ensure anonymity. An enrolment log book with each participant’s contact details was kept separate from the study information collected.

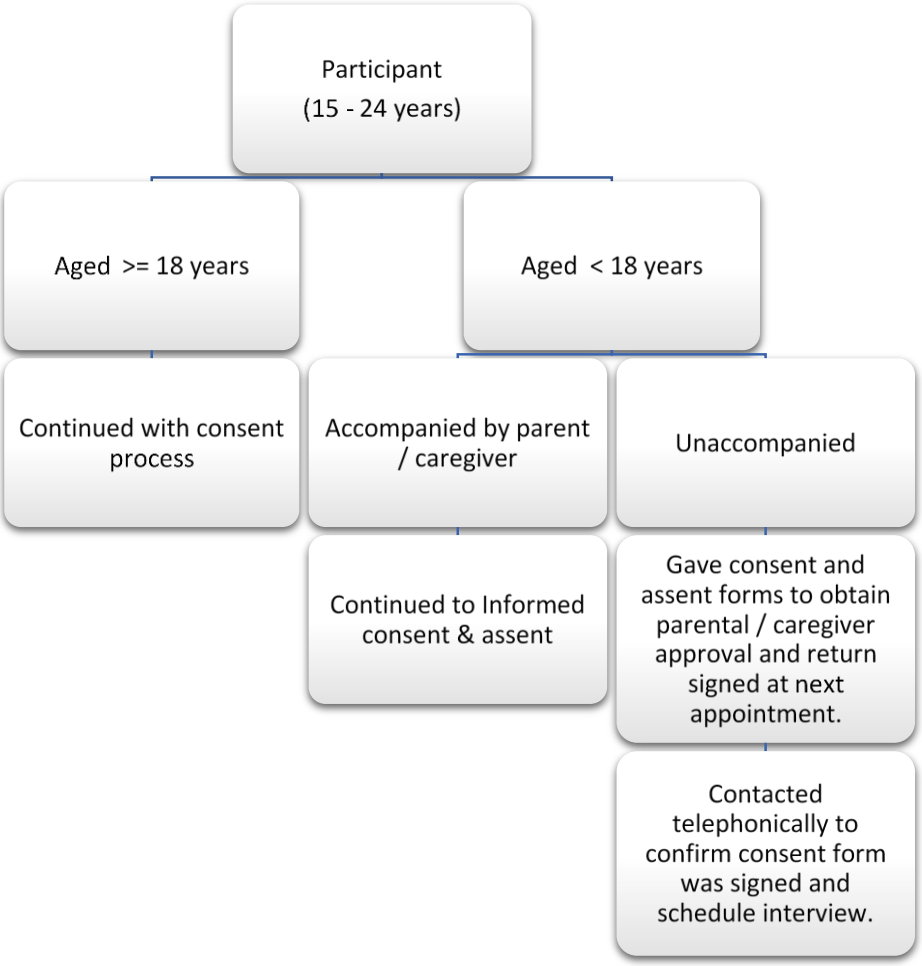

Figure 3.3: Informed consent process for Objectives 2 and 3

3.7.2.2 Data collection

On the scheduled appointment date, participants were first examined for approximately 30 minutes before completing a partially assisted self-administered questionnaire administered electronically on a handheld Android tablet. Examinations were carried out by the candidate and the research coordinator according to the study protocol standard operating procedures. The questionnaire, which was administered in English, took approximately 60 minutes to complete and included questions on socio-demographic, clinical and behavioural characteristics, household, social, and environmental factors in line with each objective.

For Objective 2, I was primarily interested in estimating the prevalence of the following pre-existing and previously unidentified NCDs and their related risk factors in AYLHIV:

a) **cardiometabolic diseases and risk factors**: hypertension and elevated blood pressure, overweight/ obesity status, abdominal obesity, diabetes and raised blood glucose;
b) **chronic respiratory diseases and risk factors**: asthma, bronchitis, respiratory symptoms;
c) **mental health conditions**: depression and psychological distress;
d) **behavioural risk factors and knowledge**: tobacco use, alcohol/substance use, physical inactivity, unhealthy diet, dietary practices and nutrition knowledge.

For Objective 3, I broadened the scope of data collection by adding the following household, social and environment-level measures:

a) **household-level factors**: family history of NCDs, housing characteristics, multidimensional poverty and food security, household composition, primary caregiver relationship and positive parenting;
b) **social environment factors**: experiences of stigma, social capital, exposure to violence and crime safety;
c) **built and food environment factors:** neighbourhood walkability, transport, access to convenience or small grocery stores, supermarkets, fruit and vegetable markets, fast-food restaurants.

3.7.2.2.1 Data collection instrument and measures

The data collection instrument for this thesis was developed based on evidence from existing studies conducted in SSA and other LMIC settings. Where available, tools that have been validated for use in adolescents and particularly AYLHIV were used. The study instrument assessed the following outcomes and measures corresponding to each objective indicated by the shading, as shown in **Table 3.4.**

Table 3.4: Overall outcome measures and data required for Objectives 2 and 3

Outcome measure	Required data	Objective 2	Objective 3
Individual-level factors			
Socio-demographic characteristics	Age, sex, language, parity	■	■
	Educational attainment, current occupation, absenteeism	■	■
	Youth poverty index	■	■
Risk behaviour and knowledge screening	Dietary intake and practices	■	■
	Physical activity and sedentary behaviour	■	■
	Tobacco, alcohol and substance use	■	
	Nutrition knowledge	■	■
Mental health assessment	Depression and psychological distress	■	■
Clinical examination	Anthropometric measurements	■	■
	Blood pressure, pulse	■	■
	Random blood glucose	■	
	Peak flow meter forced expiratory volumes	■	
Cardiometabolic and respiratory disease	Diabetes disease and symptoms	■	
	Respiratory disease and symptoms	■	
	Family history	■	■
Household and community-level factors			
Household socio-economic status	Household poverty	■	■
	Food insecurity	■	■
Household composition and family structure	Number of people in the household, whom they live with, dependents (< 15 or ≥ 65 years), orphanhood, primary caregiver, positive parenting and supervision.		■
Housing characteristics	Type of dwelling, history of flooding/fire, access to amenities, sanitation, primary source of water, waste removal, thermal comfort.		■
Experiences of stigma	Anticipated stigma, internalized stigma, enacted stigma.		■
Social capital	Family, school and neighbourhood social capital.		■
Safety and violence	Crime safety and exposure to community violence		■
Built and food environment			
Built environment	Neighbourhood environment walkability		■
	Transportation and commuting (active transport)		■
Food environment	Access to stores and food places		■

Note: The shaded areas are the indicators that were collected for each objective.

3.7.2.3 Data management

An *ODK-Collect* electronic form was developed for data capturing using Android tablets as described in **Section 3.7.1.2.** A new automatically generated PID was assigned to each participant, and no identifying information was captured to ensure anonymity. The electronic form was used to record participant responses and measurements from the clinical examinations. Data restriction rules and skip patterns were incorporated in the form to standardise data capturing. The form had similar functionality and access restrictions and was automatically synced and backed up in two locations as described before. All data were kept confidential and only accessible to the study team and the principal investigator. Data quality control and monitoring of missing data were done weekly. A data dictionary was developed outlining different codes for each variable. Data was exported from the ODK database into a CSV data file for cleaning and analysis.

The following section outlines the measures and tools used for each objective in more detail.

3.7.2.4 Objective 2 measures

3.7.2.4.1 Individual-level factors

3.7.2.4.1.1 Socio-demographic characteristics

Adolescence is often categorised into three primary developmental stages as discussed in the literature review: early adolescence (10–14 years), middle adolescence (15–17 years), and late adolescence / young adulthood (18–24 years) [401]. For purposes of this study, participants were categorised into four age groups in line with these stages, further sub-dividing the eldest age group into quartiles as follows: 15–17, 18–19, 20–21 and 22–24 years.

Sex was defined as biological sex at birth, either male or female.

Educational attainment: school attendance and performance were categorised according to educational attainment (completed primary or high school, obtained a tertiary qualification), using similar indicators as the education dimension in the poverty index described below. Additionally, absenteeism (absent on one or more days in the past month) and ever repeating a grade at school were measured as binary variables.

Poverty: is increasingly recognised as multidimensional, involving several dimensions of deprivation. Income-based poverty measures are limited in their ability to measure different facets of poverty accurately [271]. *The Youth Multidimensional Poverty Index (YMPI)* is a multidimensional individual-level measure of poverty comprising 11 weighted indicators in five dimensions: educational attainment, general health and functioning, living environment, household assets and employment, using the method by Alkire and Santos [271]. The YMPI is similar to the South African Multidimensional Poverty Index (SAMPI), is derived from the 2011 South African Census Questionnaire, but uses the young person as the unit of analysis instead of the household [402]. Each indicator is associated with a deprivation cut-off that defines whether a young person is deprived in that area [403]. A deprivation score was calculated for each dimension, and an overall composite score was derived from the weighted indicators. An individual is identified as multidimensionally poor (MPI poor) if deprived in a third or more weighted indicators, with a composite score of 33.3% or more [271]. The extent of poverty is measured by the percentage of deprivations experienced [404].

3.7.2.4.1.2 Risk behaviour and knowledge

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ) short form using the last seven days self-administered format [405] and graphic images of different kinds of vigorous and moderate-intensity forms of physical activity as an aid. The IPAQ has been validated in youth and adults in South Africa [406]. The Ainsworth et al. scoring algorithms were used to derive an average metabolic equivalent of task (MET) intensity level score for each type of physical activity: vigorous, moderate, walking and cycling [407].

According to the IPAQ scoring protocol, physical activity levels were further categorised into low, moderate and high [408]. According to WHO recommendations, insufficient physical activity was defined as a score below 600 MET minutes/week [409]. The presence or absence of sedentary behaviour was dichotomised as spending three or more hours per day watching television, playing computer games, talking with friends or other sitting activities according to the Global School-based Student Health Survey criteria [410].

Dietary intake was assessed using a 23-item food frequency questionnaire (FFQ) adapted from the Health Behaviour in School-aged Children Survey [411]. Participants reported their 'usual' consumption frequency of 23 different food groups, with response categories ranging from 'never' to 'more than once a day'. The FFQ has been found to have moderate reliability and acceptable

validity for assessing the consumption of most food groups among adolescents [412]. Dietary intake was summarised into weekly consumption frequencies: 1, never; 2, less than once a week; 3, once a week; 4, 2–4 days a week; 5, 5–6 days a week; 6, once a day, every day; and 7, every day, more than once. The proportion who ate fresh fruits and vegetables daily (once or more than once a day in the previous week) and frequently (on four or more days in the previous week) and the proportion of respondents who reported daily consumption of SSB, deep-fried foods, fast foods, salty snacks, and processed meats were estimated. Skipping breakfast was defined as eating breakfast on 0–2 days/week; semi-skipping, 3–4 days/week and not skipping, 5–7 days/week.

Tobacco, alcohol and substance use were assessed using questions from the 2011 South African Youth Risk Behaviour Survey [136]. Current smoking and drinking were defined as smoking cigarettes or other tobacco products and consuming alcohol at least once in the preceding month, respectively [136]. Heavy episodic or binge drinking was defined as drinking five or more drinks in succession on one or more days in the preceding month. Risky drinking was defined as binge drinking or underage drinking (any alcohol consumption below the legal age of 18 years). Illegal and other drug use was defined as ever using cannabis, hard drugs (mandrax, cocaine, heroin, methamphetamine/tik, club drugs), inhalants such as glue, aerosols, paint thinners, petrol or benzene or over-the-counter or prescription drugs “to get high”.

Nutritional knowledge was assessed using a revised form of the General Nutrition Knowledge Questionnaire (GNKQ-R) [413]. The GNKQ-R has demonstrated internal consistency and is a valid and reliable measure of nutrition knowledge among young people [413]. A nutritional knowledge score was generated by totalling correct answers in four nutrition domains. The maximum possible score was 88; 18 for questions on “dietary recommendations”, 36 for questions on food groups, 13 for “healthy food choices”, and 21 for “associations between diet and disease”. No norms exist to determine an adequate nutrition knowledge score [137]. Hence the average nutrition knowledge score was computed, and mean scores for each nutrition domain were compared by gender and age groups similar to a previous study of South African adults [414]. The percentage of respondents who answered the questions correctly in each domain was calculated.

3.7.2.4.1.3 Mental health assessment

Depression and psychological distress were defined using symptom screening questions from the 10-item Centre for Epidemiological Studies Short Depression Scale (CESD-10) [415, 416] and the Kessler Psychological Distress Scale (K10) [417]. Both tools have been validated in South African HIV-positive populations [205, 418] and adolescents and young adults [419]. The CESD-10 scale assesses depressive symptoms in the past week, while the K10 scale assesses symptoms of distress during the previous 30 days. Depression was defined as a binary indicator using a cut-off score of 10 or more on the CESD-10 scale [415]. The likelihood of psychological distress was categorised according to the K10 score: K10 < 20, mentally well; K10 20–24, likely to have mild psychological distress; K10 25–29, likely to have moderate psychological distress; K10 30–50, likely to have severe psychological distress [420].

3.7.2.4.1.4 Clinical assessment

Anthropometry: Height and weight were measured using a sliding balance weight-and-height measuring scale with barefoot participants wearing light clothing. Height was measured to the nearest 0.5 cm and weight to the nearest 0.1 kg. Waist and hip circumference were measured using stretch-resistant measuring tape according to the WHO STEPS protocol [421]. Readings were taken to the nearest 0.1 cm. Two measurements were taken and recorded on the electronic form, of which an average was computed during analysis. For weight, height and waist- and hip circumference, if the two readings differed by more than 100g, 2cm and 0.1 cm, respectively, a third measurement was taken, and the two closest measurements were recorded.

Sitting blood pressure and pulse were measured using a Rossmax automatic blood pressure monitor (*Rossmax (Shanghai) Incorporation Ltd*). Two readings were taken at least two minutes apart, and the average was computed. The procedures were repeated in instances where there was a significant difference between readings (more than two units), and the closest two readings were recorded.

Participants were asked whether they had a family history of diabetes or experienced any of the following symptoms over the past three months: frequent urination, increased thirst, unexplained weight loss of more than 1.5 kg in the last month, unexplained fatigue and blurry vision. Random blood glucose was measured in those with a family history or reported symptoms using a point-of-care (POC) glucometer with reactive test-strips (*Glucocheck Evolve ® Homemed Pty*).

Respiratory symptom screening was conducted, determining any difficulty breathing or shortness of breath, prolonged cough for more than two weeks with sputum, chest tightness, noisy breathing (wheezing or whistling in the chest) or a history of asthma. Respiratory volume was measured in those reporting respiratory symptoms without known asthma or chronic respiratory conditions using a hand-held peak flow meter with disposable mouthpieces. Several repeated attempts were made per standard guidelines [422]. A further two attempts were made if the variation between attempts was greater than 20 litres/minute [422]. The two largest values were recorded and the average computed.

3.7.2.4.1.5 Cardiometabolic and respiratory disease and risk factors

Overweight and obesity were categorised using standard BMI categories and cut-offs for abdominal obesity. The criterion used to identify overweight and obesity in older adolescents using growth charts and BMI-for-age weight status correspond to the criteria used for adults; thus, the latter was used for ease of comparability [423]. The abdominal obesity cut-off point for a high waist circumference (WC) was ≥ 102 cm in males and ≥ 88 cm in females and a waist-hip ratio (WHR) > 0.85 for females and > 0.90 for males [421]. The waist-to-hip ratio was calculated by dividing the waist circumference by the hip circumference in centimetres rounded to two decimal places. A threshold value of 0.5 for the waist-to-height ratio (WHtR) was used to measure abdominal obesity, calculated by dividing the waist circumference by the height in cm [424].

Hypertension and blood pressure were categorised according to the South African Hypertension practice guidelines [425]: Normal (systolic BP, SBP <130 mmHg and diastolic BP, DBP < 85 mmHg); elevated blood pressure (SBP 130–139 mmHg or DBP 85 – 89 mmHg) and hypertension (SBP ≥140 mmHg or DBP ≥ 90 mmHg) or a self-reported pre-existing diagnosis of hypertension.

Diabetes was defined as either

i) a pre-existing self-reported diagnosis;
ii) a random blood glucose reading of > 7 mmol/l and having a family history of diabetes; or
iii) a random blood glucose reading of > 7 mmol/l and experiencing any of the following diabetes-related symptoms over the past three months: frequent urination, increased thirst, unexplained weight loss of more than 1.5 kg in the last month, unexplained fatigue, blurry vision.

Respiratory disease was defined as a self-reported pre-existing diagnosis of asthma, tuberculosis, bronchitis, or another lung disease. Experiencing any of the following symptoms in the preceding three months was characterised as the presence of respiratory symptoms: prolonged cough with sputum for more than two weeks; chest tightness, and shortness of breath, difficulty breathing; or having an abnormal peak flow reading.

Table 3.5: Summary of measures and variables for Objective 2

Variable	Data or indicator required	Categories or composition
Individual characteristics		
Demographic characteristics	Age, sex, language, ever pregnant and parity	Age categories: 15–17, 18–19, 20–21 and 22–24 years. Parity: zero children, one child or more
School attendance and performance	Educational attainment, current occupation, absenteeism, ever repeated a grade at school	Education: primary, some secondary, matric or equivalent, some tertiary. Occupation: employed, in school / college / university / other tertiary institution, Neither in education/ employment nor training Absenteeism: zero days, one or more days
Socio-economic status	Youth Multidimensional Poverty Index (YMPI): five dimensions and 11 indicators [403].	General health and functioning, education, living standards, asset deprivation, economic opportunities.
Cardiometabolic disease and risk		
Weight status, abdominal obesity	Weight, height, waist circumference, hip circumference.	**Overweight/obesity:** BMI 25 - 29.9 kg/m^2 or BMI ≥30 kg/m^2, **Abdominal obesity:** • Waist circumference (WC) ≥ 102 cm in males and ≥ 88 cm in females, • Waist-hip ratio (WHR) > 0.85 for females and > 0.90 for males, • Waist-to-height ratio (WHtR) > 0.5.
Hypertension, elevated blood pressure	Medical history, Measured blood pressure (systolic / diastolic)	Previous diagnosis of hypertension OR according to the following three categories [425]: • Normal BP: < 130/85 mmHg, • Elevated BP: SBP 130-139, DBP 85-89 mmHg, • Hypertension: ≥ 140/90 mmHg.
Family history	Parental medical history of diabetes/stroke / high blood pressure	Binary variable
Diabetes	Medical history, symptom screen and random blood glucose	• Previous diagnosis of T1DM or T2DM, • Family history of diabetes OR at least two positive symptoms on screening (frequent urination, increased thirst, unexplained weight loss of more than 1.5 kg in the last month, unexplained fatigue, blurry vision) **AND** • Random blood glucose > 7 mmol/l.

Respiratory disease and risk		
Asthma, TB, bronchitis or another lung disease	Medical history, peak flow meter forced expiratory volume reading	• Previous diagnosis of asthma / TB / bronchitis / another lung disease, • Prevalence of respiratory symptoms: prolonged cough, wheezing, chest tightness, shortness of breath or difficulty breathing, • Abnormal peak flow reading in the "Red" zone.
Risk behaviour and knowledge		
Dietary intake and nutrition	Frequency of consumption of fruit, vegetables, whole grains, fast-foods, deep-fried foods, cakes and biscuits, sugar-sweetened beverages [411].	Weekly portions consumed; Frequency: never, once a week, 2 – 4 times a week, frequently (5-6 times a week), daily or more than once a day.
Physical activity and sedentary behaviour	Questions from IPAQ-short form [405]: Metabolic Equivalents and classification into insufficient, moderate, or high physical activity levels [408].	• Insufficient PA: < 600 MET/ week • High PA: > 3000 METs/week. • Sedentary behaviour: three or more hours sedentary in a typical day.
Nutrition Knowledge	Overall GNKQ Score; Four sub-domains according to revised GNKQ [413].	1. Dietary recommendations; 2. Food Groups; 3. Healthy Food choices; 4. Diet-disease and weight management
Mental health		
Depression; Psychological distress	10 item Centre for Epidemiological Studies Short Depression Scale (CESD 10) [416]; Kessler Psychological Distress Scale (K10) [426]	Significant depression: CESD-score ≥ 10. **Psychological distress:** sum of K10 responses • score <20: low distress • score 20-24: mild distress • score 25-29: moderate distress • score ≥ 30: severe distress
Home environment		
Household food security	Household Food Insecurity Access Scale (HFIAS) [427]	HFIAS prevalence categories: food secure, mildly food insecure access, moderately food insecure access, severely food insecure access.

3.7.2.4.2 Household-level factors

Food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS), consisting of nine questions intentionally developed and validated for cross-cultural use [427]. The HFIAS score is a continuous measure of the degree of food insecurity experienced in a household in the past month [428]. The participant is expected to answer for all members of the household and not just themselves. The higher the score, the more food insecurity the household experienced. Participants were categorised as living in food secure, mildly–, moderately–, or severely food insecure households depending on the severity and frequency of food insecurity experiences according to the HFIAS protocol [427].

3.7.2.4.3 Analysis

All variables were described using summary statistics (frequencies and percentages for categorical variables, means and standard deviations for normally distributed variables and medians and IQR for non-parametric variables). All data were analysed and stratified by sex and age group. Differences between sexes and age groups were compared using Pearson's $\chi 2$ and Fisher's exact tests for categorical measures. The Mann-Whitney Wilcoxon test was used to compare medians between groups, and the Kruskal-Wallis test was used for comparing continuous measures in more than two groups. All tests of significance were two-tailed and performed at the 5% significance level.

To estimate the prevalence of different NCDs and their risk factors, we categorised them into prevalence proportions according to the definitions shown in **Table 3.5.** Point prevalence estimates and their 95% confidence intervals were computed and compared by sex and age at a 5% significance level. It should be noted that the sample size calculations were based on an overall estimate for the particular NCDs resulting in limited power for prevalence estimates in any subgroup and for comparisons, for example by age and sex.

3.7.2.5 Objective 3 measures

For Objective 3, the main outcome of interest was abdominal obesity defined as a waist-to-height ratio > 0.5 [424]. A detailed outline of the variables collected for Objective 3 is shown in **Table 3.6.** In addition to the measures defined in Section 3.7.2.2, the following additional measures were used.

3.7.2.5.1 Individual-level measures

Parity: History of pregnancy or impregnating someone was assessed via self-report. We further probed for the number of children a participant had as a proxy measure for parity in those who reported ever being pregnant. Strictly defined, parity refers to the number of times a woman of reproductive age has given birth to a foetus with a gestational age of 24 weeks or more, regardless of whether the child was born alive or was stillborn [429].

Physical activity and sedentary behaviour were defined similarly as for Objective 2. PA was dichotomised into insufficient PA (< 600 Metabolic Equivalents of Task (MET)/ week) or sufficient PA.

Sedentary behaviour was dichotomised as present or absent. Additionally, active transport (walking/cycling) was assessed as part of participants' daily commute from home to school or work.

3.7.2.5.2 Household-level factors

Family history of chronic conditions was assessed via self-report and included diabetes, stroke, or hypertension.

Dwelling characteristics were assessed according to the 2011 South African census questionnaire [402]: housing informality (formal or informal dwelling), access to amenities (fuel used for lighting, heating and cooking in the home), sanitation (flush toilet inside house or yard), the main source of water (piped water inside the dwelling, piped water on-site or yard, public tap), household waste/refuse removal (removed weekly, removed less than weekly, communal dump, own dump) and history of flooding/fire or other adverse events. In addition, thermal comfort was assessed using self-report measures of perceived thermal comfort, asking whether the participant experienced any discomfort in the home environment in summer, spring, autumn, and winter months on a scale ranging from never, rarely, sometimes, often or permanently [430].

Family structure and parenting were assessed using questions on household composition and orphanhood status as well as via the "Positive Parenting" and "Poor Supervision" sub-scales of the *Alabama Parenting Questionnaire Short form* (APQ-9) [431]. The APQ-9 rates items on a 5-point Likert Scale (1 = never; 2 = almost never; 3 = sometimes; 4 = often; 5 = always). Higher scores indicate higher ratings of the measured parenting practice, with a reverse scale for supervision. We ascertained the number of people in the household who lived together regularly, the number of working-age adults (15 – 64 years) and dependents (children < 15 years and older persons ≥ 65 years).

3.7.2.5.3 Social environment characteristics

Experiences of stigma were measured using the HIV Stigma Scale for Adolescents Living with HIV (ALHIV-SS) [432]. This scale includes elements pertaining to anticipated, internalised, and enacted stigma. Anticipated stigma is the belief that prejudice, discrimination and stereotyping will be directed at the self from others in the community in future [310]. Enacted stigma refers to the degree to which PLHIV believe they have experienced prejudice and discrimination from others in their

community (via social exclusion and rejection), and internalised stigma refers to the degree to which PLHIV endorse the negative beliefs and feelings associated with HIV/AIDS about themselves [310].

Perceptions of social capital were measured using measures of family trust, school social capital and neighbourhood social capital [433, 434]. To measure family trust, we asked the following questions: "Do you feel your family understands and gives attention to you?" School social capital was measured via three items: ''Do you feel teachers and students trust each other in your high school (*vertical school trust*)?"; ''Do you feel students trust each other in your high school (*horizontal school trust*)?''; ''Do you feel students collaborate in your high school (*reciprocity at school*)?" Neighbourhood social capital was measured using three items: "Do you feel people trust each other in your neighbourhood (*neighbourhood trust*)?''; ''Do you feel that your neighbours step in to criticise someone's deviant behaviour during high school (*informal social control*)?" and "Do you feel like you belong in your neighbourhood?" (*neighbourhood belonging*). We created a dichotomous variable for each social capital response (high: 'strongly agree', agree and 'neither agree nor disagree'; low: disagree and 'strongly disagree') similar to the method used by Novak et al. [433].

Exposure to violence was measured using eight sub-items from the Survey of Exposure to Community Violence scale [435]. Violence was categorised as no violence (score < 2), moderate level (score 2 – 3), and high level of violence (score 4 – 8). Crime Safety items from the Neighbourhood Environment Walkability Scale for Youth (NEWS-Y) [355] were used to measure perceptions of neighbourhood crime. A mean composite score was computed from the Crime Safety subscale of the NEWS-Y, giving an overall score.

3.7.2.5.4 Built and food environment characteristics

Perceived Neighbourhood Environment Walkability was measured using NEWS-Y [355]. The scale has nine subscales, including land-use mix-diversity, access to neighbourhood recreational facilities, residential density, land use mix-access, street connectivity, walking or cycling facilities, neighbourhood aesthetics, pedestrian and automobile traffic safety, and crime safety. Each subscale has a set of indicators and response options which are summarised using z-scores. An overall neighbourhood environment walkability score is created by calculating z-scores for each of the nine subscales and summing them. Higher scores indicate a more walkable environment [355]. *The local food environment* was measured using access questions from the NEWS-Y land-use mix diversity

subscale [355], with walking distance defined as stores or facilities within a 20-minute walk or less from home [355]. The following food places or services were used as indicators of the food environment: access to convenience or small grocery stores, supermarkets, fruit and vegetable markets, fast-food restaurants, non-fast food restaurants, and coffee shops.

Table 3.6: Summary of measurement tools and variables for Objective 3

Variable	Data or Indicator Required	Categories or Composition
Individual characteristics		
Demographic characteristics	Age, sex, language, ever pregnant and parity	Age categories: 15–17, 18–19, 20–21 and 22–24 years. Parity: zero children, one child or more
School attendance and performance	Educational attainment, current occupation, absenteeism, ever repeated a grade at school	**Education**: primary, some secondary, matric or equivalent, some tertiary. **Occupation:** employed, in school /college/ university/ another tertiary, Neither in education/ employment nor training. **Absenteeism:** zero days, one or more days
Socio-economics	Youth Multidimensional Poverty Index (YMPI): Five dimensions and 11 indicators [403].	General health and functioning, education, living standards, asset deprivation, economic opportunities.
Cardiometabolic risk factors		
Anthropometric measurements	Weight, height, waist circumference, hip circumference.	
Hypertension, elevated blood pressure	Measured blood pressure (SBP / DBP)	Normal BP: < 130/85 mmHg, Elevated BP: SBP 130-139, DBP 85-89 mmHg, Hypertension: ≥ 140/90 mmHg.
Family history	Parental medical history of diabetes/ stroke/ high blood pressure	
Mental health and behavioural risk factors		
Depression; Psychological distress	CESD-10 [416]; Kessler Psychological Distress Scale (K10) [426]	Significant depression: CESD-score ≥ 10. Mentally well: K10 10–19, Mild distress: K10 20– 24, Moderate distress: K10 25–29, Severe distress: K10 30–50.
Dietary intake and nutrition	FFQ: Frequency of consumption of fruit, vegetables, whole grains, fast-foods, deep-fried foods, cakes and biscuits, sugar-sweetened beverages [411].	Weekly portions consumed; Frequency: Never, once a week, 2 - 4 times a week, frequently (5-6 times a week), Daily or more than once a day**.**
Physical activity and sedentary behaviour	Questions from IPAQ-short form [405]: Metabolic Equivalents and classification into insufficient, moderate, or high physical activity levels [408].	Insufficient PA: <600 MET/ week High PA: >3000 METs/week. Sedentary behaviour: 3 or more hours sedentary in a typical day.
Nutrition Knowledge	Overall GNKQ Score; Four sub-domains according to revised GNKQ [413].	1. Dietary recommendations; 2. Food Groups; 3. Healthy Food choices; 4. Diet-disease and weight management

Home environment		
Housing characteristics	Type of dwelling; History of flooding/fire; Access to amenities; Sanitation; Main source of water; Household waste/refuse removal; Dwelling ever damaged by adverse event; Thermal comfort.	Formal or informal dwelling; fuel used for lighting, heating and cooking; Flush toilet inside house or yard; Piped water inside dwelling, piped water on site or yard, public tap; Waste removal: removed weekly, removed or less than weekly, communal dump, own dump, other. Any discomfort experienced in summer, spring or autumn and winter.
Food security	Household Food Insecurity Access Scale (HFIAS) [427]	HFIAS prevalence categories: Food Secure, Mildly Food Insecure Access, Moderately Food Insecure Access, Severely Food Insecure Access.
Household composition	**Family structure:** Number of people in the household who live together regularly, Number of children (0-14 years old) and older persons (≥ 65 years), Working-age adults (15-64 years old).	Whom adolescent lives with: biological parent, grandparent, siblings, other extended family members, non-family member (social worker/ care worker, foster carer).
Primary caregiver, and relationship with parents/caregiver	**Orphanhood status:** Parents deceased or alive. "Positive Parenting" and "Poor Monitoring or Supervision" sub-scales of the Alabama Parenting Questionnaire Short form [431].	Primary caregiver relationship: biological parent as a primary caregiver. Positive parenting: Parent tells you when you are doing a good job, parent praises you for behaving well, parent compliments you when you have done something well. Poor supervision: Fail to let parent know where you are going, Stay out at night long after curfew, Parent does not know the friends you are with.
Community-level factors		
Experiences of stigma	HIV Stigma Scale for Adolescents Living with HIV (ALHIV-SS) [432].	Anticipated stigma. Internalized stigma. Enacted stigma.
Perceptions of social capital [433, 434]	**Family social capital** (Family Trust). *'Do you feel your family understands and gives attention to you?'*	Created a dichotomous variable for each response (high: strongly agree, agree and 'neither agree nor disagree'; low: 'disagree' and 'strongly disagree') High or low family trust
	School social capital: (2 items) *''Do you feel teachers and students trust each other in your high school (vertical school trust)?''* *''Do you feel students trust each other in your high school (horizontal school trust)?''* *''Do you feel students collaborate in your high school (reciprocity at school)?'*	High or low vertical school trust, High or low horizontal school trust, High or low reciprocity.
	Neighbourhood social capital: (2 items) *'Do you feel people trust each other in your neighbourhood (neighbourhood trust)?''*	High or low neighbourhood trust High or low Informal social control.

	''Do you feel that your neighbours step in to criticise someone's deviant behaviour during high school (informal social control)?'	
Safety and exposure to violence	Eight sub-items from the Survey of Exposure to Community Violence scale [435]; Crime Safety items from NEWS-Y	No violence (score < 2), moderate level (score 2 – 3), high level of violence (score 4 – 8). Mean of 6 items.
Built environment		
Perceived Neighbourhood Environment Walkability	Neighbourhood Environment Walkability Scale for Youth (NEWS-Y) [355]	
	A. *Land-use mix – diversity* ("Stores, facilities in the neighbourhood")	Responses: 1-5 min (1), 6-10 min (2), 11-20 min (3), 21-30 min (4), 31+ min (5), don't know (5)[1]. Score= mean of 20 items.
	B. *Access to Neighbourhood recreation facilities*.	Responses like A. Score= mean of 14 items.
	C. *Residential density* ("Types of homes in the neighbourhood")	None (1), A few (2), Some (3), Most (4), All (5). Score on subscale C = C1 + (12*C2) + (2*C3) + (25 * C4)
	D. *Land-use mix – access* ("Access to services")	*Responses:* Strongly disagree (1), Somewhat disagree (2), Somewhat agree (3), Strongly agree (4). Score= mean of 6 items.
	E. *Street connectivity* ("Streets in my neighbourhood")	Responses like D. Score= mean of 3 items.
	F. *Walking/cycling facilities* ("Places for walking and cycling")	Responses like D. Score= mean of 3 items.
	G. *Neighbourhood aesthetics* ("Neighbourhood surroundings")	Responses like D. Score= mean of 4 items.
	H. *Pedestrian and automobile traffic safety* ("Safety from traffic")	Responses like D. Score= mean of 7 items.
	I. *Crime safety* ("Safety from crime")	Responses like D. Score= mean of 6 items.
Transportation	Means of transport from home to school or work every day and time taken for each.	Whether or not active transport (walking/ cycling) is part of commute.
Food environment		
Access to the following food places or services	Convenience or small grocery store	Walking distance defined as stores or facilities within a 5, 10, or 20-minute walk from home [355].
	Supermarket	
	Fruit and vegetable market	
	Fast food restaurant	
	Non-fast food restaurant	
	Coffee shop	

[1] *Note: A 'don't know' response is coded as a "5" because if it is unknown whether the facility is within walking distance, the actual walk is likely more than 31 minutes.*

3.7.2.6 Data analysis

3.7.2.6.1 Descriptive statistics

Demographic and socioeconomic variables were described using summary statistics (frequencies and percentages for categorical variables; medians, IQR for non-parametric variables). Characteristics were compared by obesity status using Pearson's $\chi 2$ and Wilcoxon rank-sum tests.

3.7.2.6.2 Bivariate analysis

Bivariate associations between obesity status (overweight and obesity & abdominal obesity) and individual demographic characteristics and modifiable risk factors (dietary intake, alcohol, tobacco and other substance use, physical inactivity), metabolic risk factors (hypertension, random glucose, diabetes symptoms) and mental health comorbidity were derived using odds ratios.

Relationships between overweight and obesity status and the home environment and broader community and neighbourhood environment variables were explored using:

- Visual data displays: box plots for continuous risk factors by obesity outcomes.
- Crude odds ratios and two-by-two tables for the association between categorical risk factors and overweight or obesity status.

3.7.2.6.3 Multilevel regression analysis

Multilevel regression analysis was used to explore individual- and neighbourhood-level correlates of overweight or obesity within the hierarchical data structure displayed in **Figure 6.1** below. Multilevel analysis is an analytical approach that considers the hierarchical structure of data, allowing for the simultaneous examination of the effects of group-level and individual-level variables on an individual-level outcome [436]. The individual outcome was a binary outcome of obese versus non-obese status, with participants (level 1) nested within facilities/ neighbourhoods (level 2) and sub-districts (level 3). A multilevel logistic regression analysis adjusted for potential individual confounding factors (demographics, physical activity) was used to derive associations between socio-environmental factors and obesity.

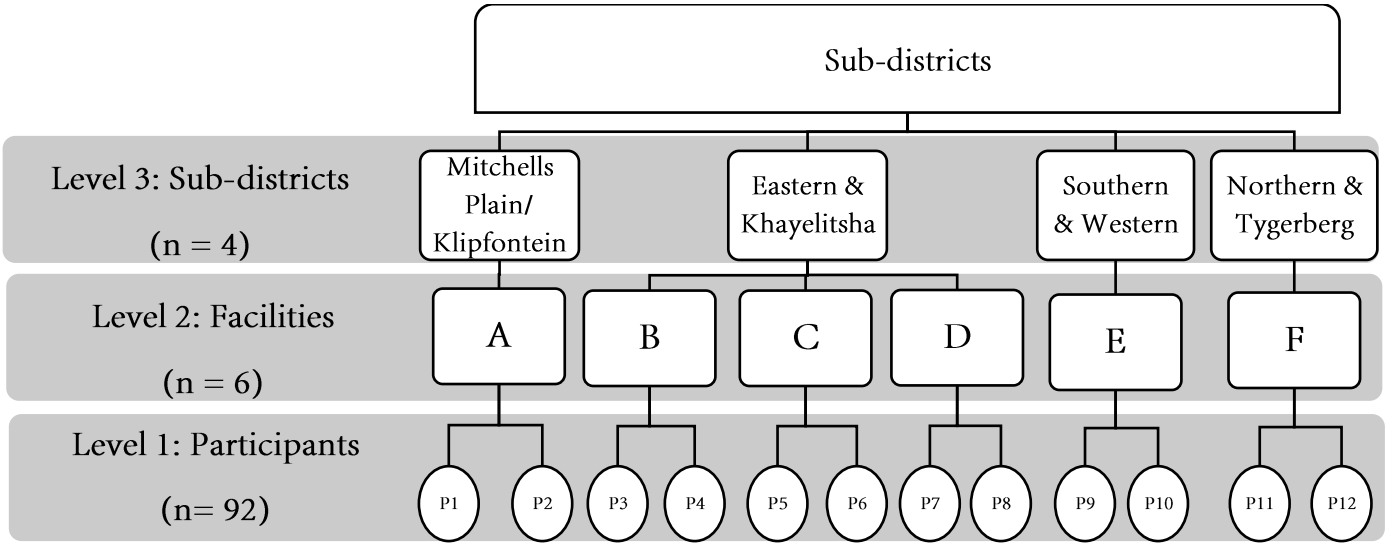

Figure 3.4: Multilevel data structure

3.7.2.6.4 Model building

Neighbourhood and household-level variables were all collected at the individual level and were not aggregate variables. The only group variable included in the analysis was the sub-district – Northern, Southern, Khayelitsha, and Klipfontein / Mitchells Plain, as displayed in **Figure 3.4**. The non-independent sub-district clustering effect was adjusted for in a mixed-effects model taking the variance structure into account.

Variables identified in the literature associated with obesity and variables with significant odds ratios ($p < 0.10$) in bivariate analysis were included in the multilevel logistic regression analysis. Model building was done in a step-wise process as outlined below. First, the null or empty model was constructed, then individual-level variables were added, followed by household-level variables, and finally neighbourhood-level built- and food environment variables. A detailed sketch of the variables included is shown in **Figure 6.1**. All models were adjusted for age and sex as confounders.

1. **Null model:** the empty model showing if differences in abdominal obesity status were random or fixed across sub-districts.
2. **Model A:** model with age and sex.
3. **Model Class B (models 3 - 6):** Individual-level variables (age, sex, YMPI, education, diet, PA).
4. **Model Class C (models 7 - 9)**: Household-level variables adjusted for age and sex.
5. **Model Class D (models 10 - 16)**: Neighbourhood environment variables (perceived built and food environment) adjusted for age and sex.

3.7.2.6.5 Model diagnostics

Diagnostic criteria for multilevel regression models were checked [437]. First, models were compared using the chi-square likelihood-ratio test, which assesses the difference between nested models and model fit. Non-nested models were compared using the *Akaike* information criterion (AIC) and the Bayesian information criterion (BIC). All models were checked for quality of fit and tested for compliance with the underlying model assumptions: linear relationships, homoscedasticity, and normal distribution of residuals [438]. The intra-class correlation coefficient (ICC) was checked to analyse the variability within and between sub-districts. Statistical significance was set at $p = 0.05$ for all analyses. Standardised coefficients (β) and odds ratios (e^β) were derived as measures of association.

3.8 Ethical considerations

In conducting this research, some critical ethical reflections arose. Conducting research with adolescents entails considering the ethical issues related to complexities involved in the consent process and in carrying out study procedures. The Children's Act (No. 38 of 2005) Section 17 defines minors as persons under the age of 18 [397]. By law, adolescents < 18 years of age are minors and lack the legal capacity to consent to research. Therefore, when conducting research with minors, it is important to be cognisant that they are a vulnerable population and that their capacity to provide informed consent is not the same as adults. Capacity is defined as the ability of a person to cognitively understand the relevant information provided and the consequences of his/ her decision that might reasonably be foreseen. Another important factor relates to mandatory reporting requirements, as indicated in the Children's Act, for any known or reasonably suspected incidents of deliberate neglect or abuse of a child [397].

Using the Society of Adolescent Health Guidelines for Adolescent Health Research [439] and the conditions set out in Section 71 (3) (b) of the Children's Act for the protection of minors participating in research, the research study was classified as "not involving greater than minimal risk". Ethical approval to conduct the study was granted by the Faculty of Health Sciences Human Research Ethics Committee at the University of Cape Town and the Departments of Health in the Western Cape Provincial Government and City of Cape Town. Some critical ethical considerations encountered in the research process are outlined below.

3.8.1 Justice

The Declaration of Helsinki states that special protection is needed for groups with diminished autonomy [440]. Minors are a vulnerable population who should be protected from the burdens of research. However, the protection of persons does not mean avoidance and exclusion from research. The principle of justice calls for a fair distribution of the benefits and burdens of research, as highlighted in the Declaration of Helsinki, which states that "Groups that are underrepresented in medical research should be provided appropriate access to participation in research" [440]. Unfortunately, adolescents have often been excluded from research that is potentially beneficial to them due to the ethical rigidity involved in enrolling them in research studies. In our context, the significant proportion of AYLHIV in South Africa and poor HIV treatment outcomes of adolescents

compared to other age groups highlights the need for evidence-based research in this population to generate evidence on ways to ensure better adolescent health outcomes. This research study provided a unique opportunity to bridge this gap and explore the intersection of chronic disease comorbidity and risk factors in adolescents living with HIV.

3.8.2 Autonomy and respect

Our study population consisted of adolescents aged 15 years and older. The law recognises that children older than 12 years can independently consent to certain medical interventions and presumably have the decision-making capacity to provide assent for research participation [397]. Since the research posed minimal risk, the assent of the adolescent and permission from one parent or guardian met regulatory requirements. To ensure non-coercion during the informed consent process, we explained to participants that there would be no negative repercussions should they choose not to participate in the study or choose to withdraw participation at any time during the study.

3.8.3 Informed consent and assent

Participant information sheets, consent and assent forms were translated into isiXhosa and Afrikaans to ensure adequate understanding. With assistance from the adolescent lay counsellors at the respective facilities, the candidate and research coordinator guided participants through the informed consent and assent process. Written informed consent was sought from caregiver/ guardians of minors < 18 years. A schematic of the procedure is outlined in **Figure 3.3**. Participants were requested to return the signed consent and assent forms at their next clinic appointment before enrolment in the study. Study procedures were explained and demonstrated to potential participants to ensure they understood what they were consenting to. The teach-back method was used to ascertain whether potential participants understood important study aspects and were comfortable with the physical examination [441].

3.8.4 Confidentiality

The candidate and study coordinator signed a confidentiality agreement at the start of the study, agreeing to keep all research information confidential and protect the security of identifiable information. Interviews with adolescents were conducted one-on-one in a separate room outside of the HIV treatment area where possible to prevent stigmatisation. Paper-based records were kept in a secure location only accessible to the study team and maintained for a minimum of five years. Electronic records were only accessible to the study team through the use of access privileges and passwords. All electronic participant data was de-identified with a generic study ID. No information requiring mandatory reporting to authorities came to light during the study.

3.8.5 Beneficence and non-maleficence

The principles of beneficence and non-maleficence emphasise the importance of balancing the desire to protect children from the potential harms of research while allowing them to benefit from the results. The research objectives were explicitly targeted towards adolescents as we aimed to investigate chronic disease risk in AYLHIV in an LMIC setting. Previous research has primarily been conducted in adults and in high-income settings, which cannot be extrapolated to adolescents as they are undergoing a transitional phase of rapid growth and development significantly different from adults. Hence, the research study could not be replicated in an adult study population. Little is known about the burden and the risk for NCD comorbidity in AYLHIV in LMIC settings growing up in a time of rapid urbanisation and increasing NCD prevalence.

As previously mentioned, the research did not involve greater than minimal risk to the participants than encountered in everyday life. The most invasive procedure was a finger-prick blood draw which is categorised as no more than minimal risk [439]. Possible stigma related to HIV status may have arisen and been attached to adolescents who participated in the research. To counter this, we interviewed participants in a neutral setting, separate from the ART clinic, where possible. Unfortunately, by nature of the HIV clinic set-up, this was not always possible. All study procedures were conducted during routine clinic visits and required no additional travelling by participants. However, participants were reimbursed for any additional travel costs incurred due to participation in the study.

Chapter 4

Missed Opportunities for NCD Multimorbidity Prevention in Adolescents and Youth Living with HIV in Urban South Africa

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I conceptualised the study, conducted data collection, data analysis and interpretation and wrote the first draft of the manuscript. B. Gausi conducted data collection, contributed to data interpretation and manuscript preparation. T. Oni conceptualised the study, was responsible for funding and strategic leadership, contributed to data interpretation and manuscript preparation. All authors read and approved the final manuscript.

4.1 Introduction

4.1.1 Emerging NCD epidemic in low- and middle-income countries

NCDs are responsible for more than half of the global burden of disease [442], with 71% of global deaths in 2016 due to NCDs [443]. The burden of NCDs is increasing most rapidly in LMICs, with NCDs projected to account for nearly half of the burden of disease in LMICs by 2030 and a four-fold higher probability of NCD-related premature deaths compared to high-income countries [443]. This trend is driven by rapid unplanned urbanisation, globalisation of unhealthy diets and behaviours such as tobacco use, physical inactivity, unhealthy diet, harmful use of alcohol [444] and population ageing [72, 445], resulting in a protracted epidemiological transition [13] with an emerging epidemic of obesity, diabetes and other NCDs alongside persisting infectious disease epidemics [373].

Of note, NCDs are affecting younger populations and are associated with worse health and economic outcomes in LMICs compared to high-income countries [98]. The estimated overall cost of diabetes in sub-Saharan Africa (SSA) was US$19·45 billion or 1·2% of the cumulative gross domestic product in 2015 [446], with health systems unable to provide adequate management for diabetes and its associated risk factors and sequelae [446]. This growing cost of NCDs is of particular concern as LMICs are grappling with higher levels of NCD at earlier stages of economic development, with fewer resources, and with less time to respond effectively [447]. These factors highlight the importance of focusing on the prevention of NCDs by early identification of modifiable risk factors at the primary care level across the life course as the most feasible and cost-effective approach to maintaining population health [29].

4.1.2 NCD prevention in adolescents

Adolescence, a period of transition from childhood to adulthood, is defined as the period between the ages of 10- 19 years [448], with some definitions extending this life stage to 24 years [1]. It is a period that comes with unique challenges as adolescents strive to develop autonomy and self-identity through exploration and risk-taking [22, 50, 193, 449], with a significant part of adolescence lying in its power to translate childhood experiences into competencies and statuses that facilitate the transition to adulthood [22].

Adolescents and youth aged 10–24 years make up over 25% of the global population, and their numbers are set to rise to two billion by 2032 [450]. Africa has the youngest population in the world, with more than one-third of the total population of SSA aged 10 to 24 years [451]. Although adolescents are generally healthy, up to 70% of premature adult deaths reflect behaviours started or reinforced during adolescence [452]. Worldwide, over 10% of young people smoke [130], 81% of adolescents have insufficient physical activity, and 11.7% of adolescents partake in heavy episodic drinking [444, 453]. These risk behaviours are further shaped by the social and commercial determinants of health which influence health-related behaviours. Reinforcing healthier behaviours and protective factors during this critical period of adolescence can significantly change the health trajectory into adulthood [135].

4.1.3 The rise of multimorbidity in the context of HIV

With the introduction of antiretroviral therapy (ART), HIV can be considered a chronic disease [454, 455]. In countries with a high burden of HIV undergoing rapid urbanisation and epidemiological transition, HIV/NCD multimorbidity is becoming increasingly prevalent [144] as people are living longer with HIV [456]. HIV-infected individuals are at increased risk of NCDs compared to HIV-uninfected persons, due partly to HIV infection [146, 232] and the complications of long-term ART [10-12]. A study in the United States reported that HIV-infected adults had a 1.5 fold increased risk of having a heart attack [371] and were nearly 50% more likely to have received a diagnosis of chronic obstructive pulmonary disease (COPD) compared to demographically and behaviourally similar uninfected controls [194]. Other NCDs more commonly reported in HIV-infected compared to uninfected persons include cardiovascular events [251], hypertension [457, 458], osteoporosis [459], renal impairment [460], diabetes [461], and depression and neurocognitive disorders [462].

In high HIV-burden settings, multimorbidity occurs at younger ages, with younger persons at a higher risk of heart-related conditions attributed to HIV infection [232]. HIV-infected adolescents, particularly those with increased HIV viral load, have been reported to have increased levels of cholesterol and triglycerides [150] and increased biomarkers of vascular dysfunction than HIV-exposed, uninfected adolescents [145]. This phenomenon is concerning for LMICs, where there is a younger age distribution of HIV-infected populations [232]. In a review by Lowenthal et al., the

authors found that in SSA, one of the striking features of HIV infection in adolescence is the high prevalence of chronic complications like chronic lung disease, cardiac disease, growth failure, neurocognitive disease, skin, renal and bone diseases [208]. This trend, and the fact that many unhealthy behavioural patterns develop in adolescence, make integrated prevention efforts necessary and highlight the importance of focusing on HIV-infected adolescents and youth for multimorbidity prevention.

4.1.4 Adolescents, HIV and the epidemiological transition in South Africa

South Africa has the biggest HIV epidemic worldwide and the largest ART programme in the world. In 2016, an estimated seven million people were living with HIV in South Africa, with four million of those receiving ART [463]. This epidemic persists in the context of epidemiological transition characterised by a quadruple burden of communicable, non-communicable, perinatal and maternal, and injury-related disorders [8]. Of the 1.6 million adolescents (aged 10 - 19 years) living with HIV globally in 2018, 310,000 (19%) are in South Africa [94]. These adolescents are growing up in an era of epidemiological transition, characterised by the increasing burden of NCDs driven by the unhealthy environments within which they live, necessitating interventions to enhance protective environmental factors and minimise risk behaviours [140].

4.1.5 The opportunity for NCD prevention in adolescents living with HIV

While young people generally do not access health care services regularly, living with a chronic condition like HIV, which requires regular interaction with the health care system [218], represents an opportunity to identify NCD risk and early intervention to reduce NCD morbidity.

In South Arica, HIV patients in the public sector are primarily seen and treated in HIV clinics. They are routinely monitored via physical examination, point of care and laboratory assessments as part of routine clinical management for HIV. Routine monitoring includes general health screening, patient history and biomedical assessments, which can also be used for other chronic disease screening. There has been a gradual move away from vertical services within HIV care towards more integrated

care, including NCD screening and management in LMICs, which face a dual burden of HIV and NCDs. An integrated approach that harnesses the successful programmatic approach of the HIV treatment program is recommended to scale up services for NCDs [229]. In South Africa, the National Health Department introduced the Integrated Chronic Disease Management (ICDM) model into primary health care facilities in 2011 to bridge fragmented chronic disease care within the public health care system and improve chronic disease health outcomes [230, 231]. However, to date, these efforts have focused on adults, despite recognition of an increasing burden of NCDs among people living with HIV occurring at increasingly earlier ages [144, 232, 233] and the importance of the adolescent and early youth period for the development of NCD risk factors that increase the risk of NCDs [1, 50].

Although systematic NCD screening is not formally integrated within adolescent primary care HIV services, general health screening and laboratory tests are done to identify biomedical risk factors. However, it is unclear the extent to which these preventive activities are conducted. We, therefore, set out to investigate the extent to which NCD comorbidity (prevention, screening and management) are incorporated within existing adolescent HIV primary healthcare services in Cape Town, South Africa.

4.2 Methods

4.2.1 Setting

4.2.1.1 Cape Town- demographics and epidemiology

The study was conducted in Cape Town, the second-most populous city in South Africa, with an estimated 3.8 million people [464]. In 2016, adolescents aged 10- 19 years comprised 16.1% of the population in the Western Cape province, where Cape Town is located [465].

Data for this study were collected from public primary health care facilities across Cape Town: Khayelitsha, Gugulethu, Langa, Brooklyn, Michell's Plain, Kraaifontein and Delft. These peri-urban neighbourhoods, located on the outskirts of Cape Town, are comprised of a mix of formal and informal dwellings (with 20.5% of the population residing in informal dwellings) and are characterised by high unemployment levels (30%) [466]. These locations are representative of the peri-urban population in Cape Town, consisting of predominantly Coloured (59%) and Black African (34%) people

[392]. Approximately 63% of households in the Khayelitsha/ Mitchells Plain district fall into the low-income bracket (earning < 280 USD per month) [467].

Non-communicable diseases and HIV are ranked among the top causes of premature deaths in Cape Town [449], with the top five causes of death in the Western Cape in 2016 ranked as diabetes, HIV, ischemic heart diseases, cerebrovascular diseases and tuberculosis [468]. Antenatal HIV prevalence in Cape Town was estimated at 21.6% in 2015 [469] and as high as 34.3% in Khayelitsha in 2012 [470].

4.2.1.2 Health system and HIV/NCD healthcare delivery

The City of Cape Town Metro Health District has eight legislated sub-districts. Primary health care services are delivered through four sub-structures (comprised of two sub-districts in each sub-structure): Khayelitsha/Eastern, Mitchell's Plain/Klipfontein, Western/Southern and Northern Tygerberg sub-districts [466]. ART care is delivered through government clinics and is free for all patients, with patients with well-controlled disease managed in ART "clubs". There were 5723 children under 15 years receiving ART in the public health system in Cape Town in November 2016 *(personal communication with Director of HIV Treatment Programme: Provincial Government of the Western Cape*).

NCD screening, prevention and care is provided at the primary care level as an entry point, with the routine clinical management of NCDs in primary care outpatient clinics. NCD patients with well-controlled disease are primarily managed through chronic disease "clubs" similar to patients on ART within these clinics.

4.2.2 Study design and sampling

We conducted a descriptive retrospective study from November 2018 to March 2019, reviewing medical records of adolescents and youth enrolled in HIV care across Cape Town.

4.2.2.1 HIV clinic selection

The total number of children under 15 years receiving HIV care in all clinics across all four legislated sub-structures was extracted from an internal report provided by the Western Cape Department of Health. As there were no routinely collected data for adolescents, we utilised data for children under 15 years as a proxy for adolescents and to identify healthcare facilities with the largest number of adolescent and youth populations in care. We selected clinics with the highest number of children under 15 registered as of November 2016, and we submitted a request for access to these clinics to the Western Cape Department of Health. We received approval for nine clinics, with the busiest 1-3 clinics selected from each sub-structure (see **Table 3.1)**.

4.2.2.2 Folder selection within each clinic

A de-identified population master list of all adolescents and youth aged 10-24 years receiving ART was generated with the assistance of data clerks at each facility. This master list of 10-24-year-old patients was used as a sampling frame. We aimed to sample 10% of adolescents on ART from each sub-structure (n= 463 overall) with the required sample size at each clinic in each substructure calculated proportionally to the total adolescent patient population (**Figure 4.1**). Systematic random sampling was used to select folders from the sampling frame master list as described in **Section 3.6.1** until we reviewed 10% of folders of adolescents in each sub-structure. Data collection was conducted from November 2018 until March 2019.

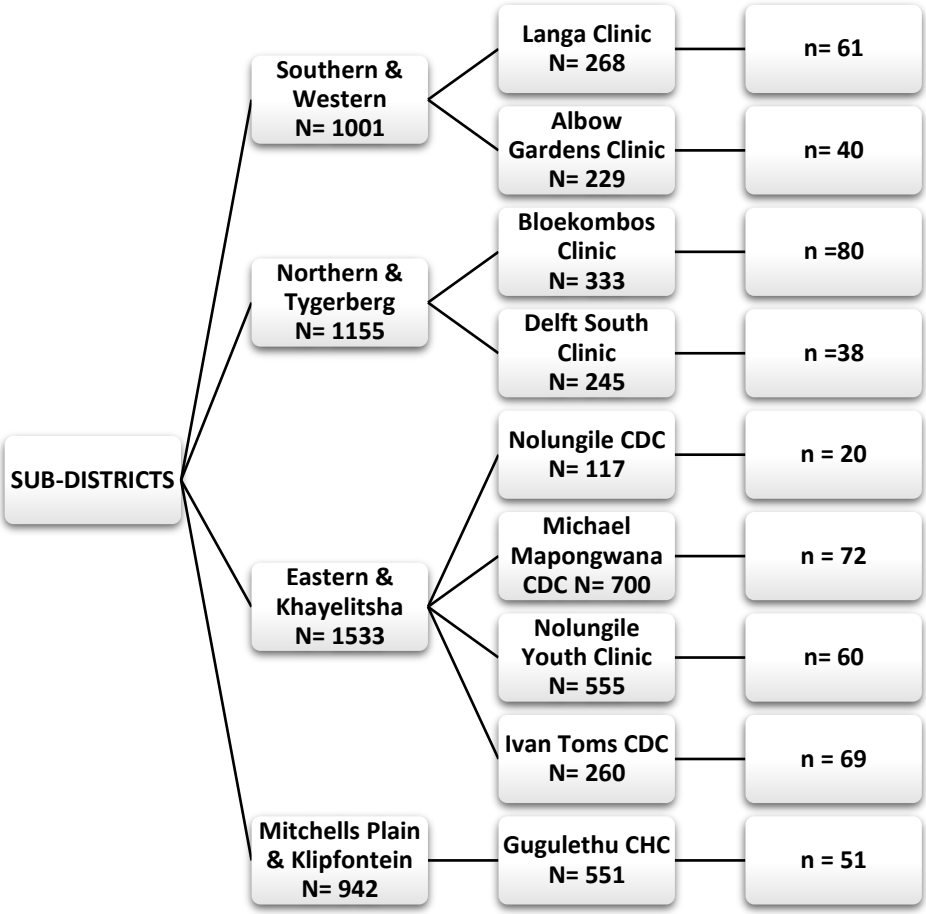

Figure 4.1: Study population and number of folders sampled across sub-districts and facilities

4.2.2.3 Data extracted from folders

We reviewed health care visits in the preceding 12 months in each folder. In patients with another chronic disease diagnosis recorded, all episodes recorded in the folder were extracted irrespective of date.

Data relating to HIV including treatment and opportunistic infections, NCD diagnosis and treatment (diabetes, hypertension, asthma, mood disorders, epilepsy), NCD risk (overweight/obesity, raised blood pressure, substance abuse, and smoking), and general medical history, including family history, were extracted from participant folders (see **Table 4.1**). Any recorded health promotion interventions related to HIV, sexual health or NCD risks were also extracted. A more detailed description of data collected and definitions used are included in an additional file (see **Appendix 4.1**).

4.2.3 Analysis

Descriptive statistics (median (IQR) and frequencies and percentages) were used to describe continuous and categorical variables, respectively. All analyses were conducted using STATA v14.0 (*StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP*).

4.3 **Results**

A total of 491 (10.6%) folders were reviewed from a master list of 4631 patients, keeping with our planned target of 10% of patients. The median participant age was 20 years (interquartile range (IQR): 14- 23 years); 74% were female; median age at ART initiation was 18 years (IQR: 6 –21 years), and the median duration on ART was three years (IQR: 1.1 –8.9 years) (
Table 4.1).

4.3.1 HIV management

The majority of patients were virally suppressed (69%) (median CD4 count of 489 cells/mm^3 (IQR (355—690 cells/mm^3)) and on first-line ART regimens (78%), (fixed-dose tenofovir-based (61%); abacavir- lamivudine based regimens (17%)) as shown in **Table 4.1.**

4.3.2 HIV opportunistic infections

Seven per cent (36/491) had a documented HIV opportunistic infection or an ART-related condition. Of those, the most prevalent conditions were herpes zoster/shingles (39%), followed by pruritic papular eruption (PPE) (29%), and oral thrush (7%) or oral candida (7%). The reported cases of opportunistic infections were documented to have received appropriate treatment (antibiotics, antivirals or antifungals). In addition, 14% of non-ARV medications prescribed in the previous 12 months consisted of cotrimoxazole prophylaxis to prevent particular opportunistic infections.

Table 4.1: Demographic and HIV-related characteristics of adolescents on ART across Cape Town

	Characteristic	N= 491[1]	median (IQR) or n (%)[2]
Demographics	Age at medical record review (years)		20 (14 –23)
	Male		127 (26%)
HIV-related			
HIV management	Age at ART initiation (years)	473 (96%)	18 (6 – 21)
	Duration on ART (years)	471 (96%)	3.1 (1.1 –8.9)

	CD4 count (cells/mm^3)	395 (80%)	489 (355 --690)
	Viral suppression (< 20 copies/ml)	369 (75%)	256 (69%)
Current ART regimen[3]	**First line:** ABC 3TC EFV		84 (17%)
	TDF FTC EFV		298 (61%)
	Second line: ABC 3TC LPV/r		39 (8%)
	AZT 3TC LPV/r		29 (6%)
	Other regimens		41 (8%)
HIV opportunistic infections		28 (6%)	
	Herpes zoster (shingles)		11 (39%)
	Pruritic papular eruption		8 (29%)
	Oral thrush		2 (7%)
	Oral candida		2 (7%)
	Oral hairy leucoplakia		1 (3.6%)
	Oesophageal candidiasis		1 (3.6%)
	Pneumocystis jirovecii pneumonia		1 (3.6%)
	HIV Encephalopathy		1 (3.6%)
	Cytomegalovirus disease		1 (3.6%)
ART-related conditions[4]		8 (2%)	
	AZT-neutropenia		1 (13%)
	D4T-lipodystrophy, lipoatrophy		7 (87%)

[1] *Denominator = 491, unless otherwise indicated in this column;* [2] *Percentages may not total 100 due to rounding;*
[3] *Current ART regimens: ABC= abacavir, 3TC= lamivudine, EFV= efavirenz, TDF= tenofovir, FTC= emtricitabine, LPV/r= lopinavir/ritonavir;* [4]*ART-related conditions: AZT= zidovudine, D4T= stavudine*

4.3.3 NCD comorbidity

Fifty-five per cent (n = 268) of folders reviewed had documented information on comorbidities, of which 11% were NCD comorbidities. Of these, the most prevalent NCDs documented were chronic respiratory diseases (asthma, bronchitis, COPD (60%)) and mental health disorders (depression, anxiety or other mental health conditions (37%)) (see **Table 4.2**). Despite this, only one participant was documented as receiving asthma treatment. Other documented NCD treatment in the previous twelve months was for high blood pressure, psychosis, and high cholesterol/ triglycerides.

4.3.4 NCD risk

NCD risk factors were not routinely captured in patient folders. In terms of NCD risk factors documented, 4% were current smokers or had a history of smoking, and 3% used alcohol, drugs or other substances. Only 62% of folders reviewed had documented anthropometric data (height and weight). Of these, 48% of patients were overweight or obese (26% and 22% respectively), and 10% were underweight. Fifty-nine per cent of folders reviewed had a documented blood pressure. Of

these, the majority (73%) were normal (< 130/85 mmHg), 14% had elevated blood pressure, and 13% showed signs of hypertension (SBP > 140 mmHg or DBP > 90 mmHg).

Table 4.2: NCD comorbidity, general medical information and health promotion interventions of AYLHIV aged 10 - 24 years receiving ART across Cape Town

	Characteristic	N= 491[1]	n (%)[2]
Comorbidity Information		268 (55%)	
NCD diagnosis		30 (11%)	
	Depression, anxiety or other mental health conditions		11 (37%)
	Bronchitis, lung disease, asthma or other chronic respiratory disease[3]		18 (60%)
	Cancer		1 (3%)
NCD treatment		4 (1%)	
	Asthma treatment		1 (25%)
	High Blood Pressure treatment		1 (25%)
	Antipsychotic medication		1 (25%)
	High cholesterol/ triglycerides		1 (25%)
NCD risk factors		305 (62%)	
	Smoking: current or history of smoking		11 (4%)
	Alcohol, drugs or other substance abuse		9 (3%)
Body Mass Index (BMI) kg/m²		305 (62%)	
	Underweight: BMI< 18.5		30 (10%)
	Normal weight: BMI 18.5- 25		129 (42%)
	Overweight: BMI 25- 30		80 (26%)
	Obese: BMI ≥30		66 (22%)
Blood Pressure in mmHg[4]		289 (59%)	
	Normal: SBP < 130 and DBP < 85		210 (73%)
	Elevated BP: SBP 130-139 / DBP 85-89		41 (14%)
	Hypertension: SBP > 140 / DBP > 90		38 (13%)
General medical information			
Contraception *(females: n=364)*			18 (5%)
Family history		29 (6%)	
	Tuberculosis		20 (69%)
	Diabetes		4 (14%)
	High blood pressure		2 (7%)
	Alcoholism		2 (7%)
	Cancer		1 (3%)
Other conditions		52 (11%)	
	Pregnancy		31 (60%)
	Trauma- injury and violence		6 (11%)
	Epilepsy		5 (10%)
	Learning difficulties		5 (10%)
	Failure to Thrive		5 (10%)
Non-HIV infectious diseases		185 (38%)	
	Tuberculosis		114 (62%)
	Sexually Transmitted Infections		40 (22%)
	Scabies		12 (6%)
	Pneumonia		9 (5%)

	Herpes Simplex Virus		5 (3%)
	Meningitis		5 (3%)
Non-ARV medications prescribed in the last 12 months		135 (27%)	
	TB prophylaxis		30 (22%)
	Cotrimoxazole		19 (14%)
	STI treatment		23 (17%)
	Antibiotics		44 (33%)
	Steroids		16 (12%)
	Antivirals		3 (2%)
Health Promotion		93 (19%)[5]	
HIV-related	Disclosure counselling		9 (7%)
	Adherence counselling		11 (9%)
NCD-related	Alcohol counselling		14 (11%)
	Mental health counselling		13 (10%)
	Healthy diet or weight counselling		12 (9%)
	Smoking counselling		11 (9%)
	Substance abuse counselling		2 (2%)
	Diabetes screening		1 (1%)
Sexual and Reproductive Health	Family planning		14 (11%)
	Basic antenatal counselling		14 (11%)
	Postnatal care & Infant feeding counselling		10 (8%)
	Pap smear & Breast examination		6 (5%)
	Safe sex counselling		2 (2%)
	Medical male circumcision		2 (2%)
Other Health Promotion	Hygiene counselling		4 (3%)
	Physiotherapy/Occupational Therapy		2 (2%)

[1] Denominator= 491, unless otherwise indicated in this column.
[2] Percentages may not total 100 due to rounding.
[3] Includes asthma, chronic obstructive pulmonary disease, and other respiratory conditions.
[4] SBP= Systolic Blood Pressure and DBP= Diastolic Blood Pressure.
[5] Total interventions > 93 as some individuals had more than one form of health promotion documented.

4.3.5 General medical information

Family history was documented in 6% of the folders reviewed. Of these, the most common condition documented was tuberculosis (69%), followed by diabetes (14%), high blood pressure (7%) and alcoholism (7%). Other non-infectious conditions were documented in 11% of the folders reviewed. These conditions ranged from current/ previous pregnancy (60%), experiences of trauma due to injury or violence (11%) and epilepsy, learning difficulties (10%) and failure to thrive (10%). There were isolated cases reported of peripheral neuropathy, hearing loss, impetigo, severe dermatitis and lymphadenopathy.

4.3.6 Non-HIV infectious diseases and treatment

Thirty-eight per cent had non-HIV infectious diseases on record, of which tuberculosis was the most documented infectious disease. Of the 38% with infectious comorbidities reported, 62% had been diagnosed with tuberculosis, 22% with an STI, and 6% had a history of scabies. Five per cent had been diagnosed with pneumonia as an infant or continued to experience severe recurrent bacterial/ viral pneumonia (not PJP). Herpes simplex virus and meningitis were reported in 3% of the folders. Other non-ARV medications prescribed in the last 12 months (27%) were TB prophylaxis (22%), antibiotics (33%), STI treatment (17%), steroids (12%), antiviral medication (2%) and contraceptives (4%).

4.3.7 Health promotion interventions

Twenty-six per cent of participants had a documented health promotion intervention, ranging from HIV- and NCD- to sexual and reproductive health-related interventions. These interventions are usually offered by lay counsellors and social workers (outside of standard of care) after an adolescent has been referred by a health worker for additional support. These include interventions such as adherence counselling for those defaulting treatment, alcohol and substance abuse counselling and family planning for adolescent girls. Seven per cent received disclosure counselling to facilitate full disclosure of their HIV status, and 9% underwent adherence counselling (**Table 4.2**). For NCD-related health promotion, 13% received alcohol or substance abuse counselling, 10% received mental health counselling, 9% were advised on healthy weight or diet, and 9% were counselled about smoking tobacco. One single case was documented of a diabetes screening intervention. Eleven per cent underwent family planning or basic antenatal care counselling each, while 5% were referred for a pap smear or breast examination. Medical male circumcision and safe sex counselling were documented in 2% of the folders. Other health promotion interventions documented were hygiene counselling (3%) and physiotherapy/ occupational therapy (2%).

4.4 Discussion

This study describes documentation of NCD and NCD risk screening and health promotion in HIV-infected adolescents and youth receiving ART in an urban setting in South Africa. We found that only 55% of the folders reviewed had any information on other comorbidities, and 62% had risk factor information. Of these, 11% were NCD comorbidities ranging from mental health conditions to chronic

respiratory diseases. A key finding of this study is the lack of data on NCD and NCD risk captured as part of clinical care of adolescents with HIV. Poor documentation and screening of NCD risk factors for most participants in our study demonstrate a missed opportunity for detecting comorbidity and NCD risk in primary health care and for early intervention in AYLHIV, who represent a substantial population and are less inclined to seek regular or preventive care. Early identification and intervention to modify behaviour would prevent a costly future epidemic of NCDs and avert morbidity and mortality due to NCDs [447].

Data paucity notwithstanding, our results highlight evidence of co-existing NCD multimorbidity and NCD risk factors (overweight and obesity, elevated BP and smoking, alcohol and substance use) in AYLHIV. A similar study in the US conducted a retrospective chart review in HIV-positive children and adolescents aged 2- 25 years and found an 18% prevalence of high blood pressure [165]. There were significant associations with other medical comorbidities and risk factors such as tobacco exposure and male gender in that study. The authors highlighted that the life-long cardiovascular risks associated with HIV infection and its management call for closer monitoring and possibly treatment of elevated BP in this population [165]. In another study conducted in Cape Town, adults in similar peri-urban informal settings as our study demonstrated that 19% of HIV-infected patients on ART were on treatment for another chronic disease (diabetes, tuberculosis or hypertension), with 77% and 17% of them receiving anti-hypertensive and diabetic treatment respectively [144].

Previous studies in healthy young people have shown prevalence rates of overweight and obesity of 23% to 7%, respectively [136] and hypertension/elevated blood pressure rates of 6.7% in respondents in the 15-24-year age group [471]. While these conditions' reported prevalence was substantially higher in this study's HIV cohort, the accurate prevalence of these NCD risks cannot be estimated from our study due to the limited documentation. However, these previous surveys in South Africa demonstrate already elevated risk factors for NCDs in adolescents in the general population. Given the data from adults with HIV in South Africa, there is an indication that the prevalence of NCD risk in adolescents with HIV is potentially higher than their healthy counterparts [144, 191], strengthening the argument for targeted NCD prevention efforts in this population group to prevent multimorbidity. Given that some NCDs (such as mental disorders) and many NCD risk behaviours such as substance abuse also influence HIV control, our finding that 69% of participants were virally suppressed further emphasises the need for strengthened integrated health systems.

In this study, we noted that only 19% had a documented health-promoting intervention, ranging from alcohol or substance abuse (13%) to healthy weight or diet (13%) and mental health counselling (10%). Family history of an NCD has been shown to be a significant risk factor for NCD in South Africa [87] and should form an essential component of NCD risk assessment. In this study, only 6% had a documented family history recorded. Other upstream determinants of NCD risk, such as the social environment, were not noted.

As demonstrated in adult patients, chronic disease care requires a comprehensive, holistic approach that integrates treatment and prevention of multiple conditions [472, 473]. Such an approach, integrating NCD primary prevention with HIV care, will be an essential component of strategies to reduce multimorbidity and the future burden of NCDs in high HIV-burden settings. In South Africa, strategies like the ICDM and Chronic Disease Clubs, responding to the observed epidemiological transition and rise of HIV/NCD multimorbidity, are aimed at integrating chronic (infectious and non-communicable) disease programs using established and existing frameworks to expand access to primary care that includes services for both HIV and NCDs [229].

Pilot projects are underway in selected primary health care facilities to investigate the most effective integrated care models [474]. Early findings demonstrate provider and patient satisfaction with several dimensions of the models [474]. However, leveraging elements of HIV programs for NCDs, like hypertension management, was noted to be inadequate, in part due to malfunctioning equipment and drug stock-outs [475]. To date, these models have focused on the general adult population, with no integrated clinics for adolescents planned mainly due to a paucity of data on NCD comorbidities and NCD risk in adolescents with HIV.

As suggested by the low rate of recording of NCD risks in the clinical notes reviewed, these efforts have largely ignored adolescents and youth, focusing solely on HIV-specific outcomes, neglecting an opportunity to intervene holistically in a target at-risk population regularly accessing care. Our results demonstrate a missed opportunity to improve health and prevent multimorbidity in this important population group with unique health needs.

A key limitation of our study was the retrospective nature of data collection. We were unable to estimate the prevalence of NCD or NCD risk in this population due to the possibility of screening bias

and underreporting. Furthermore, the health promotion activities assessed are those which were documented in patient folders which may underestimate actual health promotion interventions delivered. Given the limitations of the study design, we instead set out to describe the extent to which NCD comorbidity screening, prevention and management is incorporated within existing adolescent HIV primary healthcare services as opposed to determining NCD prevalence rates in AYLHIV. Another limitation is that we could not explore determinants of NCD comorbidity due to the low number of NCD diagnoses recorded. Such information could be used to inform targeted and cost-effective approaches to NCD screening.

However, the NCD data paucity noted represents an important finding for the health system. It demonstrates limited consideration of NCD prevention in HIV care and highlights a missed opportunity for NCD prevention in a patient group regularly accessing health care. Therefore, this study was an important first step to inform future research on the epidemiology of NCD and NCD risk factors in AYLHIV.

4.5 **Conclusion**

Our data demonstrate the existence of NCD risk factors in adolescents and youth, though poorly documented, at the primary care level. These findings highlight a missed opportunity in multimorbidity prevention for AYLHIV. However, in the context of resource limitations, particularly in LMICs, cost benefit analyses will be needed to inform the prioritisation of interventions such as early screening Furthermore, studies designed to better ascertain NCD prevalence and NCD risk epidemiology in AYLHIV would provide insight into the burden of NCD comorbidity in AYLHIV. While our study focused on HIV, these findings are relevant for adolescents with any chronic condition who regularly interact with health services.

Addressing this missed opportunity would require an integrated health system. Further research is needed to inform the most effective models of care for HIV management and integrated NCD prevention to respond to communicable and NCD prevention and control effectively. In addition, intersectoral collaboration with non-health sectors incorporating upstream environmental, socio-economic and cultural determinants of NCD risk into prevention efforts are vital to multimorbidity prevention efforts, particularly in the context of rapid urbanisation. An early identification and

prevention approach to NCD control in HIV-infected adolescents and young adults is vital to turn the tide on the NCD and multimorbidity epidemic and avert the economic implications of NCDs to individuals, families and societies, whilst simultaneously improving HIV outcomes and reducing the risk of NCD in this key population group.

Chapter 5

High Prevalence of NCD Multimorbidity in South African Adolescents and Youth Living with HIV: Implications for Integrated Prevention

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5.1 Introduction

5.1.1 Global burden of NCDs and NCD risk factors

Globally, non-communicable diseases (NCDs) are the leading cause of disability and premature mortality accounting for 71% of deaths worldwide and 80.6% of years lived with disability (YLD) in 2016 [67, 68]. The largest number of NCD deaths are caused by cardiovascular diseases, followed by cancers, chronic respiratory diseases and diabetes [67]. There has been a global epidemiological transition from communicable, maternal, neonatal, and nutritional deficiency (CMNN) diseases to patterns of disease and mortality dominated by NCDs and injuries [476]. This transition is driven by multiple interrelated factors, including population growth, ageing, nutritional transition and increased urbanisation.

Globally one in four adults are not sufficiently physically active, and physical inactivity accounted for 1 in 10 deaths worldwide [75] and 34.6 million disability-adjusted life years (DALYs) in 2016 [76], making physical inactivity the fourth leading risk factor for mortality globally [72]. Unhealthy diets contribute to a range of NCDs, specifically diabetes, cancers, and cardiovascular diseases. Dietary risk factors - low intake of fruits, vegetables and whole grains; high sodium intake and added sugar from processed foods and sugar-sweetened beverages - are significant contributors to mortality and DALYs globally [77]. In 2017, one in five global deaths were associated with unhealthy diets [77]. Depression and anxiety disorders are also important leading causes of disability worldwide [101] and, together with substance use disorders, are the largest contributors to disability in young adults [68]. Mental health disorders commonly co-occur with NCDs and NCD risk factors like tobacco use, unhealthy diet and physical inactivity, while the harmful use of alcohol has been shown to cluster in people with mental disorders [103].

NCDs affect all countries, but people in low- and middle-income countries disproportionately face premature mortality and disability due to NCDs with 85% of premature deaths of people between the ages of 30 and 69 years occurring in LMICs[9]. In 2017, the burden of NCDs in sub-Saharan Africa (SSA) was higher than the global average and was almost equivalent to the total burden associated with CMNN diseases [14]. South Africa, an upper-middle-income country, faces a quadruple disease burden with high levels of HIV/AIDS and tuberculosis (TB); CMNN diseases and deficiencies; NCDs, and injuries and trauma [83]. In 2016, NCDs accounted for 57.4% of deaths in South Africa, of which

60% were premature (under 70 years of age). CMNN diseases accounted for 31.3% of deaths and injuries, 11.2% of deaths [468].

5.1.2 Rising levels of NCD risk factors with increased urbanisation in sub-Saharan Africa

NCD risk factors are increasing in SSA, where NCDs are emerging in the context of rapid urbanisation, contributing to unhealthy diets and sedentary behaviour, especially amongst the poor residing in urban settings [79]. Most adults in SSA are exposed to at least one risk factor for NCDs, including tobacco, harmful alcohol use, unhealthy diet, physical inactivity, obesity, or high blood pressure [80]. Epidemiological analyses from 1980–2014 show that age-standardized average body mass index (BMI) and diabetes prevalence have increased steadily across Africa, at least as steeply as the global average [82]. In South Africa, the prevalence of NCD risk factors has increased over the last two decades. For example, the prevalence of overweight and obesity among adult South African women increased from 56% to 68% between 1998 and 2016 [85]. One in three South African adults has hypertension, 16.2% smoke daily [87], and 18.3% engage in heavy episodic drinking [88]. South African adults aged 15 years and older who consume alcohol account for the fifth-highest consumption rate of absolute alcohol in the world [88].

5.1.3 Life course approach to NCD prevention

Young people are not immune to the scourge of NCDs. Of the global NCD deaths recorded in 2016, an estimated 1.7 million (4% of NCD deaths) occurred in people younger than 30 years [477]. Adolescents in SSA are growing up in a time of epidemiological and nutrition transition. Furthermore, many NCD-related risk factors are initiated or reinforced during adolescence, and many adult illnesses have been identified to have roots in childhood and adolescence [1], which makes it a critical period for intervention to prevent future disease.

5.1.4 NCD risk factors in adolescents and youth in South Africa

South Africa has the highest prevalence of childhood and adolescent overweight and obesity in sub-Saharan Africa (19% of boys and 26% of girls under 20 years), rivalling that of many high-income countries [86]. Overweight and obesity rates have increased steadily, especially amongst adolescents

residing in urban settings [478]. Paradoxically, South Africa faces a double burden of malnutrition, with undernutrition and overweight or obesity coexisting in the same populations and even within the same households [478]. Moreover, over 40% of young people have insufficient physical activity levels, with significantly more inactivity in females compared to males [136]. Despite these data highlighting the existing burden of NCD risk factors among adolescents and youth in South Africa, there is limited evidence on effective strategies to intervene for NCD prevention, particularly as adolescents and youth are less likely to routinely present in the health care system [479]. This raises the potential for primary and secondary prevention of NCDs among adolescents who do regularly have contact with the healthcare system by virtue of having a chronic disease such as HIV.

5.1.5 HIV and NCD multimorbidity and health system implications

Of the 1.6 million adolescents (10 -19 years) reported to be living with HIV worldwide in 2018, 19% are South African [3]. Adolescents and youth living with HIV (AYLHIV) in South Africa bear a disproportionate burden of the HIV epidemic due partly to paediatric cohorts of mother-to-child transmission reaching adolescence [166] and increased sexual transmission amongst young adolescent girls associated with gender inequality and poverty [480].

AYLHIV face elevated health risks resulting from both infection with HIV and the complications of long-term antiretroviral treatment (ART) [291, 481]. Inflammation resulting from HIV replication causes vascular abnormalities, which can result in heart disease, stroke, altered glucose metabolism, malignancy, and neurologic disease [145, 146]. Evidence on an increased risk of comorbidities, including osteoporosis, metabolic syndrome, cardiovascular and renal diseases, was initially documented in adult populations living with HIV, but similar patterns have since been identified in paediatric and adolescent cohorts [147-149]. An excess burden of NCD risk factors has also been documented in people living with HIV (PLHIV) compared to the general population [232]; 49% are insufficiently physically active [244], 40–70% are current smokers [248, 482] and 37–66% are current drinkers [483, 484]. Almost half (46%) of adult patients attending HIV clinics in Cape Town engaged in hazardous or harmful alcohol use, and 15% had problematic drug use [259].

In addition to physical health risks, AYLHIV face several psychosocial challenges associated with living with a highly stigmatized communicable disease [153]. HIV/AIDS in Africa occurs in the context of orphanhood, poverty and inconsistent guardianship, resulting in an elevated risk of mental health problems [154-156]. AYLHIV are known to experience emotional and behavioural problems at higher rates in comparison to the general population, including post-traumatic stress disorder (PTSD), depression, severe anxiety and neurocognitive deficits, which affect their school performance, career prospects, relationships and autonomy [153] and increase their susceptibility to risk-taking behaviours [485-487].

To date, NCD prevention efforts have focused on adults, despite evidence of an increasing burden of NCDs and NCD risk among PLHIV occurring at younger ages [144, 232, 233]. In a previous study conducted in Cape Town, we demonstrated that, despite existing NCD comorbidity and risk factors in AYLHIV, there was limited NCD screening and health promotion in adolescent and youth HIV healthcare services [488]. While a few studies have explored alcohol and tobacco use [489-491] in AYLHIV in SSA, there is overall data paucity on the burden of NCDs and other NCD risk factors in this population group in Africa. With the first cohorts of AYLHIV now entering adulthood and the move towards more comprehensive health services aimed at improving the quality of life of PLHIV, questions remain on the prevalence of NCD comorbidity and NCD risk factors in AYLHIV and the best way to ensure holistic adolescent health and well-being. Therefore, we set out to investigate the prevalence of common NCDs and associated NCD risk factors, as well as knowledge on health risks among AYLHIV accessing primary health care in Cape Town.

5.2 Methods

5.2.1 Study setting and population

This was a cross-sectional study of adolescents and youth living with HIV aged 15-24 attending primary care health facilities in Cape Town. As previously noted, the study was conducted in Cape Town, the second biggest metropolitan city in South Africa, with an estimated population of 4.2 million people [362]. In 2016, adolescents and youth aged 15 - 24 years comprised 16.3% of the population in the Western Cape province, where Cape Town is located [465]. Cape Town is a city

undergoing rapid nutritional and epidemiological transition with an increasing prevalence of NCDs and high rates of associated risk factors like hypertension, overweight, obesity and smoking. The 2012 South African National Health and Nutrition Examination Survey (SANHANES) revealed that over 50% of people in the Western Cape were overweight or obese (43% males and 62.4% females), a third were smokers, and two-thirds were physically unfit [87]. The Western Cape also has the highest rates of tobacco smoking and alcohol use nationally for both men and women [87].

There has been an increasing prevalence of NCDs in the province, with a hypertension prevalence of 30% and diabetes prevalence of 11% recorded in 2013 [87]. Provincial HIV prevalence in women and men aged 15-49 years was estimated at 18% in 2016 [85]. However, HIV prevalence amongst antenatal care (ANC) public sector clients within Cape Town Metro was slightly higher at 21.6% in 2015 [469] and as high as 34.3% in Khayelitsha sub-district in 2012 [470]. NCDs and HIV are ranked among the top causes of premature deaths in Cape Town [449], with the top five causes of death in 2016 ranked as DM, HIV, ischaemic heart diseases, cerebrovascular diseases, and TB [468]. NCDs alone accounted for approximately two-thirds of all deaths in the Western Cape in 2015 and 50% of the premature mortality burden [492].

The City of Cape Town delivers primary health care through four legislated substructures: Khayelitsha /Eastern, Mitchells Plain/Klipfontein, Western/Southern and Northern/Tygerberg [466]. Recruitment and data collection took place at six public-sector HIV clinics, with 1-3 clinics selected within each of the four sub-structures (see **Figure 3.2**). These facilities serve patients living in peri-urban, high-density, low-income townships, collectively known as the Cape Flats, in the south-eastern part of Cape Town, consisting of approximately 583 380 predominantly black African and 'coloured' mixed-ancestry populations [392]. The area consists of a mix of formal and informal dwellings, with 56% of the population residing in formal dwellings, high unemployment levels (29%) [392], and approximately 63% of households falling within the low-income bracket [467].

5.2.2 Study design and sampling

The sample size was determined using prevalence estimates from SANHANES-2012 for the 15 - 24 years age group [87]. The confidence level was set at 95%, with a 5% degree of precision, and an

obesity prevalence of 5.6%. The minimum required sample size was 82, and the final sample size determined to accommodate a non-response rate of 5% was 86 participants.

Prior to data collection, we conducted stakeholder engagement, liaising with facility managers and adolescent healthcare providers. Each facility has different schedules and models of HIV care for AYLHIV, necessitating customised recruitment plans. We previously described the method used to estimate the number of AYLHIV accessing care at each facility [488]. The AYLHIV population size was used to guide the proportion required for recruitment at each facility. Facilities in the Eastern and Khayelitsha substructure had the biggest number of adolescents and youth receiving care and therefore had the biggest number of participants. Given the challenges of recruiting adolescents, a convenience sampling approach was used in order to reach the required sample size, recruiting all who showed an interest in participating. Participant recruitment commenced in March 2019 after ethical clearance (HREC ref no: 520/2017) and approval from Provincial and Local government Departments of Health. Recruitment and study procedures were then conducted after gaining written informed consent and assent (for participants under 18 years) at six facilities until January 2020 (**Figure 3.2**). A total of 176 adolescents and youth were recruited and invited to participate, of which 92 attended the follow-up appointment and were successfully interviewed, yielding a response rate of 52%.

5.2.3 Study procedures

5.2.3.1 Informed consent process

Informed consent and assent forms were developed in English and translated into two local languages; isiXhosa and Afrikaans. At the first encounter, participants were given information sheets and a detailed overview of the study procedures and invited to participate during routine clinical visits. Prior to enrolment, those aged less than 18 years received the informed consent and assent forms in order to gain parental or caregiver approval and a return date was scheduled on which the interview would take place (usually the date of their next clinic appointment). A flowchart of the recruitment process is shown in **Figure 3.3.** Teach-back questions on the nature of the study were incorporated into the assent form to ascertain adequate understanding. Those of legal age (18- 24 years) were immediately enrolled after signing the consent forms, and a future time was scheduled for their interview if they were unable to participate on the same day.

On the scheduled appointment date, participants first underwent a 30-minute physical examination before completing a partially assisted self-administered questionnaire using electronic forms on a handheld Android tablet. The questionnaire, which was administered in English, took approximately 90 minutes to complete and included questions on socio-demographics, self-reported health status, family history, household characteristics, mental health, self-reported physical activity and dietary practices, use of alcohol, tobacco and illicit substances, and nutritional knowledge.

5.2.3.2 Physical examination

The candidate and the study coordinator carried out physical examinations according to the study protocol standard operating procedures. Height and weight were measured using a sliding balance weight-and-height measuring scale with participants barefoot and wearing light clothing. Height was measured to the nearest 0.5 cm and weight to the nearest 0.1 kg. Waist and hip circumference were measured using stretch-resistant measuring tape according to the WHO STEPS protocol [421]. Readings were taken to the nearest 0.1 cm. Two measurements were taken and recorded on the electronic form, of which an average was computed during analysis. For weight, height and waist and hip circumference, if the two readings differed by more than 100g, 2cm and 0.1cm, respectively, a third measurement was taken, and the two closest measurements were recorded.

Sitting blood pressure (BP) and pulse were measured using a ROSSMAX automatic blood pressure monitor (*Rossmax (Shanghai) Incorporation Ltd*). Two readings were taken at least two minutes apart, and the average was computed. The procedures were repeated in instances where there was a significant difference between readings (more than two units), and the closest two readings were recorded.

Participants were asked whether they had a family history of diabetes or experienced any of the following symptoms over the past three months: frequent urination, increased thirst, unexplained weight loss of more than 1.5 kg in the last month, unexplained fatigue and blurry vision. In addition, random blood glucose was measured in those with a family history or reported symptoms using a point-of-care (POC) glucometer with reactive test-strips (*Glucocheck Evolve ® Homemed Pty*).

Respiratory symptom screening was conducted, determining any difficulty breathing or shortness of breath, prolonged cough for more than two weeks with sputum, chest tightness, noisy breathing (wheezing or whistling in the chest) or a history of asthma. Respiratory volume was measured in those reporting respiratory symptoms without known asthma or chronic respiratory conditions using a hand-held peak flow meter with disposable mouthpieces. Several repeated attempts were made in accordance with standard guidelines [422]. A further two attempts were made if the variation between attempts was greater than 20 litres/minute [404]. The two largest values were then recorded and the average computed.

5.2.4 Data collection tools and definitions of composite measures

5.2.4.1 Structural and household risk factors

Adolescence is often categorized into three primary developmental stages: early adolescence (10–14 years), middle adolescence (15–17 years), and late adolescence/ young adulthood (18–24 years) [401]. For the purposes of this study, we categorized participants into four age groups in line with these stages and further sub-divided the older age group into quartiles as follows: 15–17, 18–19, 20–21 and 22–24 years.

Questions on socioeconomic status were derived from the 2011 South African Census Questionnaire's subset of variables used to measure multidimensional poverty [402]. The Youth Multidimensional Poverty Index (YMPI) is a multidimensional individual-level measure of poverty comprised of 11 weighted indicators in five dimensions: educational attainment, general health and functioning, living environment, household assets and employment, using the method by Alkire and Santos [271]. Each indicator is associated with a deprivation cut-off that defines whether a young person is deprived in that area [403]. A more detailed explanation of how the YMPI score is derived is given in **Section 3.7.2.4.1.1**. An individual is identified as multidimensionally poor – MPI poor– if deprived in a third or more weighted indicators, with a composite score of 33.3% or more [271].

Food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS) score. The HFIAS score is a continuous measure of the degree of food insecurity experienced in a household in the past month [428]. Participants were categorized as living in food secure, mildly–, moderately–,

or severely food insecure households depending on the severity and frequency of food insecurity experiences according to the HFIAS protocol [427].

5.2.4.2 Behaviour and knowledge

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ) short form using the last seven days self-administered format [405] and graphic images of different kinds of vigorous and moderate-intensity forms of physical activity as an aid. The IPAQ has been validated in youth and adults in South Africa [406]. We used the Ainsworth et al. scoring algorithms to derive an average metabolic equivalent (MET) intensity level score for each type of physical activity: vigorous, moderate, walking and cycling [407]. Physical activity levels were further categorised according to the IPAQ scoring protocol into low, moderate and high [408]. Insufficient physical activity was defined as a score below 600 MET minutes/week according to the World Health Organization (WHO) recommendations [409]. The presence or absence of sedentary behaviour was dichotomized as spending three or more hours per day watching television, playing computer games, talking with friends or other sitting activities according to the Global School-based Student Health Survey criteria [410].

Dietary intake was assessed using a 23-item food frequency questionnaire (FFQ) adapted from the Health Behaviour in School-aged Children Survey [411]. Participants reported their 'usual' consumption frequency of 23 different food groups, with response categories ranging from 'never' to 'more than once a day'. The FFQ has been found to have moderate reliability and acceptable validity for assessing the consumption of most food groups among adolescents [412]. We estimated the proportion who ate fresh fruits and vegetables daily (once or more than once a day) and frequently (on four or more days in the previous week) and the proportion of respondents who reported daily consumption of SSBs, deep-fried foods, fast foods, salty snacks, and processed meats. Skipping breakfast was defined as eating breakfast on 0–2 days/week; semi-skipping, 3–4 days/week and not skipping, 5–7 days/week.

Tobacco, alcohol use and substance use were assessed using questions from the South African Youth Risk Behaviour Survey conducted in 2011 [136]. Heavy episodic or binge drinking was defined as drinking five or more drinks in succession on one or more days in the preceding month. Risky drinking

was defined as binge drinking or underage drinking (any alcohol consumption below the legal age of 18 years).

Nutritional knowledge was assessed using a revised form of the General Nutrition Knowledge Questionnaire (GNKQ-R) [413]. The GNKQ-R has demonstrated internal consistency and is a valid and reliable measure of nutrition knowledge among young people [413]. A nutritional knowledge score was generated by totalling correct answers in four nutrition domains. The maximum possible score was 88; 18 for questions on "dietary recommendations", 36 for questions on food groups, 13 for "healthy food choices", and 21 for "associations between diet and disease". We computed the average nutrition knowledge score and compared the mean scores for each nutrition domain by gender and age group comparable to a previous study of South African adults [414].

5.2.4.3 Comorbidities

Respiratory disease was defined as a self-reported pre-existing diagnosis of asthma, tuberculosis, bronchitis, or another lung disease. Furthermore, experiencing any of the following symptoms in the preceding three months was characterised as the presence of respiratory symptoms: prolonged cough with sputum for more than two weeks, chest tightness, shortness of breath, difficulty breathing, or having an abnormal peak flow reading. Similarly, diabetes was defined either as i) a pre-existing self-reported diagnosis; ii) a random blood glucose reading of > 7 mmol/l and having a family history of diabetes; or iii) random blood glucose reading of > 7 mmol/l and experiencing any of the following diabetes-related symptoms over the past three months: frequent urination, increased thirst, unexplained weight loss of more than 1.5 kg in the last month, unexplained fatigue, blurry vision.

Depression and psychological distress were defined using symptom screening questions from the Centre for Epidemiological Studies Short Depression Scale (CESD- 10) [415, 416] and the Kessler Psychological Distress Scale (K10) [417]. Both tools have been validated in South African HIV-positive populations [205, 418] and in adolescents and young adults [419]. The CESD-10 scale assesses depressive symptoms in the past week, while the K10 scale assesses symptoms of distress during the previous 30 days. Depression was defined as a CESD-10 score equal to or above 10 [415], and the likelihood of psychological distress was categorized according to the K10 score: K10 <20 mentally

well; K10 20-24 likely to have mild psychological distress; K10 25-29 likely to have moderate psychological distress; K10 30 – 50 likely to have severe psychological distress [420].

5.2.4.4 Measured clinical signs

Overweight and obesity were categorized using standard BMI categories and cut-offs for central obesity. The criterion used to identify overweight and obesity in children and adolescents using growth charts corresponds to the criteria used for adults. Thus we opted for the latter for ease of comparability [423]. The abdominal obesity cut-off point for a high waist circumference (WC) was ≥ 102 cm in males and ≥ 88 cm in females and a waist-hip ratio (WHR) > 0.85 for females and > 0.90 for males [421]. The waist-to-hip ratio was calculated by dividing the waist circumference by the hip circumference in centimetres rounded to two decimal places. A threshold value of 0.5 for the waist-to-height ratio (WHtR) was used as a measure of central obesity, calculated by dividing the waist circumference by the height in cm [424]. Blood pressure (BP) was categorized according to the South African Hypertension practice guidelines [425]: Normal (systolic BP, SBP < 130 mmHg and diastolic BP, DBP < 85 mmHg); elevated blood pressure (SBP 130 – 139 mmHg or DBP 85 – 89 mmHg) and hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg) or a self-reported pre-existing diagnosis of hypertension.

5.2.5 Data management and statistical analysis

Data from the physical examination and self-administered interviews were captured into an electronic form on an Android device using a unique anonymous study ID for each participant. Data was synced to a password-protected server only accessible to the study team at the end of each day. Data were then imported into Stata 14.0 (*StataCorp, College Station, Texas, USA*) for cleaning and statistical analyses.

Visual data exploration and Shapiro-Wilk's tests were used to test for the normality of variables. All data were analysed and reported by sex and age group. Demographic and socioeconomic variables were described using summary statistics (frequencies, percentages, median and interquartile range (IQR)). Characteristics between sexes and age groups were compared using Pearson's $\chi 2$ and Fisher's exact tests for categorical measures. The Wilcoxon-Mann-Whitney test was used to compare

medians between groups, and the Kruskal-Wallis test was used for comparing continuous measures in more than two groups. Point prevalence estimates for comorbidities and symptoms were described, and their exact binomial 95% confidence intervals were computed. All tests of significance were two-tailed and performed at the 5% significance level ($p < 0.05$).

5.2.6 Ethical considerations

This study was approved by the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (HREC ref no: 520/2017). Approval was also granted by the Western Cape Government and City of Cape Town Departments of Health to access facilities for medical records and participant enrolment. Parents or legal guardians permitted their children to participate in the study, and participants provided informed assent (or consent if 18 years or older) for participation in the study. Participants received reimbursement for transport costs.

5.3 **Results**

5.3.1 Socio-demographic characteristics and household risk factors

A total of 92 participants completed study procedures, 76% of whom were female. The median age was 20.5 years (IQR 18.9–22.9), and the majority of our respondents (60%) were in the young adulthood stage between 20–24 years old (**Table 5.1**). Over half (58%) were enrolled in school/college/university or other tertiary education or training. The majority lived with a biological parent or a relative, and 2% reported living with non-family members in foster care or children's homes. More than a quarter of female respondents reported ever being pregnant (28%) compared to only 5% of male participants reporting ever impregnating someone.

5.3.1.1 Multidimensional poverty

Overall, 44% of participants could be considered multi-dimensionally poor as they were deprived in a third or more of the five dimensions of MPI indicators, as shown in **Table 5.1**. More than half were living-environment deprived, with more than one-third living in informal housing, a quarter living in asset-deprived households, 28% living in households that do not use electricity, gas or solar power

for heating and 17% living in households without piped water available on site. In addition, almost a quarter of our respondents were deprived in the educational attainment dimension, 27% were neither in education (school/tertiary institute), employment or training (NEET) (median age 20.8 (IQR 19.8–23.3 years)), while 15% were living in households with no employed adults of working age. While 3% were deprived in both economic indicators, i.e. they were NEET and living in households with no employed adults.

5.3.1.2 Food insecurity

Seventy per cent of participants were living in food-insecure households, with 38% considered as severely food insecure: either having to cut back on meal size, number of meals or going a whole day and night without eating due to a lack of resources or receiving relief food in the last 30 days.

5.3.2 Behaviour and knowledge

5.3.2.1 Physical activity

Overall, a third of respondents had insufficient weekly physical activity levels, 41% had moderate levels, and 27% had high levels of physical activity [408]. A greater proportion of males had high physical activity levels than females (44% versus 22%). The total median MET-minutes of physical activity a week (total of all activities including active transport) was higher for males (2504.25 minutes) compared to females (1173 minutes), but this was not statistically significant **(Table 5.2**). The youngest age group reported the highest rates of vigorous-intensity physical activity. Over two-thirds of all participants reported using active transport in the preceding week (mostly walking or cycling to school/work for at least ten minutes continuously). Almost half of the respondents (49%) spent more than three hours sedentary during a typical day, with no difference in sedentary behaviour by gender.

5.3.2.2 Dietary intake

Overall, less than a third of respondents ate fruits and whole grains daily (**Table 5.2**). Significantly more males ate fruit frequently compared to females (p= 0.028). More than half ate vegetables daily (either dark green, orange or other vegetables). Younger adolescents had the lowest daily

consumption of fruits, vegetables and whole grains compared to older age groups. A third of respondents had a high dietary intake of sugar, either reporting drinking SSB daily (including regular soft drinks, energy drinks and sports drinks) or eating sweets and cakes daily. SSB consumption was similar across gender and age groups. Older adolescents aged 18–19 years had the highest daily consumption of deep-fried and fast foods compared to other age groups (see **Table 5.3**). Daily dietary intake of fruits, vegetables, wholegrain, SSBs, deep-fried foods, sweets and cakes and fast foods did not vary by educational attainment or by overall MPI poverty status. Daily SSB intake differed by NEET status, with a greater proportion of those in education, employment or training consuming more SSBs daily compared to those who were NEET *(p= 0.002)*.

5.3.2.2.1 Meals eaten outside the home

Two-thirds of respondents ate at least one meal that was prepared outside the home in the previous week. Those who ate food prepared outside the home ate a median of two takeaway or sit-down meals in the past week (IQR 2–4 meals). Males had more variability in meals consumed that were prepared outside the home compared to females; median two meals (IQR 1–10 meals) versus (IQR 2–3 meals) respectively.

5.3.2.2.2 Breakfast

Over half of participants (58%) reported eating breakfast on at least five days in the previous week, 21% ate breakfast on 3–4 days of the week, and 21% reported skipping breakfast or eating breakfast on less than two days in the previous week. Breakfast skipping did not differ significantly by gender or age. Skipping breakfast also did not differ by educational attainment or NEET status, but overall, more of those who were MPI poor semi-skipped breakfast (i.e., skipped breakfast more frequently during the week).

5.3.2.3 Nutrition knowledge

Overall, adolescents' mean general nutrition knowledge score was 33 out of a total of 88 points (37.5%). Knowledge of dietary recommendations was the highest-scoring domain with an average of 44%, while knowledge of healthy food choices was the lowest-scoring domain at a 32% average score.

There were no significant differences in nutrition knowledge amongst adolescents by sex and age group (see **Figure 5.1**).

5.3.2.4 Tobacco use and exposure

Significantly more males (58%) than females (30%) reported ever smoking cigarettes. The median age when participants first smoked a cigarette was 16 years (IQR 15–17 years). Overall, 30% had smoked cigarettes in the past month: 9% reported smoking daily while 21% smoked less often than daily (37% males and 16% females). The oldest age group (22–24 years) reported the highest rates of ever smoking (41%), while the prevalence of daily smoking was highest for those aged 18–19 years (13%). In the youngest age group of 15–17-year olds, 45% reported smoking cigarettes in the past month (**Table 5.5**). Overall, 21% reported using tobacco products other than cigarettes (including hookah pipes and vaping) during the past month, with 6% reporting using these products on six or more days in the past month. Those in the youngest age group reported the most use of tobacco products other than cigarettes in the past month; 45% compared to less than 30% in the other age groups. Almost half the participants (45%) reported being exposed to secondary smoke from people who smoked in their presence in the past week. More than half (15/26) of current smokers also drank alcohol in the preceding month.

5.3.2.5 Alcohol use

Over two-thirds of participants reported ever drinking alcohol (68%). Overall, the median age of first alcohol use was 16.5 years (IQR 15–18 years) with no significant difference by gender. However, the age of first alcohol use was significantly earlier in the youngest age group, with 82% of 15–17-year-olds reporting ever drinking alcohol and a median age of first alcohol use of 14 (IQR 12–14) years. Overall, 41% had drunk alcohol in the past 30 days, and 24% reported binge drinking in the past month. Those who reported binge drinking were significantly younger (median 18.8 (IQR 16.9 – 21.5) years) than those who did not binge drink (median 21.1 (IQR 19.5- 23.4) years) (p= 0.0152). Current drinking and binge drinking did not differ by gender (see **Table 5.4**). The youngest age group (15–17 years) reported the highest rates of risky drinking: 45% had drunk alcohol in the past 30 days (underage drinking), and 55% reported binge drinking compared to less than 30% in older age groups (see **Table 5.5**).

5.3.2.6 Substance use

More than a quarter (27%) reported ever using cannabis. The median age at first cannabis use was 16 (IQR 14.5–18.5 years) and did not differ significantly by gender. The frequency of cannabis use in the past year ranged from once or twice (5%) to almost every day (6%). Participants aged 18–19 and 20–21 years reported the most frequent use of cannabis, with 13% reporting daily or weekly cannabis use each in the past year. Six participants (7%), all over 18 years old, reported ever taking "hard" drugs (cocaine, methamphetamine or mandrax); three of them reported taking hard drugs 20 or more times in their lifetime. Nine participants (10%) reported ever using inhalants such as glue, aerosols, paint thinners, petrol or benzene "to get high," and 15% reported ever using over-the-counter or prescription drugs at least once or twice "to get high". Overall, more males (53%) reported ever using any illegal drugs or substances "to get high" compared to females (31%).

5.3.3 Comorbidities and symptom screening

5.3.3.1 Pre-existing diagnosis

Overall, 35% reported a previous comorbidity diagnosis. The most common pre-existing diagnoses or previous comorbidities were TB and depression/anxiety, followed by asthma and high blood pressure. There were no significant differences in the proportions of male and female participants diagnosed with pre-existing conditions (**Table 5.6**).

5.3.3.2 Respiratory symptoms

Eleven participants (12% 95% CI: 6.3–21%) reported experiencing one or more of the following respiratory symptoms over the past three months: shortness of breath (3%), chest tightness (3%), prolonged cough with sputum for more than two weeks (7%), or difficulty breathing (3%). Peak flow measurements were done for five participants who reported respiratory symptoms but had no known asthma diagnosis. All the measurements were within the normal –green– peak flow zone.

5.3.3.3 Diabetes

Only one participant reported a previous diabetes diagnosis. A quarter of participants (95% CI: 16–35%) reported experiencing one or more diabetes-related symptoms over the past three months (see

Table 5.6). Of those with symptoms, one reported a previous diabetes diagnosis. Younger age groups (15–17 years and 18–19 years) reported more diabetes-related symptoms compared to older age groups. Overall, 27% reported a family history of diabetes (95% CI: 18–37%). None of those with reported symptoms or a reported family history of diabetes who had their blood glucose measured (n=31) had a measured random blood glucose of more than 7 mmol/L.

5.3.3.4 Mental health screening

According to the CESD-10 depression scale, 43% of participants were classified as experiencing significant depression in the past week (95% CI: 32–54%). CESD scores differed significantly by gender, with female participants more likely to report depressive symptoms compared to males (*p= 0.011)* (see **Table 5.6**). Of those with significant depression, 6/35 (17%) reported a previous diagnosis of depression or anxiety. There were no significant differences in depression scores by age. Almost half the participants reported some level of psychological distress over the past month (45%; 95% CI: 34–56%), with 8% indicating symptoms of severe psychological distress. Only 11% of those with mild, moderate or severe psychological distress reported previously being diagnosed with depression or anxiety. The prevalence of psychological distress symptoms was comparable across age groups (**Table 5.7**).

5.3.4 Measured clinical signs

5.3.4.1 Overweight and obesity

Overall, 36% of participants were either overweight (25%) or obese (11%), with significant differences by gender (see **Figure 5.6**). The median BMI for males was significantly lower than for females. A greater proportion of participants aged 18–19 years were overweight or obese compared to the other age groups (see **Table 5.7**).

5.3.4.2 Abdominal obesity

There was a markedly significant difference in the waist-hip ratio (WHR) of males and females. More than a quarter of females and no males had abdominal obesity, as shown in **Table 5.6**. Using the WHtR, 44% of females had abdominal obesity compared to 14% of males. Waist circumference

increased with age, with those aged 22–24 years having the highest waist circumference, but WHR did not differ by age. It is important to note that a quarter of participants with normal BMI had abnormal WHR or WHtR and could be classified as having abdominal obesity.

5.3.4.3 Measured blood pressure

Overall, 75% of participants had normal blood pressure, 20% had elevated blood pressure, and 5% had hypertension. The prevalence of elevated blood pressure and hypertension was higher in males than females (*p= 0.0367*). Systolic and diastolic blood pressure showed an increasing trend with age **(Table 5.7)**. The median age of those with elevated blood pressure or hypertension was 21.2 (IQR 18.8 – 22.7) years, similar to those with normal blood pressure (median 20.2, IQR: 19.0–22.8 years). Of those with elevated blood pressure or hypertension, 11 (35%) were overweight or obese, and 2 (6%) reported a previous diagnosis of hypertension (data not shown in tables).

Table 5.1: Participant socio-demographic and household characteristics by gender

Variable	Description median (IQR) or n (%)	Male: n= 22 (24%)	Female: n=70 (76%)	Total n= 92
Age (years)		20.7 (18.9 - 21.6)	20.4 (19.0 - 23.0)	20.5 (18.9- 22.9)
Adolescent stage by age group	middle adolescence: 15–17 years	3 (14%)	10 (15%)	13 (14%)
	late adolescence: 18–19 years	5 (23%)	18 (26%)	23 (26%)
	young adulthood: 20–21 years	9 (41%)	16 (24%)	25 (28%)
	young adulthood: 22–24 years	5 (23%)	24 (35%)	29 (32%)
Family structure- whom they live with	Biological parents	10 (45%)	35 (50%)	45 (49%)
	Grandparents	4 (18%)	8 (11%)	12 (13%)
	Relative (aunt or uncle)	6 (27%)	23 (33%)	29 (32%)
	Siblings	15 (68%)	33 (47%)	48 (52%)
	Non-family (foster care/ children's home)	0	2 (3%)	2 (2%)
Ever pregnant/ impregnated someone [α]		1 (5%)	19 (28%)	20 (22%)
Parity (n= 20)	0 children	0	5 (26%)	5 (25%)
	1 child	1 (100%)	13 (68%)	14 (70%)
	2 children	0	1 (5%)	1 (5%)
Current occupation/ employment status	In school/college/university/ other tertiary education	7 (32%)	37 (54%)	44 (48%)
	In training	3 (14%)	6 (9%)	9 (10%)
	Employed	5 (23%)	8 (11%)	13 (14%)
	Not in education, employment or training (NEET)	7 (32%)	18 (26%)	25 (27%)
Ever repeated a grade at school		14 (64%)	33 (47%)	47 (52%)
Days absent from school or work in past month	0 days	13 (59%)	34 (49%)	47 (52%)
	1- 2 days	7 (32%)	26 (38%)	33 (36%)
	3 or more days	2 (9%)	9 (13%)	11 (12%)
Youth multidimensionally poor[2] (n= 88)		9 (41%)	30 (45%)	**39 (44%)**

Educational attainment		4 (18%)	16 (24%)	20 (22%)
	Aged 17 – 20 & completed less than nine years of schooling	1 (5%)	2 (3%)	3 (3%)
	Aged 21 – 24 & completed less than matric or equivalent	3 (14%)	14 (21%)	17 (19%)
General health and functioning		16 (73%)	46 (67%)	62 (68%)
	Difficulty hearing	3 (14%)	13 (19%)	16 (18%)
	Difficulty seeing	7 (33%)	26 (39%)	33 (38%)
	Difficulty moving around	2 (10%)	15 (22%)	17 (20%)
	Difficulty concentrating	12 (57%)	32 (48%)	44 (50%)
	Difficulty with self-care	0	14 (21%)	14 (16%)
Living environment		0 (0 - 0.036)	0.036 (0 - 0.071)	0.036 (0 - 0.071)
	Fuel for lighting other than electricity, gas/ solar power	0	1 (1%)	1 (1%)
	Fuel for heating other than electricity, gas/ solar power	5 (23%)	21 (30%)	26 (28%)
	Fuel for cooking other than electricity or gas	0	1 (1%)	1 (1%)
	Sanitation: Household without a flush toilet	3 (14%)	5 (7%)	8 (9%)
	Water: Household without piped water on site	1 (5%)	15 (21%)	16 (17%)
	Dwelling that is an informal shack /caravan/ tent/ other	4 (18%)	28 (41%)	32 (35%)
Household assets[3]: Household with ≤ two assets below & no motor vehicle		3 (14%)	20 (29%)	23 (25%)
	no radio	9 (41%)	32 (46%)	41 (45%)
	no television	2 (9%)	6 (9%)	8 (9%)
	no landline	22 (100%)	67 (96%)	89 (97%)
	no cell phone	1 (5%)	14 (20%)	15 (16%)
	no refrigerator	6 (27%)	24 (34%)	30 (33%)
	no motor vehicle [α]	10 (45%)	55 (79%)	65 (71%)
Household adult unemployment: no employed adults (18 – 64 years)		1 (5%)	13 (19%)	14 (15%)

Household Food Insecurity Access Score		2.5 (1 – 5)	3 (0 – 7)	3 (0 – 7)
	food secure	4 (19%)	24 (34%)	28 (30%)
	mildly food insecure	7 (32%)	11 (16%)	18 (20%)
	moderately food insecure	4 (19%)	7 (10%)	11 (12%)
	severely food insecure	7 (32%)	28 (40%)	35 (38%)

α *Denotes: p < 0.05;*

[2] *Youth MPI poor: those with composite score > 33.3%;*

[3] *Individual living in a household that does not own more than two of radio, TV, landline, mobile phone, bike, motorbike or refrigerator AND does not own a car or truck*

Table 5.2: Physical activity, dietary behaviour and nutrition knowledge by gender

Variable: median (IQR) or n (%)		**Male: n= 19 (22%)**	**Female: n= 67 (78%)**	**Total: n =86**
Physical Activity				
Vigorous-intensity physical activity	Any vigorous-intensity PA for ≥10 minutes*	0.58 [0.34–0.80]	0.39 [0.27–0.52]	0.43 [0.32–0.54]
	Time spent doing vigorous-intensity PA per day in minutes	75 (30 – 240)	60 (30 – 120)	60 (30 – 120)
	Vigorous intensity activity MET-minutes/week	2400 (1200 – 4320)	1680 (480 – 3840)	1920 (720 – 4320)
Moderate-intensity physical activity	Any moderate-intensity PA for ≥10 minutes*	0.79 [0.54–0.94]	0.79 [0.67–0.88]	0.79 [0.69–0.87]
	Time spent doing moderate- intensity PA per day in minutes	75 (30 – 120)	60 (30 – 90)	60 (30 – 90)
	Moderate intensity activity MET-minutes/week	1440 (480 – 1680)	720 (480 – 1200)	720 (480 – 1440)
Active travel	Walking or cycling for ≥10 minutes continuously for travel*	0.84 [0.60–0.97]	0.67 [0.55–0.78]	0.71 [0.60–0.80]
	Time spent walking or cycling on a typical day in minutes	40 (30 – 60)	30 (30 – 60)	35 (30 – 60)
	Walking MET-minutes/week	610.5 (396 – 1386)	495 (247.5 – 990)	528 (297 – 990)
Total physical activity MET-minutes/week		2504.25 (690 – 7146)	1173 (495 – 2826)	1215 (495 – 3348)
Insufficient physical activity (achieved < 600 MET-minutes per week) *		0.21 [0.06– 0.46]]	0.34 [0.23–0.47]	0.31 [0.22–0.42]
High physical activity (≥3000 MET minutes per week)		0.42 [0.20–0.67]	0.22 [0.13–0.34]	0.27 [0.18–0.37]
Sedentary behaviour (≥3 hours of sedentary time per day)		0.53 [0.29–0.76]	0.48 [0.35–0.60]	0.49 [0.38–0.60]
Dietary behaviour (n= 82)				
Fruit consumption $^{\alpha}$	Never	0	2 (3%)	2 (2%)
	Once a week / less than once a week	4 (21%)	27 (43%)	31 (28%)
	2 – 4 times a week	5 (26%)	15 (24%)	20 (24%)
	Frequently (5 – 6 times a week)	4 (21%)	2 (3%)	6 (7%)
	Daily or more than once daily*	0.32 [0.13–0.57]	0.25 [0.15–0.37]	0.27 [0.18–0.37]
Vegetable consumption	Never	0	4 (6%)	4 (5%)
	Once a week / less than once a week	3 (17%)	9 (14%)	12 (15%)
	2 - 4 times a week	1 (6%)	9 (14%)	10 (12%)

	Frequently (5 – 6 times a week)	6 (33%)	7 (11%)	13 (16%)
	Daily or more than once daily*	0.42 [0.20–0.67]	0.51 [0.38–0.63]	0.49 [0.38–0.60]
Whole-grain bread or cereal consumption (n= 68)	Never	1 (5%)	4 (6%)	5 (6%)
	Once a week / less than once a week	5 (26%)	16 (25%)	21 (26%)
	2 – 4 times a week	2 (11%)	6 (10%)	8 (10%)
	Frequently (5 – 6 times a week)	3 (16%)	4 (6%)	7 (9%)
	Daily or more than once daily*	0.26 [0.09–0.51]	0.33 [0.22–0.45]	0.31 [0.22–0.42]
Daily consumption of sugar-sweetened beverages*		0.26 [0.09–0.51]	0.30 [0.19–0.42]	0.29 [0.20– 0.40]
Daily consumption of deep-fried foods*		0.16 [0.03–0.40]	0.22 [0.13–0.34]	0.21 [0.13– 0.31]]
Daily consumption of fast foods*		0.05 [0.00–0.26]	0.18 [0.10–0.29]	0.15 [0.08–0.24]
Daily consumption of sweets & cakes*		0.11 [0.01–0.33]	0.37 [0.26–0.50]	0.31 [0.22–0.42]
Ate a meal prepared outside the home in the past week*		0.53 [0.29–0.76]	0.67 [0.55–0.78]	0.64 [0.53–0.74]
	Meals eaten outside the home in past week: (n= 55)	2 (1 – 10)	2 (2 – 3)	2 (2 – 4)
Breakfast consumption: number of days in the past week		5 (3 – 6)	5 (3 – 7)	5 (3 – 7)
Breakfast consumption	Skippers: ate breakfast 0 – 2 days/week*	0.26 [0.09–0.51]	0.19 [0.11–0.30]	0.21 [0.13–0.31]
	Semi-skippers: ate breakfast 3 – 4 days/week*	0.26 [0.09–0.51]	0.19 [0.11–0.30]	0.21 [0.13–0.31]
	Non-skippers: ate breakfast 5 – 7 days/week*	0.63 [0.38–0.84]	0.58 [0.46–0.70]	0.59 [0.48–0.70]
Nutrition Knowledge				
GNKQ score percentage % (score /88) (95% CI)		40.3% (34.5 -46.1)	36.5% (34.0 - 38.9)	37.3% (35.1 - 39.6)
	1. Dietary recommendations (score/18)	44.2% (35.3 - 53.0)	42.5% (38.7 - 46.3)	42.9% (39.4 - 46.4)
	2. Food Groups (score/36)	40.4 (35.5 - 45.4)	37.1 (34.1 - 40.1)	37.9 (35.3 - 40.4)
	3. Healthy food choices (score/13)	36.8 (27.3 - 46.2)	30.5 (26.0 - 35.1)	31.9 (27.9 - 36.0)
	4. Diet, disease and weight management (score/21)	36.8 (28.2 - 45.3)	33.9 (30.6 - 37.1)	34.5 (31.4 - 37.6)

[α] *Denotes: p < 0.05; MET = Metabolic Equivalent; n= number; % = percentage; PA = physical activity, GNKQ= General Nutrition Knowledge Questionnaire.*
** Denotes the Binomial Exact Confidence Interval*

Table 5.3: Physical activity, dietary behaviour and nutritional knowledge by age

Variable: Median (IQR) or n (%)	**Description**	**15- 17 years: n=11 (13%)**	**18- 19 years: n= 23 (27%)**	**20- 21years: n= 23 (27%)**	**22- 24 years: n= 29 (34%)**	**Total: n= 86**
Physical activity						
Vigorous intensity physical activity	Prevalence of PA for ≥10 minutes	8 (80%)	9 (39%)	11 (50%)	9 (31%)	37 (43%)
	Time spent per day in minutes	120 (30 – 240)	90 (30 – 120)	105 (30 – 180)	60 (30 – 60)	60 (30 – 120)
	MET-minutes/week	4800 (720 – 9600)	2160 (1200-2400)	2520 (960–4320)	1440 (480-1920)	1920 (720 – 4320)
Moderate-intensity physical activity	Prevalence of PA for ≥10 minutes	5 (50%)	17 (74%)	19 (86%)	25 (86%)	68 (79%)
	Time spent per day in minutes	60 (30 – 60)	60 (40 – 120)	30 (30 – 120)	30 (30 – 60)	60 (30 – 90)
	MET-minutes/week	720 (360 – 720)	1440 (640– 1680)	600 (420 –1680)	600 (480 – 840)	720 (480 – 1440)
Active travel Walking or cycling	Walking or cycling for ≥ 10 minutes	7 (70%)	19 (83%)	14 (64%)	20 (69%)	60 (71%)
	Time spent daily in minutes	30 (30 – 120)	30 (30 – 60)	60 (30 – 60)	30 (30 – 60)	35 (30 – 60)
	Walking MET-minutes/week	495 (495 – 495)	693 (396 –1386)	742.5 (495–1188)	495 (198 – 693)	528 (297 – 990)
Total physical activity MET-minutes/week		984 (280 – 5295)	2160 (800 –3756)	1638.75 (420-6624)	876 (509 - 1878)	1215 (495 – 3348)
Insufficient physical activity (< 600 MET-minutes per week)		5 (45%)	5 (22%)	7 (30%)	10 (34%)	27 (31%)
High physical activity (≥3000 MET minutes per week)		3 (27%)	8 (35%)	9 (39%)	3 (10%)	23 (27%)
Sedentary behaviour (≥3 hours of sedentary time per day)		7 (70%)	9 (39%)	12 (54%)	14 (49%)	42 (49%)
Dietary Behaviour (n= 82)						
Dietary intake						
Fruit consumption	Never	0	0	0	2 (7%)	2 (2%)
	Once a week / less than once a week	5 (50%)	9 (39%)	10 (45%)	7 (26%)	31 (38%)
	2 – 4 times a week	2 (20%)	5 (22%)	4 (18%)	9 (33%)	20 (24%)
	Frequently (5 – 6 times a week)	2 (20%)	0	3 (14%)	1 (4%)	6 (7%)
	Daily or more than once daily	1 (10%)	9 (39%)	5 (23%)	8 (30%)	23 (28%)

Vegetable consumption	Never	0	1 (4%)	1 (5%)	2 (7%)	4 (5%)
	Once a week / less than once a week	2 (20%)	5 (22%)	3 (14%)	2 (7%)	12 (15%)
	2 – 4 times a week	2 (20%)	1 (4%)	0	7 (265)	10 (12%)
	Frequently (5 – 6 times a week)	2 (20%)	4 (17%)	6 (29%)	1 (4%)	13 (16%)
	Daily or more than once daily	4 (40%)	12 (52%)	11 (52%)	15 (56%)	42 (52%)
Whole-grain bread or cereal consumption (n=68)	Never	0	1 (4%)	1 (5%)	3 (11%)	5 (6%)
	Once a week / less than once a week	5 (50%)	7 (30%)	5 (23%)	4 (15%)	21 (26%)
	2 – 4 times a week	2 (20%)	1 (4%)	1 (5%)	4 (15%)	8 (10%)
	Frequently (5 – 6 times a week)	1 (10%)	4 (17%)	1 (5%)	1 (4%)	7 (9%)
	Daily or more than once daily	1 (10%)	9 (39%)	7 (32%)	10 (37%)	27 (33%)
Daily consumption of sugar-sweetened beverages		3 (27%)	6 (26%)	9 (39%)	7 (24%)	25 (29%)
Daily consumption of deep-fried foods [α]		1 (9%)	8 (35%)	5 (22%)	4 (14%)	18 (21%)
Daily consumption of fast foods		2 (18%)	6 (26%)	2 (9%)	3 (10%)	13 (15%)
Daily consumption of sweets & cakes		4 (36%)	9 (39%)	6 (26%)	8 (28%)	27 (31%)
Ate meal prepared outside the home in past week		5 (50%)	14 (64%)	15 (68%)	21 (78%)	55 (67%)
	Total meals eaten outside the home (n= 55)	2 (1 – 3)	2 (2 – 4)	2 (2 – 4)	2 (2 – 3)	2 (2 – 4)
Breakfast consumption	Skippers: ate breakfast 0 - 2 days/week	2 (20%)	7 (30%)	3 (14%)	7 (26%)	19 (23%)
	Semi-skippers: ate breakfast 3 - 4 days/week	1 (10%)	4 (17%)	6 (27%)	3 (11%)	14 (17%)
	Non-skippers: ate breakfast 5 - 7 days/week	7 (70%)	12 (52%)	13 (59%)	17 (63%)	49 (60%)
Nutrition Knowledge						
GNKQ score percentage % (score /88) mean (95% CI)		35.6 (28.4–42.9)	38.1 (34.1 -42.1)	34.3 (28.9–39.6)	39.6 (35.7–43.4)	37.3 (35.1–39.6)
	1. Dietary recommendations (score/18)	39.9 (27.8 – 52.0)	46.1 (39.8 – 52.4)	40.2 (32.3 – 48.1)	43.4 (37.5–49.3)	42.9 (39.4 – 46.4)
	2. Food groups (score/36)	37.6 (31.6 – 43.7)	37.4 (32.3 – 42.5)	35.0 (29.7 – 40.3)	40.4 (35.5–45.4)	37.9 (35.3 – 40.4)
	3. Healthy food choices (score/13)	33.6 (21.5 – 45.6)	35.1 (28.4 – 41.8)	27.7 (17.8 – 37.6)	31.6 (24.2–39.0)	31.9 (27.9 – 36.0)

	4. Diet, disease relationships (score/21)	29.9 (20.6 – 39.2)	34.4 (29.4 – 39.3)	30.2 (23.3 – 37.1)	39.7 (34.0–45.3)	34.5 (31.4 – 37.6)

MET = Metabolic Equivalent; n= number; mins= minutes; PA = physical activity; GNKQ= General Nutrition Knowledge Questionnaire; [α] Denotes p-value from Kruskal Wallis test if significant at: p < 0.05

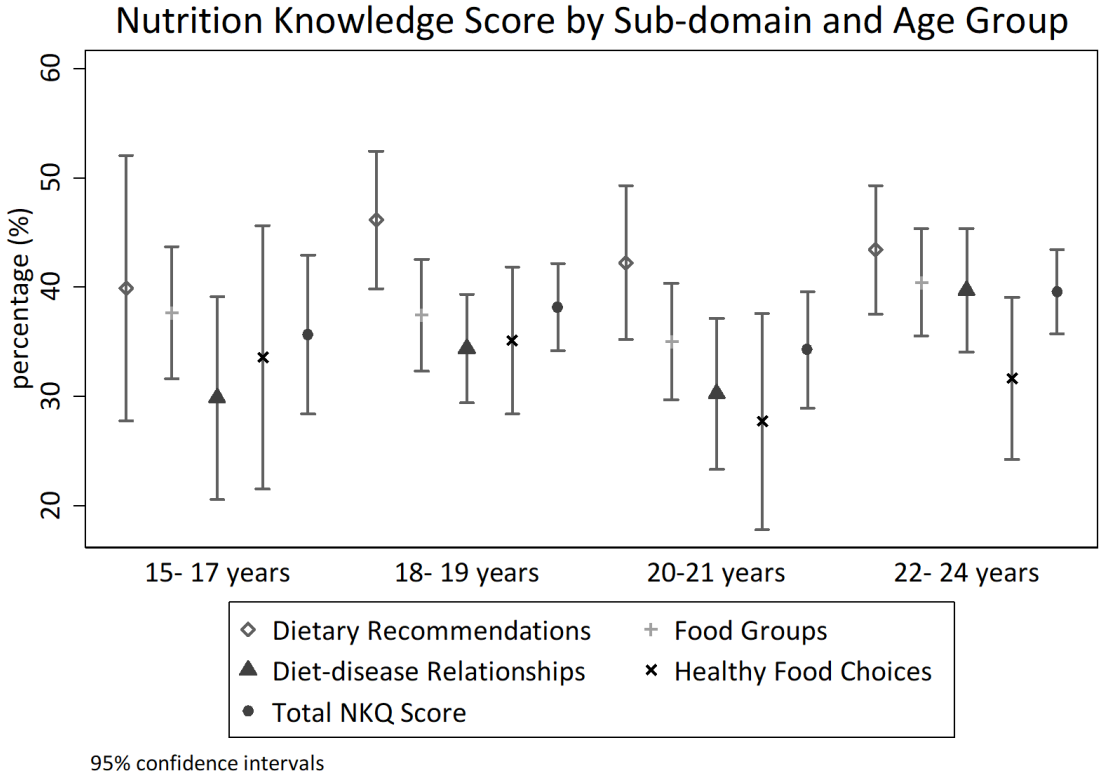

Figure 5.1: Nutrition knowledge by sub-domain and age group

Table 5.4: Tobacco use and exposure, alcohol and substance use by gender

Variable: Median (IQR) or n (%)	Description	Male: n= 19 (22%)	Female: n= 67 (78%)	Total: n= 86
Tobacco and Alcohol Use				
Ever smoked cigarettes in lifetime[β] *		0.58 [0.34–0.80]	0.30 [0.19–0.42]	0.36 [0.26–0.47]
Age when first smoked cigarettes		15 (13 – 16)	16 (15 – 17)	16 (15 – 17)
Days smoked during the past 30 days	0 days	10 (53%)	50 (75%)	60 (70%)
	1 or 2 days	3 (16%)	8 (12%)	11 (13%)
	3 to 5 days	4 (21%)	2 (3%)	6 (7%)
	20 to 29 days	0	1 (1%)	1 (1%)
	Daily: all 30 days	2 (11%)	6 (9%)	8 (9%)
Days used any tobacco products other than cigarettes, during past month[β]	0 days	13 (68%)	55 (82%)	68 (79%)
	1 or 2 days	3 (16%)	8 (12%)	11 (13%)
	3 to 5 days	2 (11%)	0	2 (2%)
	6 or more days	1 (5%)	4 (6%)	5 (6%)
People smoked around you during past 7 days*		0.79 [0.54–0.94]	0.70 [0.58–0.81]	0.72 [0.61–0.81]
Days people smoked in their presence during the past 7 days	0 days	4 (21%)	20 (30%)	24 (28%)
	1 or 2 days	4 (21%)	25 (37%)	29 (34%)
	3 or 4 days	6 (32%)	8 (12%)	14 (16%)
	5 or 6 days	2 (10%)	5 (7%)	7 (8%)
	All 7 days	3 (16%)	9 (13%)	12 (14%)
Ever drunk alcohol (n= 85)*		0.68 [0.43–0.87]	0.67 [0.55–0.78]	0.67 [0.56–0.77]
	Age at alcohol initiation in years	16 (14 – 19)	17 (15 – 18)	16.5 (15 – 18)
	Drunk alcohol in the past 30 days	0.58 [0.34–0.80]	24 (36%)	35 (41%)
	Binge drinking in past 30 days	0.37 [0.16–0.62]	0.21 [0.12–0.33]	0.24 [0.16–0.35]

Illicit substance use				
Ever used cannabis [α*]		0.42 [0.20–0.67]	0.22 [0.13–0.34]	0.27 [0.18–0.37]
	Age at first cannabis use	16 (13 – 19)	16 (15 – 18)	16 (14.5– 18.5)
	Cannabis use in the past year	6 (32%)	13 (19%)	19 (22%)
Frequency of cannabis use in the past year	Almost every day	2 (11%)	3 (4%)	5 (6%)
	Once a week or more	1 (5%)	3 (4%)	4 (5%)
	About once a month	1 (5%)	5 (7%)	6 (7%)
	Only once or twice	2 (11%)	2 (3%)	4 (5%)
	Never	13 (68%)	54 (81%)	67 (78%)
Ever taken cocaine, heroin, mandrax, club drugs or methamphetamine*		0.05 [0.00–0.26]	0.07 [0.02– 0.17]	0.07 [0.03– 0.15]
Lifetime use of cocaine, heroin, mandrax, club drugs or methamphetamine	0 times	18 (95%)	62 (93%)	80 (93%)
	1 or 2 times	0	2 (3%)	2 (2%)
	3 to 9 times	0	1 (1%)	1 (1%)
	20 or more times	1 (5%)	2 (3%)	3 (3%)
Ever used inhalants[1] "to get high" *		0.21 [0.06–0.46]	0.07 [0.02– 0.17]	0.10 [0.05– 0.19]
Lifetime use of inhalants to get high	0 times	16 (84%)	64 (96%)	80 (93%)
	1 or 2 times	2 (11%)	3 (4%)	5 (6%)
	3 to 9 times	1 (5%)	0	1 (1%)
Ever used OTC[2] or prescription drugs "to get high" *		0.26 [0.09–0.51]	0.12 [0.05– 0.22]	0.15 [0.08–0.24]
Lifetime use of OTC to "to get high"	0 times	15 (79%)	61 (91%	76 (88%)
	1 or 2 times	3 (16%)	6 (9%)	9 (10%)
	3 to 9 times	1 (5%)	0	1 (1%)
Ever used any illegal drugs or substance "to get high" [α*]		0.53 [0.29–0.76]	0.31 []0.21–0.44]	0.36 [0.26–0.47]

*[α]Denotes: p < 0.10; [β]Denotes: p < 0.05; [1]Inhalants= glue, aerosols, paint thinners, petrol or benzene; [2]OTC= over-the-counter. * Denotes the Binomial Exact Confidence Interval*

Table 5.5: Tobacco use and exposure, alcohol and substance use by age group

Variable: Median (IQR) or n (%)	**Description**	**15– 17 years: n = 11 (13%)**	**18– 19 years: n= 23 (27%)**	**20 – 21 years: n= 23 (27%)**	**22– 24 years: n= 29 (34%)**	**Total: n= 86**
Tobacco and Alcohol Use						
Ever smoked cigarettes in lifetime		5 (45%)	7 (30%)	7 (30%)	12 (41%)	31 (36%)
Age when first smoked cigarettes* α		16 (13 – 16)	15.5 (13 – 16)	15 (14 – 16)	17 (16 – 20)	16 (15 – 17)
Days smoked during the past 30 days	0 days	6 (55%)	16 (70%)	17 (74%)	21 (72%)	60 (70%)
	1 or 2 days	5 (45%)	2 (9%)	1 (4%)	3 (10%)	11 (13%)
	3 to 5 days	0	1 (4%)	3 (13%)	2 (7%)	6 (7%)
	20 to 29 days	0	1 (4%)	0	0	1 (1%)
	All 30 days	0	3 (13%)	2 (9%)	3 (10%)	8 (9%)
Days used any tobacco products other than cigarettes, during past month	0 days	6 (55%)	19 (83%)	17 (74%)	26 (90%)	68 (79%)
	1 or 2 days	4 (36%)	3 (13%)	2 (9%)	2 (7%)	11 (13%)
	3 to 5 days	0	0	2 (9%)	0	2 (2%)
	6 or more days	1 (9%)	1 (4%)	2 (9%)	1 (3%)	5 (6%)
People smoked around you during past week		10 (91%)	16 (70%)	18 (78%)	18 (62%)	62 (72%)
Days people smoked in their presence during the past 7 days	0 days	1 (9%)	7 (30%)	5 (22%)	11 (38%)	24 (28%)
	1 or 2 days	5 (45%)	9 (39%)	8 (35%)	7 (24%)	29 (34%)
	3 or 4 days	2 (18%)	0	5 (22%)	7 (24%)	14 (16%)
	5 or 6 days	2 (18%)	1 (4%)	3 (13%)	1 (3%)	7 (8%)
	All 7 days	1 (9%)	6 (26%)	2 (9%)	3 (10%)	12 (14%)
Ever drunk alcohol		9 (82%)	14 (61%)	14 (61%)	21 (75%)	58 (68%)
	Age at alcohol initiation in years* α	14 (12 – 14)	16.5 (15 – 18)	15.5 (15 – 18)	17 (16 – 19)	16.5 (15 – 18)
	Drunk alcohol in the past month	5 (45%)	10 (43%)	7 (30%)	13 (45%)	35 (41%)
	Binge drinking in past month** α	6 (55%)	6 (26%)	4 (17%)	5 (17%)	21 (24%)

Illicit substance use						
Ever used cannabis		3 (27%)	7 (30%)	5 (22%)	8 (28%)	23 (27%)
	Age at first cannabis use	15 (13– 16)	16.5 (14– 18)	16 (15– 16)	18.5 (16– 21)	16 (14.5– 18.5)
	Cannabis use in the past year	3 (27%)	5 (22%)	4 (17%)	7 (24%)	19 (22%)
Frequency of cannabis use in the past year	Almost every day	0	1 (4%)	2 (9%)	2 (7%)	5 (6%)
	Once a week or more	0	2 (9%)	1 (4%)	1 (3%)	4 (5%)
	About once a month	2 (18%)	1 (4%)	1 (4%)	2 (7%)	6 (7%)
	Only once or twice	1 (9%)	1 (4%)	0	2 (7%)	4 (5%)
	Never	8 (73%)	18 (78%)	19 (83%)	22 (76%)	67 (78%)
Ever taken cocaine, heroin, mandrax, club drugs or meth		0	1 (4%)	1 (4%)	4 (14%)	6 (7%)
Lifetime use of cocaine, heroin, mandrax, club drugs or methamphetamine	0 times	11 (100%)	22 (96%)	22 (96%)	25 (86%)	80 (93%)
	1 or 2 times	0	1 (4%)	0	1 (3%)	2 (2%)
	3 to 9 times	0	0	0	1 (3%)	1 (1%)
	20 or more times	0	0	1 (4%)	2 (7%)	3 (3%)
Ever used inhalants[3] "to get high"		1 (9%)	1 (4%)	5 (22%)	2 (7%)	9 (10%)
Lifetime use of inhalants to get high	0 times	10 (91%)	22 (96%)	20 (87%)	28 (97%)	80 (93%)
	1 or 2 times	1 (9%)	1 (4%)	2 (9%)	1 (3%)	5 (6%)
	3 to 9 times	0	0	1 (4%)	0	1 (1%)
Ever used OTC[4] or prescription drugs "to get high"		2 (18%)	4 (17%)	5 (22%)	2 (7%)	13 (15%)
Lifetime use of OTC to get high	0 times	9 (82%)	20 (87%)	20 (87%)	27 (93%)	76 (88%)
	1 or 2 times	2 (18%)	3 (13%)	2 (9%)	2 (7%)	9 (10%)
	3 to 9 times	0	0	1 (4%)	0	1 (1%)
Ever used any illegal drugs or substance "to get high"		4 (36%)	9 (39%)	8 (35%)	10 (34%)	31 (36%)

[*]P-value associated with Kruskal-Wallis equality-of-populations rank test; [**]Fisher's exact p-value; [α]Denotes: p < 0.10; [3]Inhalants= glue, aerosols, paint thinners, petrol or benzene; [4] OTC= over-the-counter.

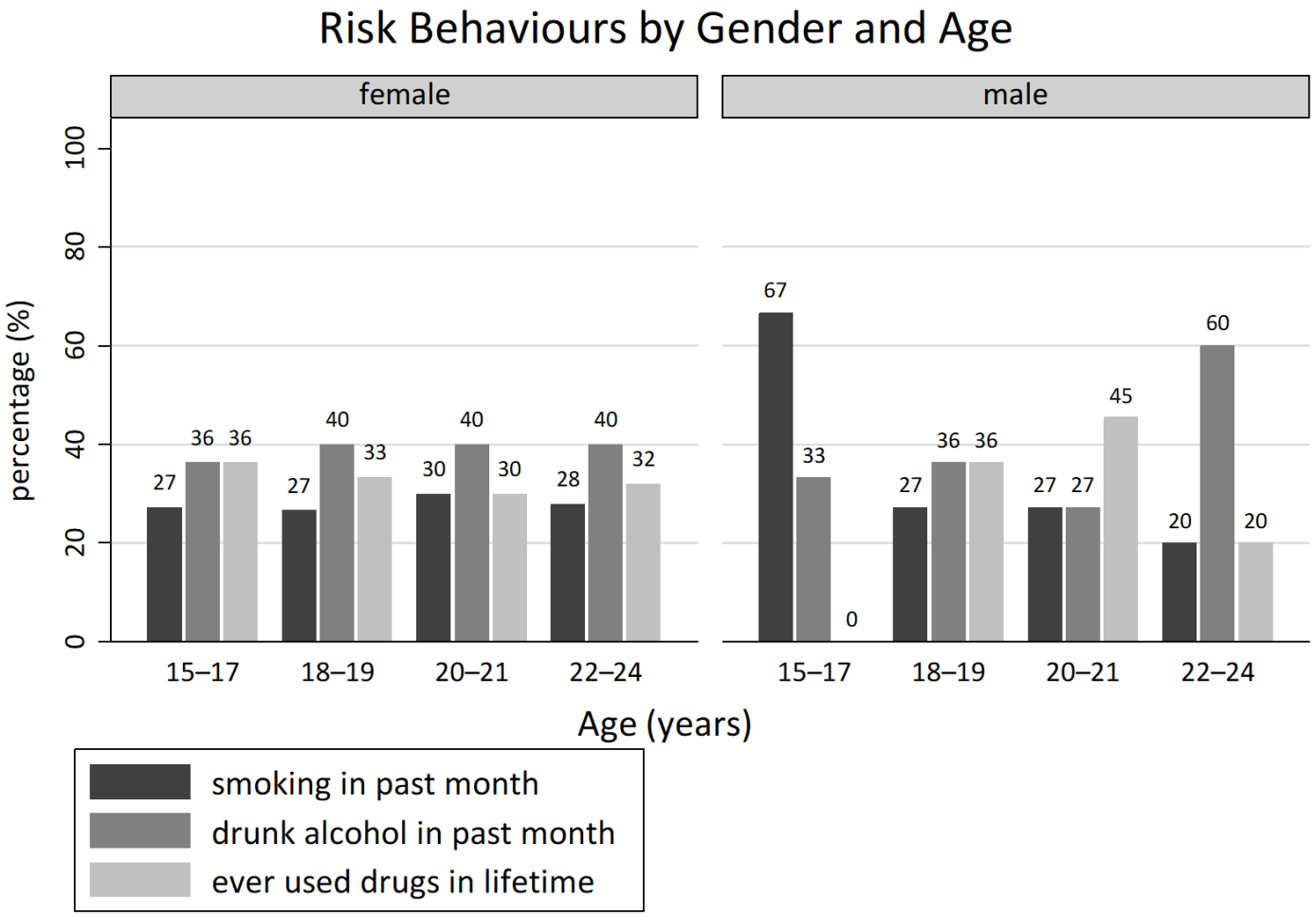

Figure 5.2: Current smoking, alcohol consumption, and lifetime substance use by gender and age

Table 5.6: Comorbidities, measured clinical signs and symptoms by gender

Variable: median (IQR) or n (%) or proportion [95% CI]		**Male: n= 22**	**Female: n= 70**	**Total n= 92**	**p-value[1]**
Self-reported pre-existing diagnosis: proportion [95% CI] [2]		0.45 [0.24 – 0.68]	0.31 [0.21 – 0.44]	0.35 [0.25 – 0.45]	0.228
	Tuberculosis	0.32 [0.14 – 0.55]	0.2 [0.11 – 0.31]	0.23 [0.15 – 0.33]	0.229
	Depression or Anxiety	0.14 [0.029 – 0.35]	0.071 [0.024 – 0.16]	0.087 [0.038 – 0.16]	0.332
	Asthma	0.045 [0.0012 – 0.23]	0.043 [0.0089 – 0.12]	0.043 [0.012 – 0.11]	0.946
	High Blood Pressure	0 [0.00 – 0.15]	0.043 [0.089 – 0.12]	0.033 [0.0068 – 0.092]	0.327
	Diabetes	0 [0.00 – 0.15]	0.014 [0.00036 – 0.077]	0.011 [0.00028 – 0.061]	0.576
Symptoms					
Respiratory symptoms over past 3 months (n= 89): prop [95% CI]		0.10 [0.012 – 0.30]	0.13 [0.062 – 0.24]	0.12 [0.063 – 0.21]	0.651
Diabetes symptoms over past 3 months: proportion [95% CI]		0.29 [0.11 – 0.52]	0.24 [0.14 – 0.35]	0.25 [0.16 – 0.35]	0.640
Individual symptoms n (%)	Frequent urination	1 (5%)	3 (4%)	4 (4%)	0.969
	Increased thirst	2 (9%)	7 (10%)	9 (10%)	0.900
	Weight loss >1.5 kg in past month	0	6 (9%)	6 (7%)	0.152
	Unexplained fatigue	5 (23%)	9 (13%)	13 (15%)	0.261
	Blurry vision	2 (10%)	5 (7%)	7 (8%)	0.747
Family history of diabetes: proportion [95% CI]		0.38 [0.18 – 0.62]	0.24 [0.14 – 0.35]	0.27 [0.18 – 0.37]	0.189
Random blood glucose in mmol/L (n=31) [3] median (IQR)		3.7 (0.75 – 4.95)	4.8 (4.0 – 5.5)	4.7 (3.1– 5.3)	0.1672
Mental Health					
CESD-10 Depression score (n=82) median (IQR)		8 (4 – 9)	10 (6 – 14)	9 (6 – 14)	0.055
	Significant depression (CESD ≥10): prop [95% CI]	0.19 [0.054 – 0.42]	0.51 [0.38 – 0.64]	0.43 [0.32 – 0.54]	0.011
Kessler Psychological Distress score (K10) (n= 85) median (IQR)		17 (13 – 23)	19 (13 – 25)	19 (13 – 25)	0.959
Categories n (%)[2]	Mentally well (K10 <20) prop [95% CI]	0.55 [0.32 –0.76]	0.50 [0.38 –0.62]	0.51 [0.40– 0.62]	0.407
	Mild distress (K10 20–24) prop [95% CI]	0.18 []0.05 – 0.40]	0.14 [0.07 –0.25]	0.15 [0.09–0.24]	
	Moderate distress (K10 25–29) prop [95% CI]	0.09 [0.01 –0.29]	0.21 [0.13 –0.33]	0.18 [0.11– 0.28]	

	Severe distress (K10 ≥30) prop [95% CI]	0.14 [0.03 –0.35]	0.06 [0.02 –0.14]	0.08 [0.03– 0.15]	
Measured Clinical Signs					
BMI in kg/m$^{2;}$ median (IQR)		21.0 (19.1 – 22.6)	23.3 (20.2 – 27.2)	22.8 (19.9 – 26.2)	0.0102
Categories n (%)[2]	Underweight (BMI<18.5)	0.23 [0.08 – 0.45]	0.07 [0.02 – 0.16]	0.11 [0.05–0.19]	0.032
	Normal weight (18.5 ≤ BMI< 25)	0.64 [0.41 – 0.83]	0.47 [0.35 – 0.59]	0.51 [0.40– 0.62]	
	Overweight (25≤ BMI< 30)	0.14 [0.03 – 0.35]	0.27 [0.17 – 0.39]	0.24 [0.16 – 0.34]	
	Obese (BMI ≥ 30)	0 [0.00– 0.15]	0.15 [0.07 – 0.25]	0.11 [0.05–0.19]	
Waist circumference (WC) in cm; median (IQR)		74 (71.5 – 81.0)	78.4 (71.5 – 88.0)	76 (71.5 – 87)	0.2135
Hip circumference in cm; median (IQR)		87.5 (84 – 94)	97.5 (90.5– 108)	95 (86.75– 106.5)	0.0011
Waist-hip ratio (WHR) median (IQR)		0.85 (0.82– 0.87)	0.82 (0.77 – 0.85)	0.82 (0.78 – 0.87)	0.0265
Waist-to-height ratio (WHtR) median (IQR)		0.43 (0.42 – 0.48)	0.49 (0.45 – 0.56)	0.48 (0.44 – 0.54)	0.0006
Abdominal obesity[2]	WC > 88cm in females, WC > 102 cm in males	0.05 [0.00– 0.23]	0.24 [0.15 – 0.36]	0.20 [0.12 – 0.29]	0.049
	WHR > 0.85 in females and > 0.95 in males	0 [0.00– 0.15]	0.27 [0.17 – 0.39]	0.21 [0.13 – 0.30]	0.007
	WHtR > 0.5	0.14 [0.03 – 0.35]	0.44 [0.32 –0.57]	0.37 [0.27 – 0.48]	0.020
Blood pressure in mmHg median (IQR) (Systolic/ Diastolic Blood Pressure)		119.5/74.75 (110/66.5 –131.5/80.5)	115/74 (109.5/68.5 – 124.5/78)	117.5/74.25 (109.5/68 – 125.5/79)	0.9635 0.2097
Categories n (%)[2]	Normal BP: SBP <130 & DBP <85	0.59 [0.36 – 0.79]	0.80 [0.69 –0.89]	0.75 [0.65 – 0.83]	0.056
	Elevated BP: SBP 130–139 or DBP 85–89	0.27 [0.11– 0.50]	0.17 [0.09 – 0.28]	0.20 [0.12 – 0.29]	
	Hypertension: SBP 140–159/ DBP 90- 99	0.14 [0.03 – 0.35]	0.03 [0.0035 –0.10]	0.05 [0.02 – 0.12]	

[1] Wilcoxon rank-sum test p-value for continuous variables and Pearson χ^2 test for categorical variables;

[2] Binomial exact 95% Confidence interval;

[3] Blood glucose measured if a participant had one or more symptoms of diabetes and OR family history;

Table 5.7: Comorbidities, measured clinical signs and symptoms by age group

Variable: median (IQR) or n (%)		**15– 17 years: n=14 (15%)**	**18– 19 years: n= 23 (25%)**	**20 – 21 years: n= 26 (28%)**	**22– 24 years: n= 29 (32%)**	**Total: n= 92**
Self-reported pre-existing diagnosis: n (%)		1 (7%)	9 (39%)	9 (35%)	13 (45%)	32 (35%)
	Tuberculosis	1 (7%)	5 (22%)	6 (23%)	9 (31%)	21 (23%)
	Depression or Anxiety	0	4 (17%)	2 (8%)	2 (7%)	8 (9%)
	Asthma	0	2 (9%)	2 (8%)	0	4 (4%)
	High Blood Pressure	0	0	1 (4%)	2 (7%)	3 (3%)
	Diabetes	0	1 (11%)	0	0	1 (3%)
Symptoms						
Respiratory symptoms over past 3 months (n= 89)		4 (29%)	4 (17%)	2 (8%)	1 (3%)	11 (12%)
Diabetes symptoms over past 3 months[*α]		6 (46%)	8 (35%)	4 (16%)	4 (14%)	23 (25%)
Symptoms n (%)	Frequent urination[*α]	2 (15%)	2 (9%)	0	0	4 (4%)
	Increased thirst[*α]	4 (31%)	3 (13%)	2 (8%)	0	9 (10%)
	Weight loss >1.5 kg in past month	1 (8%)	2 (9%)	1 (4%)	2 (7%)	6 (7%)
	Unexplained fatigue	4 (31%)	5 (22%)	4 (16%)	1 (3%)	14 (16%)
	Blurry vision	1 (8%)	3 (14%)	1 (4%)	2 (7%)	7 (8%)
Family history of diabetes		6 (46%)	7 (30%)	4 (16%)	7 (24%)	24 (27%)
Random blood glucose in mmol/L (n=31)[2] median (IQR)		3.65 (1 – 4.9)	4.4 (2.75 – 5.5)	5 (2.4 – 5.45)	5.2 (4.7 – 5.5)	4.7(3.1 – 5.3)
Mental Health						
CESD-10 Depression score (n=81) median (IQR)		9 (6 – 12)	10.5 (7.5 – 14)	9 (7.5 – 13.5)	8.5 (6 – 12)	9 (6 – 14)
	Significant depression (CESD ≥10)	5 (38%)	12 (60%)	8 (33%)	10 (42%)	35 (43%)
Kessler score (K10) (n= 85) median (IQR)		15 (14 – 24)	19 (15 – 25)	18 (12 – 25)	18.5 (13 – 25)	19 (13 – 25)
Categories n (%)	Mentally well (K10 <20)	7 (54%)	12 (55%)	13 (54%)	15 (58%)	47 (55%)
	Mild distress (K10 20–24)	3 (23%)	3 (14%)	5 (21%)	3 (12%)	14 (16%)

	Moderate distress (K10 25–29)	1 (8%)	5 (23%)	4 (17%)	7 (27%)	17 (20%)
	Severe distress (K10 ≥30)	2 (15%)	2 (9%)	2 (8%)	1 (4%)	7 (8%)
Measured Clinical Signs						
BMI in kg/m^2 (n= 87); median (IQR)		20.8 (19.5 – 24.1)	23.2 (19.3 – 26.4)	22.1 (20.6 – 25.9)	24.2 (20.2 – 27.1)	22.8 (19.9 – 26.2)
Categories n (%)	Underweight (BMI<18.5)	2 (14%)	4 (19%)	1 (4%)	3 (10%)	10 (11%)
	Normal weight (18.5 ≤ BMI< 25)	9 (64%)	8 (38%)	15 (60%)	15 (52%)	47 (53%)
	Overweight (25≤ BMI< 30)	1 (7%)	7 (33%)	6 (24%)	8 (28%)	22 (25%)
	Obese (BMI ≥ 30)	2 (14%)	2 (10%)	3 (12%)	3 (10%)	10 (11%)
Waist circumference (WC) in cm; median (IQR)		74.5 (71 – 76)	74.6 (67.5 – 88)	78.8 (73 – 85)	79 (71 – 88)	76 (71.5 – 87)
Hip circumference in cm; median (IQR)		91 (83.5 – 104)	90.5 (84.8 – 107)	96.7 (93 – 107)	95 (90 – 105)	95 (86.5 – 106)
Waist-hip ratio (WHR); median (IQR)		0.83 (0.79 – 0.87)	0.83 (0.77 – 0.87)	0.82 (0.78 – 0.85)	0.82 (0.79 – 0.87)	0.82 (0.78 – 0.87)
Waist-to-height ratio (WHtR); median (IQR)		0.47 (0.43 – 0.48)	0.45 (0.43 – 0.53)	0.48 (0.44 – 0.52)	0.49 (0.44 – 0.57)	0.48 (0.44 – 0.54)
Abdominal obesity	WC >88cm female, WC >102 cm in male	2 (15%)	5 (23%)	4 (12%)	7 (24%)	17 (19%)
	WHR > 0.85 in female and > 0.95 in male	3 (23%)	5 (23%)	3 (8%)	8 (28%)	18 (20%)
	WHtR > 0.5	2 (14%)	9 (39%)	11 (42%)	12 (41%)	34 (37%)
Systolic Blood Pressure in mmHg; median (IQR)		117.5 (112 – 125.5)	118 (108.5 – 124.5)	118 (111 – 131)	117 (107.5 – 123.5)	117.5 (109.5– 125.5)
Diastolic Blood Pressure in mmHg; median (IQR)		73.5 (66.5 – 77)	75 (67 – 76.5)	76 (71 – 80)	74 (68.5 – 80)	74.25 (68 – 79.5)
Categories n (%)	Normal BP: SBP<130 & DBP<85	11 (79%)	18 (78%)	18 (69%)	22 (76%)	69 (75%)
	Elevated BP: SBP 130–139 or DBP 85–89	3 (21%)	4 (17%)	6 (23%)	5 (17%)	18 (20%)
	Hypertension: SBP 140–159/ DBP 90- 99	0	1 (4%)	2 (8%)	2 (7%)	5 (5 %)

[*]P-value derived from Fisher's exact text; [α]Denotes: p < 0.05;

[2] Blood glucose measured only if a participant had one or more symptoms of diabetes and OR family history;

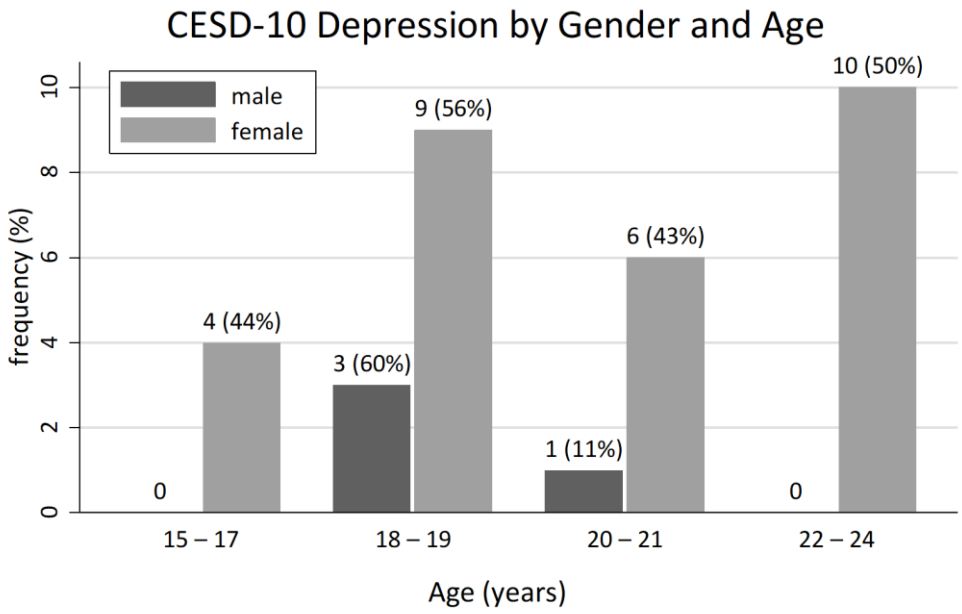

Figure 5.3: Significant depression score by gender and age

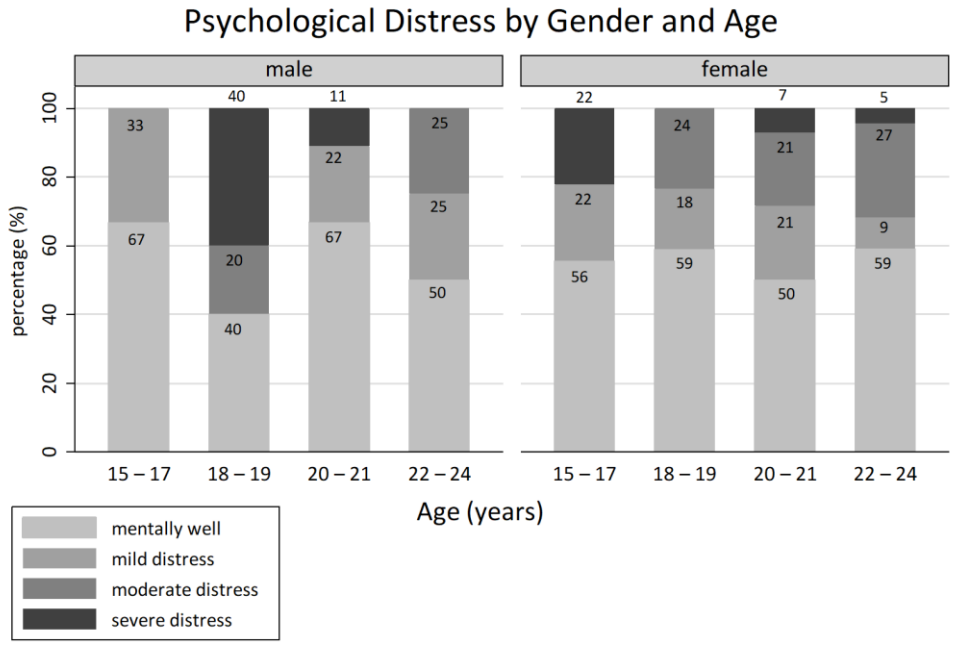

Figure 5.4: Psychological distress by gender and age

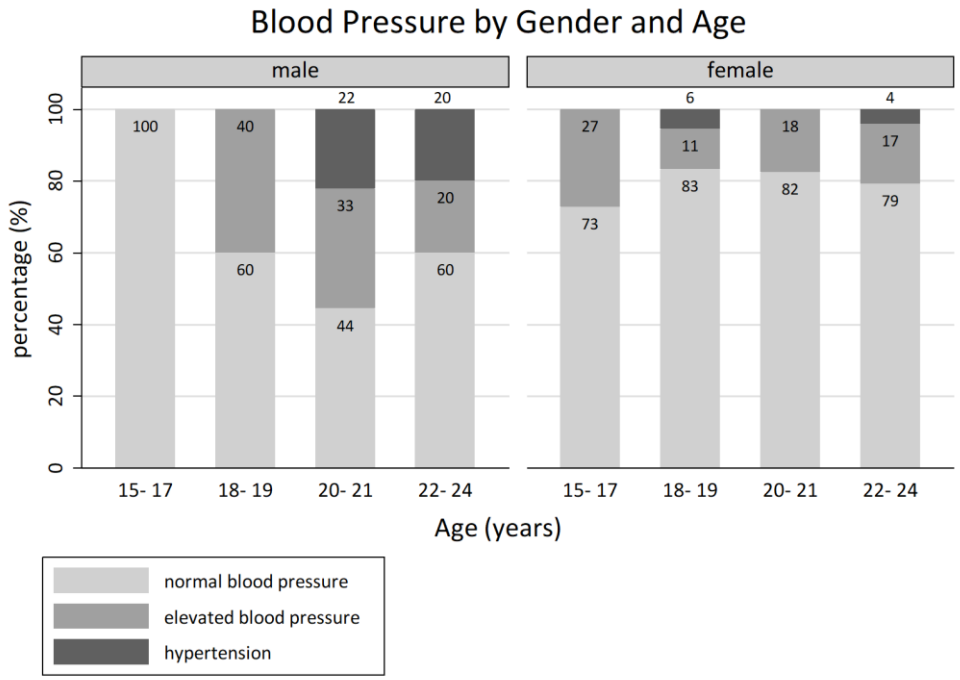

Figure 5.5: Hypertension and elevated blood pressure by gender and age

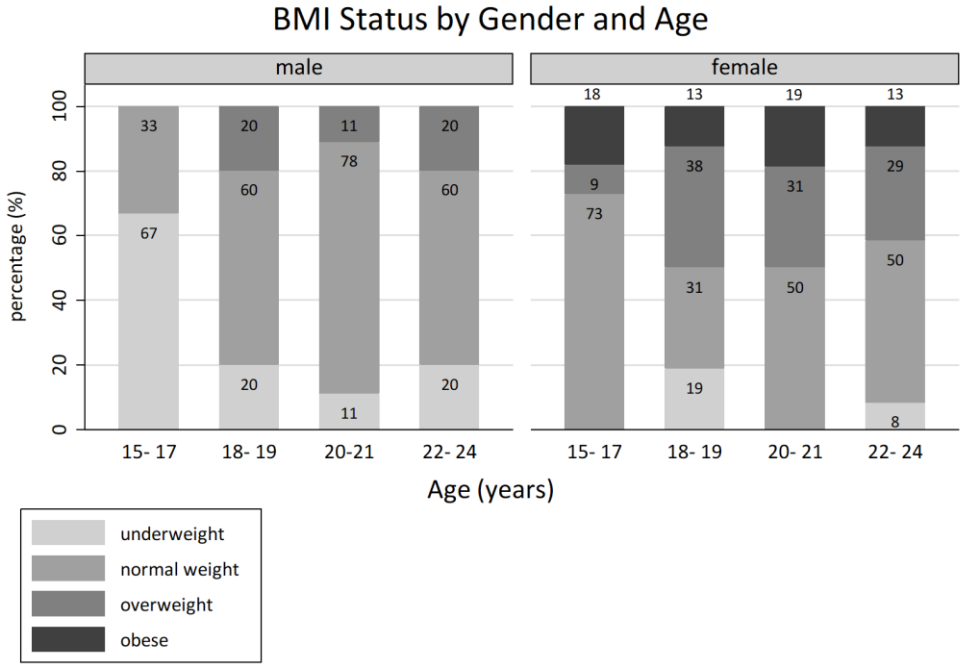

Figure 5.6: Weight status by gender and age

5.4 Discussion

This study describes the prevalence of NCDs and NCD risk factors among South African AYLHIV in an urban setting. Previous studies in sub-Saharan Africa have described NCD comorbidities in adults living with HIV [151, 481, 493-495]. Risk behaviour research on adolescents and youth living with HIV in sub-Saharan Africa has predominantly focused on sexual risk behaviour [261]. We, therefore, set out to investigate NCD prevalence and risk factors given the emerging NCD epidemic in SSA occurring against a background of a high HIV burden and increased comorbidity risk in PLHIV.

We highlight several key findings. First, almost half of our participants faced multiple deprivations of poverty, significant depression and psychological distress symptoms, and multiple risk factors for NCDs. Second, more than a third were overweight or obese, and although two-thirds had sufficient levels of weekly physical activity, the majority did not meet dietary guidelines for fruit and vegetable intake. Third, there was low nutritional knowledge, particularly on healthy food choices and diet-disease relationships. Fourth, tobacco use and exposure and binge drinking were highly prevalent, with male participants engaging in more substance use than females. Finally, an alarming pattern of early initiation of high-risk behaviours, including underage and binge drinking, smoking and experimentation with cannabis, emerged in the youngest age group. A detailed interpretation of these findings, comparisons to the general population and previous findings in PLHIV, and implications for integrated prevention are discussed below.

5.4.1 Socio-demographic characteristics

More than two-thirds of our respondents were female, which is consistent with national data for adolescents in HIV care [496]. This reflects the gendered nature of the HIV epidemic in South Africa, where almost a quarter of all new HIV infections occur in young women aged 15–24 years [471], and also reflects much higher rates of healthcare-seeking among young women compared to young men [92, 480].

More AYLHIV were multidimensionally poor (44%) than national estimates, indicating that 33,4% of young people aged 15–24 years are MPI poor [497]. Although the proportion of NEETs in this study was lower than the national average of 34% [498], with 73% of respondents either in education or

engaged in income-generating activities, they experienced other deprivations, including food insecurity which may interact to exacerbate vulnerability to NCDs. According to the Quarterly Labour Force survey, in 2020, the majority of NEETs in the working age population (15-60-year age group) were female (55.8%)[499]. Therefore, this estimate did not appear to be skewed by the gender demographics in this study consisting of predominantly females. Furthermore, an "idle" youth not only impacts the social cohesion and safety of a community but is also linked to the uptake of risk behaviours [500]. Previous studies in South Africa have demonstrated that HIV/AIDS-affected and infected youth face multiple deprivations of poverty [156, 207], including poor educational outcomes [274], informal housing, lack of necessities like warm clothing, toiletries and school fees [275] and food insecurity [276]. Socioeconomic barriers such as poverty and food insecurity are commonly cited challenges for adolescents receiving HIV treatment and care in SSA [279]. This is concerning because socioeconomic factors like food insecurity impact adherence to ART and retention in HIV care [501], which has implications for viral suppression and chronic disease pathways [233, 280, 281]. Addressing this challenge requires a multi-sectoral approach for NCD prevention with appropriate social protection systems to meet the needs of the most vulnerable [275].

5.4.2 Overweight and obesity

More than a third of our respondents were overweight (25%) or had obesity (11%), with significantly more females with overweight and abdominal obesity than males. Although our rates of overweight and obesity in AYLHIV are slightly lower than prevalence rates for youth in the Western Cape (31.5% overweight and 11.3% obesity) [136], the rates for ALYHIV appear to be catching up with obesity trends in the general population. A previous study in adult patients attending primary health care HIV-clinics in South Africa found that more than half of female patients were overweight or had obesity compared to 16% of male patients [502]. Obesity in PLHIV is well documented in high-income countries and is emerging as a major challenge in Africa [232], with numerous studies showing increased rates of obesity in PLHIV [502-507]. However, few studies in Africa have reported overweight and obesity levels in AYLHIV other than in the context of ART-associated dyslipidaemia [245, 508, 509].

One study conducted among South African university students living with HIV (majority aged 20–25 years) found that 21% were overweight and 30% had obesity [510]. Findings from the United States

Adolescent Trials Network showed that more than 40% of behaviourally HIV-infected young women (14 – 24 years) were overweight or had obesity [511], and approximately 36% of perinatally HIV-infected adolescents were overweight or had obesity [512]. Our results are consistent with these findings and confirm results from a medical records review conducted in this same population that reported similar levels of overweight and obesity [488]. Overweight and obesity in AYLHIV may accelerate their lifetime risk of cardiovascular diseases, in addition to the effects of HIV infection and exposure to ART [511]. In our study, obesity co-occurred with hypertension – 35% of those with elevated blood pressure or hypertension were also overweight or had obesity. By screening for obesity, other related conditions which tend to cluster with obesity can also be detected. Closer monitoring of overweight and obesity profiles in young PLHIV in SSA is needed as they transition into adulthood, especially with prolonged exposure to ART regimens which are linked to obesity, altered glucose metabolism and dyslipidaemia [513].

In addition to BMI, we assessed abdominal obesity using waist and hip circumference. We found that 26% of our respondents with normal BMI had high WHR or WHtR, meeting the criteria for abdominal obesity. Another South African study in adults attending three HIV-clinics reported a high prevalence of abdominal obesity, primarily in women – 45% (4% in men) [510]. In contrast, in a study conducted in Brazil, only 2.5% of children and adolescents on ART were overweight or obese based on subscapular skinfold thickness, and less than 1% had a high WC [514]. In that study, the authors highlight that they expected a higher prevalence of overweight and obesity, but this was likely influenced by parallel gains in height and weight observed in adolescents [514].

In a study in Cameroon, Dimala et al. found that markers of adiposity like WC, WHR and WHtR are better than BMI at predicting cardiometabolic risk in HIV patients [515]. The WHO and the International Diabetes Federation (IDF) recommend monitoring changes in waist circumference in addition to measuring BMI, as this can provide an estimate of increased abdominal fat even without a change in BMI, particularly in HIV-positive populations on ARV medication and in female patients who have a higher prevalence of obesity [421, 516]. Furthermore, waist circumference and WHtR are better predictors of cardiovascular disease risk factors in children and adolescents than BMI [517]. The waist-to-height ratio has the additional merit of not being dependent on age, sex or ethnicity, as the standard cut-off value of 0.5 is indicative of an increased cardiometabolic risk universally [424]. These findings underline the importance of anthropometry beyond BMI, especially in females.

Anthropometric measurements and calculations are non-invasive, low-cost and easy-to-use interventions that can be used in primary care to identify AYLHIV who are at increased cardiometabolic risk.

5.4.3 Mental health conditions

Almost half our participants reported symptoms of psychological distress, compared to less than a quarter of young people nationally [87]. Only 11% of those with mild, moderate or severe psychological distress reported previously being diagnosed with anxiety or depression. Mental health conditions are prevalent in AYLHIV in both high-income and resource-limited settings [217]. Our results are generally consistent with prevalence rates of depression among children and adolescents living with HIV from other African countries, which ranged from 18.9% in Malawi [489], 25% in Rwanda [518], 27% in Tanzania [519] and 51.2% prevalence of significant psychological distress in Uganda [520]. However, these results are difficult to pool together due to non-uniformity in the methods used for mental health screening [217].

Significantly more female participants reported depressive symptoms compared to males (51% compared to 19%), which is in line with global statistics on depression [521]. After the age of 15, girls and women are twice more likely to experience depression than boys and men [522]. Our findings show that only 17% of those identified as having significant depression via CESD-10 reported being previously diagnosed with anxiety or depression. In a retrospective medical records review in the same population (Chapter 4), mental health conditions were documented in less than 5% of folders reviewed [488]. These findings highlight a missed opportunity for identifying youth with mental health problems before suboptimal ART adherence or other adverse HIV and mental health outcomes occur.

A recent study conducted amongst ALHIV aged 9–19 years attending a primary care clinic in Johannesburg found that 8% screened positive for symptoms of depression which is much lower than our findings. However, 60% of study participants were young adolescents aged 9–12 years and almost all were perinatally infected (92%) [523]. Older adolescents in that study (aged 16–19) were more likely to screen positive for depression compared to younger adolescents, which is in line with our findings of higher depression scores in older adolescents and young adults. It has been documented that perinatally infected adolescents may present with fewer psychological problems than

behaviourally infected adolescents [207, 524]. But similar rates of mental health conditions have been reported in HIV-exposed but uninfected youth entering adolescence [218]. The use of inappropriate comparison groups in studies showing higher rates of mental health disorders in AYLHIV makes it challenging to determine whether these impairments are, in fact, due to HIV infection or other social confounding factors. In a recent study conducted in Soweto, South Africa, the authors found similar rates of mental illness in perinatally infected and uninfected adolescents, suggesting that other contributing social factors prevalent in the community may override the effect of HIV, especially in the era of highly active antiretroviral treatment [525].

Mental health screening is crucial in HIV care due to multiple psychological vulnerabilities associated with living with HIV and high rates of suicide in PLHIV [526-528]. Recommendations calling for the integration of mental health services into HIV care have been made for adults [529]. It is important that adolescents are not overlooked in this respect. Another study conducted in Johannesburg found that a simple way of identifying youth struggling with mental health problems at the primary care level is by asking them about their future aspirations. Those who do not feel like they have control of their future or do not have a dream for the future are more likely to have symptoms of depression, anxiety or PTSD requiring further support [319].

5.4.4 Nutrition knowledge

On average, participants scored less than 40% on general nutrition knowledge questions and particularly had poor knowledge of healthy food choices and associations between diet and diseases. For example, only 22% correctly identified that eating less trans-fats can prevent heart disease. To our knowledge, this is the first study to assess nutrition knowledge in AYLHIV in Africa. The inadequate knowledge on nutrition related NCDs amongst AYLHIV in our study is concerning in a country undergoing nutritional transition [321]. However, this may reflect inadequate nutrition knowledge in the general youth population. A study in school-going South African adolescents aged 15–18 years found that 77.5% scored below average on diet and nutrition knowledge questions [138].

Nutrition knowledge is strongly correlated with dietary intake and is needed for better dietary habits [137]. Although adolescents may lack autonomy in navigating their food environment, this life stage is characterised by increasing independence, and as such, they need to be informed about the

importance of diet and how it can affect their current health status and future adult health [138]. Some practices like healthy cooking methods requiring steaming, roasting or baking can be adopted in their homes with the cooperation of parents and caregivers [530]. With adequate knowledge, older adolescents in our study who ate more fast food and more meals prepared outside the home could be encouraged to make healthier food choices.

5.4.5 Dietary intake and behaviour

Almost three-quarters of AYLHIV did not eat fruit daily, and almost half did not eat vegetables daily, falling below recommended dietary guidelines of eating at least five portions of fruit and vegetables daily necessary to reduce the risk of NCDs [531]. Female participants ate less fruit and ate more fast food, deep-fried foods and foods with added sugar daily compared to males. Younger adolescents ate fewer fruits, vegetables and whole grains compared to older age groups.

More respondents, particularly females, consumed deep-fried foods and fast foods daily compared to provincial estimates for youth in the Western Cape, while the proportion who consumed SSB daily was lower (29% compared to 42%) [85]. A recent study on fast food and carbonated soft drink consumption among adolescents aged 12–15 years in 44 LMICs (not including South Africa) found that 44% of adolescents consumed a carbonated soft drink at least once per day in the past month [532]. A meta-analysis on SSB intake found that individuals who consumed 1–2 servings per day had a 26% greater risk of developing T2DM and a 20% greater risk of metabolic syndrome compared to those who did not consume SSB or had less than one serving/month [533]. SSB consumption appears to be associated with some measures of socio-economic status with those in employment, training and education consuming more SSBs. This is likely related to access within the working or educational environment, which presents an area for intervention via health promotion.

More than two-fifths of participants skipped breakfast regularly (on three or more days). Furthermore, breakfast skipping was associated with multidimensional poverty which speaks to the deprivations experienced by these young people who might not necessarily have the functional means to choose how to navigate their food environment. Skipping breakfast in adolescence tends to persist until adulthood and has been associated with cardiometabolic risk factors, including higher prevalence of excess body weight, central obesity [534], and greater risk for NCDs [535]. Notably, a

greater proportion of AYLHIV reported skipping breakfast regularly, compared to national estimates of 13 - 36% [536] and other LMICs (40%) [537].

In order to promote healthy diets, a multi-sectoral approach that promotes a healthy food environment is required. The South African government has made strides in promoting healthier food environments by implementing mandatory legislation for salt reduction in processed foods in June 2016 [538] and a tax on sugar-sweetened beverages in April 2018 [539]. These measures were introduced in efforts to reduce the prevalence of hypertension, obesity, NCDs and excess salt and sugar consumption [540]. More efforts are needed to translate these measures into action at a community and household level, especially amongst young girls who have a higher prevalence of obesity which is likely to persist till adulthood without intervention.

5.4.6 Physical activity

Our results support findings of gender differences in physical activity levels among South African adolescents similar to global reports [541, 542]. Despite more than two-thirds of our respondents using active transport, either walking to and from school or work, one-third had insufficient physical activity levels necessary to promote health and prevent chronic diseases. Almost half spent three or more hours per day of their leisure time sedentary. This is similar to physical inactivity levels reported in urban-based South African students [541]. Sedentary behaviour was higher than general population estimates, which showed that 30% of youth watched TV or played computer games for over three hours per day [136] and higher than estimates from other LMICs, which found that 27.0% of adolescents engaged in three or more hours of sedentary behaviour per day.

Our results are consistent with those from a study in Brazil which found that 71% of ALHIV were sedentary, with a higher proportion among girls [543]. Another study conducted in Botswana found that youth living with HIV had significantly lower levels of daily PA compared to uninfected controls [245]. Similarly, a study in Brazil in 10–15-year-old perinatally infected adolescents and age-sex matched controls also found that participants living with HIV had lower physical activity scores compared to healthy peers [246]. Additional research is needed in this setting to explore the relationship between PA and HIV in adolescents. A study with an age-and sex-matched uninfected

control group from the same community would help elucidate whether this relationship exists in South Africa.

5.4.7 Smoking, alcohol and substance use

The median age at smoking initiation of 16 years found in our study was similar to the national average of 15.8 years for youth aged 15–24. However, our findings that 48% of male and 25% of female AYLHIV smoked daily or occasionally was much higher than national estimates for young people aged 15–24 years reported in the 2016 Demographic and Health Survey (29% of males and 5% of females [85]). Furthermore, almost half of those in the youngest age group reported at least occasional cigarette smoking in the past month and used more alternative tobacco products like water pipes compared to older age groups**.**

Adolescents in South Africa increasingly use water pipes (known as hookah pipes), often available without restriction [544, 545]. Our results likely reflect trends in the Western Cape – the province with the highest prevalence of tobacco smoking in South Africa– where a quarter of school-going youth are current smokers [136], and the mean age of smoking initiation is significantly lower than the national average at 14.5 years [87]. Only a few studies, most from high-income settings, address the prevalence of smoking among AYLHIV [256-258]. These studies report higher rates of smoking among AYLHIV compared to the general population, particularly among those who were behaviourally infected [253]. Our findings corroborate this and add to the limited literature from LMIC settings.

Smoking increases the vulnerability of PLHIV for adverse lung health and multiplies their risk of developing cardiovascular diseases compared to HIV-negative smokers [250-252]. Smoking often co-occurs with other health risk behaviours like alcohol consumption [546]. More than half (58%) of current smokers in our study also drank alcohol in the preceding month. Our results also indicate higher rates of current alcohol consumption than national estimates for South African youth (41% versus 33%) [136]. A few studies in SSA have reported a higher occurrence of alcohol consumption in AYLHIV compared to HIV-negative adolescents [261]. Auvert et al. reported that 29% of ALHIV in South Africa drank alcohol at least once a month, although this study was conducted almost 20 years ago [547]. Another study conducted in Zimbabwe reported that 5.6% of adolescent females living

with HIV drank alcohol in the past month, compared to 4.5% of HIV-negative females [548]. Several studies conducted in young people from other regions have reported increased alcohol and drug use, especially among male AYLHIV [262]. Our results suggest that this may be the case, but further research is needed in South Africa and SSA to elucidate whether HIV infection is associated with increased alcohol consumption in young people living in settings like South Africa where heavy drinking is endemic [88].

Our respondents reported higher rates of binge drinking in the past month compared to estimates for the general population [85] (21% of females and 37% of males in our study, compared to 5% and 21% nationally). Alarmingly, half of the underage respondents (< 18 years) were current drinkers, and 55% of them engaged in recent binge drinking. Males reported significantly more use of illicit substances compared to females. Previous studies on risk behaviour among AYLHIV in SSA report a high prevalence of alcohol and substance use behaviour, especially among males in late adolescence [260, 261]. In a study conducted amongst young people aged 15–26 years in the rural Eastern Cape province of South Africa, 4% of female AYLHIV reported problem alcohol drinking and 5% reported ever using drugs [263], whilst 31% of male AYLHIV reported problem drinking and 54% reported ever using drugs [264]. Alcohol and drug use did not differ from HIV-uninfected young people residing in the same setting [263].

The Western Cape has significant rates of stimulant use such as methamphetamine and cocaine compared to the rest of the country [549]. Approximately 5% of learners in the Western Cape have used methamphetamine within their lifetime [550]. Our findings may indicate a general underlying substance use problem in young people in this setting, not necessarily related to HIV, but which predisposes AYLHIV to more vulnerability. High rates of substance use and implications for brain development, particularly amongst males and younger adolescents, is concerning and warrants targeted intervention. Prevention and early intervention strategies aimed at harm reduction are needed that incorporate environmental factors beyond individual behaviour.

5.4.8 Other NCD comorbidity

Our blood pressure findings are consistent with findings from studies in general adolescents in urban South Africa which have reported hypertension prevalence rates ranging from 8–16% [551] and

elevated BP prevalence of 35% [552]. A study in the US reported a significantly higher prevalence of elevated blood pressure in a cohort of HIV-infected, predominantly African-American adolescents and young adults compared to healthy children [165]. Globally, studies involving HIV-infected adults have demonstrated higher hypertension prevalence than the general population [553] and hypertension has been found to be associated with ART [554, 555]. One in five young adults (18–35 years) attending an HIV clinic in the same setting in Khayelitsha had comorbid hypertension [144].

There is no clear link in the literature between HIV infection and elevated BP in paediatric and adolescent populations. Nevertheless, routine monitoring of blood pressure in HIV care, even in younger populations, is warranted in settings like South Africa with a high background prevalence of hypertension to avert future disease. BP monitoring in young people is especially relevant in light of evidence that blood pressure trajectories in childhood and adolescence predict future elevated BP and cardiovascular risk in adulthood [551, 552, 556].

None of the 25% with self-reported diabetes symptoms in our study had an abnormal measured random blood glucose. In a cohort study of South African youth living with perinatally acquired HIV, the authors found a high prevalence of insulin resistance, but it did not differ from that in uninfected age-matched adolescents [557]. A systematic review and meta-analysis of research studies in Africa recently reported no statistically significant association between HIV infection or ART exposure and T2DM prevalence in adults [558]. This finding is in contrast with study findings from European and North American settings that have shown a higher prevalence of T2DM in HIV-infected adults, particularly those on ART [162, 181, 559]. However, the cumulative incidence of T2DM in patients with HIV across Africa was higher than international incidence data for HIV-infected individuals. The IDF estimates that 60% of people with diabetes in Africa are undiagnosed [560], suggesting that T2DM might be a significant, underdiagnosed public health problem in African populations in general due to the increasing prevalence of traditional risk factors such as obesity and unhealthy diets.

5.4.9 Strengths and limitations

Our study adds to the limited evidence base on NCD prevalence and risk factors in AYLHIV in SSA. To our knowledge, only four other studies in SSA have investigated modifiable NCD risk factors besides alcohol and substance use in AYLHIV [245, 510, 561, 562]. While our study provides novel findings for the SSA context, the findings should be interpreted within the following limitations.

Firstly, participants were recruited using convenience sampling from healthcare facilities in a peri-urban setting. Second, there was an almost 50% non-response rate. The low response rate and lack of random sampling may limit the generalizability of our findings. However, sampling from six different facilities across all substructures in the City of Cape Town, proportional to the total numbers of AYLHIV within each substructure, mitigated unmeasured facility-specific effects. Limited participation and low response rates are a major challenge in adolescent research due to the complexities of enrolment and consent procedures [563, 564]. Although we recruited younger adolescents, requiring parental consent may have led to participant bias as the majority enrolled were older adolescents and young adults (aged ≥ 18 years) who could provide independent consent to participate. We, therefore, conducted an age-stratified analysis of participant characteristics.

Although we were not statistically powered to detect differences by gender or age groups, distinct differences emerged, particularly gender differences in physical activity, obesity levels and mental health, which have been previously documented. Striking differences in high-risk behaviours were also identified in the younger age group. Due to the cross-sectional design, we could not establish temporality and whether NCD risk factors and risky behaviours preceded an HIV diagnosis amongst behaviourally infected youth. Furthermore, our study did not include a control group of HIV-uninfected adolescents, neither did we differentiate between perinatally and behaviourally infected adolescents who may have very different risk profiles [153, 207]. Nevertheless, since young people come from the same communities and access the same HIV services, irrespective of the mode of transmission, interventions targeting risk factors generally may be more effective.

We used subjective recall methods of measuring physical activity, which may be prone to over-reporting [565, 566], recall bias and cultural misinterpretation [567, 568]. However, self-report methods like the IPAQ have acceptable validity and are most widely used to measure physical activity in PLHIV [244]. The use of point-of-care random blood glucose testing may have underestimated diabetes risk. Nevertheless, POC methods are better suited for community screening of diabetes, have high specificity (90%) and provide reliable and immediate results [569, 570].

Similarly, the mental health tools used are screening tools– a diagnosis of depression or anxiety was not confirmed using these tools. Nevertheless, they are appropriate for case-finding in primary care and have been validated in HIV-positive populations in South Africa [418, 571]. Also, despite using a

self-administered questionnaire, there remains a possibility that social desirability or other reporting biases may affect reports of mental health and substance use, with potential for underreporting. To minimise this risk, we used tablet computers for data collection, which have been found to reduce reporting bias on sensitive questions [572, 573]. Moreover, the reported rates were still high and, if underreported, warrant further attention. Despite these limitations, this study is an essential contribution to the limited literature on NCD comorbidity in AYLHIV in SSA.

5.5 Conclusion

Despite the limited sample size, the findings highlight the existence of cardiometabolic risk factors (obesity, abdominal obesity, hypertension, smoking, unhealthy diet), excessive drinking, physical inactivity, and mental health problems in this vulnerable population of AYLHIV, signalling possible future risk for NCDs in adulthood. Health services for AYLHIV should consider the integration of NCD risk factor screening and mental health assessments into routine care.

NCDs and their ensuing burden of disability and premature mortality are costly to health systems and broader societal development. Beyond primary care, the complex and interlinked social, economic and environmental factors that influence these behaviours highlight the importance of intersectoral action for disease prevention. Therefore, it is necessary to go beyond the healthcare sector to address the root causes and multiple deprivations that increase the risk of NCDs and ill health and support equitable access to the necessary physical and social infrastructure required to make the healthy choice the easy choice. Upstream strategies that incorporate the basic living conditions and environments in which young people live are necessary to ensure their well-being and interrupt disease pathways. More studies are needed to assess risk factors at a broader socio-ecological level and explore inter-relationships between HIV/NCD comorbidity and the environment to identify effective and sustainable risk-reduction interventions.

Chapter 6

Neighbourhood Environment and Multilevel Correlates of Obesity in Adolescents and Youth Living with HIV in Urban Cape Town

6.1 Introduction

6.1.1 Obesity prevalence globally and in low- and middle-income countries

Obesity is a major global health challenge and the leading risk factor for NCDs, including cardiovascular disease, diabetes, several cancers and osteoporosis [574]. It is increasingly recognized that obesity is a disease in its own right that is rising in all regions of the world and was subsequently declared a pandemic by the WHO in the year 2000 [575, 576]. The global prevalence of overweight in adults aged 18 and older increased from 22% in 1975 to 39% in 2016 [577]. Globally in 2014, 13% of adults had obesity, of which 62% were residing in LMICs [86]. Overweight and obesity prevalence among children and adolescents aged 5 – 19 years increased more than four-fold in four decades, from just 4% in 1975 to over 18% in 2016 [577].

6.1.2 Obesity prevalence in sub-Saharan Africa and South Africa

Epidemiological analyses show that from 1980- 2014, age-standardized average BMI increased across African regions at least as steeply as the global average [82]. Overweight and obesity rates are increasing in all African regions, and the Southern African region is the most affected [578]. The prevalence of overweight in Southern Africa increased from 6% in 1990 to 21% in 2015 [578]. South Africa has the highest prevalence of overweight and obesity in SSA, with up to 70% of women and 33% of men classified as overweight or obese [86]. The prevalence of overweight and obesity among adult South African women increased from 56% to 68% between 1998 and 2016 [85]. Women in SSA have disproportionately higher rates of overweight and obesity compared to men, a trend already emergent during adolescence [579, 580]. A study among South African adolescents found that obesity incidence among girls was highest in adolescence, while obesity among boys did not increase from childhood [581].

The majority of overweight or obese children live in LMICs, where the rate of increase has been more than 30% higher than that of high-income countries [577, 582]. Similar to adults, South Africa has the highest prevalence of childhood overweight and obesity in Africa, with 19% of boys and 26% of girls under 20 years classified as overweight or obese, rivalling many high-income countries [86]. Obesity rates typically increase with age, plateauing in middle age or declining thereafter [578].

6.1.3 Obesity in the context of a co-existing HIV epidemic

In addition to a growing obesity epidemic, as previously discussed, South Africa has the biggest antiretroviral therapy (ART) program in the world and the highest reported burden of adolescent HIV infection globally [583]. Although wasting and thinness were previously associated with HIV infection before the advent of highly active ART, obesity has now been described as the latest epidemic in PLHIV [190, 504]. Previous studies found that overweight and obesity rates increased significantly in cohorts of adults after starting ART [507], particularly in those who were already overweight prior to ART initiation and were subsequently at greater risk of weight gain [584].

Other factors associated with overweight/obesity in PLHIV include female gender, older age, increased CD4 count, high haemoglobin (≥ 9.5 g/dL) as well as hypertension and dyslipidaemia [504] and similar socio-economic and behavioural risk factors to those documented in the general population such as high SES [507], physical inactivity and poor dietary quality [234]. Type of ART regimen, particularly use of protease inhibitors, has also been associated with overweight and obesity or weight gain [585]. However, this finding is inconsistent as some longitudinal studies have found no relationship between weight gain and type of ART regimen or duration on ART [504, 507]. It remains unclear what effect HIV and ART have on BMI in adolescents. Studies comparing perinatally HIV-infected youth to uninfected youth have reported similar BMIs and waist circumferences and comparable rates of overweight and obesity [512]. In settings like South Africa, where HIV is highly prevalent and stigmatized, weight gain among PLHIV may also be intentional and related to perceptions of beauty or affluence [586] and anticipated stigma [87]. More data, beyond demographic and clinical factors, are needed on the causes of weight gain among PLHIV, particularly AYLHIV.

6.1.4 Urbanisation as a driver of obesity

In 2018, more than half of the world's population were residing in urban areas, with a projected increase from 55% to 68% by 2050 [587]. In South Africa, 66% of the population lived in urban areas in 2018 [587]. The rural-urban divide is often cited as a driver of obesity in LMICs [15]. Urbanisation is a complex process shaped by socio-economic and spatial shifts that transform the food and built environment [587], accompanied by shifts in dietary practices, family composition, work-related commuting and occupational activities [587]. Increased urbanisation is associated with lower levels

of physical activity in work, decreased levels of active transport and decreased energy expenditure during leisure time [444].

Furthermore, opportunities or barriers for physical activity are shaped by infrastructure and the built environment. Environmental attributes like neighbourhood walkability, access to recreational spaces, pedestrian infrastructure, land use mix access and diversity impact willingness to walk and engage in physical activity [588]. Additionally, rapid urbanisation and population growth in cities may result in increased crime rates, low air quality and destruction of recreational areas and green spaces, inhibiting walkability and opportunities for engaging in physical activity [589].

South Africa is said to be undergoing an epidemiological [310] and nutrition transition [311] with a shift in mortality and disease patterns, dietary consumption, and energy expenditure. Typically, in countries undergoing economic development, diets tend to shift from traditional and predominantly plant-based diets to highly refined food high in energy, saturated fats, salt, and sugar [590]. In turn, this leads to a rise in obesity levels and nutrition-related NCDs [15, 591]. Urban food environments, with supermarkets, food vendors, fast-food outlets and restaurants, facilitate access to a variety of foods [591]. However, micronutrient poor, energy-dense foods that tend to be lower in cost are usually in oversupply in urban areas. Thus, the most readily available and affordable diets for the urban poor are often made up of unhealthy, calorie-dense foods [592].

It is widely recognized that the built and food environment in which young people live in LMICs is increasingly obesogenic and promotes high energy intake and sedentary behaviour [592, 593]. Given that most factors that influence obesity lie outside healthcare, it is important to understand the lived realities of young people in terms of environmental and contextual factors in order to understand how best to intervene.

6.1.5 Study rationale

The life course theory asserts that causal pathways for chronic disease start early in life, even before conception, and persist throughout growth and later adult life [29]. Specific periods in the life course are critical to the development of future disease. Many behavioural risk factors and uptake of risk behaviours occur or are established during adolescence [593]. Adopting a life course approach to

obesity prevention can interrupt disease pathways before they become entrenched and continue into adulthood.

Africa has the largest concentration of young people globally, with youth aged 15-24 years making up 20% of Africa's population [594]. However, youth health and well-being are under-researched in SSA, with most research focussing on sexual and reproductive health [42]. There is particularly a paucity of data from LMICs to guide interventions to address childhood and adolescent obesity. Adolescence is a key 'window of opportunity' when interventions can prevent excess weight gain in a sustained manner [595]. Interventions aimed at preventing obesity during adolescence would lead to a reduction in comorbidities in adolescents, reduce the long-term burden of NCDs and ensure the health of future generations [595]. Failure to address obesity at this life stage will further aggravate inequalities in health, both within and between countries, over-burdening fragile health systems and causing economic losses [595, 596].

Adolescents are generally healthy and do not frequently interact with the healthcare system. However, AYLHIV regularly access healthcare by virtue of living with a chronic condition requiring regular follow-up and treatment. Furthermore, AYLHIV face heightened vulnerability for developing NCDs due to the clinical manifestations of HIV and long-term use of ART [151], but also due to social and environmental determinants of health [218]. Coupled with the uptake of high-risk behaviours in adolescence, this represents a critical opportunity for intervention in a group at higher risk for NCDs [151]. With HIV now being a manageable, chronic condition [232], PLHIV face similar challenges as the general population, including excessive weight gain [504, 597]. By focussing on AYLHIV, we aimed to gain insight into their health beyond HIV-related outcomes and reduce future NCD risk in a vulnerable, accessible group.

Adolescent development is greatly influenced by the context in which adolescents develop. This ranges from the immediate environment of family, peers and neighbourhood to the greater cultural and social macro-system [17]. There is growing recognition that the health of children and adolescents, maybe more so than other age groups, is largely determined by factors that lie outside of the healthcare system [19]. Traditionally research on obesity has focussed on proximate, individual-level factors such as physical activity and dietary intake, and associated factors such as the school environment [598, 599] and household SES [15]. Although individuals may choose what they

eat and how active they are, these behaviours are primarily shaped by the broader food and built environment. A few previous studies have explored the relationship between the built environment and physical activity [354, 600] and nutrition [601] in young people. To our knowledge, none have explored the relationship between abdominal obesity in AYLHIV and environmental-level factors in an LMIC setting.

Changes in adiposity and body composition are important considerations for monitoring health, especially in PLHIV, who are subject to visceral adiposity. Fat redistribution has emerged as a significant issue in PLHIV with certain ART regimens linked to abnormal body fat distribution [160, 161, 191]. BMI is the most widely used adult, population-level measure of overweight and obesity. However, BMI may not correspond with body fat percentage in different populations [421]. Measures of abdominal obesity may be more sensitive in detecting changes caused by changes in medication and immunosuppression compared to BMI and hence better at detecting PLHIV who are at increased cardiometabolic risk [602]. Furthermore, waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk in children and adolescents than BMI [517].

6.1.6 Aims and objectives

We, therefore, set out to investigate the prevalence of abdominal obesity and associated individual, household, community, and neighbourhood-level factors among AYLHIV in urban Cape Town.

6.2 **Methods**

6.2.1 Study population and setting

This was a cross-sectional study enrolling AYLHIV aged 15-24 years attending primary healthcare facilities in peri-urban Cape Town. The City of Cape Town experiences high levels of circular migration from the surrounding Eastern and the Northern Cape provinces, leading to a proliferation of unplanned informal settlements lacking access to basic amenities and subject to fires and forced removals [389-391].

The City of Cape Town delivers primary health care through four legislated substructures as described in the methodology. Recruitment and data collection took place at six public-sector HIV clinics selected within each of the four sub-structures. These primary care facilities serve a catchment population living in peri-urban, high-density, low-income townships, collectively known as the Cape Flats [392]. The area consists of a mix of formal and informal dwellings, with 56% of the population residing in formal dwellings [392], high rates of poverty [393], and high levels of violent and drug-related crime [394, 395].

The sampling and recruitment procedures have been described in detail before (see **Chapter 3**). The study, which was facility-based with participants recruited using convenience sampling, commenced in March 2019 until January 2020 after ethical clearance was gained from the Human Research Ethics Committee at the University of Cape Town (HREC ref no: 520/2017) and approval was obtained from Provincial and Local Government Departments of Health. Recruitment and study procedures were conducted after gaining written informed consent/assent (and parental/caregiver consent for participants less than 18 years).

6.2.2 Data collection

Except for physical examination measures, all measures were obtained via self-report using a self-administered electronic form on a hand-held Android device. The candidate and study coordinator conducted physical examinations according to the study protocol standard operating procedures. An overview of the data collected is detailed in **Table 6.1** below. In addition, detailed descriptions of each variable can be found in Chapter 3 (subsections **3.7.2.5** and **Table 3.6**). The primary outcome of interest was abdominal obesity status (characterised by a waist-to-height ratio greater than 0.5 as detailed in Chapter 3). Details on the measurement procedure for waist circumference and height are given in **Section 3.7.2.4.1.4**.

Table 6.1: Summary of data collected for Objective 3

Variables		Measures	Section
Outcome variable	abdominal obesity	*WHtR* > 0.5	Section 3.7.2.4.1.4
Independent variables			
Socio-demographics	Age	15–17, 18–19, 20–21 and 22–24 years	Section 3.7.2.4.1.1
	Sex	male, female	
	Poverty	Youth Multidimensional Poverty Index (YMPI)	
	Educational attainment	completed primary or high school, obtained a tertiary qualification, ever repeated a grade at school	
	Absenteeism	absent on one or more days in the past month	
	Parity	History of pregnancy or impregnating someone, number of children	Section 3.7.2.5.1
Clinical characteristics	Blood pressure	normal, elevated BP, hypertension	Section 3.7.2.4.1.5
	Mental health	Depression and psychological distress	Section 3.7.2.4.1.3
Knowledge and behaviour	Dietary intake	Food frequency, skipping breakfast, school lunch consumption, and meals prepared outside the home.	Section 3.7.2.4.1.2
	Nutrition knowledge	General nutrition knowledge	
	Physical activity and sedentary behaviour, active transport	moderate and vigorous-intensity physical activity, sufficient and insufficient PA, more than 3 hours sedentary/ day, walking/cycling as part of daily commute	
Household factors	Family history	Any chronic conditions, e.g. diabetes, stroke, or hypertension	Section 3.7.2.5.2
	Dwelling characteristics	Housing informality, access to amenities, waste removal, thermal comfort, history of adverse events, e.g. flooding/ fire	
	Food security	mild, moderate, severe food insecurity	Section 3.7.2.4.2
	Family composition, orphanhood, and parenting	Positive parenting and poor supervision, household composition, working-age adults, dependents	Section 3.7.2.5.2
Social environment characteristics	Stigma	Anticipated, internalized, and enacted stigma	Section 3.7.2.5.3
	Social capital	Family trust, school social capital and neighbourhood social capital	
	Exposure to violence	No violence, moderate level, and high level of violence.	
	Crime safety	Perceptions of neighbourhood crime	
Built environment characteristics	Walkability	Perceived neighbourhood environment walkability	Section 3.7.2.5.4
	Local food environment	Access to grocery stores, supermarkets, and food outlets	

6.2.3 Statistical analysis

6.2.3.1 Descriptive statistics

Categorical and continuous variables were described using summary statistics: frequencies and percentages for categorical variables; medians, interquartile ranges for non-parametric variables; means and standard errors for normally distributed variables (e.g. the NEWS-Y scale variables). Differences between variables were compared by abdominal obesity status using Pearson's $\chi 2$ goodness of fit tests and Fisher's exact test for categorical variables. Continuous nonparametric variables were compared using the Wilcoxon rank-sum test, while normally distributed variables were compared using t-tests. All statistical analyses were done using Stata (version 14) (*Stata Corporation, College Station, Texas, USA*).

6.2.3.2 Bivariate analysis

We explored relationships between individual-level, household-level and broader social and environment-level variables and obesity status using graphical displays (box plots for continuous risk factors over obesity outcomes), two-by-two tables for categorical risk factors and crude odds ratios (ORs) from bivariate logistic regression models. Variables identified in the literature related to the outcome and variables that reached a significance level of $p < 0.10$ in bivariate analysis were included in model-building.

6.2.3.3 Multilevel logistic regression

The primary outcome variable was abdominal obesity, defined as a waist-to-height ratio of > 0.5. Multilevel logistic regression was used to investigate individual- and environment-level correlates associated with abdominal obesity within the clustered data structure, as displayed in **Figure 6.1.** Although we had household- and neighbourhood-level variables, these were all collected at the individual level and were not aggregate variables. Individual participants were the primary sampling units. The only group-level variable included in modelling was the sub-district – Northern, Southern, Khayelitsha, and Klipfontein/Mitchells Plain, for which the non-independent clustering effect was adjusted for in a mixed-effects model taking the variance structure into account.

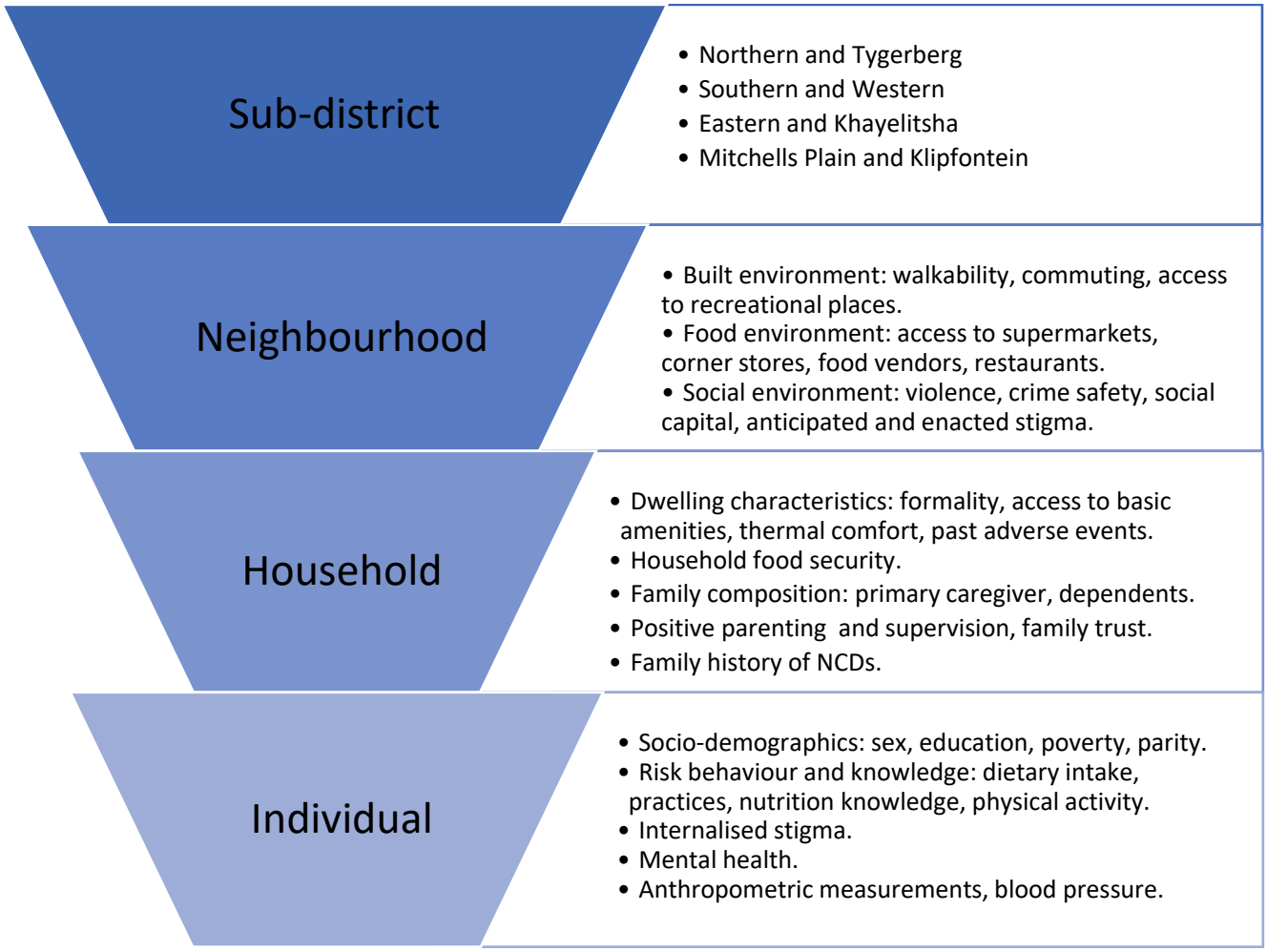

Figure 6.1: Multilevel data structure and variables

Multilevel models were developed *a priori* based on a review of the literature with participants (level 1) nested within sub-districts (or health zones), which were used as a proxy for neighbourhoods (level 2). Variables identified in the literature associated with obesity and variables with significant odds ratios ($p < 0.10$) in bivariate analysis were included in the multilevel logistic regression analysis. All models were adjusted for age and sex as known confounders.

6.2.3.4 Model building

Variables with significant odds ratios ($p < 0.10$) in bivariate analysis were included in the multilevel logistic regression analysis. Initially, the null model was constructed, and then individual-level variables were added, followed by household-level variables, and finally, neighbourhood-level built- and food environment variables were added. All models were adjusted for age and sex. The full model with all significant bivariate parameters included failed to converge; therefore, we used a sequential model-building process adding individual parameters into the model with age and sex as follows:

1. **Null model:** the empty model showing if differences in abdominal obesity status were random or fixed across sub-districts.
2. **Model 2:** model with age and sex.
3. **Models 3 – 6:** individual-level variables (youth poverty, education, physical activity, dietary intake, behaviour).
4. **Models 7 – 9**: household-level variables (family history, dwelling characteristics, food security, family structure, and parenting).
5. **Models 10 – 16**: neighbourhood environment variables (social environment, perceived built and food environment).

6.2.3.5 Model diagnostics

Different models were compared using the Chi-squared likelihood ratio (LR) test, which assesses the difference between nested models. Non-nested models were compared using the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). The final models presented included variables that had the greatest association with obesity status, with the greatest explanatory power, adjusted for age and sex.

We checked the quality of fit for all models and tested the underlying model assumptions of linear relationships, homoscedasticity, and normal distribution of the residuals. We also checked the intra-class correlation coefficient (ICC) in order to analyse the variability within and between neighbourhoods. Statistical significance was set at p = 0.05 for the multilevel analyses. Standardized coefficients (β) and odds ratios (e^{β}) were presented as measures of association, with the degree of precision displayed via confidence intervals and p-values.

6.3 Results

6.3.1 Individual-level characteristics

6.3.1.1 Socio-demographic characteristics

Participant characteristics are shown in **Tables 6.2**- **6.4**, stratified by abdominal obesity status. A total of 87 participants were interviewed, a third of whom were 22- 24 years old (median 20.7 (IQR 18.9-

23.0) years), and 76% were female. More than half of participants (52%) reported ever repeating a grade at school. Of those 20 years or older, 31 (58%) had completed high school or the equivalent, and 17% were enrolled in some tertiary form of education. Overall, 27% were neither in education, employment or training (NEET) at the time of the study, with no significant differences by sex or age. According to the Youth MPI definition, 43% of participants were multidimensionally poor, being deprived in a third or more of indicators that constitute the YMPI. Overall, 23% of participants reported that they had ever been pregnant or had impregnated someone, and 17% had at least one child.

6.3.1.2 Primary outcome

Forty-one per cent of participants met the primary outcome criteria for abdominal obesity (95% CI 31.0- 51.7%). The median waist circumference was 76 cm (IQR 71– 87 cm), and the median BMI was 22.6 kg/m^2 (IQR 19.6 – 26.5 kg/m^2). Assessing weight status by BMI, 24% of participants were overweight, and 11% had obesity. Notably, 24% of those with normal BMI had abdominal obesity (data not shown). Abdominal obesity status differed significantly by sex, ever being pregnant and parity (**Table 6.3**); 47% of females had obesity compared to 24% of males (*p= 0.05*) and more of those who had ever been pregnant or had a child had obesity compared to those who had never been pregnant (37% versus 14%; *p= 0.012)*. Obesity rates did not differ significantly by age, although the youngest age group had the lowest rates of obesity compared to the older age groups. Obesity rates were also similar across educational attainment and multidimensional poverty levels.

6.3.1.3 Clinical characteristics

With respect to clinical characteristics, 18% of participants had elevated blood pressure, and 6% had hypertension. No participants had elevated random blood glucose, but 28% self-reported family history of diabetes. More than half of the participants screened had significant depression with a CESD score of ten or more, and 43% experienced some level of psychological distress, with 26% reporting moderate or severe distress. Anthropometric characteristics were correlated with abdominal obesity and differed significantly by obesity status, as shown in **Table 6.3.** Blood pressure differed by abdominal obesity; those who had obesity had higher median blood pressure than those who did not have obesity. Other clinical characteristics, including mental health measures, did not differ significantly by obesity status.

6.3.1.4 Physical activity, dietary behaviour and knowledge

The majority of participants reported engaging in some form of physical activity, with two-thirds meeting the criteria for sufficient levels of physical activity of > 600 MET-minutes per week, while half spent three or more hours sedentary in a typical day. In addition, 72% of participants used active transport as part of their daily commute. Physical activity levels and MET minutes/week (vigorous-, moderate-intensity, or walking) did not differ significantly by obesity status (see **Table 6.3** and **Figure 6.2**). Of those currently enrolled in an educational institution or working (n= 52), 31% reported that their daily commute from home to school or work was more than 31 minutes long, and 43% used more than one means of transport daily. Almost half (44%) walked as part of their commute.

Fruit and whole-grain consumption differed significantly by obesity status, with a significantly higher proportion of those who did not have obesity consuming more fruits and whole grains daily (see **Table 6.4**). More than a quarter of participants reported daily consumption of deep-fried foods (28%), sugar-sweetened beverages (SSBs) (27%), sweets and cakes (34%) and 20% reported consuming fast foods daily or more than once daily. This did not differ significantly by obesity status.

More than two-thirds (69%) of participants reported eating a meal prepared outside the home in the week preceding the survey. Participants ate a median of two meals in the week prepared outside the home (IQR 2 – 4 meals). Forty per cent of participants skipped breakfast frequently or almost every day in the week, and 41% of those enrolled in a school serving school lunch ate lunch at school on most days in the week. Skipping breakfast and attendance at a school where lunch was provided differed significantly by obesity status. Significantly more of those who did not have abdominal obesity ate breakfast daily compared to those who had abdominal obesity (75% versus 39%), while more of those who did not have abdominal obesity attended a school where school lunch was provided compared to those who were obese (73% versus 38%). The overall general nutrition knowledge score was low at 37.7% (95% Confidence Interval (CI): 35.5 – 39.9) and did not differ significantly by obesity status, as shown in **Table 6.4**.

Table 6.2: Socio-demographic characteristics of AYLHIV in Cape Town by abdominal obesity status

Variable: median (IQR) or n (%)		**Non-obese n= 51 (59%)**	**Obese n= 36 (41%)**	**Total n= 87**
Age (years)		20.2 (18.6-22.7)	21.7 (19.6-23.5)	20.7 (18.9-23.0)
Age distribution	15 – 17 years	11 (22%)	2 (6%)	13 (15%)
	18 – 19 years	12 (24%)	9 (25%)	21 (24%)
	20 – 21 years	13 (25%)	11 (31%)	24 (28%)
	22 – 24 years	15 (29%)	14 (39%)	29 (33%)
Gender*$^{\alpha}$	Male	16 (76%)	5 (24%)	21 (24%)
	Female	35 (53%)	31 (47%)	66 (76%)
Language spoken the most at home	isiXhosa	45 (88%)	29 (81%)	74 (85%)
	English	3 (6%)	3 (8%)	6 (7%)
	Afrikaans	0	2 (6%)	2 (2%)
	Other	3 (6%)	2 (6%)	5 (6%)
Ever pregnant/ impregnated someone*$^{\alpha}$		7 (14%)	13 (37%)	20 (23%)
Number of children *$^{\alpha}$	0 children	45 (88%)	27 (75%)	72 (83%)
	1 child	6 (12%)	8 (22%)	14 (16%)
	2 children	0	1 (3%)	1 (1%)
Educational attainment	Primary school	2 (4%)	1 (3%)	3 (3%)
	Some secondary school	25 (49%)	19 (53%)	44 (51%)
	Completed matric or equivalent	19 (37%)	12 (33%)	31 (36%)
	Some tertiary education	5 (10%)	4 (11%)	9 (10%)
Current occupation/ employment status	In school, college, university or other tertiary	23 (46%)	19 (53%)	42 (49%)
	In training	7 (14%)	2 (6%)	9 (10%)
	Employed	6 (12%)	6 (17%)	12 (14%)
	Not in education, employment or training	14 (28%)	9 (25%)	23 (27%)
Ever repeated a grade at school		24 (47%)	21 (58%)	45 (52%)
Days absent from school or work in past month	0 days	31 (62%)	14 (39%)	45 (52%)
	1- 2 days	17 (34%)	13 (36%)	30 (35%)
	3 or more days	2 (4%)	9 (24%)	11 (12%)
Youth multidimensional poverty index score (n= 83)		0.26 (0.25-0.39)	0.38 (0.25-0.38)	0.28 (0.25-0.39)
Prevalence of multidimensional poverty (Youth MPI > 1/3)		18 (37%)	18 (53%)	36 (43%)

** p-value from Chi-squared test or Fisher's exact test, $^{\alpha}$ Denotes $p \leq 0.05$.*

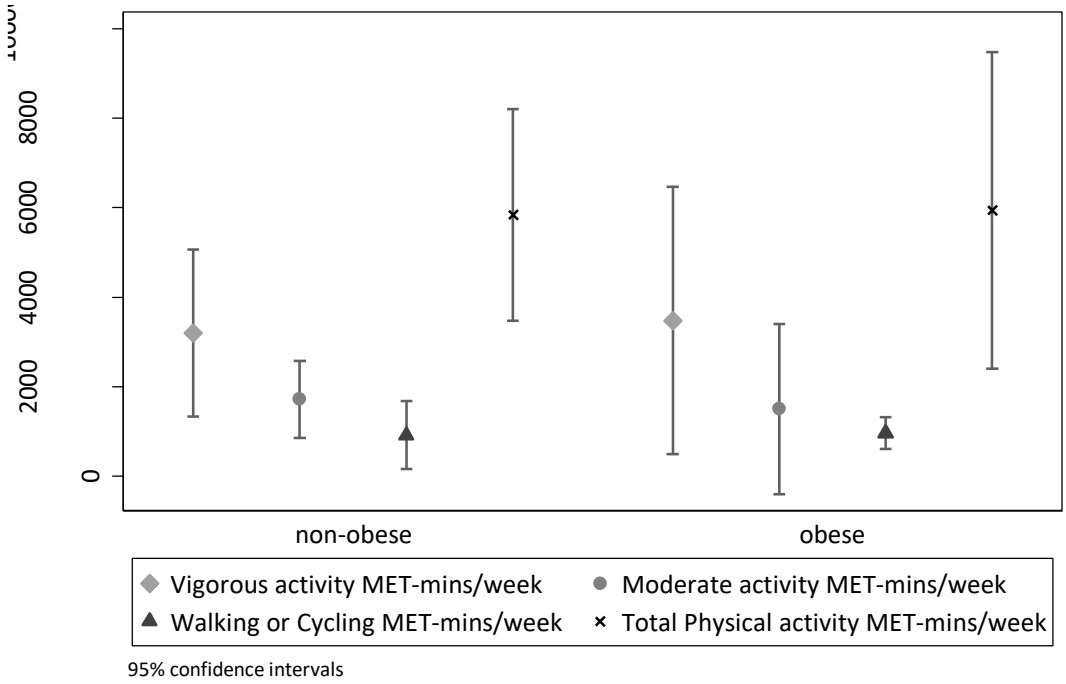

Figure 6.2: Physical activity MET minutes/week by abdominal obesity status

Table 6.3: Clinical characteristics and physical activity of AYLHIV in Cape Town by abdominal obesity status

Variable: median (IQR) or n (%)		**Non-obese: n = 51 (59%)**	**Obese: n = 36 (41%)**	**Total: n= 87**
Waist circumference (WC) in cm* $^{\alpha}$		72.25 (68– 75)	89 (82– 102)	76 (71– 87)
Hip circumference in cm* $^{\alpha}$		90 (85 – 96.65)	106.5 (98.5– 118)	95 (86.5- 106)
Waist-hip ratio (WHR) * $^{\alpha}$		0.81 (0.74 - 0.84)	0.85 (0.82 - 0.90)	0.83 (0.78 - 0.87)
BMI in kg/m^2 * $^{\alpha}$		20.25 (18.93; 22.22)	27.12 (24.45; 31.31)	22.55 (19.59; 26.45)
Blood Pressure in mmHg (SBP/DBP) $^{\beta}$ * $^{\alpha}$		115/ 71.5 (107.5/66.5 -123/78)	120/ 75 (109.5/70.25- 126.25/80.25)	117.5/ 74 (109.5/ 67.5 - 124.5/79.5)
	Normal BP: SBP<130 & DBP<85	41 (80%)	25 (69%)	66 (76%)
	Elevated BP: SBP 130–139/ DBP 85–89	7 (14%)	9 (25%)	16 (18%)
	Hypertension: SBP 140–159/ DBP 90– 99	3 (6%)	2 (6%)	5 (6%)
Family history of diabetes		16 (31%)	8 (22%)	24 (28%)
CESD-10 depression score		10 (8– 14)	10 (7–17)	10 (8 – 14)
	Significant depression (CESD ≥10)	30 (59%)	19 (53%)	49 (56%)
Kessler psychological distress score (K10) (n= 86)		17 (12 – 25)	19 (14- 25)	18.5 (13–25)
	Mentally well (K10 <20)	31 (61%)	18 (51%)	49 (57%)
	Mild distress (K10 20-24)	7 (14%)	8 (23%)	15 (17%)
	Moderate distress (K10 25-29)	9 (18%)	7 (20%)	16 (19%)
	Severe distress (K10 ≥30)	4 (8%)	2 (6%)	6 (7%)
Physical activity (n= 81)		**46**	**35**	**81**
Vigorous-intensity physical activity	Prevalence of PA for ≥10 minutes	21 (46%)	13 (37%)	34 (42%)
	Time spent per day in minutes	60 (30 –150)	105 (30 – 120)	60 (30 – 120)
	MET-minutes/week	1560 (720 – 3840)	2040 (480 – 4800)	1800 (600 – 4320)
Moderate-intensity physical activity	Prevalence of PA for ≥10 minutes	41 (89%)	28 (80%)	69 (85%)
	Time spent per day in minutes	60 (30 –120)	35 (30– 60)	60 (30 – 90)
	MET-minutes/week	720 (480– 1440)	720 (520– 1200)	720 (480 – 1440)
Active transport $^{\epsilon}$	Walking or cycling for ≥ 10 minutes	34 (74%)	24 (69%)	58 (72%)
	Time spent walking/ cycling daily in minutes	30 (30 – 60)	50 (30 –60)	30 (30 – 60)
	Walking MET-minutes/week	495 (280.5– 1188)	693 (396 – 1188)	528 (297 –1188)
Total physical activity MET-minutes/week		1314 (480 – 3396)	1173 (560 – 3348)	1207.5 (495 – 3372)
Insufficient physical activity (< 600 MET-minutes per week)		16 (36%)	10 (29%)	26 (33%)
High physical activity (≥ 3000 MET minutes per week)		12 (27%)	9 (26%)	21 (26%)
Sedentary behaviour: three or more hours per day		21 (46%)	19 (54%)	40 (49%)
Currently enrolled in an educational institution or working		**31 (61%)**	**21 (58%)**	**52 (60%)**

Travel time from home to school/ work (n= 52)	1-5 min	4 (13%)	1 (5%)	5 (10%)
	6-10 min	1 (3%)	2 (10%)	3 (6%)
	11-20 min	8 (26%)	3 (14%)	11 (21%)
	21-30 min	10 (32%)	7 (33%)	17 (33%)
	31+ min	8 (26%)	8 (38%)	16 (31%)
Additional transport mode (more than one means)		12 (40%)	10 (48%)	22 (42%)

**p-value from Wilcoxon rank-sum (Mann-Whitney) test; **p-value from Fisher's exact test; [α] Denotes p ≤ 0.05; [β] Significant difference for diastolic blood pressure, insignificant for systolic; [ε] Only reported walking, none used bicycles or motorcycles for active transport*

Table 6.4: Food frequency, dietary practices and nutrition knowledge of AYLHIV in Cape Town by abdominal obesity status

Variable: median (IQR) or n (%)		**Non-obese: n = 51 (59%)**	**Obese: n = 36 (41%)**	**Total: n= 87**
Food Frequency				
Weekly portions of fruit consumed: median (IQR)		**3 (0.5 – 7)**	**3 (1 – 3)**	**3 (1 – 7)**
Fruit consumption (n= 77) ** [α]	Never	2 (5%)	0	2 (3%)
	Once a week / less than once a week	17 (39%)	12 (36%)	29 (38%)
	2 - 4 times a week	6 (14%)	14 (42%)	20 (26%)
	Frequently (5 – 6 times a week)	4 (9%)	2 (6%)	6 (8%)
	Daily or more than once daily	15 (34%)	5 (15%)	20 (26%)
Weekly portions of vegetables consumed: median (IQR)		**7 (3– 7)**	**7 (3– 10)**	**7 (3– 10)**
Vegetable consumption (n= 76)	Never	2 (5%)	1 (3%)	3 (4%)
	Once a week / less than once a week	8 (19%)	4 (12%)	12 (16%)
	2 - 4 times a week	4 (9%)	5 (15%)	9 (12%)
	Frequently (5 – 6 times a week)	7 (16%)	6 (18%)	13 (17%)
	Daily or more than once daily	22 (51%)	17 (52%)	39 (51%)
Weekly portions of whole grain consumed: median (IQR)		**7 (1– 10)**	**2 (0.5– 6.25)**	**5.5 (1– 7)**
Wholegrain bread or cereal consumption (n= 64) ** [α]	Never	1 (3%)	4 (14%)	5 (8%)
	Once a week / less than once a week	9 (25%)	10 (36%)	19 (27%)
	2 - 4 times a week	3 (8%)	4 (14%)	7 (11%)
	Frequently (5 – 6 times a week)	4 (11%)	3 (11%)	7 (11%)
	Daily or more than once daily	19 (53%)	7 (25%)	26 (41%)
Weekly portions of deep-fried foods consumed: median (IQR)		**3 (0.5 – 7)**	**1 (0.5 –7)**	**2 (0.5 – 7)**
Deep-fried food consumption (n= 64)	Never	3 (8%)	3 (12%)	6 (9%)
	Once a week / less than once a week	15 (39%)	11 (42%)	26 (41%)
	2 - 4 times a week	6 (16%)	1 (4%)	7 (11%)
	Frequently (5 – 6 times a week)	4 (11%)	3 (12%)	7 (11%)
	Daily or more than once daily	10 (26%)	8 (31%)	18 (28%)

Weekly portions of fast foods consumed: median (IQR)		**1 (0.5 – 5.5)**	**0.75 (0.5 – 4.25)**	**1 (0.5 – 5.5)**
Fast food consumption (n= 65)	Never	6 (16%)	5 (18%)	11 (17%)
	Once a week / less than once a week	16 (43%)	13 (46%)	29 (45%)
	2 - 4 times a week	5 (14%)	3 (11%)	8 (12%)
	Frequently (5 – 6 times a week)	1 (3%)	3 (11%)	4 (6%)
	Daily or more than once daily	9 (24%)	4 (14%)	13 (20%)
Weekly portions of SSBs consumed: median (IQR)		**3 (0.5 – 7)**	**3 (1 – 7)**	**3 (0.5 – 7)**
Sugar-sweetened beverage consumption (n= 74)	Never	3 (7%)	1 (3%)	4 (5%)
	Once a week / less than once a week	15 (36%)	8 (25%)	23 (31%)
	2 - 4 times a week	9 (21%)	8 (25%)	17 (23%)
	Frequently (5 – 6 times a week)	4 (10%)	6 (19%)	10 (14%)
	Daily or more than once daily	11 (26%)	9 (28%)	20 (27%)
Weekly portions of sweets and cakes consumed: median (IQR)		**3 (0.5 – 7)**	**3 (1 – 10)**	**3 (1– 7)**
Sweets and cakes consumption (n= 76)	Never	4 (9%)	1 (3%)	5 (7%)
	Once a week / less than once a week	17 (40%)	8 (24%)	25 (33%)
	2 - 4 times a week	4 (9%)	9 (27%)	13 (17%)
	Frequently (5 – 6 times a week)	4 (9%)	3 (9%)	7 (9%)
	Daily or more than once daily	14 (33%)	12 (36%)	26 (34%)
Dietary practices				
Ate meal prepared outside the home in past week (n= 74)		28 (68%)	23 (70%)	51 (69%)
Meals eaten outside home in past week: median (IQR)		2 (1.5 – 4.5)	2 (2 – 3)	2 (2 – 4)
Breakfast consumption (n= 77)**$^{\alpha}$	Skippers: breakfast 0 – 2 days/week	7 (16%)	10 (30%)	17 (22%)
	Semi-skippers: breakfast 3 - 4 days/week	4 (9%)	10 (30%)	14 (18%)
	Non-skippers: breakfast 5 - 7 days/week	33 (75%)	13 (39%)	46 (60%)
School serves school lunch $^{\pi}$ (n= 38) **$^{\alpha}$		16 (73%)	6 (38%)	22 (58%)
School lunch in the week (n= 22)	Never	4 (25%)	0	4 (18%)
	Occasionally (1- 3 days)	6 (37.5%)	3 (50%)	9 (41%)
	Always (4- 5 days)	6 (37.5%)	3 (50%)	9 (41%)
General Nutrition Knowledge Score (% Score /88) mean (95% CI)		37.8 (34.9 – 40.7)	37.7 (34.1 – 41.3)	37.7 (35.5 – 39.9)
(n= 76)	1. Dietary recommendations % (score/18)	44.3 (39.4 – 49.2)	42.4 (36.9 – 47.8)	43.5 (39.9 – 47.1)
	2. Food Groups % (score/36)	38.2 (35.1 – 41.3)	37.8 (33.7- 41.9)	38.0 (35.6 - 40.4)
	3. Healthy Food choices % (score/13)	31.8 (26.7 – 36.9)	33.7 (26.5 – 40.8)	32.6 (28.5- 36.7)
	4. Diet, disease relationships % (score/21)	34.3 (30.0 – 38.6)	36.0 (31.1 – 40.9)	35.0 (31.9- 38.2)

**p-value from Wilcoxon rank-sum (Mann-Whitney) test; **p-value from Fisher's exact test; $^{\alpha}$ Denotes $p \leq 0.05$; $^{\pi}$ in primary or high school that is part of National School Nutrition Program.*

6.3.2 Household-level factors

More than half of participants were orphans with either one or both parents deceased, as shown in **Table 6.5**. The most frequently reported primary caregiver was either a biological parent (46%) or another relative (21%). The median number of people residing in the same house was five (range 4 – 6 individuals). More participants without abdominal obesity lived with grandparents and siblings compared to those with abdominal obesity. On average, households had two adults of working age (IQR 1– 3). More than two-thirds of households experienced some level of food insecurity, with 37% reporting severe food insecurity. Household food security did not differ significantly by obesity status.

More than a third of participants resided in informal dwellings, either an informal shack made of corrugated iron or a backyard dwelling (see **Table 6.5**). Thirty-nine per cent had moved residences at least once in their lifetime, and 19% reported that their dwelling had ever been damaged by flooding, fire, or another adverse event in the past. Participants with abdominal obesity were more likely to experience some level of thermal discomfort in their homes, particularly in the autumn and spring months, compared to participants without abdominal obesity. A quarter of households were asset deprived, 29% used fuels other than electricity or gas for heating, 8% did not have a flush toilet inside or onsite, and 16% did not have access to piped water on site (see **Table 6.5**). Housing characteristics and access to amenities did not differ significantly by obesity status.

Participants self-reported high rates of positive parenting with high scores on the positive parenting subscale with a median of 13 (IQR 11– 15) out of a total possible score of 15 points. Similarly, participants reported low scores on poor supervision, median 6 (IQR 5 – 9), indicating that parents and primary caregivers provided strong supervision in the form of enforcing curfews and being aware of their friends and whereabouts. Positive parenting and supervision did not differ significantly by obesity status.

Table 6.5: Household-level characteristics of AYLHIV in Cape Town by abdominal obesity status

Variable: median (IQR) or n (%)		**Non-obese n= 51 (59%)**	**Obese n= 36 (41%)**	**Total n= 87**
Housing characteristics				
Dwelling type	Formal dwelling	33 (66%)	24 (67%)	57 (66%)
	Informal shack /caravan/ backyard dwelling	17 (34%)	12 (33%)	29 (34%)
Time lived in current residence in years (n= 81)		9.5 (4 – 19)	8 (2– 18)	9 (3– 18)
Residential stability in lifetime	never moved	32 (63%)	21 (58%)	53 (61%)
	moved once	14 (27%)	8 (22%)	22 (25%)
	moved twice	3 (6%)	5 (14%)	8 (9%)
	moved three or more times	2 (4%)	2 (6%)	4 (5%)
Dwelling ever damaged by flooding, fire/ another negative event (n= 81)		8 (17%)	7 (20%)	15 (19%)
	Flooding	1 (2%)	2 (6%)	3 (4%)
	Fire	5 (11%)	4 (11%)	9 (11%)
	Forced removal	1 (2%)	1 (3%)	2 (2%)
Assets deprivation[μ]	Does not own more than two assets below	12 (24%)	10 (28%)	22 (25%)
	No radio	19 (37%)	20 (56%)	39 (45%)
	No television	5 (10%)	3 (8%)	8 (9%)
	No landline	49 (96%)	35 (97%)	84 (97%)
	No cell phone	7 (14%)	6 (17%)	13 (15%)
	No refrigerator	17 (33%)	13 (36%)	30 (34%)
	No motor vehicle	36 (71%)	25 (69%)	61 (70%)
Thermal discomfort[β] (n= 81)	Summer	16 (35%)	17 (49%)	33 (41%)
	Autumn or spring[α]	13 (28%)	19 (54%)	32 (40%)
	Winter	25 (54%)	25 (71%)	50 (62%)
Household tobacco exposure		22 (43%)	15 (42%)	37 (43%)
Access to amenities				
Fuel for lighting: Households using paraffin, candles, nothing / other		0	1 (3%)	1 (1%)
Fuel for heating: Households using paraffin, wood, coal, nothing / other		15 (29%)	10 (28%)	25 (29%)
Fuel for cooking: Households using paraffin, wood, coal, dung / other		0	1 (3%)	1 (1%)
Sanitation and type of toilet facility	Households without a flush toilet	4 (8%)	3 (8%)	7 (8%)
	Flush toilet with onsite disposal	10 (20%)	10 (28%)	20 (23%)
	Flush toilet with offsite disposal	25 (49%)	13 (36%)	38 (44%)
	Flush toilet outside house	12 (24%)	10 (28%)	22 (25%)
	Chemical toilet	2 (4%)	0	2 (2%)
	Pit latrine with Ventilated Improved Pit (VIP)	0	1 (3%)	1 (1%)
	Bucket toilet	2 (4%)	2 (5%)	4 (5%)
Source of water	Households without piped water on site	9 (18%)	5 (14%)	14 (16%)
	Piped (tap) water inside dwelling	33 (65%)	21 (58%)	54 (62%)
	Piped (tap) water on site or in yard	9 (18%)	10 (28%)	19 (22%)
Household waste removal (n= 80)	Removed weekly by local authorities	30 (67%)	25 (71%)	55 (69%)
	Removed less often than once a week	5 (11%)	1 (3%)	6 (8%)
	Communal refuse dump	3 (7%)	3 (9%)	6 (8%)
	Dump anywhere or own refuse dump	7 (15%)	6 (17%)	13 (16%)
Family dynamics				
Orphanhood status	Both parents alive	18 (35%)	13 (36%)	31 (36%)
	Death of a parent	29 (57%)	22 (61%)	51 (59%)
	Don't Know	4 (8%)	1 (3%)	5 (6%)
Deceased parent (n= 51)	Mother	11 (38%)	5 (24%)	16 (32%)
	Father	12 (41%)	12 (57%)	24 (48%)
	Both parents deceased	6 (21%)	4 (19%)	10 (20%)
Primary caregiver	Biological parent(s)	22 (43%)	18 (50%)	40 (46%)
	Legal guardian/ adoptive parent	3 (6%)	1 (3%)	4 (5%)
	Grandparent(s)	7 (14%)	1 (3%)	8 (9%)
	Relative (aunt, uncle, etc.)	9 (18%)	9 (25%)	18 (21%)

	Non-family member (e.g., foster care)	2 (4%)	2 (6%)	4 (5%)
	Older sibling	6 (12%)	3 (8%)	9 (10%)
	Other (spouse or none)	2 (4%)	2 (6%)	4 (5%)
Family structure	Number of people residing in same house	5 (4 – 6)	5 (4 – 6)	5 (4 – 6)
Whom they live with	Biological parents	21 (41%)	20 (56%)	41 (47%)
	Grandparents[¥ α]	11 (22%)	1 (3%)	12 (14%)
	Relative (aunt or uncle)	16 (31%)	12 (33%)	28 (32%)
	Siblings[¥ α]	32 (63%)	15 (42%)	47 (54%)
	Non-family member (e.g., foster care)	1 (2%)	1 (3%)	2 (2%)
People younger than 15 years	0	14 (27%)	13 (36%)	27 (31%)
	1	19 (37%)	7 (19%)	26 (30%)
	2	7 (14%)	11 (31%)	18 (21%)
	3 or more	10 (20%)	5 (14%)	15 (17%)
People older than 64 years (n=83)	0	36 (73%)	28 (82%)	64 (77%)
	1	13 (27%)	6 (18%)	19 (23%)
Household working-age adult employment (aged 18 – 64 years)		2 (1– 3)	2 (1– 2.5)	2 (1– 3)
Household food security	Food secure	15 (29%)	12 (33%)	27 (31%)
	Mild food insecurity	5 (10%)	5 (14%)	10 (11%)
	Moderate food insecurity	12 (24%)	6 (17%)	18 (21%)
	Severe food insecurity	19 (37%)	13 (36%)	32 (37%)
Positive Parenting and Supervision [ɣ]				
Positive Parenting (maximum score= 15)		13 (11– 15)	13 (10.5- 15)	13 (11– 15)
	Parent tells you when you are doing a good job	5 (3– 5)	5 (3.5 – 5)	5 (3– 5)
	Parent praises you for behaving well	5 (3– 5)	4 (3– 5)	5 (3– 5)
	Parent compliments you when you have done well	5 (3– 5)	5 (3 – 5)	5 (3– 5)
Poor Monitoring or Supervision (maximum score= 15)		6 (4 – 9)	6 (5 – 9)	6 (5 – 9)
	Fail to let parent know where you are going	1 (1 – 3)	2 (1 – 3)	2 (1 – 3)
	Stay out at night long after curfew	3 (1 – 3)	3 (1 – 3)	3 (1 – 3)
	Parent does not know friends you are with	1 (1 – 3)	1 (1 – 3)	1 (1 – 3)

[¥] Fisher's exact test p-value; [α] Denotes: p < 0.05; [μ] Individual living in a household that does not own more than two of radio, television, landline, cell phone, bike, motorbike or refrigerator AND does not own a motor car or truck; [6] Thermal discomfort experienced in the home sometimes, often or permanently; [ɣ] Parenting as provided by a parent or primary caregiver.

6.3.3 Community-level factors

Overall, 43% of participants reported belonging to an extra-mural group in their community not run by their school (**Table 6.6**). The majority reported high levels of family social capital (92%), neighbourhood reciprocity (79%), friendliness (87%) and belonging (77%). Neighbourhood trust and horizontal school trust were the lowest scoring indicators of social capital, with 36% and 35% of participants reporting low levels of each, respectively. Those who had abdominal obesity reported higher neighbourhood belonging and horizontal school trust compared to those without abdominal obesity.

Overall, participants reported experiencing low levels of stigma. The median score for anticipated stigma was 2 (IQR 1– 2.5) out of a maximum possible score of 8, enacted stigma score was 1 (IQR 1–

1.67) out of a maximum score of 12, and internalised stigma score was 1.6 (IQR 1 – 2) out of 20. Participants who had abdominal obesity reported significantly lower levels of anticipated stigma compared to those without obesity.

Overall, 61% of participants were exposed to high levels of violence, according to the Exposure to Violence scale; 76% had heard of a killing in their community, and more than half knew someone personally who had been stabbed or shot. However, only a quarter of participants perceived their neighbourhoods as risky or unsafe to walk in at night. Crime safety and exposure to violence did not differ significantly by obesity status.

6.3.4 Food and built environment factors

Compared to participants with obesity, those who did not have abdominal obesity reported significantly greater land-use mix-diversity (*p= 0.044*), greater access to recreational places (*p= 0.003*), greater residential density / types of homes *(p= 0.078*), better neighbourhood aesthetics (*p= 0.041*), and better pedestrian and traffic safety (*p= 0.026*) (see **Figure 6.3**). They also reported greater access to supermarkets and non-fast-food restaurants within walking distance from their homes, although this was not statistically significant.

Table 6.6: Community and built environment characteristics of AYLHIV by abdominal obesity status

Variable: Median (IQR) or n (%)		**Non-obese n= 51**	**Obese n= 36**	**Total n= 87**
Social networks: Belong to extra-mural group (not run by school)		22 (43%)	15 (42%)	37 (43%)
Social Capital				
	High family social capital	47 (92%)	33 (92%)	80 (92%)
	High neighbourhood trust	35 (69%)	21 (58%)	56 (64%)
	High neighbourhood reciprocity	41 (80%)	28 (78%)	69 (79%)
	High neighbourhood friendliness	45 (88%)	31 (86%)	76 (87%)
	High neighbourhood belonging[¥*]	36 (71%)	31 (86%)	67 (77%)
	High "I like my neighbourhood"	38 (75%)	27 (75%)	65 (75%)
	High "I like *people* in my neighbourhood"	43 (84%)	28 (78%)	71 (82%)
	High informal social control [β] (n= 46)	23 (76%)	13 (81%)	36 (78%)
	High vertical school trust (n= 46)	23 (77%)	15 (94%)	38 (83%)
	High horizontal school trust (n= 46) [¥*]	17 (57%)	13 (81%)	30 (65%)
	High reciprocity at school (n= 46)	25 (83%)	15 (94%)	40 (87%)
Experiences of Stigma: Anticipated (2 items), Enacted (3 items), Internalised (5 items)				
	Anticipated stigma (max= 8) [ñ**]	2 (1.5 – 3)	1.5 (1– 2.5)	2 (1– 2.5)
	Enacted stigma (max= 12)	1 (1– 1.67)	1 (1– 1.67)	1 (1– 1.67)
	Internalised stigma (max= 20)	1.6 (1.2 – 2)	1.6 (1– 2.4)	1.6 (1 – 2)
Exposure to Community Violence (maximum score= 8)		4 (2 – 5)	5 (3 – 5.5)	4 (3 – 5)
Heard of any killing in your community		37 (73%)	29 (81%)	66 (76%)
Seen a dead body (not at a funeral)		23 (45%)	18 (50%)	41 (47%)

Afraid of anyone in your community or yard		18 (35%)	17 (47%)	35 (40%)
Seen someone pointing or shooting a gun at someone		21 (41%)	15 (42%)	36 (41%)
Seen someone other than police pointing or shooting a gun at someone		22 (43%)	15 (42%)	37 (43%)
Someone personally known to you has been:	Shot	23 (45%)	21 (58%)	44 (51%)
	Stabbed	29 (57%)	24 (67%)	53 (61%)
	Raped	15 (29%)	16 (44%)	31 (36%)
Exposure to violence category	No or little violence (score 0 – 1)	9 (18%)	5 (14%)	14 (16%)
	Moderate level of violence (score 2 – 3)	14 (27%)	6 (17%)	20 (23%)
	High level of violence (score ≥ 4)	28 (55%)	25 (69%)	53 (61%)
Crime safety (NEWS-Y Subset$^{\mu}$) (n= 76)	Perceived high crime rate in neighbourhood	10 (23%)	9 (27%)	19 (25%)
	Unsafe to walk at night	9 (21%)	10 (30%)	19 (25%)
	Worried to be outside alone around home area	17 (40%)	13 (39%)	30 (39%)
	Worried about being outside with someone around home area	13 (30%)	11 (33%)	24 (31%)
	Worried about being or walking around neighbourhood alone or with friends	16 (37%)	13 (39%)	29 (38%)
	Worried about being in a local or nearby park	16 (37%)	9 (27%)	25 (33%)
Built Environment: Neighbourhood Environment Walkability Scale				
NEWS-Y Composite Score Mean (± SD)	A. Land use mix-diversity**	2.97 (0.78)	2.58 (0.92)	2.80 (0.86)
	B. Access to Recreational Places$^{\Sigma**}$	2.78 (0.90)	2.18 (0.76)	2.53 (0.89)
	C. Residential density*	3.84 (0.76)	3.55 (0.62)	3.71 (0.71)
	D. Land use mix-access (Access to services)	2.58 (0.63)	2.51 (0.57)	2.55 (0.60)
	E. Street connectivity	2.31 (0.80)	2.49 (0.72)	2.39 (0.77)
	F. Walking or cycling facilities	2.63 (0.88)	2.55 (0.76)	2.60 (0.83)
	G. Neighbourhood Aesthetics$^{\Sigma**}$	2.46 (0.94)	2.04 (0.77)	2.27 (0.89)
	H. Pedestrian and Traffic safety$^{\Sigma**}$	2.66 (0.43)	2.45 (0.38)	2.57 (0.42)
	I. Crime safety	2.83 (0.89)	2.94 (0.88)	2.88 (0.88)
Food Environment: Within walking distance from home to destination $^{\pi}$				
Kiosk, corner store or small grocer (n= 73)		38 (86%)	25 (86%)	63 (86%)
Supermarket (n= 75)		29 (66%)	15 (48%)	44 (59%)
Fruit or vegetable market (n= 73)		38 (90%)	27 (87%)	65 (89%)
Fast food restaurant (n= 75)		27 (63%)	17 (53%)	44 (59%)
Non-fast-food restaurant (n= 74) *		25 (50%)	12 (39%)	37 (50%)
Coffee shop (n= 73)		18 (43%)	9 (30%)	27 (37%)

* p < 0.10; **p< 0.05; $^{\beta}$ Do you feel that your neighbours' step in to criticise someone's deviant behaviour during high school? (informal social control); $^{¥}$ Fisher's exact test p-value; $^{\Sigma}$ Kruskal-Wallis p-value; $^{\mu}$ Dichotomous variable for crime safety elements: strongly agreed or somewhat agreed versus somewhat disagreed or strongly disagreed;
$^{\Phi}$ Two-sample t-test with equal variances p-value;
$^{\pi}$ Within walking distance defined as ≤ a 20-minute walk from home.

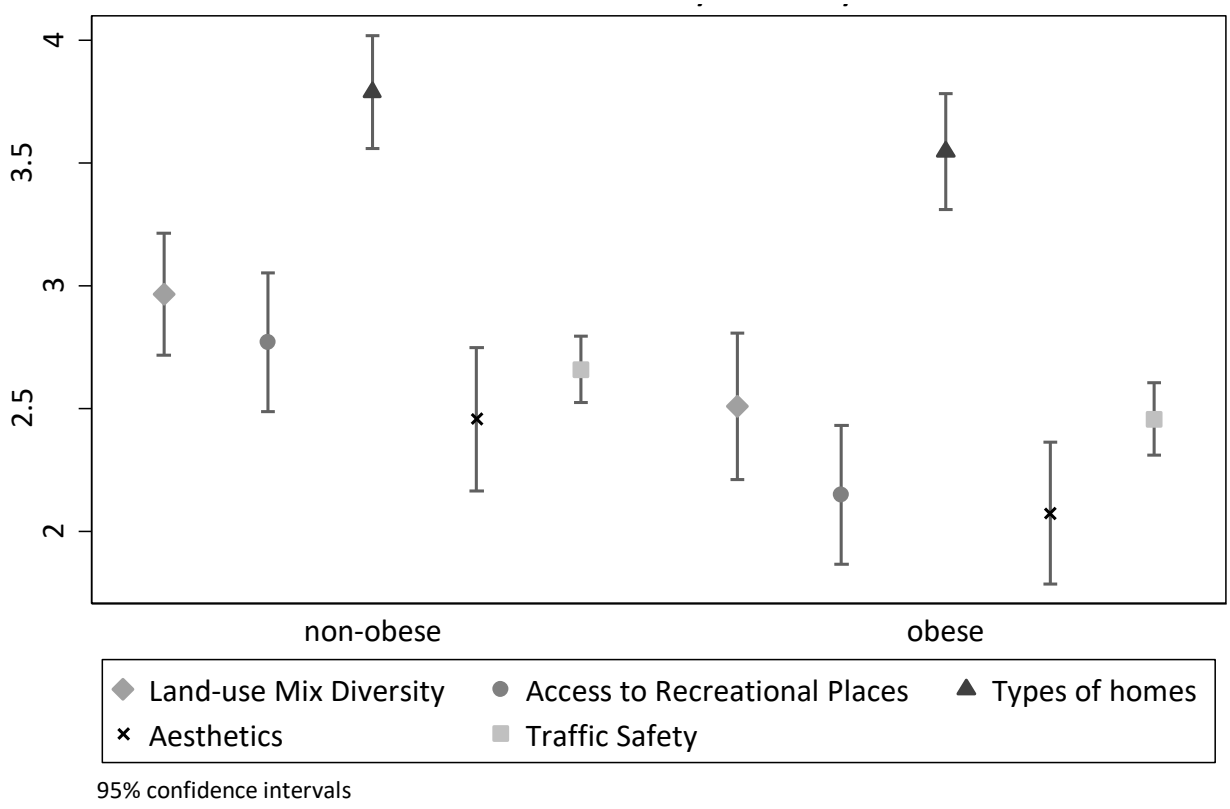

Figure 6.3: Selected NEWS-Y sub-items by obesity status

6.3.5 Multilevel factors associated with abdominal obesity

After exploring bivariate associations between respective variables and abdominal obesity, multilevel mixed-effects logistic regression models were built with the sub-district as the group variable (as shown in **Table 6.7** and **Table 6.8**). The LR test was used to assess whether all random-effects parameters of the mixed model were simultaneously zero [603]. The null model showed that the variance component and group-level random effects were not equal to zero, justifying the use of mixed-effect models instead of standard logistic regression. The LR test for the mixed-effects model compared to a logistic model also showed that using a mixed-effect model with group-level random effects was better than standard regression.

6.3.5.1 Individual-level factors

Females had four-fold increased odds of abdominal obesity compared to males in the bivariate logistic model. Bivariate models also showed an age gradient by abdominal obesity status, with the odds of abdominal obesity increasing with age, as shown in **Table 6.7.** The multilevel model, including individual level one predictors, age, and sex, was not significantly different from the null model (*p*=

0.124), but since sex and age are clinically significant confounders, we included them in subsequent models. The model with age and sex is hereafter referred to as model 2.

Those who were absent from school or work on one or more days in the past month had increased odds of abdominal obesity compared to those who were not absent from school or work (OR= 2.56; 95% CI: 1.06 – 6.18). This association emerged in the multilevel model after adjusting for age and sex and the covariance structure. Individual-level poverty measures were not significantly associated with abdominal obesity in bivariate analysis, and the model with individual-level poverty (YMPI poor) did not improve on model 2 (*p = 0.297*).

Blood pressure and mental health characteristics were not significantly associated with abdominal obesity in bivariate analysis.

Those who engaged in at least ten minutes of moderate-intensity physical activity per week had 76% reduced odds of abdominal obesity compared to those who did not engage in physical activity (OR = 0.24; 95% CI: 0.06 – 0.92). Including moderate physical activity improved on the model with just age and sex (*p= 0.028*). The model, including dietary behaviour and breakfast skipping, improved on model 2 (*p = 0.004*). Those who skipped breakfast had higher odds of abdominal obesity compared to those who ate breakfast on five or more days per week. The model with daily fruit and whole-grain intake improved on model 2 (*p= 0.006*) but was imprecise. Those who ate whole grains and cereals daily had lower odds of abdominal obesity compared to those who ate these less frequently. Daily fruit intake was not significantly associated with abdominal obesity in the adjusted multilevel model.

6.3.5.2 Household-level factors

Household food security and orphanhood status were not significantly associated with abdominal obesity in bivariate analysis. Family history of diabetes was also not associated with obesity in bivariate or multilevel analysis. Experiencing any thermal discomfort in the home was associated with four-fold increased odds of abdominal obesity (OR= 4.42; 95% CI: 1.43 – 13.73). The model with thermal discomfort experienced in the home improved on model 2. Other measures of the home environment and access to amenities were not significant in bivariate or multilevel modelling.

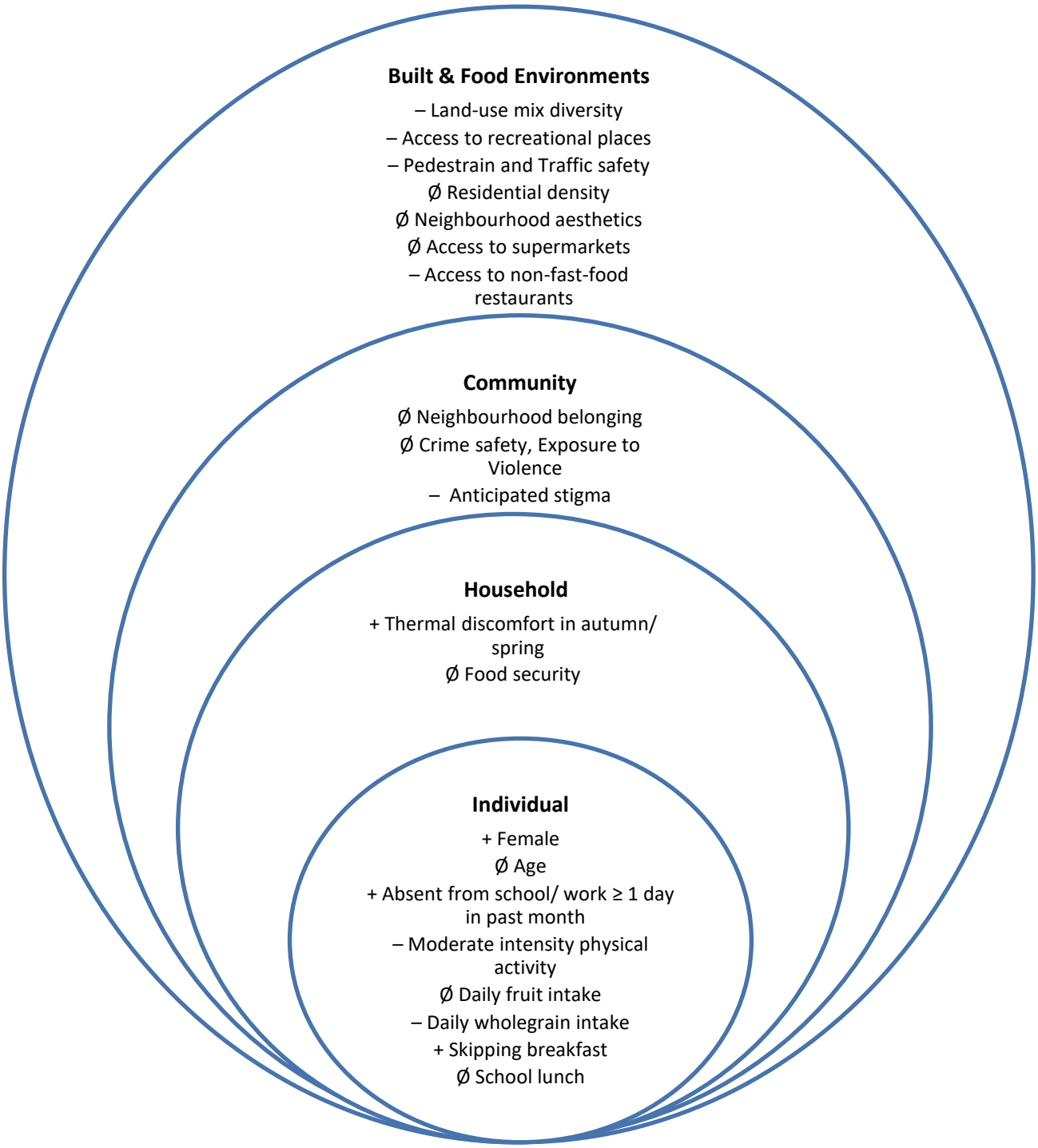

Figure 6.4: Multilevel factors associated with abdominal obesity

Ø: no significant association; +: significant positive association; –: significant negative association. Covariates included in the figure if statistically significant ($p < 0.10$) in bivariate regression.

6.3.5.3 Community factors

Those with higher neighbourhood belonging had higher odds of having abdominal obesity (OR= 2.68; 95% CI: 0.81 – 8.89) in bivariate analysis. But this was not statistically significant, and the model with neighbourhood belonging did not improve significantly on model 2 (*p= 0.095*). Other measures of social capital did not have significant bivariate associations, except for horizontal school trust. However, the multilevel model with horizontal school trust failed to converge and did not meet the LR test assumptions. Those with higher anticipated stigma had 42% reduced odds of having abdominal obesity compared to those with lower anticipated stigma from the community (OR= 0.58; 95% CI: 0.33 – 1.00).

6.3.5.4 Built environment factors

Those with perceived higher land-use mix diversity had 48% reduced odds of having abdominal obesity compared to those with lower neighbourhood diversity (OR= 0.52; 95% CI: 0.27 – 0.97). The model significantly improved on model 2 (*p= 0.029*). Those with perceived better access to recreational spaces had 63% reduced odds of having abdominal obesity compared to those with lower perceived access to recreational spaces (*p= 0.005*). The model significantly improved on model 2 (*p= 0.002*). Adding perceived pedestrian and automobile traffic safety to the model resulted in a non-convergent model. We, therefore, could not compare it to the mixed-effects models using the LR test statistic. However, the parameters suggest that those with perceived higher pedestrian and traffic safety had 80% reduced odds of having abdominal obesity compared to those with lower perceived traffic safety (*p= 0.023*). The models with residential density and neighbourhood aesthetics did not improve the model fit, and the effects were not statistically significant. Other NEWS-Y items (street connectivity, places for walking and cycling, and crime safety) were not significant in bivariate analysis and were therefore not included in the multilevel models.

6.3.5.5 Food environment factors

The model with "supermarket within walking distance from home" did not improve significantly on model 2 (*p= 0.0783*), but suggests that those with supermarkets within walking distance had lower odds of abdominal obesity compared to those without access to a supermarket (OR= 0.37; 95% CI: 0.12–1.16). The model with "non-fast-food restaurant within walking distance" improved significantly on model 2 (*p= 0.027*). Those with non-fast-food restaurants within walking distance had 70% reduced odds of having abdominal obesity compared to those without non-fast-food restaurants

within walking distance (OR= 0.30; 95% CI: 0.10 – 0.93). The rest of the food environment variables: access to a corner shop/ small grocery store, food market, fast-food restaurant, and coffee shops within walking distance from home, did not improve the model fit and were not statistically significant.

Table 6.7: Bivariate and multivariate associations between individual-level factors and abdominal obesity

Explanatory variables OR [95% CI]		**Bivariate logistic regression**	**p-value**	**Multilevel model $^{\mu}$**	**p-value**
Female		4.57 (1.21; 17.21)	**0.025***	3.02 (0.89; 10.23)	0.076
Age group	15 – 17 years	1.00 (ref)			
	18 – 19 years	4.125 (0.73; 23.43)	0.110	4.48 (0.74; 27.26)	0.104
	20 – 21 years	4.65 (0.84; 25.66)	**0.077***	5.39 (0.87; 33.50)	0.071
	22 – 24 years	5.13 (0.96; 27.36)	**0.055***	3.87 (0.63; 23.58)	0.143
Ever pregnant or impregnated someone		3.77 (1.29; 11.01)	**0.015***	2.97 (0.79; 11.22)	0.108
Educational attainment: completed secondary school		0.94 (0.39; 2.26)	0.886		
Neither in education employment nor training (NEET)		0.96 (0.36; 2.58)	0.942		
Ever repeated a grade at school		1.64 (0.67; 4.02)	0.276		
Days absent from school or work in past month	0 days	1.00 (ref)		1.00 (ref)	
	1 or more days	2.56 (1.06; 6.18)	**0.036***	3.06 (1.11; 8.40)	**0.030***
Individual level multidimensional poverty (YMPI poor)		1.94 (0.80; 4.71)	0.145	1.69 (0.63; 4.54)	0.299
Blood pressure	Normal BP	1.00 (ref)		1.00 (ref)	
	Elevated BP	2.04 (0.65; 6.34)	0.219	2.37 (0.66; 8.51)	0.185
	Hypertension	1.19 (0.18; 7.64)	0.856	1.77 (0.21; 14.97)	0.599
Family history of diabetes		0.70 (0.26; 1.89)	0.481	0.94 (0.30; 2.94)	0.909
Significant depression (CESD ≥10)		0.95 (0.39; 2.31)	0.910		
Kessler psychological distress score (K10)	Mentally well (K10 <20)	1.00 (ref)		1.00 (ref)	
	Mild distress (K10 20 – 24)	1.48 (0.43; 5.08)	0.537	2.82 (0.71; 11.20)	0.141
	Moderate distress	1.34 (0.43; 4.21)	0.617	1.31 (0.36; 4.82)	0.682
	Severe distress (K10 ≥ 30)	0.86 (0.14; 5.18)	0.870	1.63 (0.21; 12.90)	0.645
Physical activity per week					
Any vigorous-intensity physical activity for ≥10 minutes		0.71 (0.28; 1.79)	0.474		
Any moderate-intensity physical activity for ≥10 minutes		0.39 (0.13; 1.18)	**0.097***	0.24 (0.06; 0.92)	**0.038***
Walking or cycling for ≥ 10 minutes		0.77 (0.29; 2.10)	0.619		
Insufficient physical activity (< 600 MET-minutes/week)		0.73 (0.28; 1.88)	0.509		
High physical activity (≥3000 MET minutes per week)		0.95 (0.35; 2.60)	0.923		
Three or more hours sedentary per day		1.41 (0.58; 3.42)	0.442	1.77 (0.67; 4.701)	0.253
Current enrolment in school, college, university or working		0.73 (0.29; 1.81)	0.492		
Commuting time is less than 20 minutes		0.55 (0.17; 1.81)	0.329		
Active Transport (Any walking or cycling in daily commute)		0.51 (0.16; 1.57)	0.238		
Additional transport mode (more than one means)		1.36 (0.44; 4.20)	0.589		
Dietary intake and behaviour					
Daily intake of fruits		0.35 (0.11; 1.08)	**0.067***	0.32 (0.074; 1.41)	0.133
Daily intake of vegetables		0.90 (0.36; 2.25)	0.822		

Daily intake of wholegrain bread or cereal		0.30 (0.10; 0.88)	**0.028***	0.20 (0.054; 0.71)	**0.013***
Daily intake of deep-fried foods		1.24 (0.41; 3.75)	0.697		
Daily intake of fast-foods		0.52 (0.14; 1.90)	0.321		
Daily intake of sugar-sweetened beverages		1.00 (0.37; 2.70)	1.000		
Daily intake of processed items with added sugar		1.24 (0.48; 3.24)	0.657		
Ate meal prepared outside the home in the past week		1.07 (0.40; 2.88)	0.897		
Meals eaten outside home in past week		0.97 (0.80; 1.16)	0.722		
Breakfast consumption	Non-skippers	1.00 (ref)		1.00 (ref)	
	Semi-skippers	6.35 (1.69; 23.88)	**0.006***	6.59 (1.51; 28.79)	**0.012***
	Skippers	3.63 (1.14; 11.56)	**0.029***	5.42 (1.32; 22.25)	**0.019***
School serves school lunch (n= 38 in high school)		0.23 (0.057; 0.89)	**0.034***	**0.23 (0.038; 1.408)**	**0.112**
General Nutrition Knowledge Score[Σ]		0.99 (0.95; 1.05)	0.962		
1. Dietary recommendations (score/18)		0.96 (0.81; 1.12)	0.587		
2. Food Groups (score/36)		0.99 (0.88; 1.12)	0.859		
3. Healthy Food choices (score/13)		1.05 (0.86; 1.27)	0.658		
4. Diet, disease relationships (score/21)		1.04 (0.89; 1.22)	0.594		

**p-values less than 0.10 in bivariate logistic regression and less than 0.05 in multilevel logistic regression are shown in bold.*

[μ]*The multilevel model estimates reflect the odds ratio for each factor added separately to model 2, adjusted for age and sex and accounting for the sub-district covariance structure.*

[Σ]*The GNKQ scores are continuous measures and were included as continuous predictors/ linear terms in the bivariate models after checking the linearity of the logit function using the Box-Tidwell test.*

Table 6.8: Bivariate and multivariate associations between social factors, built and food environment factors and abdominal obesity

Explanatory variables OR [95% CI]		Bivariate logistic regression	p-value	Multilevel model[μ]	p-value
Family and experiences of parenting					
Death of a parent		1.19 (0.50; 2.84)	0.692		
Biological parent(s) as primary caregiver		1.32 (0.56; 3.10)	0.527		
Number of people residing in the same house		0.94 (0.83; 1.07)	0.341		
Household working-age adult employment		1.50 (0.44; 5.09)	0.516		
Positive parenting score		0.97 (0.85; 1.11)	0.694		
Poor monitoring or supervision score		1.01 (0.87; 1.18)	0.902		
Household food security	food secure	1.00 (ref)			
	mild food insecurity	1.25 (0.29; 5.35)	0.764	1.77 (0.33; 9.46)	0.504
	moderate food insecurity	0.63 (0.18; 2.16)	0.457	0.62 (0.15; 2.47)	0.496
	severe food insecurity	0.86 (0.30; 2.41)	0.767	0.96 (0.30; 3.00)	0.938
Housing characteristics					
Formal dwelling		1.00 (ref)			
Informal shack /backyard dwelling		0.97 (0.39; 2.40)	0.949		
Residential stability	never moved	1.00 (ref)			
	moved once	0.87 (0.31; 2.44)	0.792		
	moved two or more times	2.13 (0.60; 7.62)	0.243		
Dwelling ever damaged by negative event		1.19 (0.39; 3.66)	0.765		
Thermal discomfort in summer		1.77 (0.72; 4.35)	0.213		
Thermal discomfort in autumn or spring		3.01 (1.20; 7.60)	**0.019***	4.42 (1.43; 13.73)	**0.010***
Thermal discomfort in winter		2.10 (0.82; 5.35)	0.120		
Household tobacco exposure		0.94 (0.40; 2.23)	0.891		
Household assets deprivation (does not own more than two essential assets)		1.25 (0.47; 3.31)	0.654		
Access to amenities					
Households not using electricity or gas for heating[β]		0.92 (0.36; 2.38)	0.868		
Households without a flush toilet		1.07 (0.22; 5.09)	0.934		
Households without piped water on site		0.75 (0.23; 2.47)	0.639		
Household waste removed weekly by local authorities		1.25 (0.48; 3.27)	0.649		
Social capital					
Social networks: Belongs to an extra-mural group		0.91 (0.38; 2.16)	0.829		
High family social capital		0.94 (0.20; 4.46)	0.934		
High neighbourhood trust		0.64 (0.26; 1.56)	0.325		
High neighbourhood reciprocity		0.85 (0.30; 2.43)	0.767		
High neighbourhood friendliness		0.83 (0.23; 2.95)	0.769		
High neighbourhood belonging		2.58 (0.84; 7.92)	**0.097***	2.68 (0.81; 8.89)	0.107

I like my neighbourhood (agrees)	1.03 (0.38; 2.74)	0.959		
I like the people in my neighbourhood	0.65 (0.22; 1.94)	0.440		
High informal social control[β]	1.32 (0.29; 5.99)	0.720		
High vertical school trust[α]	4.57 (0.51; 40.95)	0.175		
High horizontal school trust[α]	3.31 (0.78; 14.10)	0.105		
High reciprocity at school[α]	0.85 (0.30; 2.43)	0.767		
Overall stigma score	0.89 (0.68; 1.17)	0.411		
Anticipated stigma	0.60 (0.36; 1.00)	**0.051***	0.58 (0.33; 1.00)	**0.052***
Enacted stigma	0.93 (0.47; 1.85)	0.843		
Internalised stigma	1.39 (0.73; 2.64)	0.317		
Community violence score	1.13 (0.93; 1.37)	0.212		
No or little violence (score 0 – 1)	1.00 (ref)		1.00 (ref)	
Moderate level of violence (Score 2 – 3)	0.77 (0.18; 3.30)	0.726	0.71 (0.13; 3.81)	0.690
High level of violence (Score ≥ 4)	1.61 (0.47; 5.44)	0.446	2.79 (0.59; 13.26)	0.197
Perceived high crime rate in neighbourhood	1.24 (0.44; 3.51)	0.689		
Crime rate makes it unsafe to walk at night	1.55 (0.54; 4.41)	0.415		
Worried about being outside alone around home area	1.05 (0.41; 2.66)	0.924		
Worried about being outside with someone around home area	1.17 (0.44; 3.11)	0.755		
Worried about being or walking around neighbourhood alone or with friends	1.10 (0.43; 2.79)	0.846		
Worried about being in a local or nearby park	0.63 (0.24; 1.69)	0.362		
Built Environment: Neighbourhood Environment Walkability Scale				
A. Land use mix-diversity	0.56 (0.31; 1.00)	**0.050***	0.52 (0.27; 0.97)	**0.039***
B. Access to recreational places	0.41 (0.21; 0.77)	**0.006***	0.37 (0.18; 0.74)	**0.005***
C. Residential density (types of homes)	0.55 (0.28; 1.08)	**0.082***	0.51 (0.24; 1.09)	0.081
D. Land use mix-access (access to services)	0.83 (0.39; 1.77)	0.634		
E. Street connectivity	1.37 (0.74; 2.51)	0.314		
F. Walking or cycling facilities	0.89 (0.51; 1.55)	0.688		
G. Neighbourhood aesthetics	0.57 (0.33; 0.99)	**0.044***	0.64 (0.34; 1.19)	0.161
H. Pedestrian and traffic safety	0.26 (0.08; 0.89)	**0.031***	0.20 (0.048; 0.80)	**0.023***
I. Crime safety	1.14 (0.68; 1.93)	0.615		
Food Environment: within walking distance[π] from home to selected destinations				
Kiosk, corner store or small grocer	0.99 (0.25; 3.85)	0.985		
Supermarket within walking distance	0.48 (0.19; 1.24)	0.132	0.37 (0.12; 1.16)	0.088
Fruit or vegetable market within walking distance	0.71 (0.16; 3.09)	0.649		
Fast-food restaurant within walking distance	0.67 (0.27; 1.70)	0.401		
Non-fast-food restaurant within walking distance	0.45 (0.18; 1.17)	0.101	0.30 (0.10; 0.93)	**0.036***
Coffee shop within walking distance	0.57 (0.21; 1.54)	0.269		

[μ]The multilevel model estimates reflect the odds ratio for each factor added separately to model 2, adjusted for age and sex and accounting for the sub-district covariance structure.

**P-values less than 0.10 in bivariate logistic regression and less than 0.05 in multilevel logistic regression are shown in bold.*

[α] n= 46 in school or college; [β]Lighting fuel and cooking fuel deprived omitted because of collinearity; [π]Within walking distance defined as ≤ a 20-minute walk from home.

6.4 Discussion

We set out to explore the prevalence and multilevel determinants of abdominal obesity as defined by the waist-to-height ratio in AYLHIV in urban Cape Town. We found several multilevel factors associated with abdominal obesity, as displayed in **Figure 6.4.** Overall, we found a 41% prevalence of abdominal obesity with various factors from the individual to the community level associated with this outcome. At the built and food environment levels, land-use mix diversity, access to recreational places, pedestrian and traffic safety, and a non-fast-food restaurant within walking distance were associated with reduced odds of abdominal obesity in AYLHIV.

6.4.1 Individual-level factors

In multivariate analysis, at the individual level, female sex, skipping breakfast and absence from school were strongly associated with higher odds of abdominal obesity. In contrast, daily intake of whole grains and engaging in weekly moderate physical activity were significantly associated with lower odds of abdominal obesity. The finding of a strong association between female sex and obesity, compared to males, is in line with the literature on sex differences in obesity rates [111, 580]. In LMICs, overweight and obesity rates are higher in women than men and older compared with younger individuals [582]. While we observed an age gradient with those in the older age groups more likely to have abdominal obesity than the younger age groups in bivariate analysis, age was not statistically significant in multivariate analysis because most of our sample were between the ages of 22– 24 years.

Engaging in moderate-intensity physical activity and daily whole grain intake were associated with reduced odds of abdominal obesity. This is similar to documented findings in AYLHIV from other LMIC settings showing reduced odds of obesity and dyslipidaemia in those who engaged in at least moderate forms of physical activity [604]. Whole grain intake is indicative of a healthier dietary pattern and possibly eating breakfast which reduces the odds of obesity, as further discussed below.

The proliferation of fast-food outlets and consumption of SSBs in LMICs has increasingly been associated with childhood and adolescent obesity [332, 532]. However, we found no significant bivariate or multilevel associations between obesity and daily intake of deep-fried foods, fast foods, SSB, or eating food prepared outside the home. This suggests that dietary intake, although a proximal factor that varied individually, may only have a direct effect on obesity later in the life course. Nutrition knowledge also did not differ by obesity status, which is important to note as an individual-level factor usually targeted by interventions.

Skipping breakfast was associated with higher odds of abdominal obesity. Several studies have established an association between skipping breakfast and overweight and obesity [605]. A recent meta-analysis showed that skipping breakfast increased the risk of abdominal obesity by 31% [606]. Absence from school or work was also associated with increased odds of obesity, which potentially relates to access to nutrition through interventions like the National School Nutrition Programme (NSNP). The NSNP aims to reduce food insecurity and improve school-going children's health and nutritional status by providing nutritious meals and nutrition education [607]. Although we were not sufficiently powered to explore the mediating effect of access to school lunch on obesity, literature suggests that the school food environment may play a protective role by providing food security and foods with higher nutritional value than foods available in the outside food environment [608].

Eating regular breakfast and school feeding initiatives are amenable approaches that can be encouraged with appropriate interventions at the individual or school level. Adolescents who benefit from school nutrition interventions have been documented to have beneficial outcomes, including changes in nutritional knowledge, behaviours and physical activity [609]. Although our study found some significant individual-level predictors of abdominal obesity, the log-likelihood values for the multilevel models were small, indicating that other factors beyond demographic and behavioural factors may be more critical in determining the weight status of AYLHIV.

Contrary to expectation, no poverty gradient was apparent in obesity status. Those who were multidimensionally poor had similar odds of having abdominal obesity compared to those not

classified as MPI poor. Those who experienced food insecurity also had similar odds of abdominal obesity compared to those who lived in households that did not experience food insecurity. Previous studies have established associations between low SES and poor health outcomes in youth, including mental health and obesity [270]. Our results may reflect the homogeneity of our study population, living in similar settings where poverty and food insecurity are rife.

Economists have written extensively about the association between weight gain and socio-economics in adults living in LMICs and how the burden of obesity in LMICs tends to shift towards groups with lower SES as a country's gross national product increases [610, 611]. In settings where income inequality is high, the burden of obesity shifts to the most deprived in society, following the so-called obesity inequity gradient [610]. In the South African context where undernutrition, inequality and obesity co-exist, the relationship between SES and obesity may not be linear. It may follow more of a social gradient where vulnerabilities and inequities are compounded over the life course in the most disadvantaged groups, especially in women and children [612]. Interventions will need to address gaps and inequities using a life course approach starting from maternal and early infant nutrition.

6.4.2 Household- and community-level factors

In multivariate analysis, at the household level, experiencing thermal discomfort in the home in autumn or spring was associated with increased odds of abdominal obesity. While at the community level, higher anticipated stigma was associated with reduced odds of abdominal obesity.

One unexpected finding was that abdominal obesity was associated with thermal discomfort in autumn and spring and not in the more extreme temperature seasons of summer and winter. Research from higher-income settings has explored how ambient temperatures influence body weight and energy intake, and expenditure, suggesting that higher ambient temperatures are associated with increased odds of obesity [613, 614]. One hypothesis is that the indoor thermal environment affects food intake and body weight via diet-induced

thermogenesis [615]. This may very well be the case in our setting given Cape Town's temperate climate; however, thermal comfort as a concept requires more detailed exploration as a potential contributor to obesity in diverse climatic LMIC settings. It is important to note that the seasonal thermal discomfort reported did not differ by multidimensional poverty status. Other housing characteristics, access to amenities, and individual-level poverty measures that may be correlated with thermal discomfort were not significantly associated with abdominal obesity. This somewhat contradictory result may be due to unmeasured household exposures. Using more objective measures of thermal discomfort experienced in the home in future studies would shed further light on how this relationship plays out in this context of housing informality.

Family environment factors such as orphanhood status, caregiver relationship and family structure did not emerge as significantly related to obesity status. Studies have found that children who live with grandparents or single mothers tend to have higher levels of overweight and obesity than those living with both parents, and children without siblings have a higher risk of obesity than children with siblings [616, 617]. However, these findings are from high-income settings, and this relationship might not be translatable to an LMIC setting. Also, we did not measure parental/maternal obesity status, which has been found to be a better predictor of childhood obesity status and obesity in adulthood [123]. However, less than half of the participants lived with a biological parent. Further research is required to elucidate the influence of family structure on nutritional behaviours and obesity status in a non-nuclear family environment.

We found no association between crime safety, exposure to violence and obesity, which appears contrary to previous studies that have suggested that high neighbourhood crime levels increase the risk of obesity in adolescent and adults [618, 619]. This is probably due to the homogeneity of our study population. Our participants were equally exposed to high levels of violence, which is endemic to informal and urban settings in Cape Town [395]. It is important to note that these were perceptions of violence and crime as opposed to objective police or other reports on crime levels in these neighbourhood environments, which we know to be high in these settings [396]. It also remains likely that the effects of exposure to violence

and crime might have a cumulative effect on health and lead to future obesity in adulthood, as demonstrated in a cohort of African-American youth for whom fear of neighbourhood violence during adolescence was predictive of obesity almost a decade later, particularly in women [367].

Measures of social capital did not have significant associations with obesity in multilevel analysis. However, in bivariate analyses, higher perceived neighbourhood belonging was associated with increased odds of abdominal obesity. Kawachi argues that social networks and social capital, particularly neighbourhood social capital, are the mechanism by which neighbourhood poverty affects health [341]. However, social capital as a concept is not entirely adequate for explaining the effects of poverty on health and well-being [620]. One mechanism could be buying into and emulating the eating behaviours of neighbourhood social contacts, which often entails consuming more processed, low-quality foods in urban settings, and becoming part of new social networks where being overweight is more normative [589].

We also found high neighbourhood reciprocity but slightly lower neighbourhood trust. One possible explanation is that perceived trustworthiness may be tied to perceptions of crime and safety and may not be aligned with belief in the helpfulness of others in the community, as argued by Abbott et al. [621]. Low social capital or negative social capital is associated with adverse health outcomes in PLHIV, including low quality of life [622], depression [623] and even destruction of livelihoods [624]. The dynamics of social capital and health are contentious and vary depending on the type of social capital and how it plays out in a specific context [620].

In the context of HIV, stigma is a critical form of negative social capital that plays out in the form of social exclusion of those living with HIV [309]. Those with higher anticipated stigma had reduced odds of abdominal obesity compared to those with lower anticipated stigma from the community. Given that all participants were living with HIV, this implies that those who are not obese anticipate experiencing more stigma from the community. This finding also speaks to perceptions of body image in the South African context, where people perceive

being overweight as desirable given the perceived association between being underweight and being HIV positive and also given cultural connotations of affluence and beauty [87, 625]. Other measures of stigma, including internalised and enacted stigma, which measure more direct and internalised expressions of stigma, did not emerge as significant in bivariate or multilevel models. It might be that perceptions of weight and stigma do not impact adolescents and young adults growing up in the current ART era, similar to older cohorts impacted by the visual signs of HIV wasting and dystrophy. Furthermore, adolescents, particularly girls, may be influenced by social media and peers, which may impact their body image perception differently from cultural norms [626].

6.4.3 Built and food environment factors

Several subscales of perceived walkability in the neighbourhood environment were significantly associated with abdominal obesity. Land-use mix diversity, access to recreational places, pedestrian and traffic safety, and access to non-fast-food restaurants were strongly associated with reduced odds of abdominal obesity.

In previous studies conducted in the US, land-use mix had the strongest association with obesity [627, 628]. Being able to walk easily from home to commercial areas in neighbourhoods with “mixed land use” is associated with reduced body weight and increased walking and physical activity behaviours [629]. Our findings corroborate these findings; those with perceived easier access to stores and facilities in their neighbourhoods had lower odds of abdominal obesity. This highlights the importance of a mix of residential, commercial, industrial and open spaces in urban design to promote non-motorised forms of transport. Urban space diversity is crucial in the urban planning of a city like Cape Town with its history of displacement and continuing spatial segregation [630, 631].

Access to recreational places also emerged as significantly associated with lower odds of abdominal obesity in multilevel analysis, similar to studies that document that access to recreational facilities is correlated with adolescent physical activity and weight status [632]. Proximity to parks and other recreational spaces may increase physical activity, improve HIV-

related health outcomes, and reduce depression in PLHIV [633, 634]. However, this relationship may be mediated by SES and neighbourhood safety in urban, low-income settings [635]. Therefore, local governments need to consider developing parks and other open recreational spaces in urban areas with safety measures in place as a means to promote physical activity in young people [636].

Previous multilevel studies suggest that the availability of food stores is significantly related to individual-level obesity [629]. Access to supermarkets that sell healthy foods has been linked to improved dietary choices. People who have access to supermarkets consume more fruits and vegetables than those who rely on convenience stores and corner shops [637, 638]. Except for non-fast-food restaurants, access to supermarkets, fruit and vegetable markets, and fast-food restaurants were not significantly related to abdominal obesity in our analysis. However, we did not measure the mediating effect of the availability of healthy foods on healthy food choices and abdominal obesity. Our findings illustrate similar food environments across the communities studied. These areas typically have informal fruit and vegetable traders as part of their food landscape, which are accessible to residents within the area and small grocers or corner shops and very few supermarkets [639].

The emergence of non-fast food restaurants related to lower odds of abdominal obesity is an interesting finding in this context compared to other settings where proximity to non-fast food restaurants had no discernible effect on obesity or weight gain [640]. Conversely, literature from higher-income settings suggests that a typical fast-food meal has fewer calories than the average sit-down restaurant meal [641]. However, this relationship is unclear in this setting and warrants further investigation. It is crucial to elucidate how young people navigate their food environments in this setting, especially in light of homogenous exposures to food advertising, availability and accessibility of foods.

Obesity is a complex and multifactorial problem requiring multi-sectoral interventions ranging from the individual or family level to the community and broader food and built environments, ideally ranging across the life course. The South African government implemented mandatory legislation for salt reduction in processed foods [538] and a tax on

SSB [539]. However, more measures are needed at a community and micro level to promote healthier food environments and encourage regular physical activity. Amongst these measures are nutritional education to promote healthier food choices and supplying healthier foods to people in low-income urban settings.

6.4.4 Strengths and limitations

This study adds to the limited literature on multilevel determinants of obesity in AYLHIV. Previous studies in PLHIV in LMICs have explored individual, particularly treatment-related factors related to obesity. The inclusion of environmental determinants in this study expands the understanding of obesity risk in AYLHIV beyond individual and healthcare factors. Furthermore, abdominal obesity measured using the WHtR may more accurately reflect NCD risk than BMI, especially in this population of AYLHIV. In addition, obesity prevention and treatment interventions have traditionally focused on pharmacological, educational and behavioural interventions, with limited success. Our findings demonstrate the significance of household, community and environment-level factors that drive obesity in this vulnerable population requiring further research.

Our study has important limitations. First, due to the limited sample size, we were not sufficiently powered to control for all possible confounders and experienced convergence and precision issues when attempting to do so. However, by using multilevel analysis, we accounted for the hierarchical structure of the data and neighbourhood-level differences. Furthermore, given the multiple comparisons made, it is possible that some variables were significantly correlated with the outcome variable by chance. The choice of representation of each variable in the model and the categorisations used for the bivariate and multilevel models may have also led to a loss of information. Future research with adequate sample size should use adjusted methods to correct for multiple comparisons and experiment with various dummy variables and representations of factors. Second, our variables were based on self-report, which might be prone to reporting bias, especially diet and physical activity-related measures. Moreover, the tools used for composite measures pertaining to thermal comfort, social capital and the food environment have not been previously validated in this

population and were extrapolated from studies conducted in higher-income settings. Thus, their reliability may be limited in this setting. Nonetheless, this study provides a framework for more detailed future studies using multilevel methods in settings like South Africa.

6.5 Conclusion

Our findings highlight that complex factors at multiple levels from proximal to distal, affect obesity risk and that an intersectoral approach to obesity prevention that intervenes across household, community, and environment levels is necessary in this setting, as AYLHIV enter adulthood. Our findings further show that evidence from high-income settings on obesity prevention is not necessarily transferable to a setting like Cape Town undergoing epidemiological, urban and nutritional transitions. Obesity continues to increase and is a major health issue in LMICs. There is a need for research conducted in this and similar contexts to generate contextually relevant evidence to effectively turn the tide of the obesity epidemic in rapidly urbanising LMIC cities. Obesity prevention efforts that target adolescents have the greatest potential to avert obesity into adulthood due to the critical nature of adolescence as a development period. Important areas to explore include the role of a non-nuclear family structure on obesity risk, thermal discomfort and housing informality, social norms and community perceptions, food availability and urban design to support healthy food choices. The diverse range of interventions required highlights the importance of intersectoral action, engaging diverse sectors and actors to reduce obesity risk in this priority population group.

Chapter 7 Discussion

7.1 Introduction

In this chapter, I will begin by revisiting my research questions and summarising my key findings. I previously developed a conceptual framework for adolescent/youth HIV-NCD comorbidity. I will re-examine this framework in light of evidence drawn from my results. I will then explain the significance of my findings and what this thesis contributes to existing literature, considering its limitations. I will then outline the practical implications of this thesis and propose recommendations for policy and adolescent care in this and similar settings. Finally, I will conclude with suggestions for future research.

7.2 Revisiting the research questions

7.2.1 To what extent is NCD prevention and risk factor screening incorporated within existing adolescent HIV primary healthcare services in Cape Town?

The first question in this thesis sought to determine the extent to which NCD prevention and risk factor screening are incorporated within existing adolescent HIV primary healthcare services in Cape Town. It was hypothesised that AYLHIV were not routinely screened for NCDs as part of HIV care. The results confirmed that NCD screening and management was not routinely captured in HIV primary care services for this population group. There was a striking paucity of data on NCDs and NCD risk documented as part of clinical care of adolescents with HIV. Poor documentation and screening of NCD risk factors for most participants demonstrated a missed opportunity for detecting comorbidity and NCD risk in primary healthcare and early intervention in AYLHIV, who represent a significant population that are less inclined to seek regular or preventive care. Data paucity notwithstanding, these results provided evidence of co-existing NCD multimorbidity and NCD risk factors (mental health conditions, chronic respiratory diseases, overweight and obesity, elevated BP and smoking, alcohol and substance use) in AYLHIV. These results corroborate the findings of previous studies, which showed high rates of NCD multimorbidity, but under-diagnosis, under-treatment, and poor NCD control in primary care in South Africa [8, 642]. From my findings,

it is evident that there is limited consideration of NCD prevention and screening for youth in HIV care in primary care settings. This is concerning given the elevated risk for NCDs associated with HIV infection and ART, which is not exclusive to adults. Several studies call for closer monitoring and possibly treatment of NCDs in AYLHIV [164, 165].

Nurses usually see AYLHIV in primary care clinics. Nurses form the backbone of primary healthcare in South Africa and are also primarily responsible for overseeing chronic care in a nurse-based, doctor-supported model of care [643]. One possible reason for the limited NCD screening in adolescent HIV care is that nurses may not feel empowered to screen for and treat NCDs. The medical records reviewed in my study showed that very few of those already diagnosed with NCDs received treatment, indicating that management is inadequate. Although it was outside the scope of this thesis to explore barriers to screening amongst healthcare workers, our findings suggest that capacity strengthening of healthcare workers could be beneficial.

To promote task-shifting and leverage the health system reforms that accompanied the scale-up of ART, Primary Care 101 (PC101), now known as Adult Primary Care, was launched by the SA government as part of the Ideal Clinic initiative [65]. PC101 was designed to support and expand the role of nurses in NCD care, consisting of education, training and a clinical management tool with enhanced prescribing provisions [644], as regulated by the Medicines Control Act [645]. Despite interventions like PC101, which have been implemented in primary care clinics country-wide, the quality of NCD care is still characterised by poor integration with vertical models of health care undermining efforts towards comprehensive primary care [644]. My findings may reflect a broader health systems issue that would require targeted health system strengthening intervention. Future research to explore the possible barriers to NCD screening and management, as part of integrated HIV management and NCD prevention care among healthcare workers responsible for adolescent HIV care, is needed.

7.2.2 What is the prevalence of common NCDs and associated cardiometabolic, respiratory and behavioural risk factors in AYLHIV?

The second objective was to quantify the prevalence and risk factors for NCDs in AYLHIV. Overweight and obesity prevalence and mental health comorbidity were high. Participants reported significant symptoms of depression and psychological distress. Despite the low prevalence of hypertension and diabetes, a fifth had elevated measured BP and more than a quarter self-reported family history of diabetes. Participants also had multiple risk factors for NCDs, including smoking, harmful alcohol use, and sedentary behaviour. Encouragingly, the majority of participants met WHO criteria for recommended levels of weekly physical activity. However, many did not meet dietary guidelines for fruit and vegetable intake, had high fast-food and SSB consumption, and displayed low nutritional knowledge. An alarming pattern of early initiation of high-risk behaviours, including underage and binge drinking, smoking and experimentation with cannabis, emerged in the youngest age group. Similar to previous estimates in the general youth population, females had higher rates of obesity and more males engaged in risk behaviours pertaining to alcohol, smoking and illicit drug use [136].

My findings suggest that rates of overweight and obesity in AYLHIV are on par with those of young people in the general population [136]. At the same time, mental health comorbidity and symptoms of depression and anxiety were much higher than rates reported in the general population [87]. These results corroborate findings from previous work on high rates of mental health disorders in children and adolescents living with HIV in South Africa and from other African countries [217, 489, 518-520]. Furthermore, it is concerning that less than a fifth of those identified as having significant depression reported being previously diagnosed with anxiety or depression. These results support the hypothesis that there is a growing unmet need for mental health and NCD screening and intervention.

It has been suggested that AYLHIV in SSA have sub-optimal levels of nutrients and low dietary diversity [239, 240]**.** This thesis did not explore whether AYLHIV had more limited dietary diversity and unhealthier diets than the general population, as this was beyond the scope of the study objectives. Nevertheless, most participants interviewed fell below recommended

dietary guidelines for fruit and vegetable intake necessary to reduce the risk of NCDs, particularly females [531]. Dietary practices like frequently skipping breakfast and eating meals prepared outside the home were commonplace. Furthermore, skipping breakfast and not eating school lunch were positively associated with obesity. These findings contribute to existing knowledge on adolescent obesity in the South African context more generally. Subsequently, they could inform tailored interventions towards specific groups of young people, such as older adolescents who may have more disposable income to afford to eat takeaways and other meals prepared outside the home.

Although most AYLHIV met recommendations for sufficient weekly physical activity levels, these results should be interpreted with caution because of possible reporting bias. Several studies from other LMICs have found that youth living with HIV have significantly lower daily physical activity levels than their uninfected counterparts [245, 246]. I did not compare physical activity levels by HIV status in this study. Therefore, additional research is needed in this setting to explore the relationship between physical activity and HIV in adolescents. A study with an age-and sex-matched HIV-uninfected control group from the same community would help elucidate whether this relationship exists in South Africa.

Younger adolescents were found to have a higher prevalence of risk-taking behaviours, particularly harmful alcohol use, underage drinking and smoking, compared to adolescents older than 18 years. This finding suggests that experimentation with substances begins quite early in this context before middle adolescence, and interventions aimed at reducing risk behaviours should be tailored to the stage of adolescent development with a focus on younger adolescents. In terms of smoking, the findings reflect studies from higher-income settings, which indicate higher rates of smoking among AYLHIV compared to the general population [256, 258], particularly among those who were horizontally infected [253].

Respondents also reported higher rates of current drinking and binge drinking in the past month compared to estimates for the general population [85]. These results align with those obtained from higher-income settings, which report increased alcohol and drug use, especially among male AYLHIV [262]. However, research comparing substance use in

perinatally (HIV)-infected (PHIV+) and perinatally exposed, uninfected (PHEU) youth in the United States suggests that perinatal HIV infection is not a risk factor for alcohol or marijuana use [257]. Lifetime substance use prevalence and risk factors for PHIV+ and PHEU adolescents were similar to national norms for adolescents and included emotional and conduct problems and substance use in the home [257].

An important area of further research is whether the mode of HIV transmission impacts adolescent risk behaviour. Recent research from sub-Saharan Africa suggests that behavioural risk profiles and mental health challenges may differ between adolescents who were perinatally infected with HIV and horizontally infected adolescents [207, 646]. Findings from the US comparing PHIV+ to PHEU youth suggest that mental health and the family and social environment are critical in determining uptake of risk behaviours in youth, irrespective of HIV infection [257]. The few previous studies on risk behaviour among AYLHIV in SSA report a high prevalence of alcohol and substance use behaviour, especially among males in late adolescence [260, 261, 263, 264]. In the rural Eastern Cape of South Africa, alcohol and drug use did not differ from HIV-uninfected young people residing in the same setting [263]. Further research, ideally disaggregated by mode of transmission, is needed to clarify whether HIV infection is associated with increased alcohol and substance use in young people living in settings like Cape Town, where alcohol and drug use are endemic [549].

7.2.3 Which multilevel factors are associated with abdominal obesity in AYLHIV?

I found a high prevalence of abdominal obesity and various factors from the individual to the community and environmental level associated with abdominal obesity. At the individual level, unsurprisingly, given existing literature, female sex was associated with higher odds of obesity. Additionally, skipping breakfast and absence from school were strongly associated with higher odds of abdominal obesity. Traditional factors relating to diet and physical activity also emerged from the analysis: daily intake of whole grains and engaging in daily moderate physical activity were significantly associated with lower odds of abdominal obesity.

At the household level, experiencing thermal discomfort in the home was associated with increased odds of abdominal obesity. At the community level, higher anticipated stigma was associated with reduced odds of abdominal obesity. At the built and food environment levels, land-use mix diversity, access to recreational places, pedestrian and traffic safety, and a non-fast-food restaurant within walking distance were associated with reduced odds of abdominal obesity in AYLHIV. These factors are important to explore in light of the multilevel determinants of obesity and the collision of obesity and HIV epidemics. Efforts to address the dual epidemics will need to go beyond individual-level risk factors such as diet and physical activity and incorporate the household and environmental risk factors.

Previous studies have found positive associations between obesity and socioeconomic status (SES). Contrary to expectation, this study did not find a significant difference between obesity levels and poverty as measured using a multidimensional index and food insecurity. There are several possible explanations for this result. Firstly, it seems possible that these results are due to the homogeneity of the study population who faced similar levels of poverty and deprivation, irrespective of obesity status. Second, there may be unmeasured effects not captured by the poverty dimensions and food security measures used. This is highly likely due to the low explanatory power of the multilevel models fitted. An interesting caveat is the finding of thermal discomfort in the home as positively associated with obesity. More than a third of AYLHIV lived in informal housing (shacks or backyard dwellings), which are characterised by inadequate ventilation and poor insulation [647]. Thermal discomfort in housing can have serious health impacts [648] and is under-investigated in PLHIV in sub-Saharan Africa [649]. Thermal discomfort, likely more common in deprived households, could be an important, neglected source of health inequality for PLHIV, as highlighted in a study from Ghana [649].

Thirdly, additional confounders and effect modifiers other than sex and age could confound or mediate the relationship between SES and obesity. These variables include neighbourhood social capital and crime, which I could not adjust for in the multilevel models as the models failed to converge due to overfitting parameters, given the sample size [650]. Neighbourhood poverty is correlated with poor social environments, including higher crime rates, poor social

cohesion and low social capital [618], which are also associated with obesity. The effect of SES on obesity may therefore be mediated through its effects on other neighbourhood social characteristics pertaining to crime, social cohesion, and residential segregation, which I did not measure at the aggregate level [618]. Therefore, the lack of association between obesity and deprivation as measured by the multidimensional poverty index should be interpreted with caution. Finally, the impact of SES on health may be cumulative, acting across the life course, and it is difficult to restrict measurement thereof to one time-point in a cross-sectional study design [25].

While we identified a negative association between anticipated stigma and obesity, questions remain on the role of stigma in mediating the relationship between obesity and HIV status. Having obesity may decrease life expectancy [651] compared to well-managed HIV [652], but it is unclear how that translates into a community setting in terms of norms and attitudes. Future research should investigate community and adolescent perceptions of desirable weight and the perceived health risk of being overweight/ obese versus being stigmatised or labelled as HIV-positive within their immediate social circle and community. Given the sex differences in obesity identified in my study, this is particularly pertinent for adolescent girls who struggle with their self-perception and body image [299, 653]. This research will be crucial as obesity rates continue to rise in the country and AYLHIV transition into adulthood and gain more autonomy to navigate their social, food and built environments. To this end, my finding of inadequate nutritional knowledge in AYLHIV highlights the importance of nutritional education as part of integrated HIV management / NCD prevention and care. Public health messaging and health interventions will need to be sensitive towards the lived experiences of young people, tailored to different stages of adolescence, as they grapple with stigma, societal pressures and what may be confusing messages from different media.

Additionally, features of urban design are also important determinants of NCDs. Focussing solely on social determinants of health may overlook structural features of urban design such as connectedness and land-use mix, which may influence health outcomes in rapidly urbanising contexts [654, 655].

7.3 The conceptual framework re-examined

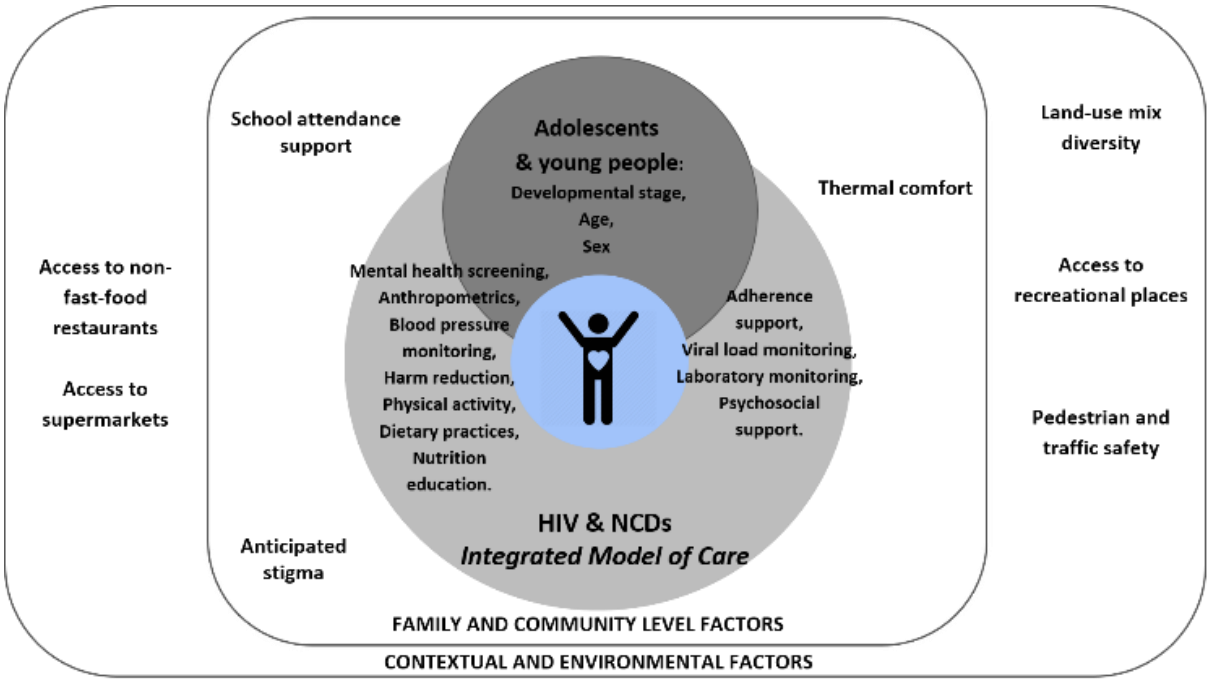

Figure 7.1: A revised integrated HIV-NCD model of care conceptual framework to reduce the risk of NCDs in adolescents/youth living with HIV

I previously developed a conceptual framework for this thesis based on my literature review (shown in **Figure 2.1**). After synthesising significant findings from the studies in this thesis, I revised the framework to create an evidence-based integrated model of multilevel interventions and desired outcomes that our findings show should be included in an integrated model of care. The multilevel factors displayed are those which were significant in the bivariate and multivariate models. The revised conceptual framework for AYLHIV (**Figure 7.1**) details the multilevel components of an integrated model of care that would be necessary to lower the risk of NCDs in AYLHIV. Components from the original framework (in **Figure 2.1**) that were not significantly associated with abdominal obesity and NCD risk were not included in this revised framework. Accordingly, **Figure 7.1** represents the essential components of integrated efforts to reduce obesity risk as part of HIV care in AYLHIV.

A host of screening and health promotion activities to be conducted within healthcare settings are proposed, including regular broad-based mental health screening, anthropometric measurements (particularly waist circumference and WHtR), and blood

pressure monitoring. In addition, health promotion activities should encourage healthy eating, provide nutrition education, promote physical activity, and harm reduction on the dangers of alcohol and substance use. Ideally, a multidisciplinary team of dieticians, fitness and wellness instructors would rotate across facilities to conduct demonstrations and health promotion activities with young people to provide more engaging and impactful content. Interventions should be targeted to the developmental stage of adolescents, particularly tailored towards their age and sex, as risk factors and behaviours differ significantly between older and younger adolescents and between males and females.

Beyond healthcare, thermal discomfort can be assessed at the household level as a significant indicator of inequality and a predictor of general health and obesity risk. Thermal comfort assessments could be done by community health workers as part of their household assessment visits and communicated to their team leader, who would then identify vulnerable adolescents and families [656]. Moreover, it would be beneficial to involve the Department of Human Settlements, which oversees the allocation of subsidised government housing to low-income families. Various criteria are used in housing allocation, including earning below a threshold amount, but the scheme also gives preference to the disabled and child-headed households [657]. As part of intersectoral action for NCD prevention, families affected by HIV, especially those with AYLHIV, could be prioritised on housing waiting lists.

Although household SES, access to services, food security, and exposure to violence did not emerge as significant and were thus not included in **Figure 7.1**, based on the literature review, these factors likely have a significant, cumulative effect on NCD risk over time. Hence, it would be beneficial to screen for them frequently over the life course and provide psychosocial support. Individuals identified as high-risk using these screening measures can be referred to social and development services for additional intervention. Other social factors to consider are the role of stigma and weight perceptions. Higher anticipated stigma was associated with lower odds of obesity. This relationship warrants further investigation to draw out dynamics concerning cultural connotations around thinness and HIV and how AYLHIV navigate these perceptions in the ART era, as previously discussed. Asking AYLHIV about experiences of

stigma would be a helpful way to gauge community influences and how these may affect their weight and self-perception.

Many AYLHIV reported high positive parenting and supervision levels, implying that even non-biological caregivers have an influential role in adolescents' upbringing and potential risk-taking behaviour. Additionally, parents and caregivers can play a vital role in encouraging school attendance which was protective in reducing obesity risk. Assessing positive parenting and supervision would help healthcare providers identify those adolescents needing extra psychosocial and material support. However, despite reporting high levels of parental monitoring and supervision, early initiation of high-risk behaviours like underage drinking and smoking raises concerns about harmful social norms and the possible contagion effects of school and neighbourhood social capital [303, 304].

The food environment can be assessed by asking about access to supermarkets, and non-fast-food restaurants, although it should be noted that this is merely a proxy of access to healthy foods. Features of the built environment that were significantly associated with obesity were land-use mix diversity, access to recreational places, and pedestrian and traffic safety. Each of these was negatively associated with obesity and indicates whether an environment is walkable or not. Another measure to assess walkability is asking about active transport as part of a young person's commute to school or work.

7.4 Contributions and limitations

This thesis provides deeper insight into NCD prevalence and risk factors in AYLHIV in urban South Africa from a socio-ecological perspective, adding to the limited evidence on NCDs in AYLHIV in sub-Saharan Africa. Young people are the biggest population group in SSA, but their health, particularly factors not related to sexual and reproductive health, is often neglected. Furthermore, risk behaviour research on AYLHIV in SSA has predominantly focused on sexual risk behaviour, failing to incorporate mental health and NCD risk factors [261].

Previous studies in SSA have described NCD comorbidities in adults living with HIV [151, 481, 493-495]. Besides mental health [207, 319, 523, 623, 658-662] and lung diseases [197, 663-666], few studies have assessed the prevalence of NCD and particularly NCD risk factors in AYLHIV in SSA other than as incidental findings [245, 263, 264, 547, 548, 557, 562, 667]. These findings contribute in several ways to our understanding of NCDs in AYLHIV and provide a basis for targeted interventions. For example, few studies in Africa have reported overweight and obesity levels in AYLHIV other than in the context of ART-associated dyslipidaemia [245, 508, 509]. By investigating abdominal obesity as an outcome using multilevel analysis, this thesis expands the knowledge base on obesity in AYLHIV. This approach will prove helpful in extending our understanding of how various factors, from individual to environmental, shape health outcomes.

Numerous studies report on nutrition outcomes of CLHIV and AYLHIV, focusing on stunting and undernutrition [237, 238], but minimal data exists on dietary behaviour of AYLHIV in SSA. This study contributes to the limited evidence on dietary intake of AYLHIV and highlights the importance of unhealthy diets and the food environment as a driver of obesity. To our knowledge, this is the first study to assess nutrition knowledge in AYLHIV in Africa. The inadequate knowledge on nutrition related NCDs and healthy food choices amongst AYLHIV in this study are important factors to consider when designing interventions in a country undergoing nutritional transition [321].

It was beyond the scope of this study to examine the effects of ART on NCD risk or ART-related NCDs. However, ART regimens and their side effects, such as high cholesterol and triglycerides, have been reported in adults and warrant further investigation in AYLHIV.

An overall study limitation is a potential for selection bias. Patients who present at facilities are not necessarily representative of the general population of PLHIV as they are the diagnosed cases who have opted to access care and remain in care. In 2017, UNAIDS estimated that 85% of PLHIV in South Africa aged 15–64 years knew their HIV status, of whom 71% were enrolled on ART [668]. The numbers for adolescents on ART and retained in care are significantly lower than adults [95]. In 2013, it was estimated that only 14% of AYLHIV

aged 15–24 years were on ART, and only 12% were retained in care [95]. From the records review, it was unclear how many adolescents had been lost to follow up or had died at each clinic which poses a significant limitation. These estimates, though outdated, also indicate that a significant number of AYLHIV would not be reached by healthcare facility-based interventions alone. These young people may be even more vulnerable than those in care, with psychological, structural and economic barriers inhibiting their ability to access care. Although identifying AYLHIV who are not in care was beyond the scope of this thesis, linkage and retention in care is indeed a recognised global challenge for AYLHIV and is an important consideration for future research [669, 670]. Any integrated HIV/ NCD interventions will only be as effective in as far as they can reach a significant proportion of the population of AYLHIV. Future research would need to include efforts to identify those not in care as part of integrated HIV management and NCD screening and prevention. Community and school-based interventions would be a possible strategy to reach adolescents who are not enrolled in healthcare, as further discussed under recommendations.

In addition, by the nature of the cross-sectional study design, recall bias cannot be ruled out as information on past exposures was dependent on the participant's memory of events. Furthermore, the sensitive nature of some of the questions may have led participants to give the socially desirable response, leading to under-reporting of risk behaviours like illicit substance use and over-reporting of healthy behaviours like physical activity and dietary intake. It is well-known that self-reported measures can overestimate physical activity levels [671]. Future studies should use objective measures of physical activity such as accelerometers and pedometers.

Another limitation was that a control group of HIV-uninfected adolescents was not included in the study design. Although this would have been ideal for comparison purposes, using a catchment population of school-going youth from the same communities for example, the ethical and logistical requirements proved too arduous considering the study timeline. Additional approval was needed from School Governing Boards and the Department of Education, which was not factored into the study timeline. Furthermore, HIV testing would have been required to screen for negative controls which would add a layer of ethical

complexity given the sensitive nature of disclosing an HIV diagnosis, especially to a minor. In future, researchers conducting adolescent health research should involve appropriate stakeholders such as Community Advisory Boards (CABS) and School Governing Boards who can facilitate access to eligible participants and controls from inception at the design phase.

The food environment was characterised using geographic measures of proximity to restaurants and supermarkets. Although geographic measures of the food environment are correlated with dietary behaviour, they do not reflect the nutritional quality of people's diets. For example, access to supermarkets is related to increased fruit and vegetable consumption and higher overall dietary quality in high-income settings [672]. However, a study in Cape Town found that supermarkets in low-income neighbourhoods sold less healthy foods than those in higher-income neighbourhoods, demonstrating that access to supermarkets cannot be used as a proxy indicator of healthy diets [673]. Further research is required, measuring elements of the food environment and their relation to dietary behaviour and obesity using more sensitive and detailed measures in low-income settings.

7.5 Implications for policy and practice

AYLHIV are growing up in an era of epidemiological transition, with the increasing burden of NCDs driven by the high-risk environments within which they live, necessitating interventions to enhance protective environmental factors and minimise risk behaviours [140]. The younger age distribution of PLHIV in SSA [583] means that in the long run, adopting a life course approach to NCD prevention at the primary care level is the most cost-effective approach to maintaining population health. Health systems based on the "disease model" of care cannot successfully meet individual and community health needs [674]. Therefore, a primary prevention approach to NCD control in AYLHIV is essential with prolonged ART duration and age.

Early identification and intervention to modify behaviour would prevent a costly future epidemic of NCDs and avert morbidity and mortality due to NCDs [447]. NCDs are costly to individuals, health systems and the productivity of a country as a whole [675]. The growing cost of NCDs is of particular concern as LMICs grapple with higher levels of NCDs at earlier

stages of economic development, with fewer resources and less time to respond effectively [447]. In the following section, we propose recommendations for improving adolescent care using a socio-ecological approach.

7.5.1 Recommendations for adolescent care

7.5.1.1 Individual level

Some NCDs and many NCD risk behaviours (e.g. mental disorders, alcohol, substance abuse) tend to cluster and influence HIV control [676]. Adolescents lag behind other age groups in the 90-90-90 targets and are at risk of being left behind without urgent intervention [677]. According to their medical records, less than 70% of AYLHIV in this study were virally suppressed, which may be related to the impact of their mental health on adherence [678]. Sub-optimal HIV outcomes further emphasise the need for strengthened integrated health systems that incorporate mental health care.

Mental health screening is crucial in HIV care due to multiple psychological vulnerabilities associated with living with HIV and high rates of serious mental illness and suicide in PLHIV [526-528]. Mental health problems not only increase the risk for HIV acquisition but further increase the risk for adverse health outcomes among PLHIV at each step in the HIV care continuum [678]. Several studies call for integrating routine mental health screening in paediatric and adolescent ART programmes in South Africa [523, 676]. There are a variety of brief, validated screening tools that healthcare providers can use for mental health screening in adolescent HIV care, including the Patient Health Questionnaire-9 (PHQ-9) [679], the Children's Depression Inventory–Short [680], and the Revised Manifest Anxiety Scale [681]. Initial screening can also be done less formally, identifying youth struggling with motivation or lacking aspirations for the future that are more likely to have symptoms of depression, anxiety or PTSD requiring further psychosocial support or referral [319].

Various psychotherapeutic treatments and psychosocial interventions have been tailored for cross-cultural use and PLHIV, including cognitive-behavioural therapy, group therapy, motivational enhancing therapy and mindfulness treatments [682, 683]. Interventions

delivered by mental health professionals are the most effective in terms of overall mental health outcomes [678]. These recommendations are made in consideration of limited resources, human and otherwise. Considering the limited availability of mental health professionals in South Africa and other LMIC settings, broad-based interventions incorporating mental health screening and care into primary care or community services without requiring specialised workers are likely to be more cost-effective [684, 685].

Harm reduction and tailored health promotion on the dangers of alcohol and substance abuse are also necessary, especially amongst younger adolescents and males who are more likely to initiate experimentation with substances. Technology-based solutions like social networking and mobile applications can be used to promote health and harm reduction campaigns for young people. Young people are often early adopters of technology [297], and it is estimated that about 72% of youth between the ages of 15 and 24 in South Africa have access to a cell phone [686].

Young people today have the unique advantage of access to information through the internet. They could potentially provide novel perspectives on raising awareness on NCDs and NCD prevention to their peers [140]. A peer-led mental health intervention run in Zimbabwe by adolescent Community Adherence Treatment Supporters known as CATS successfully improved both virological suppression and mental health outcomes in AYLHIV in Zimbabwe [687]. Peer-to-peer interventions could be helpful to reach adolescents who may fear communicating openly with healthcare providers and prevent pathologising behaviours characteristic of normal adolescent development. Additionally, health promotion interventions could form part of regular youth clubs where medication is dispensed. At present, lay counsellors discuss sexuality, reproductive health and ART adherence in these sessions, but this could be expanded to incorporate dieticians, exercise groups and psychological wellness.

A notable finding was that obesity co-occurred with hypertension – more than a third of those with elevated blood pressure or hypertension also had overweight or obesity. By screening for obesity, other related conditions which tend to cluster with obesity can also be detected.

As explained in the literature review, closer monitoring of overweight and obesity profiles in AYLHIV in SSA is needed as they transition into adulthood, especially with prolonged exposure to ART regimens linked to obesity, altered glucose metabolism and dyslipidaemia [513]. One interesting finding was that a quarter of participants with normal BMI had abnormal WHtR and could be classified as having central obesity. Anthropometric measurements and calculations (waist circumference, WHtR, WHR) are essential to determine obesity beyond BMI, especially in females [517]. Anthropometric measurements and blood pressure monitoring are a non-invasive, low-cost and easy-to-use method to identify AYLHIV at increased cardiometabolic risk in primary care [515]. Stadiometers, measuring tape and BP cuffs are readily available in most facilities and can be used by lay personnel with appropriate training.

7.5.1.2 Family and household level

A family history of an NCD has been shown to be a significant risk factor for NCD in South Africa [87] and should form an essential component of NCD risk assessment. In the first study, only 6% had a documented family history recorded. Additional evidence from the second study showed that although none of the participants met the criteria for diabetes, and only one had a previous diagnosis, more than a quarter self-reported family history of diabetes, signalling a possible genetic risk. Failure to document family history is a critical oversight as adolescents with HIV may have adult family members receiving care at the same facility. Data clerks could trace and link this information with minimal training to provide a holistic picture of genetic/familial NCD predisposition. The IDF projects that diabetes is set to become a major public health challenge in Africa as most cases are undiagnosed [688]. Healthcare providers could use the information on family history of diabetes to screen for pre-diabetes in those with genetic risk, especially those who do not present with traditionally associated risk factors like obesity and high blood pressure [689]. This information can also be used as a tool for health promotion to ameliorate household and environmental factors which may interact with a genetic predisposition [690].

Additionally, adolescents can adopt practices like healthy cooking methods requiring steaming, roasting or baking at the household level with the cooperation of parents and

caregivers, especially in genetically high-risk households [530]. With adequate nutrition knowledge, adolescents in our study who ate more fast food and more meals prepared outside the home could be encouraged to make healthier food choices.

7.5.1.3 Community level

At the community level, interventions can be introduced targeting social norms and beliefs to establish a healthier food and walkable environment. One example of this is introducing community food gardens and outreach programs to encourage walking and physical activity. The Western Cape Government has been piloting the WoW! Active Public program in open city spaces to promote regular physical activity through a range of free exercise events offered to the public of all age groups [691]. The initiative is an intersectoral effort involving various departments, including Health, Education, Social Development, Community Safety, Cultural Affairs and Sport and Transport and Public Works [692]. Overall, the WoW! Initiative aims to prevent and reduce the burden of NCDs through advocacy and actively promoting physical activity and healthy eating in the Western Cape. Through schools and community settings, adolescents are also targeted to become champions and recruit other team members [692]. Although impact assessment results are still unpublished, the program has had good uptake and engagement from the public (*personal communication with programme director*).

The youth stage is generally characterised by a high degree of mobility. In the South African context, young people move to cities, or so-called urban metros in search of economic opportunities, better education and access to health care, housing and welfare services [36]. A study on youth mobility from the Eastern Cape to the Western Cape showed that youth and their parents viewed migration as a pathway out of rural poverty and to upward social mobility [693]. However, moving to the city is not always associated with improved life chances or improved youth wellbeing [36]. Large numbers of young people live in the informal settlements on the peripheries of the Cape Town facing high levels of food insecurity [694], unemployment, and social disillusionment [695], possibly leading to an increase in risk behaviour, crime-related activities and increased vulnerability. Interventions targeting risk behaviours will need to consider the plight of these young urban migrants who may be further marginalised by lack of support systems and family networks. At the structural level, urban

planning process also need to consider growing populations and the needs of young people, so as not to exacerbate inequality.

Interventions at the community level could simultaneously link migrant and other AYLHIV who are not in HIV care to healthcare. For example, pilot projects like mobile testing for HIV and NCDs are currently underway to reach adolescents who are not in care [696]. Other initiatives like Open Streets, a model developed in Latin America, promoting physical activity through car-free, walkable streets within the city [697], are another possible avenue for attracting youth and identifying AYLHIV through free health and wellness screening and HIV testing and counselling.

7.5.1.4 Broader structural level

Almost half of our participants faced multiple deprivations of poverty and moderate-severe food insecurity. Socioeconomic barriers such as poverty and food insecurity are commonly cited challenges for AYLHIV in SSA [279]. Poverty and deprivation are risk factors for several NCDs and lead to an accumulation of risk across the life course [30], also impacting HIV disease control [233, 280, 281]. Addressing this challenge requires a multi-sectoral approach for NCD prevention with appropriate social protection systems [275]. Initiatives like (un)conditional cash transfers have been piloted across SSA to address poverty and risk behaviours in adolescents [698, 699]. Evaluations of these initiatives have demonstrated positive outcomes in increased schooling, decreased teen pregnancies and improved sexual and reproductive health [700]. However, there have been mixed reports on their direct effects on anthropometry and nutritional outcomes in LMICs [701].

To promote healthy dietary behaviours, a multi-sectoral approach that promotes a healthy food environment is required. The South African government has made macro-level efforts towards promoting healthier food environments by implementing mandatory legislation for salt reduction in processed foods [538] and a tax on sugar-sweetened beverages [539]. However, interventions to support healthier food environments need to be implemented at the social and physical environment levels to increase their efficacy. For example, informal food vendors characterise the retail food environment in urban low-income neighbourhoods

in SSA; however, their role in shaping dietary behaviour is understudied [327]. Informal food vendors represent potentially valuable outlets for ensuring accessibility of healthy foods like fruit and vegetables in urban, low-income neighbourhoods.

7.5.2 Recommendations for policy

Strategies like the ICDM and Chronic Disease Clubs, aimed at integrating chronic (infectious and non-communicable) disease programs using established and existing frameworks in primary care that includes services for both HIV and NCDs, should not exclude adolescents [229]. Pilot projects are underway in selected primary health care facilities to investigate the most effective integrated care models [474]. To date, these models have focused on the general adult population, with no integrated clinics for adolescents planned. Using a disease model of care focusing solely on HIV-specific outcomes neglects an opportunity to intervene holistically in a target at-risk population regularly accessing care.

In the Western Cape, integrated internal audits are run annually to monitor and evaluate norms and standards for NCDs within primary health care facilities [702]. Indicators collected for monitoring purposes include disease-specific outcomes (e.g., monitoring and optimal management of diabetes, hypertension) and ensuring availability of equipment like blood pressure cuffs and glucometers within facilities. Audits like these can improve care processes over time and ultimately improve patient outcomes [702]. These tools could be integrated into youth HIV services to encourage and motivate healthcare workers to conduct NCD screening and management. To this end, I have drafted a tool integrating significant variables from my thesis studies and variables identified to be important from the literature review (see *Appendix 4: Integrated HIV/NCD management tool)*. Future implementation research could be conducted to further develop, validate and evaluate the use of this tool at scale to support the integration of NCD prevention into HIV care for AYLHIV. Ideally, an electronic version of this tool as a mobile application with automated calculations, in-built skip patterns, prompts and reminders would save healthcare workers time and provide ease-of-use.

Given that most factors that influence adolescent health lie outside healthcare, an intersectoral approach incorporating environmental and contextual factors is essential. A

range of interventions are required that engage diverse sectors and actors targeting socio-economic factors, built and food environment factors while actively engaging young people. The National Strategic Plan for the prevention and control of NCDs recognises the importance of multisectoral intervention but fails to outline concrete actions necessary to achieve the targets set for NCD reduction beyond the health sector [703]. The United Nations Human Settlements Programme and WHO have developed a tool to guide the integration of health and well-being into the design and planning of cities using an intersectoral approach [704]. In South Africa, local governments are well-placed to coordinate across sectors, including food supply networks and urban planning. Furthermore, local authorities can facilitate the inclusion of public open spaces and parks in their spatial planning, convenient transit hubs and access to safer walking spaces in peri-urban areas [704].

One example of an existing programme with the potential for alignment is the School Feeding Scheme offered to children and adolescents of school-going age. The initial basis of the scheme was to address food insecurity, absenteeism and school performance [607]. Given my findings of the significant association between school absenteeism and abdominal obesity, school feeding schemes could be considered a potential intervention to simultaneously address food insecurity, improve school attendance and reduce NCD risk. Additionally, extending such schemes to include community food gardens could be a leverage point for improving neighbourhood food environments, especially in low-income communities with inadequate access to healthy foods.

7.6 Suggestions for further research

Table 7.1 summarises suggestions for further research as highlighted in the preceding sections. These suggestions are presented using a multilevel framing including some health system considerations. A summary is outlined below.

More NCD risk behaviour research, ideally segregated by mode of transmission and comparing AYLHIV to uninfected age and sex-matched controls, is needed at the individual level. Longitudinal research using a life course approach and investigating the cumulative

effect of individual and household-level exposures such as SES and food insecurity would shed further light on chronic disease pathways and ways to interrupt chains of risk. Seeing that many AYLHIV are orphans and live in non-nuclear family structures, the impact of non-nuclear family structures and family social capital on obesity risk might differ from what is documented in higher-income settings and requires further exploration. It would have been ideal to translate and validate questionnaires, especially those on sensitive topics like mental health and stigma. More objective measures of physical activity and dietary intake like accelerometers or photovoice would have been ideal compared to self-report.

Additionally, research on the effect of social capital on obesity using culturally sensitive measures is also necessary, especially considering the role of stigma and community violence as possible mediators. Longitudinal studies are needed that explore the cumulative effect of life-long exposures such as poverty, violence and victimisation on adolescent and future adult health. At the environmental level, the cumulative effect of prolonged exposure to environmental stressors and an obesogenic food and built environment is another important issue for future research.

Further work is required to establish the most effective models of care for integrated HIV management and NCD prevention to respond to communicable and NCD prevention and control effectively. A review of HIV/NCD integration models in sub-Saharan Africa highlighted limited research and evaluation of the process and clinical outcomes for existing models of care integration and the best ways to deliver integrated comprehensive care for all [705]. These models will need to be tailored to the individual needs of adolescents and young people.

An important limitation of this thesis was that AYLHIV who were not accessing healthcare were excluded from the study as recruitment was health-facility based. As noted previously, AYLHIV who are not in care form a significant proportion of young people living with HIV. Future research needs to include efforts to identify AYLHIV who fall outside of the HIV care cascade as part of integrated HIV/NCD prevention and care.

Furthermore, research is needed on the features of urban design, such as green spaces, street connectivity, and land use mix measured objectively and how these affect health outcomes of AYLHIV in a context of urban sprawl in South Africa. Participants struggled to understand some of the concepts in the NEWS-Y scale used, like types of homes, sidewalks, and aesthetics. But there was no validated, culturally appropriate alternative. For the food environment, geographic mapping could have offered an objective measure for comparison to perceptions. Research on urban design and health has predominantly been conducted in higher-income settings. My research highlights the growing importance of this research in Africa as African countries grapple with unplanned, rapid urbanisation [706]. Built environment characteristics such as inadequate housing and housing informality, thermal discomfort and lack of access to amenities resulting from unplanned urbanisation, important determinants of NCD risk, need further exploration. Of note, my findings highlight the need for such research focused on AYLHIV, given the particular NCD risks they face.

Table 7.1: Suggestions for further research

Multilevel	Research questions
Individual	Does mode of HIV transmission have an impact on mental health outcomes and risk behaviour?
	Do AYLHIV have lower levels of PA, unhealthier diets and are they more likely to abuse alcohol and substances compared to age-and sex-matched HIV-uninfected peers in the same environment?
	What is the prevalence of ART-associated NCDs in AYLHIV in South Africa and sub-Saharan Africa?
Household	What is the cumulative effect of life-long deprivation, poverty and thermal discomfort in the home on NCD risk among AYLHIV?
	What is the impact of a non-nuclear family structure on obesity risk in AYLHIV?
Community	Among AYLHIV, what is the cumulative effect of life-long exposure to neighbourhood poverty, violence and victimisation on adolescent well-being and future adult risk for NCDs?
	How does social capital impact obesity risk in AYLHIV in the context of HIV-related stigma and community violence as possible mediators?
	How do we identify and link AYLHIV who are not in care into integrated HIV management/ NCD prevention and care? Which community-based interventions would be feasible and effective to prevent NCDs and identify AYLHIV who are not in care?

Health system	Are nurses empowered to screen for and manage NCDs in HIV clinics?
	What are the most effective models of care for integrated HIV management and NCD prevention in AYLHIV?
Environmental	How do various dimensions of the food environment impact dietary choices, dietary diversity, weight status, the nutritional quality of foods consumed by young people, in general, and AYLHIV in particular, living in low-income settings? Particularly: How do informal food vendors shape dietary behaviour in urban, low-income neighbourhoods in this population?
	What is the cumulative effect of prolonged exposure to environmental stressors and an obesogenic food and built environment on the health of AYLHIV?
	How do urban design features, such as green spaces, street connectivity and land-use mix affect health outcomes in AYLHIV in the context of urban sprawl in South Africa and LMICs?

7.7 **Conclusion**

This thesis provides a comprehensive investigation and analysis of NCDs and risk factors in AYLHIV using a socio-ecological framework and a multilevel lens in primary care settings. The findings contribute to our understanding of NCD risk in AYLHIV living in an urban setting. Adolescent health today is adult health in the future, and an intersectoral approach is needed to ensure the next generation's health and interrupt cycles of entrenched behaviours. As highlighted by adolescents in the 2020 Virology HIV and Adolescence Workshop, interventions tend to leave young people on the periphery of their own issues, failing to involve them meaningfully in their own care [707]. Therefore, it is vital that young people understand NCDs and their risk factors and that these are included in their care. The integrated HIV/ NCD management tool developed as part of this thesis is an evidence-based first step towards prevention, early detection and management of NCDs in AYLHIV. Further work needs to be done to explore how to engage young people best in order to effectively and efficiently prevent NCDs.

Chapter 8 Conclusion

This thesis explored the intersection of HIV and NCDs in a young population in transition in an urban South African city. In summary, I identified that NCD comorbidity (particularly obesity and mental health conditions) and NCD risk factors are prevalent in AYLHIV. The second significant finding was that obesity was associated with multilevel factors ranging from social determinants of health to features of urban design.

Adolescence is a period of exploration and transition as young people grapple with establishing self-identity and autonomy. For many adolescents and young people living with HIV and their families, HIV is just one of many issues they face, and other issues like food security, housing, substance abuse, violence, and mental health may be perceived as more pressing. In addition, Cape Town is a city of immense contrast and inequality and ranks amongst the world's most violent cities. As a result, adolescents living in urban Cape Town face much social vulnerability. Overall, this thesis strengthens the idea that the additional stressor of living with a highly stigmatised condition significantly compromises their well-being.

This thesis has raised important questions about building a responsive health system that adapts to the needs of young people in an ever-changing urban landscape. This thesis lays the foundation for moving towards integrated, intersectoral, comprehensive, patient-centred models of care that are responsive to the needs of adolescents. I plan to disseminate these findings, including the integrated HIV/NCD management tool I developed, to government authorities in the Provincial and Local Government, who facilitated my access to healthcare facilities and the youth healthcare providers at each facility. Additionally, the results will be published in peer-reviewed journals to disseminate the findings to a broader audience in other LMIC settings.

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Appendices

Appendix 1: Literature review search strategy

The literature search was conducted with pre-specified themes according to the conceptual framework. After searching the electronic library catalogue, we combined Major Subject Headings (MeSH terms) and keyword searches in Medline according to the themes identified and replicated the same search in Embase. Article headings were then skimmed to assess relevance.

Keywords and MeSH Search terms

Concept	Search terms	Results	Relevant citations
Overall NCD/HIV intersection	(((((("adolescent"[MeSH Terms] OR "adolescent health/epidemiology"[MeSH Terms]) OR "young adult"[MeSH Terms]) OR "adolescent medicine"[MeSH Terms]) OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR "antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND (("noncommunicable diseases"[Title/Abstract] OR "noncommunicable diseases/epidemiology"[MeSH Terms]) OR "chronic disease"[MeSH Terms])	390	81
HIV and Mental Health:	(((((((("adolescent"[MeSH Terms] OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR "antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND ("mental disorders"[Title/Abstract] OR "mental health"[Title/Abstract])) AND 2000/1/1:2020/12/31[Date - Publication]) NOT "sexual and gender minorities"[MeSH Terms]) NOT "men who have sex with men"[All Fields]) NOT "males who have sex with males"[All Fields]) NOT "pregnant"[All Fields]	923	209
HIV and Cardiovascular + Metabolic Diseases	(((((((("adolescent"[MeSH Terms] OR "adolescent health/epidemiology"[MeSH Terms]) OR "young adult"[MeSH Terms]) OR "adolescent medicine"[MeSH Terms]) OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR	74	31

	"antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND ((metabolic diseases[MeSH Terms]) OR (cardiovascular diseases[MeSH Terms])) AND (1996:2020[pdat]))) Filters: Meta-Analysis, Review, Systematic Reviews		
HIV and Diabetes	((((((((("adolescent"[MeSH Terms] OR "adolescent health/epidemiology"[MeSH Terms]) OR "young adult"[MeSH Terms]) OR "adolescent medicine"[MeSH Terms]) OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR "antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND ("diabetes mellitus"[MeSH Terms]) NOT ("pregnant"[All Fields]) NOT ("gestational"[All Fields]) NOT ("tuberculosis"[All Fields]) AND (1996:2020[pdat]))))	156	49
HIV and Lung Diseases	((((((((("adolescent"[MeSH Terms] OR "adolescent health/epidemiology"[MeSH Terms]) OR "young adult"[MeSH Terms]) OR "adolescent medicine"[MeSH Terms]) OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR "antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND ("lung diseases"[MeSH Terms]) NOT ("pneumonia"[All Fields]) NOT ("tuberculosis"[All Fields]) AND (1996:2020[pdat])))	173	41
HIV and Hypertension	((((((((((("adolescent"[MeSH Terms] OR "adolescent health/epidemiology"[MeSH Terms]) OR "young adult"[MeSH Terms]) OR "adolescent medicine"[MeSH Terms]) OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR "antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND ("hypertension"[MeSH Terms]) NOT ("pregnant"[All Fields]) NOT ("gestational"[All Fields]) NOT ("tuberculosis"[All Fields]) NOT ("preeclampsia"[All Fields]) AND (1996:2020[pdat]))))))	118	53
HIV and Obesity	((((((((((("adolescent"[MeSH Terms] OR "adolescent health/epidemiology"[MeSH Terms]) OR "young adult"[MeSH Terms]) OR "adolescent medicine"[MeSH Terms]) OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR "antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND	96	44

	("obesity"[MeSH Terms]) NOT ("pregnant"[All Fields]) NOT ("gestational"[All Fields]) NOT ("tuberculosis"[All Fields]) AND (1996:2020[pdat]))))))		
HIV and Exercise	((((((((((((("adolescent"[MeSH Terms] OR "adolescent health/epidemiology"[MeSH Terms]) OR "young adult"[MeSH Terms]) OR "adolescent medicine"[MeSH Terms]) OR "youth"[All Fields]) OR "teenager"[All Fields]) OR "adolescent"[All Fields]) AND ((("hiv"[Title/Abstract] OR "hiv infections/epidemiology"[MeSH Terms]) OR "antiretroviral therapy, highly active"[MeSH Terms]) OR "antiretroviral therapy"[Title/Abstract])) AND (("sedentary behavior"[MeSH Terms]) OR ("exercise"[MeSH Terms])) AND (1996:2020[pdat]))))))))	78	24
HIV and Smoking, Alcohol drinking or Illicit drugs	("hiv infections"[MeSH Terms] AND "antiretroviral therapy, highly active"[MeSH Terms]) AND (((((("Alcohol Drinking"[MeSH Terms] OR "Smoking"[MeSH Terms]) OR "Illicit Drugs"[MeSH Terms]) NOT "Sexual and Gender Minorities"[MeSH Terms]) NOT "Papillomaviridae"[MeSH Terms]) NOT "Hepatitis C"[MeSH Terms])	234	100

Appendix 2: Information sheets and assent form with teach-back questions

ADOLESCENT INFORMATION SHEET AND ASSENT FORM

Introduction
Hello. I am from the University of Cape Town, Division of Public Health. I work with teenagers and young people. Right now, we are doing a study to learn more about the patterns and causes of lifestyle diseases in teenagers and young people between the ages of 15-24 years (who are living with HIV). The diseases we are studying are: hypertension ("high blood"), asthma, diabetes ("sugar in the blood"), depression, stress or anxiety, and their causes which include, being fat (overweight/obese), smoking cigarettes, not exercising, eating unhealthy food and abusing alcohol or drugs.

Why are you being invited to take part?
We are asking you to help as we do not know very much about whether these illnesses are a common problem in (HIV-infected) teenagers. You will help us understand whether you need extra support at the clinic or referral to other medical clinics. If we can pick up these illnesses or the things that cause them early, we can help you to live healthier and prevent them from getting worse when you are older. This will also help other teenagers like you.

What will happen if you decide to take part in the study?
If you agree to be in this study, then I will ask you some questions and examine you. You will be asked a few questions about yourself and where you live. Then we will measure your weight, height, waist size, blood pressure and breathing. We will also take a little blood from you using a pin-prick, which might hurt a little. We will need some of your blood to see the amount of sugar in your blood.

We will then ask you about what you eat, how you exercise, and if you smoke or drink alcohol. We will also ask you about your performance at school and questions that will help us see if you suffer from stress or depression. The interview and examinations will last for about two hours.

What are the risks and discomforts of taking part in this research?
The research involves very little risk. The finger-prick test for your blood sugar might be the most painful. But some of the questions may make you upset. If there is any question you do not want to answer or any examination that makes you uncomfortable, you can refuse to answer, and we go on to the next question, or you can ask us to stop at any time.

If there are any personal problems that come out while we are doing the interview that you need help for, we will tell the nurse or doctor on duty who will help you or send you for follow-up care or counselling.

Are there any benefits to you if you take part in this research?
There are no direct benefits for you in taking part in the study, but the study will help us understand your health and other young people like you. This will give us important information that may prevent future health problems and assist other adolescents (living with HIV).

Who will see the information which is collected about you during the study?
If you agree to help us, you should know that your parents/caregiver and friends will not know what you have said. Your answers will be entered into an electronic form on a tablet, and only the study team at UCT and I will be able to see your answers. Also, there are no right or wrong answers.

We will not tell anyone what you tell us without your permission unless there is something that could cause harm to you or someone else. If you tell us that someone is or has been hurting you, we may have to tell that to people who are responsible for protecting children, so they can make sure you are safe.

At the end of the study, we will attend the staff meeting at the clinic to inform the nurses and doctors who look after you about the overall findings. This will not show who you are. We will also contact you to find out if you are interested in attending a youth clinic day where we will present what we have found.

What happens if you do not want to take part in this research?
If you don't want to be in our study, you don't have to be in it. Remember, being in the study is up to you, and no one will be upset if you don't want to be in the study. Please talk this over with your parents/caregiver before you decide if you want to be in our study or not. I will also ask your parents to give their permission for you to be in this study, but even if your parents say "yes," you can still say "no" and decide not to be in the study.

If you don't want to answer a question, you can tell the person to skip it, as you do not have to answer all the questions you are asked. Or if you decide to stop after the questions have already begun, that's okay, too. Also, remember that no one else, not even your parents, will know what you have said. You should also know that if you decide to help us or if you decide to say "no," your choice will not affect the help that you get from the nurses and doctors here at the facility.

Will you be paid to take part in this study?
You will not receive any compensation for taking part in the study, but we will provide some refreshments for you and pay you back for any expenses that you might incur as a result of taking part.

Who do I speak to (or contact) if I have any questions about the study?
You can ask any questions that you have about the study. What else would you like to know? If you have a question later that you did not think of now, you can call me or ask your parents/caregiver to call me at 072 627 9007 or email the main investigator Prof Tolullah Oni at Tolu.Oni@mrc-epid.cam.ac.uk.

It is my job to explain things clearly. To make sure I did this properly, I would like to hear what you understand about this research. I will take you through a few questions below. Please answer them in your own words.

Teach back questions (Select five from below)

- Could you explain to me what we are going to ask you to do in this study? This will help me be sure you understand the research instead
- Why are we doing this study – tell me in your own words?
- How would you explain this research to your parent/ guardian?
- Tell me in your own words what will happen to you if you agree to be in this study?
- What is the worst thing that could happen to you if you take part in this research?
- Will anything happen to you if you refuse to be in the study?

- What happens if you say you don't want to be in the study?
- What should you do if you agree to be in this research but later change your mind?
- Who will be able to see the information you give us?
- Who should you contact if you have a problem or a question about the research /your rights/ or a complaint?

Would you like to take part in this study?

(After clear understanding has been established, ask follow-up questions to determine if participants' understanding is correct if answers are unclear.)

If you sign your name on the form below, it means that you have agreed to participate in this study.

Adolescent Participant Declaration

I, **(Your Name),** _____ declare that I understand the information about this research. By signing this assent form, I am agreeing to take part in the study.

I understand that I can withdraw myself from the research process at any time I feel that I can no longer continue without any penalties.

Your signature:_____ **Date:** _____

Interviewer Declaration

I, **(Name),** _____ declare that I have explained the details of this research to the participant. I am convinced that he/she has understood everything satisfactorily and has made an informed decision to participate in the study. She/he has the right to withdraw from the study at any time without being forced or coerced into continuing against his/her will, and it is my responsibility to honour that right.

Signature of Person Obtaining Consent: _____

Date: _____

Appendix 3: Composite indices and measures

3.1 Definitions of key variables used in the medical record review

Table 1: Definitions of key variables collected for Objective 1 as part of patient record review

HIV information	
HIV management	CD4 levels and viral load information (most recent CD4 and viral load levels, date of last CD4 and viral load assessment). Viral suppression was defined as undetectable viral load or viral load < 20 copies/ml
Antiretroviral therapy (ART)	Age at initiation, ART start date, initial ART regimen, current ART regimens ranging from first line, second line and third-line regimens
HIV opportunistic infections and ART-related conditions	Herpes zoster (shingles)
	PPE- Pruritic Papular Eruption
	Oral thrush and Oral candida
	Oral hairy leucoplakia
	Oesophageal candidiasis
	PJP- Pneumocystis jiroveci pneumonia
	HIV encephalopathy
	Cytomegalovirus (CMV) diseases (CMV- retinitis)
	AZT-neutropenia
	D4T-lipodystrophy, lipoatrophy
NCD information	
NCD diagnosis	Diagnosis of diabetes, cancer, asthma, bronchitis, lung disease or any other COPD, depression, anxiety or other mental health condition
NCD treatment	Chronic prescribed medications for diabetes, hypertension (e.g. Ciprofloxin, Hydrochlorothiazide, Enalapril maleate), epilepsy, asthma (e.g. Salbutamol metered dose inhaler, Ipratropium bromide), high cholesterol/ triglycerides (statins), antipsychotics or anti-depressants (e.g. Risperidone, Valproate Sodium, Epilim), medication for bronchitis, lung disease or any other COPD
NCD risk factors	
Overweight/obesity	Body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters. Overweight defined as BMI ≥25 kg/m^2 and BMI<30kg/m^2; obese defined as BMI ≥ 30kg/m^2.
Elevated blood pressure	Systolic blood pressure (SBP) & diastolic blood pressure (DBP) according to South African hypertension practice guidelines: Grade1/mild hypertension (SBP 140-159 or DBP 90- 99 mmHg), Grade 2/moderate hypertension (SBP 160-179 mmHg or DBP 100- 109 mmHg) or on treatment for elevated blood pressure
Smoking	Current smoker or history of smoking
Substance abuse	Current use or history of drug addiction, alcohol problem or other substance abuse
General Medical Information	
Family history	Cancer, diabetes, tuberculosis, alcoholism, high blood pressure, epilepsy, or any other documented family history recorded in the entire folder
Other conditions	Pregnancy, epilepsy, learning difficulties, Failure to Thrive, trauma-injury and violence
Contraception	Any prescribed contraception (Depo-provera or Nur-isterate)
Other non-HIV infections	

non-HIV infectious disease diagnosis	Tuberculosis, sexually transmitted infections (Herpes Simplex Virus), pneumonia, scabies
non-HIV infectious disease treatment	Tuberculosis treatment (Rifampicin, Isoniazid, Pyrazinamide, Ethambutol), TB prophylaxis, STI treatment, Antibiotics, Antivirals, Steroids
Health Promotion	
HIV-related	Disclosure counselling prior to disclosure of HIV status; Adherence counselling for issues with adherence or referral to community support group
NCD-related	
Diet or healthy weight counselling	Nutritional or healthy diet counselling or referral to a dietician
Substance abuse	Alcohol, smoking or drug abuse counselling or referral to a psychologist
Diabetes screening	Fasting blood glucose or diabetes risk factor screen
Mental health counselling	Referral to psychologist/ psychiatrist
Sexual and reproductive health	Family planning, safe sex counselling, pap smear, breast examination; basic antenatal care counselling or infant feeding counselling for pre- or post-partum mothers; Medical male circumcision
Other health promotion	Hygiene counselling; Physiotherapy/ occupational therapy

3.2 Youth multidimensional poverty index

The Youth Multidimensional Poverty Index (YMPI) follows the South African Multidimensional Poverty Index (SAMPI) and applies a nested weighting structure. As shown in brackets in Table 2, the YMPI weights are equally distributed across the four dimensions (1/4 each), and within dimensions, each indicator receives equal weight.

A poverty cut-off is used to identify whether an individual is multi-dimensionally poor based on his or her total weighted deprivations. Following the SAMPI, the YMPI uses a poverty cut-off of 1/3 (or 33.33%), which means that an individual is considered poor if he or she is deprived in a third or more of the weighted deprivations.

Table 2: Dimension, Indicators and Deprivation Cut-offs of the Youth MPI

Dimension	Indicator	Deprived if
Education	Educational attainment (1/4)	Individual is aged 15 – 16 and has completed less than primary school; individual is aged 17 – 20 and has completed less than grade 9; or individual is aged 21 – 24 and has completed less than matric or matric equivalent.
Health	General health and functioning (1/4) How much difficulty you have had, on average, while doing the activity in the way that you usually do it, difficulty meaning requiring increased effort, discomfort or pain, slowness or changes in the way you usually do the activity. *According to the defined cut-off in the Youth MPI, a young person is considered deprived if he or she experiences some difficulty in one or more of these functional areas*	Individual experiences difficulty in one or more functions: hearing, vision, communication, mobility (walking or climbing stairs), cognition (remembering or concentrating) or self-care Ask: OVERALL in the last 30 days: • How much difficulty did you have in hearing someone talking on the other side of the room in a normal voice, hearing what is said in a conversation with one other person in a quiet room (Even with your hearing aid on if you use one)? • How much difficulty did you have in seeing and recognising an object or a person you know across the road (from a distance of about 20 meters), seeing and recognising an object at arm's length (for example, reading)? *(Respondent should answer, as when wearing glasses/contact lenses if used)* • How much difficulty did you have with moving around? • How much difficulty did you have with concentrating or remembering things? • How much difficulty did you have with self-care, such as bathing/ washing or dressing? None (1), Mild (2), Moderate (3), Severe (4), Extreme/ cannot do (5)
Living environment[1]	Fuel for lighting (1/28)	Individual is living in a household that is using paraffin/candles/nothing/other for lighting
	Fuel for heating (1/28)	Individual is living in a household that is using paraffin/wood/coal/dung/other/none for heating
	Fuel for cooking (1/28)	Individual is living in a household that is using paraffin/wood/coal/dung/other/none for cooking
	Sanitation (1/28)	Individual is living in a household without a flush toilet
	Water (1/28)	Individual is living in a household without piped water on site
	Dwelling type (1/28)	Individual is living in a household that is an informal shack/traditional dwelling/caravan/tent/other
	Assets (1/28)	Individual is living in a household that does not own more than two of radio, television, landline, cell phone or refrigerator AND does not own a motorcar

[1] A young person living in a household that does not use electricity, gas or solar power as its main source of fuel for cooking, heating and/or lighting; does not have access to piped water on site; does not use a flush toilet as its main toilet facility; occupies an informal or traditional dwelling and/or does not own more than two of the listed assets and does not own a motorcar is considered deprived.

Economic Opportunities	Household adult employment (1/8)	Individual is living in a household where no adults (18 - 64) are employed
	NEET (neither in education, employment, nor training). (1/8)	Individual is not in education, employment or training: Ask • *Do you currently attend an educational institution? Attendance includes all part-time and full-time studies, whether in person or as a distance learner* • *How would you describe your present employment situation?*

Source: Adapted from Alkire & Santos, 2010 [271]

3.3 Centre for Epidemiologic Studies Short Depression Scale

The Center for Epidemiologic Studies Short Depression Scale (CES-D-10) is a self-report measure of depression consisting of 10 questions, with four possible answers, regarding a range of emotional behaviours and the number of times they have been exhibited in the past week. Items 5 and 8 are reverse-scaled. The final score ranges from 0-30. A score of ten or above indicates the presence of mild to significant depression.

Table 3: CESD-10 Scale

Items	Response
1. I was bothered by things that usually don't bother me.	None of the time (0), A little of the time (1-2 days: 1), Occasionally or a moderate amount of time (3-4 days: 2), All of the time (5-7 days: 3)
2. I had trouble keeping my mind on what I was doing.	None of the time (0), A little of the time (1), Occasionally or a moderate amount of time (2), All of the time (3)
3. I felt depressed.	None of the time (0), A little of the time (1), Occasionally or a moderate amount of time (2), All of the time (3)
4. I felt that everything I did was an effort.	None of the time (0), A little of the time (1), Occasionally or a moderate amount of time (2), All of the time (3)
5.* I felt hopeful about the future.	None of the time (3), A little of the time (2), Occasionally or a moderate amount of time (1), All of the time (0)
6. I felt fearful.	None of the time (0), A little of the time (1), Occasionally or a moderate amount of time (2), All of the time (3)
7. My sleep was restless.	None of the time (0), A little of the time (1), Occasionally or a moderate amount of time (2), All of the time (3)
8.* I was happy.	None of the time (3), A little of the time (2), Occasionally or a moderate amount of time (1), All of the time (0)
9. I felt lonely.	None of the time (0), A little of the time (1), Occasionally or a moderate amount of time (2), All of the time (3)
10. I could not "get going."	None of the time (0), A little of the time (1), Occasionally or a moderate amount of time (2), All of the time (3)

3.4 Kessler Psychological Distress Scale

This questionnaire is a measure of psychological distress. The numbers attached to the patient's ten responses are added up, and the total score is the score on the Kessler Psychological Distress Scale (K10). Scores will range from 10 to 50. People seen in primary care who

* Score under 20 are likely to be well
* Score 20-24 are likely to have a mild mental disorder
* Score 25-29 are likely to have a moderate mental disorder
* Score 30 and over are likely to have a severe mental disorder

Table 4: K10 Test

Items	Response
1. During the last 30 days, about how often did you feel tired out for no good reason?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
2. During the last 30 days, about how often did you feel nervous?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
3. During the last 30 days, about how often did you feel so nervous that nothing could calm you down?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
4. During the last 30 days, about how often did you feel hopeless?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
5. During the last 30 days, about how often did you feel restless or fidgety?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
6. During the last 30 days, about how often did you feel so restless you could not sit still?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
7. During the last 30 days, about how often did you feel depressed?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
8. During the last 30 days, about how often did you feel that everything was an effort?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
9. During the last 30 days, about how often did you feel so sad that nothing could cheer you up?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)
10. During the last 30 days, about how often did you feel worthless?	None of the time (1), A little of the time (2), Some of the time (3), Most of the time (4), All of the time (5)

3.5 Alabama Parenting Questionnaire - Short Form APQ-9

The APQ-9 is a nine-item measure consisting of three 3-item subscales: Positive Parenting, Inconsistent Discipline and Poor Supervision. Items are scored from: never (1), almost never (2), sometimes (3), often (4), always (5). The range of possible scores on the three-item scales is 0 to 15. For our purposes, we have used two subscales pertaining to Positive Parenting and Poor Supervision and paraphrased the statements from the adolescent's point of view as displayed in column 3.

Table 3: Alabama Parenting Questionnaire Subscales

Subscale	Item	Question posed
Positive parenting	1. You let your child know when he/she is doing a good job with something.	Does your parent/caregiver tell you when you are doing a good job with something? Response: Never (1), Almost Never (2), Sometimes (3), Often (4), Always (5).
Inconsistent discipline	2. You threaten to punish your child and then do not actually punish him/ her.	
Poor supervision	3. Your child fails to leave a note or to let you where he/ she is going.	Do you tell/ let your parent/caregiver know where you are going? Never (1), Almost Never (2), Sometimes (3), Often (4), Always (5).

Inconsistent discipline	4. Your child talks you out of being punished after he/she has done something wrong.	
Poor supervision	5. Your child stays out in the evening after the time he/ she is supposed to be home.	Do you stay out at night long after the time you were supposed to be home? Never (1), Almost Never (2), Sometimes (3), Often (4), Always (5).
Positive parenting	6. You compliment your child after he/she has done something well.	Does your parent/caregiver compliment you after you have done something well? Never (1), Almost Never (2), Sometimes (3), Often (4), Always (5).
Positive parenting	7. You praise your child if he/she behaves well.	Does your parent/ caregiver praise you when you behave well? Never (1), Almost Never (2), Sometimes (3), Often (4), Always (5).
Poor supervision	8. Your child is out with friends you don't know.	Do you go out with friends your parent/ caregiver doesn't know? Never (1), Almost Never (2), Sometimes (3), Often (4), Always (5).
Inconsistent discipline	9. You let your child out of punishment early (like lift restrictions earlier than you originally said)	

3.6 Exposure to violence in the community

The Exposure to violence in the community scale was adapted from the Harvard Trauma Questionnaire. It consisted of 8 items with responses coded as Yes/ No. 0 = "no," 1 = "yes," and the maximum score is 8. A score of 4 or more indicates a high level of violence, a score of 2-3 indicates a moderate amount of violence, and a score of 0-1 indicates no or little violence.

Table 5: Exposure to Violence in the Community Measure

Items	**Response**
1. Have you heard of any killing in your community?	0 = No, 1 = Yes
2. Have you seen a dead body (not at a funeral)?	0 = No, 1 = Yes
3. Are you afraid of anyone in your community or yard?	0 = No, 1 = Yes
4. Have you seen someone pointing or shooting a gun at someone?	0 = No, 1 = Yes
5. Have you seen someone other than the police pointing or shooting a gun at someone?	0 = No, 1 = Yes
Someone personally known to you has been:	
6. Shot	0 = No, 1 = Yes
7. Stabbed	0 = No, 1 = Yes
8. Raped	0 = No, 1 = Yes

Appendix 4: Integrated HIV/NCD management tool

ADOLESCENT HIV/NCD CLINICAL ASSESSMENT

FOLDER NUMBER: **FACILITY NAME:**
DATE OF FIRST VISIT / ADMISSION: **ART START DATE:**

1. PERSONAL DETAILS

Name:

Residential address:

Contact telephone nr: Guardian/ caregiver telephone nr:

Date of birth:

Sex: Male ☐ Female ☐

Language spoken at home/ preference:

2. BASELINE CLINICAL INVESTIGATION

Allergies:

Diagnosed conditions: Asthma ☐ Tuberculosis ☐ Pneumonia ☐ Bronchitis ☐ Other lung disease ☐

Diabetes ☐ Hypertension ☐ Heart disease ☐ Liver disease ☐ Kidney disease ☐

Stunting ☐ Malnutrition ☐ Obesity ☐ Anaemia ☐

Developmental delay ☐ Neurological ☐ Meningitis ☐ Depression/ anxiety/ mental illness ☐

Alcohol problem ☐ Other substance use problem ☐ Other: (specify)_____

Medication:

Does adolescent require: (A) **Epipen** Yes ☐ No ☐ (B) **Inhaler** Yes ☐ No ☐

(C) **ANY MEDICATION CURRENTLY TAKEN (Type of medication other than ART and time of administration):**
_____

Pregnancy or planning to conceive: Yes ☐ No ☐ **On hormonal/ other contraception:** Yes ☐ No ☐

Specify: _____

TB symptoms: cough ☐ night sweats ☐ fever ☐ recent weight loss ☐ (*Do GeneXpert if positive symptoms of TB)*

Respiratory symptoms (over past 3 months): shortness of breath ☐ chest tightness ☐ difficulty breathing ☐
prolonged cough (>2 weeks) with sputum ☐ asthma attack ☐
(*perform spirometry test if no confirmed respiratory condition and symptoms*) Forced expiratory volume: _____

Meningitis symptoms: headache ☐ confusion ☐ fever ☐ neck stiffness ☐ coma ☐

Diabetes symptom screen: frequent urination (not associated with burning) ☐ increased thirst ☐
unexplained weight loss (> 1.5 kg in past month) ☐ unexplained fatigue ☐ blurry vision ☐
Random blood glucose level (mg/ dl): _____ *(flag as pre-diabetic if > 140 mg/dl or > 7.8mmol/L)*

3. VITALS ASSESSMENT

Resting blood pressure in mmHg: SBP1/DBP1: _____ SBP2/DBP2: _____
(FLAG IF ELEVATED > 140/90 MMHG OR DOCUMENTED FAMILY HISTORY).

Pulse in BPM: _____

4. ANTHROPOMETRIC ASSESSMENT

Weight in kg:	Height in m:	BMI: *(FLAG AS HIGH RISK IF > 25 KG/M²)*
Waist circumference in cm: *(FLAG AS HIGH RISK IF > 94CM FOR BOYS AND > 80 CM FOR GIRLS)*	Hip circumference in cm:	Waist-hip-ratio: *(FLAG IF > 0.9 FOR BOYS AND > 0.85 FOR GIRLS)*
Waist-to-height ratio: *(FLAG AS HIGH RISK IF > 0.5)*		

5. MENTAL HEALTH ASSESSMENT

In the past week, how often did you feel…

(*0 = RARELY OR NONE OF THE TIME, 1 = SOME OR LITTLE OF THE TIME, 2 = MODERATELY OR MUCH OF THE TIME, 3 = MOST OR ALMOST ALL THE TIME)*

Bothered by things that don't normally bother you?	Have trouble keeping your mind on what you were doing?	Feel depressed?
Feel that everything you did was an effort?	Feel hopeful about the future*?	Feel fearful?
Was your sleep restless?	Feel happy*?	Feel lonely?
Feel like you could not get going?		

(ADD SCORES AND FLAG AS HAVING SIGNIFICANT DEPRESSIVE SYMPTOMS IF SCORE ≥10)

6. HIV MANAGEMENT

Date of last HIV viral load:	Viral load (copies/ ml): *WITHIN THE PAST 6 MONTHS*	Detectable/ undetectable:
Date of last CD4 level:	CD4 level (cells/*μL*):	
WHO clinical stage:		
Any adherence issues/ support required:	_____	
History of virological failure/ resistance:		

CURRENT ART REGIMEN: First line ☐ Second line ☐ Third-line ☐

Adolescent switched to dolutegravir: Yes ☐ No ☐ ARV's (specify): _____

Any adverse events or ART-related side-effects: renal impairment ☐ anaemia ☐ nausea ☐ vomiting ☐ jaundice ☐

metabolic side-effects (cholesterol, triglycerides above acceptable range): ☐

neuropsychiatric effects ☐ drug-interactions ☐ Other (specify): _____

7. SOCIAL INFORMATION- INDIVIDUAL

In school/ college/ university: Yes ☐ No ☐	Grade/ tertiary level:	
Employed: Yes ☐ No ☐	Days absent from school/ work in the past month: 0 days ☐ 1-2 days ☐ > 2 days ☐	
Social grant: Yes ☐ No ☐	specify:	
Both parents alive: Yes ☐ No ☐	If no, who is deceased: Mother ☐	Father ☐ Both ☐
Ever been pregnant/ are pregnant or impregnated someone? Yes ☐ No ☐	If yes, how many children do you have?	

8. SOCIAL INFORMATION- HOUSEHOLD

Primary caregiver name:	Relationship to adolescent:	
Employed: Yes ☐ No ☐	Work phone nr:	Cell phone nr:
Mother (if not caregiver):	Health status:	Employed: Yes ☐ No ☐
Cell phone nr:		
Father (if not caregiver):	Health status:	Employed: Yes ☐ No ☐

Cell phone nr:		
Number of siblings:	Chronological placement among siblings:	
Family history (tick where applicable) Hypertension ☐ Diabetes ☐ Cardiovascular ☐ Epilepsy ☐		
Substance use ☐	Mental illness ☐ Asthma ☐ Tuberculosis ☐ Hearing defect ☐	
Eye conditions ☐	Other (specify): _____	
Number of people living in household:	Does anyone in the household smoke cigarettes/ tobacco? Yes ☐ No ☐	
Has the house even been damaged by flooding/ fire/other negative events?		
Housing: Formal ☐ Informal ☐	**Water supply**: Not piped ☐ Piped outside/tap ☐ Piped inside ☐	
Flushing toilet inside the house: Yes ☐ No ☐		**Electricity:** Yes ☐ No ☐
Thermal comfort in the home:	In summer, I feel hot: Yes ☐ No ☐	In winter, I feel cold: Yes ☐ No ☐
	There is enough ventilation/ airflow: Yes ☐ No ☐	
Food security: (flag if yes to any of the questions below)		
Was there ever no food to eat of any kind in your house because of no money to buy food?		Yes ☐ No ☐
Did you or anyone in your household go to sleep at night hungry because there was not enough food?		Yes ☐ No ☐
Did you or anyone in your household go a whole day & night w/out eating because there was not enough food? Yes ☐ No ☐		

9. RISK BEHAVIOUR SCREEN

Tobacco, Alcohol and Substance use

Smoked cigarettes in the past month: Yes ☐ No ☐	Used smokeless tobacco in the past month (e.g. vaping, hookah: Yes ☐ No ☐	How often did you smoke in the past month?
Drunk alcohol in the past month: Yes ☐ No ☐	How often did you drink alcohol in the past month? On < 3 occasions, weekly, more than weekly	Drank 5 or more drinks in succession on one or more days in the past 30 days: Yes ☐ No ☐
Ever used cannabis (dagga): Yes ☐ No ☐	Ever used tik/ cocaine/ mandrax: Yes ☐ No ☐	How often have you used drugs in your lifetime?

Physical Activity

During the past week, on how many days did you do **vigorous physical activities** like heavy lifting, digging, aerobics, or fast bicycling?	___ days/ week No vigorous PA ☐
How much time did you usually spend doing vigorous physical activities on one of those days?	____ hours __ minutes Don't know ☐
During the past week, on how many days did you do **moderate physical** activities like carrying light loads, bicycling at a regular pace, or chores? Do not include walking.	___ days/ week No moderate PA ☐
How much time did you usually spend doing moderate physical activities on one of those days?	____ hours __ minutes Don't know ☐
During the past week, on how many days did you walk for at least 10 minutes at a time?	___ days/ week No walking ☐
How much time did you usually spend walking on one of those days?	____ hours __ minutes Don't know ☐
During the past week, how much time did you spend sitting on a weekday?	____ hours __ minutes Don't know ☐

Dietary intake and practices		
How often do you eat fresh fruit in a week?		
How often do you eat vegetables in a week		
How often do you eat fast food or deep-fried food?		
How often do you drink sugar-sweetened beverages?		
How often do you eat sweets, cakes and foods with added sugar?		
How many meals did you eat last week that were prepared outside the home?		
How often do you eat breakfast?	Most days (including weekends)☐	4- 5 days a week ☐ 3 days or less ☐
Do you eat lunch provided at school?	Yes ☐ No ☐	How often in the past week?
10. COMMUNITY ASSESSMENT		
Experiences of stigma		
People in my community think that a person with HIV is disgusting:		Never, Sometimes, Most of the time
People in my community think that HIV is a punishment from God or ancestors		Never, Sometimes, Most of the time
Social capital:		
Do you belong to a community/ religious organisation or support group that gives you the support you need?		Yes ☐ No ☐
Do you feel people trust each other in your neighbourhood?		Strongly agree, agree, neither agree nor disagree, disagree, strongly disagree
Built Environment *FOR THE FOLLOWING QUESTIONS, NEIGHBOURHOOD REFERS TO THE AREA THAT LIES WITHIN A 10-15 MINUTES' WALK FROM THE RESPONDENT'S HOME (WITHIN APPROXIMATELY ONE KM OF THEIR HOUSE).*		
Crime safety: *(Strongly disagree, somewhat disagree, somewhat agree, strongly agree)*		
There is a high crime rate in my neighbourhood.		
I am worried about being outside with a friend around my home because I am afraid of being taken or hurt by a stranger.		
I am worried about being or walking alone or with friends in my neighbourhood and local streets because I am afraid of being taken or hurt by a stranger.		
The crime rate in my neighbourhood makes it unsafe to go on walks alone or with someone at night		
Neighbourhood safety: (*strongly disagree, somewhat disagree, somewhat agree, strongly agree*)		
There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighbourhood.		
Most drivers go faster than the speed limits in my neighbourhood		
My neighbourhood streets have good lighting at night.		
People can easily see walkers and bikers on the streets in my neighbourhood in their homes		
There are signals or crosswalks/zebra crossings to help walkers cross the busy roads in my neighbourhood.		
About how long would it take you to walk from your home to the nearest recreation place listed below:		
Indoor recreation or exercise facility (public or private) (*1-5 min; 6-10 min; 11-20 min; 21-30 min; 31+ min; don't know)*		
Beach, lake, river, or creek		
A basketball court or other playing fields/courts (like soccer, football, softball, tennis, etc.)		
Youth club/ boys and girls club		
Swimming pool		
Public playground with equipment		
Public open space (grass or sand/dirt) that is not a park		
Large/ small public park		

Streets in my neighbourhood. *Please circle the answer that best applies to you and your neighbourhood (1- strongly disagree, 2- somewhat disagree, 3-somewhat agree, 4-strongly agree)*
The streets in my neighbourhood do not have many cul-de-sacs (dead-end streets)
The distance between intersections (where streets cross) in my neighbourhood is usually short (100 meters or less)
There are many (3 or more) different routes for getting from place to place in my neighbourhood. (I don't have to go the same way every time)
Places for walking
There are sidewalks on most of the streets in my neighbourhood.
Sidewalks are separated from the road/traffic in my neighbourhood by parked cars.
There is grass/dirt between the streets and the sidewalks in my neighbourhood
Neighbourhood surroundings
There are trees along the streets in my neighbourhood
There are many interesting things to look at while walking in my neighbourhood
There are many beautiful natural things to look at in my neighbourhood (e.g., gardens, views).
There are many buildings/homes in my neighbourhood that are nice to look at
Food Environment: *Please circle the answer that best applies to you and your neighbourhood 1-5 min; 6-10 min; 11-20 min; 21-30 min; 31+ min; don't know*
About how long would it take you to walk from your home to the nearest supermarket?
About how long would it take you to walk from your home to the nearest fruit/ vegetable market?
About how long would it take you to walk from your home to the nearest fast-food restaurant?
About how long would it take you to walk from your home to the nearest non-fast food restaurant?
About how long would it take you to walk from your home to the nearest food vendor?